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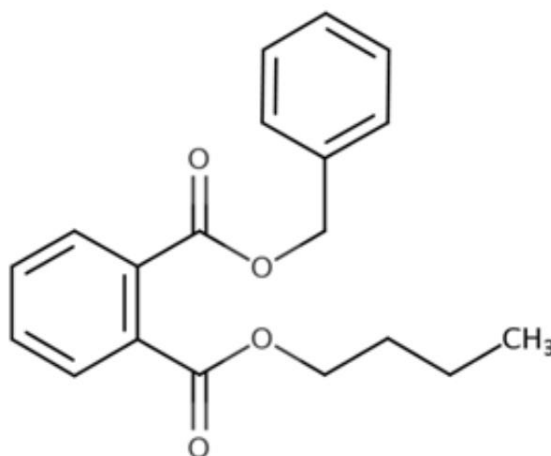
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Office of Chemical Safety and
Pollution Prevention

Environmental Release and Occupational Exposure Assessment for Butyl Benzyl Phthalate (BBP)

Technical Support Document for the Risk Evaluation

CASRN 85-68-7



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KEY ABBREVIATIONS AND ACRONYMS

AD	Acute retained dose
ADD	Average daily dose
ADC _{intermediate}	Intermediate Average Daily Concentration
APDR	Acute Potential Dermal Dose Rate
APF	Assigned protection factor
AWD	Annual Working Days
BBP	Butyl benzyl phthalate
BLS	Bureau of Labor Statistics
CASRN	Chemical Abstracts Service Registry Number
CDR	Chemical Data Reporting
CEB	Chemical Engineering Branch
CEHD	Chemical Exposure Health Database
CEM	Consumer Exposure Model
CFR	Code of Federal Regulations
CPS	Current Population Survey
CPSC	Consumer Product Safety Commission (U.S.)
CT	Central tendency
DD	Dermal daily dose
DMR	Discharge Monitoring Report
ECETOC TRA	European Centre for Ecotoxicology and Toxicology of Chemicals Targeted Risk Assessment
ELG	Effluent Limitation Guidelines
EPA	Environmental Protection Agency (U.S.)
ESD	Emission scenario document
GS	Generic scenario
HAP	Hazardous Air Pollutant
HE	High-end
IADD	Intermediate average daily dose
LADD	Lifetime average daily dose
LOD	Limit of detection
NAICS	North American Industry Classification System
NEI	National Emissions Inventory
NESHAP	National Emissions Standards of Hazardous Air Pollutants
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute of Occupational Safety and Health
OECD	Organisation for Economic Co-Operation and Development
OEL	Occupational exposure limit
OES	Occupational exposure scenario
OIS	Occupational Safety and Health Information System (U.S.)
ONU	Occupational non-users
OPPT	Office of Pollution Prevention and Toxics (EPA)
OSHA	Occupational Safety and Health Administration (U.S.)
PAPR	Power air-purifying respirator
PBZ	Personal breathing zone
PEL	Permissible exposure limit
PF	Protection factor
POTW	Publicly owned treatment works
PPE	Personal protective equipment

PV	Production volume
REL	Recommended exposure limits
RQ	Reportable quantity
SDS	Safety data sheet
SIC	Standard Industrial Classification
SIPP	Survey of Income and Program Participation
SpERC	Specific Emission Release Category
SAR	Supplied-air respirator
SCBA	Self-contained breathing apparatus
SRRP	Source Reduction Research Partnership
SUSB	Statistics of US Businesses
TDS	Technical data sheets
TLV	Threshold limit value
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TSD	Technical support document
TWA	Time-weighted average
U.S.	United States
WEEL	Workplace Environmental Exposure Level
WOSE	Weight of scientific evidence
WWT	Wastewater treatment

SUMMARY

This technical support document (TSD) accompanies the TSCA *Risk Evaluation for Butyl Benzyl Phthalate (BBP)* ([U.S. EPA, 2025e](#)). Currently, BBP is not a Toxics Release Inventory (TRI)-reportable substance; however, it is on the Toxic Substances Control Act (TSCA) Inventory and reported under the Chemical Data Reporting (CDR) rule. This TSD describes the use of reasonably available information to estimate environmental releases of BBP and to evaluate occupational exposures. See Appendix C of the risk evaluation for a complete list of all the TSDs and supplemental files for BBP.

Focus of the Environmental Release and Occupational Exposure Assessment

During scoping, the U.S. Environmental Protection Agency (EPA or the Agency) considered all known TSCA uses for BBP. The 2020 CDR indicated 1 to 20 million pounds (lb) of BBP (CASRN 85-68-7) were manufactured or imported in the United States in 2019 ([U.S. EPA, 2020a](#)). A review of preliminary information from 2024 CDR reveals that the total production volume for the years 2020 to 2023 falls within the previously report range from 2020 CDR. The largest number of reported uses of BBP was as a plasticizer in adhesive manufacturing. Secondary uses are as a plasticizer/additive in plastic products, paints, coatings, and other applications.

Exposures to workers, consumers, general populations, and ecological species may occur from releases of BBP to air, land, and water from industrial, commercial, and consumer uses of BBP and BBP-containing articles. Workers and occupational non-users (ONUs) may be exposed to BBP while handling solid and liquid formulations that contain BBP or during dust and mist generating activities that may be present during 11 of 16 occupational exposure scenarios (OESs) conditions of use (COUs). ONUs are those who may work in the vicinity of chemical-related activities but do not handle the chemicals themselves, such as managers or inspectors. This TSD provides the details of the assessment of the environmental releases and occupational exposures from each COU of BBP.

Approach for Environmental Releases and Occupational Exposures Assessment

EPA evaluated environmental releases and occupational exposures for each occupational exposure scenario (OES). Each OES is developed based on a set of occupational activities and conditions such that similar occupational exposures and environmental releases are expected from the use(s) covered under the OES. For each OES, EPA provided occupational exposure and environmental release results, which are expected to be representative of the entire population of workers and sites for the given OES in the United States.

EPA evaluated environmental releases of BBP to air, water, and land from the OES associated with the COUs assessed in this risk evaluation. EPA reviewed release data from Discharge Monitoring Report (DMR; data from 2017–2022) to identify relevant releases of BBP to the environment. These sources provide site-specific release information based on measurements, mass balances, or emission factors. In addition, EPA also considered other relevant release data to fill data gaps from other peer-reviewed or literature sources identified through systematic review. For OESs without any release data, EPA used modeling approaches to assess release estimates.

EPA evaluated acute, intermediate, and chronic exposures to workers and ONUs for each OES. The Agency identified and used inhalation monitoring data from literature sources for some of the OESs, and exposure models were used where monitoring data were not available, or these data were deemed insufficient for capturing exposures within the OES. EPA also used *ex vivo* human skin absorption data to estimate dermal exposures to workers and ONUs.

Results for Environmental Releases and Occupational Exposures in this Assessment

EPA evaluated environmental releases of BBP to air, water, and/or land for all OESs assessed in this risk evaluation. The OES with the highest expected release was Application of adhesives and sealants, followed by Application of paints and coatings, then by Formulation of adhesives and sealants. Detailed release results for each OES to each media can be found in Appendix 3.

EPA also evaluated inhalation and dermal exposures to worker populations, including ONUs and females of reproductive age, for each OES. Due to the low vapor pressure and low rate of dermal absorption of BBP, the occupational exposure assessment has shown that inhalation and dermal exposures to BBP from most industrial and commercial OES are expected to be moderate—primarily driven by dermal exposures to liquid BBP or inhalation exposure to dust particulate containing BBP. Detailed exposure results for each OES and exposure route can be found in Section 3.

Uncertainties of this Assessment

Uncertainties exist with the monitoring data and modeling approaches used to assess BBP environmental releases and occupational exposures. One factor of uncertainty includes the accuracy of the reported releases as well as the limitations in representativeness to all U.S. sites because DMR data may not capture all relevant sites due to variations in permit requirements. For modeled releases, the lack of BBP facility production volume data adds uncertainty; in such cases, EPA used throughput estimates based on CDR reporting thresholds, which may result in production volume estimates that are not representative of the actual production volume of BBP in the United States. The Agency also used generic EPA models and default input parameter values when site-specific data were not available. In addition, site-specific differences in use practices and engineering controls exist but are largely unknown. This represents another source of variability that EPA could not quantify in the assessment.

Use of the Results for Environmental Releases and Occupational Exposures – Environmental and Exposure Pathways Considered in this Assessment and Risk Evaluation

EPA assessed environmental releases to air, water, and land to estimate exposures to the general population and ecological species for BBP COUs. The environmental release estimates developed by the Agency are used to estimate the presence of BBP in the environment and biota and evaluate the environmental hazards. The release estimates were used to model exposure to the general population and ecological species where environmental monitoring data were not available.

EPA assessed risks for acute, intermediate, and chronic exposure scenarios in workers (those directly handling BBP) and ONUs for each OES. An objective of the assessment was to provide separate exposure level estimates for workers and ONUs. Dermal exposures were considered for all workers but only considered for ONUs with potential exposure to dust or mist deposited on surfaces.

1 INTRODUCTION

1.1 Overview

This TSD supports the TSCA *Risk Evaluation for Butyl Benzyl Phthalate (BBP)* (also called the “risk evaluation”) ([U.S. EPA, 2025e](#)) conducted for BBP under the Frank R. Lautenberg Chemical Safety for the 21st Century Act. The Frank R. Lautenberg Chemical Safety for the 21st Century Act amended TSCA on June 22, 2016. The amended law includes statutory requirements and deadlines for actions related to conducting risk evaluations of existing chemicals.

Under TSCA section 6(b), the EPA must designate chemical substances as high-priority substances for risk evaluation or low-priority substances for which risk evaluations are not warranted at the time, and upon designating a chemical substance as a high-priority substance, initiate a risk evaluation on the substance. TSCA section 6(b)(4) directs EPA to conduct risk evaluations for existing chemicals, to “determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator under the conditions of use.”

TSCA section 6(b)(4)(D) and implementing regulations require that EPA publish the scope of the risk evaluation to be conducted, including the hazards, exposures, conditions of use and PESS that the Administrator expects to consider, within 6 months after the initiation of a risk evaluation. In addition, a draft scope is to be published pursuant to 40 CFR 702.41. In December 2019, EPA published a list of 20 chemical substances that have been designated high priority substances for risk evaluations (Docket ID: [EPA-HQ-OPPT-2019-0131](#)) (84 FR 71924, December 30, 2019), as required by TSCA section 6(b)(2)(B), which initiated the risk evaluation process for those chemical substances. Butyl benzyl phthalate (BBP) is one of the chemicals designated as a high priority substance for risk evaluation.

BBP is a common chemical name for a chemical substance that includes the following names: benzyl butyl phthalate (CASRN 85-68-7), 1,2-benzenedicarboxylic acid, butyl phenylmethyl ester, and benzyl butyl benzene-1,2-dicarboxylate. BBP is a low volatility liquid that is used as a plasticizer in PVC and as an additive in adhesives, sealants, paints, coatings, lubricants, non-PVC materials and for other applications. All uses are subject to federal and state regulations and reporting requirements. BBP is not a TRI-reportable substance; however, it is on the TSCA Inventory and reported under the CDR rule.

1.2 Scope

EPA assessed environmental releases and occupational exposures for conditions of use as described in Table 2-2 of the *Final Scope of the Risk Evaluation for Butyl Benzyl Phthalate (BBP); CASRN 85-68-7* ([U.S. EPA, 2020b](#)). To estimate environmental releases and occupational exposures, EPA first developed OES related to the conditions of use of BBP. An OES is based on a set of facts, assumptions, and inferences that describe how releases and exposures take place within an occupational condition of use. The occurrence of releases/exposures may be similar across multiple conditions of use, or there may be several ways in which releases/exposures take place for a given condition of use. Table 1-1 of this document maps the conditions of use in Table 2-2 of the risk evaluation ([U.S. EPA, 2025d](#)) to the OESs assessed in this TSD.

In general, EPA mapped OESs to conditions of use using professional judgment based on available data and information. Several of the condition of use categories and subcategories were grouped and assessed

together in a single OES due to similarities in the processes or lack of data to differentiate between them. This grouping minimized repetitive assessments. In other cases, condition of use subcategories were further delineated into multiple OESs based on expected differences in process equipment and associated release/exposure potential between facilities. EPA assessed environmental releases and occupational exposures for the following OESs:

1. Manufacturing
2. Import and repackaging (liquids and solids)
3. Formulation into adhesives and sealants (liquids and solids)
4. Formulation into paints and coatings
5. Incorporation into other formulations, mixtures, or reaction products
6. PVC plastics compounding
7. PVC plastics converting
8. Non-PVC material compounding (liquids and solids)
9. Non-PVC material converting
10. Application of adhesives and sealants
11. Application of paints and coatings (with and without spray control)
12. Use of laboratory chemicals (liquids and solids)
13. Use of lubricants and functional fluids
14. Fabrication or use of final products and articles
15. Recycling
16. Waste handling, treatment, and disposal
17. Distribution in commerce

Table 1-1. Crosswalk of COUs Listed in the Risk Evaluation to Assessed Occupational Exposure Scenarios

Life Cycle Stage ^a	COU		OES ^d
	Category ^b	Subcategory ^c	
Manufacturing	Domestic manufacturing	Domestic manufacturing	Manufacturing
	Importing	Importing	Import and repackaging
Processing	Repackaging	Repackaging	Import and repackaging
	Processing – incorporation into formulation, mixture, or reaction product	Fillers (<i>e.g.</i> , in custom compounding of purchased resin)	PVC plastics compounding; Non-PVC materials compounding
		Plasticizer in: - Adhesive manufacturing - Paint and coating manufacturing - Printing ink manufacturing - All other basic inorganic chemical manufacturing	Formulation into adhesives and sealants; Formulation into paints and coatings; Incorporation into other formulation, mixture, or reaction products
		Laboratory chemical manufacturing	Incorporation into other formulations, mixtures, or reaction products
		Biocide carrier manufacturing	Incorporation into other formulations, mixtures, or reaction products
	Processing – incorporation into articles	Plasticizer in: - Asphalt paving, roofing, and coating materials manufacturing - Fabric, textile, and leather products not covered elsewhere manufacturing - Floor coverings manufacturing - Plastic product manufacturing - Rubber product manufacturing - Textiles, apparel, and leather manufacturing - Transportation equipment manufacturing	Formulation into paints and coatings; PVC plastics converting; Non-PVC material converting
	Recycling	Recycling	Recycling
Distribution	Distribution in commerce	Distribution in commerce	Distribution in commerce
Industrial Use	Adhesives and sealants	Adhesives and sealants	Application of adhesives and sealants
	Automotive, fuel, agriculture, outdoor use products	Automotive care products	Application of adhesives and sealants; Application of paints and coatings
	Castings	Castings	Non-PVC material compounding; Non-PVC material converting

COU			OES ^d
Life Cycle Stage ^a	Category ^b	Subcategory ^c	
	Construction, paint, electrical, and metal products	Building construction materials not covered elsewhere	Fabrication of final product from articles
	Floor coverings	Floor coverings	Application of paints and coatings
	Furnishing, cleaning, treatment/care products	Fabric, textile, and leather products not covered elsewhere	Application of paints and coatings
	Inks, toner and colorant products	Inks, toner and colorant products (<i>e.g.</i> , screen printing ink)	Application of paints and coatings
	Plastic and rubber products not covered elsewhere	Plastic and rubber products not covered elsewhere	PVC plastics converting; Non-PVC material converting
	Other uses	Chemical intermediate	Incorporation into other formulations, mixtures, or reaction products
		Laboratory chemical	Use of laboratory chemicals
		Plastic and rubber products not covered elsewhere (<i>e.g.</i> , component of compound (resin) used to cast models)	PVC plastics converting; Non-PVC material converting
	Hydraulic fluids	Hydraulic fluids	Use of lubricants and functional fluids
Commercial Use	Adhesives and sealants	Adhesives and sealants	Application of adhesives and sealants
	Automotive, fuel, agriculture, outdoor use products	Automotive care products	Application of adhesives and sealants; Application of paints and coatings
	Castings	Castings	Non-PVC material compounding; Non-PVC material converting
	Floor coverings	Floor coverings	Application of paints and coatings
	Construction, paint, electrical, and metal products	Building/construction materials not covered elsewhere	Fabrication of final product from articles
	Furnishing, cleaning, treatment/care products	Fabric, textile, and leather products not covered elsewhere	Fabrication of final product from articles
	Inks, toner and colorant products	Inks, toner and colorant products	Application of paints and coatings
	Laboratory chemical	Laboratory chemical	Use of laboratory chemicals

COU			OES ^d
Life Cycle Stage ^a	Category ^b	Subcategory ^c	
	Paints and coatings	Paints and coatings	Application of paints and coatings
	Plastic and rubber products not covered elsewhere	Plastic and rubber products not covered elsewhere	Fabrication of final product from articles
	Other uses	Chemical intermediate	Incorporation into other formulations, mixtures, or reaction products
		Plastic and rubber products not covered elsewhere (e.g., component of compound (resin) used to cast models)	Non-PVC material converting
Disposal	Disposal	Disposal	Waste handling, treatment, and disposal
^a Life Cycle Stage Use Definitions (40 CFR 711.3) “Industrial Use” means use at a site at which one or more chemicals or mixtures are manufactured (including imported) or processed. “Commercial Use” means the use of a chemical or a mixture containing a chemical (including as part of an article) in a commercial enterprise providing saleable goods or services. “Consumer Use” means the use of a chemical or a mixture containing a chemical (including as part of an article, such as furniture or clothing) when sold to or made available to consumers for their use. - Although EPA has identified both industrial and commercial uses here for purposes of distinguishing scenarios in this document, the Agency interprets the authority over “any manner or method of commercial use” under TSCA Section 6(a)(5) to reach both. ^b These categories of conditions of use appear in the Life Cycle Diagram, reflect CDR codes, and broadly represent conditions of use of <i>dibutyl phthalate</i> in industrial and/or commercial settings. ^c These subcategories represent more specific activities within the life cycle stage and category of the conditions of use of DBP. ^d An OES is based on a set of facts, assumptions, and inferences that describe how releases and exposures take place within an occupational condition of use. The occurrence of releases/exposures may be similar across multiple conditions of use (multiple COUs mapped to single OES), or there may be several ways in which releases/exposures take place for a given condition of use (single COU mapped to multiple OESs).			

The assessment of releases includes quantifying annual and daily releases of BBP to air, water, and land. Releases to air include both fugitive and stack air emissions and emissions resulting from on-site waste treatment equipment, such as incinerators. For the purposes of this assessment, releases to water include both direct discharges to surface water and indirect discharges to publicly owned treatment works (POTW) or non-POTW wastewater treatment (WWT). EPA considers removal efficiencies of POTWs and WWT plants as well as environmental fate and transport properties when evaluating risks from indirect discharges. Releases to land include any disposal of liquid or solid wastes containing BBP into landfills, land treatment, surface impoundments, or other land applications. The purpose of this module is to quantify releases; therefore, this report does not discuss downstream environmental fate and transport factors used to estimate exposures to the general population and ecological species. The *Risk Evaluation for Butyl Benzyl Phthalate (BBP)* ([U.S. EPA, 2025d](#)) describes how these factors were considered when determining risk.

For workplace exposures, EPA considered exposures to both workers who directly handle BBP and occupational non-users (ONUs) who do not directly handle BBP, but may be exposed to dust, vapors or mists that enter their breathing zone while working in locations near BBP handling. EPA evaluated

inhalation and dermal exposures to both workers and ONUs. EPA has performed a quantitative estimation on the effect of Personal Protective Equipment (PPE) on worker exposure risk estimates. The effect of PPE on occupational risk estimates is discussed in the BBP risk evaluation ([U.S. EPA, 2025d](#)) and the calculations can be found in the *Risk Calculator for Occupational Exposures for Butyl Benzyl Phthalate (BBP)* ([U.S. EPA, 2025c](#)).

2 COMPONENTS OF AN OCCUPATIONAL EXPOSURE AND RELEASE ASSESSMENT

EPA describes the assessed COUs for BBP in the Section 1.1.2 of the *Risk Evaluation for Butyl Benzyl Phthalate (BBP)* ([U.S. EPA, 2025d](#)); however, some COUs differ in terms of specific BBP processes and associated exposure/release scenarios. Therefore, Table 1-1 provides a crosswalk that maps the BBP COUs to the more specific OESs. The environmental release and occupational exposure assessments of each OES comprised the following components:

- **Process Description:** A description of the OES, including the function of the chemical in the scenario; physical forms and weight fractions of the chemical throughout the process; the total production volume associated with the OES; per site throughputs/use rates of the chemical; operating schedules; and process equipment used during the OES.
- **Facility Estimates:** An estimate of the number of sites that use BBP for the given OES.
- **Environmental Release Assessment**
 - **Environmental Release Sources:** A description of the potential sources of environmental releases in the process and their expected media of release for the OES.
 - **Environmental Release Assessment Results:** Estimates of BBP released into each environmental media (*i.e.*, surface water, POTW, non POTW-WWT, fugitive air, stack air, and each type of land disposal) for the given OES.
- **Occupational Exposure Assessment**
 - **Worker Activities:** A description of the worker activities, including an assessment of potential worker and ONU exposure points.
 - **Occupational Inhalation Exposure Results:** Central tendency and high-end estimates of inhalation exposures to workers and ONUs.
 - **Occupational Dermal Exposure Results:** Central tendency and high-end estimates of dermal exposures to workers and ONUs.
 - **Aggregate Exposure Results:** Aggregated central tendency and high-end estimates from the combination of dermal and inhalation exposures.

2.1 Approach and Methodology for Process Descriptions

EPA performed a literature search to find descriptions of processes involved in each OES. Where data were available to do so, EPA included the following information in each process description:

- Total production volume associated with the OES;
- Name and location of sites where the OES occurs;
- Facility operating schedules (*e.g.*, year-round, 5 days/week, batch process, continuous process, multiple shifts);
- Key process steps;
- Physical form and weight fraction of the chemical throughout the process;
- Information on receiving and shipping containers; and
- Ultimate destination of chemical leaving the facility.

Where BBP-specific process descriptions were unclear or not available, EPA referenced generic process descriptions from literature, including relevant emission scenario documents (ESD) or generic scenarios (GS). Sections 3.1 through 3.16 provide process descriptions for each OES.

2.2 Approach and Methodology for Estimating Number of Facilities

To estimate the number of facilities within each OES, EPA used a combination of bottom-up analyses of EPA reporting programs and top-down analyses of U.S. economic data and industry-specific data. Generally, EPA used the following steps to develop facility estimates:

1. Identify or “map” each facility that reported BBP in the 2016 and 2020 CDR ([U.S. EPA, 2020a](#)) and 2017 through 2022 DMR ([U.S. EPA, 2024a](#)) to an OES. Mapping consists of using facility reported industry sectors (typically reported as either North American Industry Classification System [NAICS] or Standard Industrial Classification [SIC] codes), chemical activity, and processing and use information to assign the most likely OES to each facility.
2. Based on the reporting thresholds and requirements of each data set, evaluate whether the data in the reporting programs is expected to cover most or all the facilities within the OES. If so, the total number of facilities in the OES were assumed equal to the count of facilities mapped to the OES from each data set. If not, EPA proceeded to Step 3.
3. Supplement the available reporting data with U.S. economic and market data using the following steps:
 - a. Identify the NAICS codes for the industry sectors associated with the OES.
 - b. Estimate total number of facilities using the U.S. Census’ Statistics of US Businesses (SUSB) data on total sites by 6-digit NAICS code.
 - c. Use market penetration data to estimate the percentage of sites likely to be using BBP instead of other chemicals.
 - d. Combine the data generated in Steps 3.a. through 3.c. to produce an estimate of the number of facilities using BBP in each 6-digit NAICS code and sum across all applicable NAICS codes to arrive at an estimate of the total number of facilities within the OES. Typically, it was assumed that this estimate encompassed the facilities identified in Step 1; therefore, the total number of facilities for the OES were assessed as the total generated from the analysis.
4. If market penetration data required for Step 3.c. are not available, EPA relied on generic industry data from GSs, ESDs, and other literature sources on typical throughputs/use rates, operating schedules, and the BBP production volume used within the OES to estimate the number of facilities. In cases where EPA identified a range of operating data in the literature for an OES, stochastic modeling was used to provide a range of estimates for the number of facilities within the OES. The approaches, equations, and input parameters used in stochastic modeling are described in the relevant OES sections throughout this report.

2.3 Environmental Releases Approach and Methodology

Releases to the environment were assessed using data obtained through direct measurement via monitoring, calculations based on empirical data, and/or assumptions and models. For each OES, EPA provided annual releases, high-end and central tendency daily releases, and the number of release days per year for each media of release (*i.e.*, air, water, and land).

EPA used the following hierarchy, laid out in the *Application of Systematic Review in TSCA Risk Evaluations* ([U.S. EPA, 2021a](#)), in selecting data and approaches for assessing environmental releases:

1. Monitoring and measured data:
 - a. Releases calculated from site- and media-specific concentration and flow rate data.

- b. Releases calculated from mass balances or emission factor methods using site-specific measurements.
2. Modeling approaches:
 - a. Surrogate release data
 - b. Fundamental modeling approaches
 - c. Statistical regression modeling approaches
3. Release limits:
 - a. Company-specific limits
 - b. Regulatory limits (*e.g.*, National Emission Standards for Hazardous Air Pollutants [NESHAPs] or effluent limitations/requirements).

EPA described the final release results as either a point estimate (*i.e.*, a single descriptor or statistic, such as central tendency or high-end) or a full distribution. EPA considered three general approaches for estimating the final release result:

- **Deterministic calculations:** A combination of point estimates of each input parameter (*e.g.*, high-end and low-end values) were used to estimate central tendency and high-end release results. EPA documented the method and rationale for selecting parametric combinations representative of central tendency and high-end releases in the relevant OES subsections in Section 3.
- **Probabilistic (stochastic) calculations:** EPA ran Monte Carlo simulations using the statistical distribution for each input parameter to calculate a full distribution of the final release results. EPA selected the 50th and 95th percentiles of the resulting distribution to represent central tendency and high-end releases, respectively.
- **Combination of deterministic and probabilistic calculations:** EPA had statistical distributions for some parameters and point estimates for the remaining parameters. For example, EPA used Monte Carlo modeling to estimate annual throughputs and emission factors, but only had point estimates of release frequency and production volume. In this case, EPA documented the approach and rationale for combining point estimates with statistical distributions to estimate central tendency and high-end results in the relevant OES subsections in Sections 3.1 through 3.16.

2.3.1 Identifying Release Sources

EPA performed a literature search to identify process operations that could potentially result in releases of BBP to air, water, or land from each OES. For each OES, EPA identified the release sources and the associated media of release. Where BBP-specific release sources were unclear or unavailable, EPA referenced relevant ESDs or GSs. Sections 3.1 through 3.16 describe the release sources for each OES.

2.3.2 Estimating Number of Release Days

Unless EPA identified conflicting information, EPA assumed that the number of release days per year for a given release source equals the number of operating days at the facility. To estimate the number of operating days, EPA used the following hierarchy:

1. **Facility-specific data:** EPA used facility-specific operating days per year data, if available. Otherwise, EPA used data for other facilities within the same OES, if possible. EPA estimated the operating days per year using one of the following approaches:

- a. If other facilities have known or estimated average daily use rates, EPA calculated the days per year as: $\text{days/year} = \text{estimated annual use rate for the facility (kg/year)} / \text{average daily use rate from facilities with available data (kg/day)}$.
 - b. If facilities with days per year data do not have known or estimated average daily use rates, EPA used the average number of days per year from the facilities with available data.
2. **Industry-specific data:** EPA used industry-specific data from GSs, ESDs, trade publications, or other relevant literature.
3. **Manufacture of large-production volume (PV) commodity chemicals:** For the manufacture of the large-PV commodity chemicals, EPA used a value of 350 days per year. This assumes the plant runs seven days per week and 50 weeks per year (with two weeks down for turnaround) and always produces the chemical.
4. **Manufacture of lower-PV specialty chemicals:** For the manufacture of lower-PV specialty chemicals, it is unlikely that the plant continuously manufactures the chemical throughout the year. Therefore, EPA used a value of 250 days per year. This assumes the plant manufactures the chemical 5 days per week and 50 weeks per year (with two weeks down for turnaround).
5. **Other chemical plant OESs:** For these OESs, EPA assumed that the facility does not always use the chemical of interest, even if the facility operates 24 hours a day for 7 days a week. Therefore, EPA used a value of 300 days/year, based on the assumption that the facility operates 6 days/week and 50 weeks/year (with 2 weeks for turnaround). However, in instances where the OES uses a low volume of the chemical of interest, EPA used 250 days per year as a lower estimate based on the assumption that the facility operates 5 days/week and 50 weeks/year (with 2 weeks for turnaround).
6. **POTWs:** Although EPA expects POTWs to operate continuously 365 days per year, the discharge frequency of the chemical of interest from a POTW will depend on the discharge patterns of the chemical from upstream facilities discharging to the POTW. However, there can be multiple upstream facilities (possibly with different OESs) discharging to the same POTW and information on when the discharges from each facility occur (*e.g.*, on the same day or separate days) is typically unavailable. Since EPA could not determine the exact number of days per year that the POTW discharges the chemical of interest, a value of 365 days per year was assumed.
7. **All Other OESs:** Regardless of the facility operating schedule, other OESs are unlikely to use the chemical of interest every day. Therefore, EPA used a value of 250 days per year for these OESs.

2.3.3 Estimating Releases from Data Reported to EPA

Of the various reporting databases (*e.g.*, Toxics Release Inventory [TRI], National Emissions Inventory [NEI], Discharge Monitoring Reports [DMR]), BBP release data were only available in DMR because BBP has not been a TRI-listed chemical since 1993. EPA's use of DMR data in this risk evaluation is described further below.

Under the Clean Water Act (CWA), EPA regulates the discharge of pollutants into receiving waters through National Pollutant Discharge Elimination System (NPDES). A NPDES permit authorizes discharging facilities to discharge pollutants to specified effluent limits. There are two types of effluent limits: (1) technology-based and (2) water quality-based. Although the technology-based effluent limits

are uniform across the country, the quality-based effluent limits vary and are more stringent in certain areas. NPDES permits may also contain requirements for sewage sludge management.

NPDES permits apply pollutant discharge limits to each outfall at a facility. NPDES permits also include internal outfalls, but they are not included in this analysis. This is because these outfalls are internal monitoring points within the facility wastewater collection or treatment system, so they do not represent discharges from the facility. As such, for risk evaluation purposes, EPA was interested only in the outfalls to surface water bodies. NPDES permits require facilities to monitor their discharges and report the results to EPA and the state regulatory agency. Facilities report these results in DMRs. EPA makes these reported data publicly available via EPA's Enforcement and Compliance History Online (ECHO) system and EPA's Water Pollutant Loading Tool (Loading Tool). The Loading Tool is a web-based tool that obtains DMR data through ECHO, presents data summaries and calculates pollutant loading (mass of pollutant discharged). For this risk evaluation, EPA queried DMRs for all BBP point source water discharges available for 2017 to 2022 ([U.S. EPA, 2024a](#)).

Generally, EPA used the facility-specific release data reported in DMR as annual releases for each site and estimated the daily release by averaging the annual release over the expected release days per year. EPA's approach to estimating release days per year is previously described in Section 2.3.2.

2.3.4 Estimating Releases from Models

EPA utilized models to estimate environmental releases for OESs without TRI, DMR, or NEI data. These models apply deterministic calculations, stochastic calculations, or a combination to estimate releases. EPA used the following steps to estimate releases:

1. Identify release sources and associated release media for each relevant process.
2. Identify or develop model equations for estimating releases from each source.
3. Identify model input parameter values from relevant literature sources.
4. If a range of input values is available for an input parameter, determine the associated distribution of input values.
5. Calculate annual and daily release volumes for each release source using input values and model equations.
6. Aggregate release volumes by release media and report total releases to each media from each facility.

For release models that utilized stochastic calculations, EPA performed a Monte Carlo simulation using the Palisade @Risk version 8.0 software with 100,000 iterations and the Latin Hypercube sampling method ([Palisade, 2022](#)). Appendix D provides detailed descriptions of the model approaches that EPA used for each OES as well as model equations, input parameter values, and associated distributions.

For some modeled releases, the media of release is dependent on site- and process-specific practices that are unknown due to lack of reasonably available information. To account for this uncertainty, these release estimates may be assessed to groups of multiple release medias based on the release point and the chemical's physical form (i.e. water, incineration, or landfill or air, water, incineration, or landfill) to account for all possible chemical waste endpoints.

The Science Advisory Committee on Chemicals (SACC) agreed with the use of generic scenarios to generate release estimates in the absence of data. When EPA released the draft Risk Evaluation for BBP, EPA acknowledged the data gap in the environmental release data and solicited alternative data sources from the public. However, no additional data sources were provided during the public comment period.

BBP is listed as a hazardous constituent in Appendix VIII of Part 261 of RCRA; therefore, wastes sent for disposal or treatment via landfill or incineration refer to hazardous waste landfills and hazardous waste incineration, respectively.

2.4 Occupational Exposure Approach and Methodology

For workplace exposures, EPA considered exposures to both workers who directly handle BBP and ONUs who do not directly handle BBP but may be exposed to vapors, particulates, or mists that enter their breathing zone while working in locations near BBP handling. EPA evaluated inhalation and dermal exposures to both workers and ONUs.

EPA provided occupational exposure results representative of central tendency and high-end exposure conditions. The central tendency is expected to represent occupational exposures in the center of the distribution for a given COU. For risk evaluation, EPA used the 50th percentile (median), mean (arithmetic or geometric), mode, or midpoint values of a distribution as representative of the central tendency scenario. EPA preferred to provide the 50th percentile of the distribution. However, if the full distribution is unknown, EPA may assume that the mean, mode, or midpoint of the distribution represents the central tendency depending on the statistics available for the distribution.

The high-end exposure is expected to be representative of occupational exposures that occur at probabilities above the 90th percentile, but below the highest exposure for any individual ([U.S. EPA, 1992a](#)). For risk evaluation, EPA provided high-end results at the 95th percentile. If the 95th percentile is not reasonably available, EPA used a different percentile greater than or equal to the 90th percentile but less than or equal to the 99.9th percentile, depending on the statistics available for the distribution. If the full distribution is not known and the preferred statistics are not reasonably available, EPA estimated a maximum or bounding estimate in lieu of the high-end.

For occupational exposures, EPA used measured or estimated air concentrations to calculate exposure concentration metrics required for risk assessment, such as average daily dose (ADD). These calculations require additional parameter inputs, such as years of exposure, exposure duration and exposure frequency. EPA estimated exposure concentrations from monitoring data, modeling, or occupational exposure limits.

For the final exposure result metrics, each of the input parameters (*e.g.*, air concentrations, working years, exposure frequency) may be a point estimate (*i.e.*, a single descriptor or statistic, such as central tendency or high-end) or a full distribution. EPA considered three general approaches for estimating the final exposure result metrics:

- **Deterministic calculations:** EPA used combinations of point estimates of each parameter to estimate a central tendency and high-end for each final exposure metric result.
- **Probabilistic (stochastic) calculations:** EPA used Monte Carlo simulations using the full distribution of each parameter to calculate a full distribution of the final exposure metric results and selecting the 50th and 95th percentiles of this resulting distribution as the central tendency and high-end, respectively.
- **Combination of deterministic and probabilistic calculations:** EPA had full distributions for some parameters but point estimates of the remaining parameters. For example, EPA used Monte Carlo modeling to estimate exposure concentrations, but only had point estimates of exposure duration and frequency.

Appendix A discusses the equations and input parameter values that EPA used to estimate each exposure metric.

For each OES, EPA provided high-end and central tendency, full-shift time-weighted average (TWA) (typically as an 8-hour TWA) inhalation exposure concentrations as well as high-end and central tendency acute potential dermal dose rates (APDR). EPA applied the following hierarchy in selecting data and approaches for assessing occupational exposures:

1. Monitoring data:
 - a. Personal and directly applicable to the OES
 - b. Area and directly applicable to the OES
 - c. Personal and potentially applicable or similar to the OES
 - d. Area and potentially applicable or similar to the OES
2. Modeling approaches:
 - a. Surrogate monitoring data (data from a different chemical and same use) or analogous monitoring data (data from the same chemical and similar use to the OES)
 - b. Fundamental modeling approaches
 - c. Statistical regression modeling approaches
3. Occupational exposure limits:
 - a. Company-specific occupational exposure limits (OELs) (for site-specific exposure assessments, *e.g.*, there is only one manufacturer who provides their internal OEL to EPA, but the manufacturer does not provide monitoring data)
 - b. Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL)
 - c. Voluntary limits (*i.e.*, American Conference of Governmental Industrial Hygienists [ACGIH] Threshold Limit Values [TLV], National Institute for Occupational Safety and Health [NIOSH] Recommended Exposure Limits [REL], Occupational Alliance for Risk Science (OARS) workplace environmental exposure level (WEEL) [formerly by AIHA])

EPA used the estimated high-end and central tendency, full-shift TWA inhalation exposure concentrations and APDR to calculate the exposure metrics required for risk evaluation. Exposure metrics for inhalation and dermal exposures include acute dose (AD), intermediate average daily dose (IADD), and ADD. Appendix A describes the approach that EPA used to estimating each exposure metric.

2.4.1 Identifying Worker Activities

EPA performed a literature search and reviewed data from systematic review to identify worker activities that could potentially result in occupational exposures. Where worker activities were unclear or not available, EPA referenced relevant ESDs or GSs. Section 3 provides worker activities for each OES.

2.4.2 Estimating Inhalation Exposures

2.4.2.1 Inhalation Monitoring Data

To assess inhalation exposure, EPA reviewed workplace inhalation monitoring data collected by government agencies such as OSHA and NIOSH, monitoring data found in published literature (*i.e.*, personal exposure monitoring data and area monitoring data), and monitoring data submitted via public comments. Studies were evaluated using the strategies laid out in the *Application of Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances, Version 1.0: A Generic TSCA*

Systematic Review Protocol with Chemical-Specific Methodologies (also called “2021 Systematic Review Protocol”) ([U.S. EPA, 2021a](#)).

EPA calculated exposures from the monitoring datasets provided in the sources discussed above, using different methodologies depending on the size of the dataset. For datasets with six or more data points, The Agency estimated central tendency and high-end exposures using the 50th and 95th percentile values, respectively. For datasets with three to five data points, EPA estimated the central tendency and high-end exposures using the 50th percentile and maximum values, respectively. For datasets with two data points, EPA presented the midpoint and the maximum value. Finally, EPA presented datasets with only one data point as-is. For datasets that included exposure data reported as below the limit of detection (LOD), EPA estimated exposure concentrations following guidance in EPA’s *Guidelines for Statistical Analysis of Occupational Exposure Data* ([U.S. EPA, 1994](#)). That report recommends using the $\frac{LOD}{\sqrt{2}}$ if the geometric standard deviation of the data is less than 3.0 and $\frac{LOD}{2}$ if the geometric standard deviation is 3.0 or greater.

If the 8-hour TWA personal breathing zones (PBZ) monitoring samples were not available, area samples were used for exposure estimates. EPA combined the exposure data from all studies applicable to a given OES into a single dataset.

For each COU, EPA endeavors to distinguish exposures for workers and ONUs. Normally, a primary difference between workers and ONUs is that workers may handle BBP and have direct contact with the chemical, while ONUs are working in the general vicinity of workers but do not handle BBP and do not have direct contact with BBP being handled by the workers. EPA recognizes that worker job titles and activities may vary significantly from site to site; therefore, EPA typically identified samples as worker samples unless it was explicitly clear from the job title (*e.g.*, inspectors) and the description of activities in the report that the employee was not directly involved in the scenario. Samples from employees determined not to be directly involved in the scenario were designated as ONU samples.

OSHA Chemical Exposure Health Data

OSHA CEHD (Chemical Exposure Health Data) is collected through industrial hygiene samples taken by OSHA compliance officers during monitoring of worker exposures to chemical hazards. OSHA CEHD represents a reasonably available source of information to obtain monitoring data and has received a rating of high from EPA’s systematic review process. Air sampling data records from inspections are entered into the OSHA CEHD that can be [accessed online](#). The database includes PBZ monitoring data, area monitoring data, bulk samples, wipe samples, and serum samples. The collected samples are used for comparing to OSHA’s PELs and STELs. OSHA’s CEHD website indicates that they do not (1) perform routine inspections at every business that uses toxic/hazardous chemicals, (2) completely characterize all exposures for all employees every day, or (3) always obtain a sample for an entire shift. Rather, OSHA performs targeted inspections of certain industries based on national and regional emphasis programs, often attempts to evaluate worst case chemical exposure scenarios, and develops “snapshots” of chemical exposures and assess their significance (*e.g.*, comparing measured concentrations to the regulatory limits).

EPA took the following approach to analyzing OSHA CEHD:

1. **Downloaded monitoring data for BBP from 1992 to 2022.** See Section 2.6 for evidence integration notes on targeted years.
2. **Organized data by site** (*i.e.*, grouped data collected at the same site together).

3. **Removed data in which all measurements taken at the site were recorded as “0” or below the LOD.** EPA could not determine what test method was used by OSHA and thus unable to determine the LOD to be used for substitution.
4. **Removed serum samples, bulk samples, wipe samples, and blanks.** These data are not used in EPA’s assessment.
5. **Assigned each data point to an OES.** Review NAICS codes, SIC codes, and as needed, company information available online, to map each sample to an OES. In some instances, EPA was unable to determine the OES from the information in the CEHD; in such cases, EPA did not use the data in the assessment. EPA also removed data determined to be likely for non-TSCA uses or otherwise out of scope.
6. **Combined samples from the same worker.** In some instances, OSHA inspectors will collect multiple samples from the same worker on the same day (these are indicated by sample ID numbers). In these cases, EPA combined results from all samples for a particular sample ID to construct an exposure concentration based on the totality of exposures from each worker.
7. **Calculated 8-hour TWA results from combined samples.** Where the total sample time was less than 8 hours (480 minutes), but greater than 330 minutes, EPA calculated an 8-hour TWA by assuming exposures were zero for the remainder of the shift. For any calculated 8-hour TWA exposures that were equal to zero or non-detects, EPA replaced this value with the LOD divided by either two or the square root of two (see step 7). EPA did consider all samples for 8-hour TWA that were marked ‘eight-hour calculation used’ in the OSHA CEHD database with no adjustment.

OSHA CEHD does not provide job titles or worker activities associated with the samples; therefore, EPA assumed all data were collected on workers and not ONUs.

Specific details related to the use of monitoring data for each COU can be found in Sections 3.1 through 3.16.

2.4.2.2 Inhalation Exposure Modeling

Where inhalation exposures are expected for an OES, but monitoring data were either unavailable or EPA determined that the monitoring data did not sufficiently capture the exposures for an OES, EPA utilized models (See Appendix D) to estimate inhalation exposures. These models apply deterministic calculations, stochastic calculations, or a combination of both deterministic and stochastic calculations to estimate inhalation exposures. EPA used the following steps to estimate exposures for each OES:

1. Identify worker activities and potential sources of exposures from each process.
2. Identify or develop model equations for estimating exposures from each source.
3. Identify model input parameter values from relevant literature sources, including activity durations associated with sources of exposures.
4. If a range of input values is available for an input parameter, determine the associated distribution of input values.
5. Calculate exposure concentrations associated with each activity.
6. Calculate full-shift TWAs based on the exposure concentration and activity duration associated with each exposure source.
7. Calculate exposure metrics (AD, IADD, ADD) from full-shift TWAs.

For exposure models that utilize stochastic calculations, EPA performed a Monte Carlo simulation using the Palisade @Risk software with 100,000 iterations and the Latin Hypercube sampling method.

Appendix D provides detailed descriptions of the model approaches used for each OES, model equations, and input parameter values and associated distributions.

2.4.3 Estimating Dermal Exposures

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. Dermal data were sufficient to characterize occupational dermal exposures to liquids or formulations containing BBP (Section 2.4.3.2) as well as solids containing BBP (Section 2.4.3.3). 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.

2.4.3.1 Dermal Absorption Data

Dermal absorption data for BBP were identified in the literature. EPA identified four studies directly related to the dermal absorption of BBP. Of the four available studies, EPA identified one study ([DuPont, 2006a](#)) that was most reflective of BBP exposure from solid products. Another study ([DuPont, 2006b](#)) was considered an upper bound of dermal exposure used for screening estimates of dermal exposure to liquids. However, the Sugino et al. ([2017](#)) was selected as most reflective of BBP exposures from liquid products and formulations during a refinement of the dermal analysis for liquids. All studies received ratings of medium from EPA's systematic review process, with detailed rationales provided in *Data Quality Evaluation and Data Extraction Information for Dermal Absorption for Butyl Benzyl Phthalate (BBP)* ([U.S. EPA, 2025a](#)).

- Relatively recent studies were preferred since they are likely more consistent with modern dermal testing techniques and guidelines. The *in vitro* human studies from ([Sugino et al., 2017](#)) and ([DuPont, 2006b](#)) published in 2017 and 2006 are more recent than ([Elsisi et al., 1989](#)) from 1989.
- Studies of human skin were preferred over animal models, and when studies with human skin were not suitable (see other criteria), animal skin studies were preferred in this order: guinea pig over rat studies. Guinea pig absorption is closer to human skin than rats. The studies selected for solids ([DuPont, 2006a](#)) and liquid ([Sugino et al., 2017](#)) are human studies and ([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 skin thickness.
- *In vivo* or freshly excised (non-frozen) skin studies were preferred, provided that there was not a significant delay between skin sample retrieval and assay initiation. ([Sugino et al., 2017](#)) contains *in vitro* human study with frozen human skin.
- Studies using an aqueous vehicle type were preferred over neat chemical studies as there is greater relevance to commercial product formulations and subsequent exposure and due to greater uncertainties from neat chemical resulting in lower absorptions than formulations which 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 is preferred. ([Elsisi et al., 1989](#)) evaluated dermal absorption after 7 days of exposure, while the ([Sugino et al., 2017](#)) and ([DuPont, 2006a](#)) had shorter exposures more relevant to occupational exposure scenarios.

Information on the toxicokinetics of dermal BBP exposure is limited. EPA identified an *in vivo* rodent study and an *ex vivo* rodent study ([Sugino et al., 2017](#); [Elsisi et al., 1989](#)) and three *in vitro* human

studies evaluating ADME (Absorption, Distribution, Metabolism, Excretion) properties following dermal application of BBP ([Sugino et al., 2017](#); [DuPont, 2006a, b](#)).

Sugino et al. ([2017](#)) used *ex vivo* epidermal membranes (0.95 cm²) prepared from abdominal excisions of male hairless rats (WBN/IIa-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 MBP and 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 *ex vivo* 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.

In the report by Elsis et al. ([1989](#)), ADME properties of eight phthalates, including BBP, were analyzed through dermal application of radiolabeled parent compounds in male F344 rats. ¹⁴C-BBP (5 to 8 mg/cm²) 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 the seven days. By end of assessment at day seven, approximately 30 percent of ¹⁴C-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, as other medium-chain phthalates with a low molecular weight, such as dibutyl phthalate, showed rapid excretion. Elsis 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 -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.

As evidenced by the Sugino *et al.* ([2017](#)) study, phthalate metabolism is critical to dermal absorption. Several studies have shown that rats metabolize monobutyl phthalate, as common mono-ester metabolite of BBP and DBP, more rapidly than humans ([Sugino et al., 2017](#); [Scott et al., 1987](#)). The other mono-ester metabolite of BBP, monobenzyl phthalate, has been shown to be the primary metabolite of BBP in humans ([Sugino et al., 2017](#); [Anderson et al., 2001](#)). In the one available controlled human BBP oral exposure study of metabolism ([Anderson et al., 2001](#)), monobenzyl phthalate was identified the predominant urinary metabolite. The difference in relative ratio of monobenzyl (67–78%) and monobutyl phthalate (0–6%) monobutyl phthalate in the in human metabolism study ([Anderson et al., 2001](#)) was much more striking than in the Sugino *et al.* ([2017](#)) study using previously frozen cadaver skin. Given that metabolism driver dermal absorption for phthalates, uncertainty in the relative rates of metabolism make it difficult to determine the relative dermal absorption across species for the uniquely asymmetrical BBP.

Lastly, Dupont et al. ([2006a, b](#)) conducted two independent assessments using *ex vivo* human abdominal skin sections. The first experiment utilized skin collections (468 to 487 µm thick) and exposed 0.64 cm² size sections to an infinite dermal load of 100µL/cm² BBP for 8 hours, which was spiked with ¹⁴C-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](#)). As allowed in the guideline, the study used frozen skin

and the membranes were equilibrated and verified to be intact by electrical impedance before and after use. However, as shown by Sugino *et al.* (2017) and described below, specific to BBP, this is not the preferred approach as metabolically active skin is preferred to capture different absorptive characteristics of the parent BBP and its metabolites. No BBP was identified within the receptor fluid after 8 hours of exposure. Measurements of BBP that was absorbed into the skin had a large standard deviation (165.3 ± 165.0 μ L) across six samples from three donors, which reduces confidence in the estimate. As described in Appendix H of the BBP Risk Evaluation (U.S. EPA, 2025d), there is evidence that *in vitro* studies that do not use metabolically active skin may underestimate dermal absorption (Hopf *et al.*, 2024; Hopf *et al.*, 2014; Bogen, 2012), which may account the high sample variability and lack of BBP or metabolites within the receptor fluid.

The second experiment by Dupont *et al.* (2006a) exposed 0.64 cm² abdominal skin sections (248–470 μ m thick) to a BBP film matrix containing ¹⁴C-BBP occluded Parafilm directly placed on the skin for 8 hours. In this case, the total estimated exposure was 5,958 μ g BBP, and the total absorbed dose at the end of 8 hours was less than 0.01 percent (0.57 μ g BBP).

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

2.4.3.2 Flux-Limited Dermal Absorption for Liquids

The estimated steady-state fluxes of BBP presented in this section, based on the results of the Sugino *et al.* (2017) study using *in vitro* human skin, is most representative of exposures to liquid materials or formulations only. As discussed in Section 2.4.3.1, EPA used the steady-state flux (6.2×10^{-4} mg/cm²/h) estimated from the *in vitro* human study (Sugino *et al.*, 2017) to estimate occupational dermal exposure to liquids or formulations containing BBP, because the human *in vitro* study (Sugino *et al.*, 2017) provides the best available science to support derivation of the flux value.

EPA considered using the Dupont (2006b) estimate of 0.8906 mg/cm² of BBP over an 8-hour period, the steady-state flux of neat BBP is estimated as 3.23×10^{-2} mg/cm²/h. EPA estimated the steady-state flux and assumed it is equal to the average flux. Since no BBP was identified within the receptor fluid after 8 hours of exposure, the flux value that EPA was calculated from the amount of BBP within the skin, rather than the amount of BBP absorbed through the skin, which is considered an upper bound of dermal exposure. Thus, this value was limited to a screening level assessment of BBP dermal exposure.

EPA considered but did not use the Elsis (1989) estimate of 30 percent absorption of 8 mg/cm² of BBP over a 7-day period, the steady-state flux of neat BBP is estimated as 1.93×10^{-2} mg/cm²/h. EPA estimated the steady-state flux and assumed it is equal to the average flux. There is evidence (Sugino *et al.*, 2017; Scott *et al.*, 1987) that some phthalates may be more readily absorbed in rat skin vs. human skin. There is also evidence that rats and humans have different metabolic profiles for the uniquely asymmetrical phthalate BBP (Sugino *et al.*, 2017), but the relative metabolic rates for the mono-ester metabolites across species are unclear. Given that metabolism driver dermal absorption for phthalates, uncertainty in the relative rates of metabolism make it difficult to determine the relative dermal absorption across species for BBP.

EPA also considered but did not use the physical chemical properties and the method from the *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E: Supplemental Guidance for Dermal Risk Assessment)* (U.S. EPA, 2004b), which estimated the steady-

state flux of aqueous BBP as 7.6×10^{-5} mg/cm²/h at 8 hours. EPA estimated the steady-state flux and assumed it is equal to the average flux.

Due to uncertainties in the study, EPA recognizes that the flux value derived from the Sugino *et al.* (2017) the flux value of 6.2×10^{-4} mg/cm²/h derived from the *in vitro* human study Sugino *et al.* {, 2017, 3859042} may represent a lower bound for BBP dermal absorption. The actual dermal flux value for BBP likely lies within the range of 3.23×10^{-2} mg/cm²/h to 7.6×10^{-5} mg/cm²/h. However, due to the limitations and uncertainties across the various lines of evidence, EPA is not able to more precisely identify a flux value to inform the dermal assessment for BBP or recommend an alternative value (Appendix H of the BBP Risk Evaluation (U.S. EPA, 2025d) for more details).

2.4.3.3 Flux-Limited Dermal Absorption for Solids

Using the Dupont *et al.* (2006a) estimate of 0.8906 mg/cm² of BBP over an 8-hour period, the steady-state flux of neat BBP is estimated as 1.113×10^{-4} mg/cm²/h. EPA estimated the steady-state flux and assumed it is equal to the average flux.

2.4.3.4 Uncertainties in Dermal Absorption Estimation

As noted above in Section 2.4.3.1, EPA identified several sets of experimental data related to the dermal absorption of BBP. EPA evaluated *in vivo* data for male F344 rats from Elsisi (1989), *in vitro* human skin data from Dupont *et al.* (2006b), and *in vitro* human skin data from Sugino *et al.* (2017) to estimate liquid permeation parameters of neat BBP. EPA assessed dermal absorption to liquid formulations using the data provided by Sugino (2017), as that study was done using human skin samples. This is generally preferable to Elsisi (1989), which used rats to generate a 7-day exposure estimate. For dermal exposure to solids, EPA only identified one study directly related to the dermal absorption of BBP from solids: Dupont (2006a), which was an absorption study conducted *in vitro* using human skin samples and BBP contained within a film matrix. The tests in Dupont (2006a) also ended after 8 hours and did not detect radiolabeled BBP in the receptor fluid. The flux-limited screening approach provides an upper bound of dermal absorption of BBP and likely results in some overestimation of dermal absorption.

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 purposes of this risk evaluation, EPA assumes that the absorptive flux (3.23×10^{-2} mg/cm²/h) of neat BBP measured from *in vitro* human skin experiments Dupont *et al.* (2006b) serves as an upper bound of potential absorptive flux of chemical into and through the skin for dermal contact with all liquid products or formulations, and that the absorptive flux (1.113×10^{-4} mg/cm²/h) from *in vitro* human skin experiments to film containing BBP serves as an upper bound of potential absorptive flux of chemical into and through the skin for dermal contact with all solid products. EPA used the steady-state flux (6.2×10^{-4} mg/cm²/h) estimated from the *in vitro* human study (Sugino *et al.*, 2017) to estimate occupational dermal exposure to liquids or formulations containing BBP, because it is expected to be the most representative study for derivation of the flux value. However, 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 may lead to enhanced dermal absorption, even at lower concentrations. Therefore, it is uncertain whether the products or formulations containing BBP would result in decreased or increased dermal absorption. Based on the available dermal absorption data for BBP, EPA made assumptions that result in exposure assessments that are the most human health protective in nature.

2.4.4 Estimating Acute, Intermediate, and Chronic (Non-Cancer) Exposures

For each OES, the estimated exposures were used to calculate acute, intermediate, and chronic (non-cancer) inhalation and dermal doses. These calculations require additional parameter inputs, such as

years of exposure, exposed surface area (for dermal exposure), exposure duration and exposure frequency.

For the final exposure result metrics, each of the input parameters (*e.g.*, air concentrations, dermal doses, working years, exposure frequency) may be a point estimate (*i.e.*, a single descriptor or statistic, such as central tendency or high-end) or a full distribution. As described in Section 2.4, EPA considered three general approaches for estimating the final exposure result metrics: deterministic calculations, probabilistic (stochastic) calculations, and a combination of deterministic and probabilistic calculations. Equations for these exposures can be found in Appendix A.

2.5 Consideration of Engineering Controls and Personal Protective Equipment

OSHA and NIOSH recommend employers utilize the hierarchy of controls¹ to address hazardous exposures in the workplace. The hierarchy of controls strategy outlines, in descending order of priority, the use of elimination, substitution, engineering controls, administrative controls, and lastly personal protective equipment (PPE). The hierarchy of controls prioritizes the most effective measures, which eliminate or substitute the harmful chemical (*e.g.*, use a different process, substitute with a less hazardous material), thereby preventing or reducing exposure potential. Following elimination and substitution, the hierarchy recommends engineering controls to isolate employees from the hazard, followed by administrative controls or changes in work practices to reduce exposure potential (*e.g.*, source enclosure, local exhaust ventilation systems). Administrative controls are policies and procedures instituted and overseen by the employer to protect worker exposures. OSHA and NIOSH recommend the use of PPE (*e.g.*, respirators, gloves) as the last means of control, when the other control measures cannot reduce workplace exposure to an acceptable level.

2.5.1 Respiratory Protection

OSHA's Respiratory Protection Standard (29 CFR 1910.134) requires employers in certain industries to address workplace hazards by implementing engineering control measures and, if these are not feasible, providing respirators that are applicable and suitable for the purpose intended. Respirator selection provisions are provided in section 1910.134(d) and require that appropriate respirators be selected based on the respiratory hazard(s) to which the worker will be exposed, in addition to workplace and user factors that affect respirator performance and reliability. Assigned protection factors (APFs) are provided in Table 1 under section 1910.134(d)(3)(i)(A) (see below in Table 2-1) and refer to the level of respiratory protection that a respirator or class of respirators is expected to provide to employees when the employer implements a continuing, effective respiratory protection program according to the requirements of OSHA's Respiratory Protection Standard.

If respirators are necessary in atmospheres that are not immediately dangerous to life or health, workers must use NIOSH-certified air-purifying respirators or NIOSH-approved supplied-air respirators with the appropriate APF. Respirators that meet these criteria include air-purifying respirators with organic vapor cartridges. Respirators must meet or exceed the required level of protection listed in Table 2-1. Based on the APF, inhalation exposures may be reduced by a factor of 5 to 10,000, if respirators are properly worn and fitted.

¹ https://www.osha.gov/sites/default/files/Hierarchy_of_Controls_02.01.23_form_508_2.pdf (accessed December 15, 2025).

Table 2-1. Assigned Protection Factors for Respirators in OSHA Standard 29 CFR 1910.134

Type of Respirator	Quarter Mask	Half Mask	Full Facepiece	Helmet/Hood	Loose-Fitting Facepiece
1. Air-Purifying Respirator	5	10	50	—	—
2. Power Air-Purifying Respirator (PAPR)	—	50	1,000	25/1,000	25
3. Supplied-Air Respirator (SAR) or Airline Respirator					
• Demand mode	—	10	50	—	—
• Continuous flow mode	—	50	1,000	25/1,000	25
• Pressure-demand or other positive-pressure mode	—	50	1,000	—	—
4. Self-Contained Breathing Apparatus (SCBA)					
• Demand mode	—	10	50	50	—
• Pressure-demand or other positive-pressure mode (<i>e.g.</i> , open/closed circuit)	—	—	10,000	10,000	—
Source: 29 CFR 1910.134(d)(3)(i)(A)					

2.6 Evidence Integration for Environmental Releases and Occupational Exposures

Evidence integration for the environmental release and occupational exposure assessment includes analysis, synthesis, and integration of information and data to produce estimates of environmental releases and occupational exposures. During evidence integration, EPA considered the likely location, duration, intensity, frequency, and quantity of releases and exposures while also considering factors that increase or decrease the strength of evidence when analyzing and integrating the data. Key factors that EPA considered when integrating evidence include:

1. **Data Quality:** EPA only integrated data or information rated as *high*, *medium*, or *low* obtained during the data evaluation phase of systematic review. EPA did not use data and information rated as *uninformative* in exposure evidence integration. In general, EPA gave preference to higher rankings over lower rankings; however, EPA may use lower ranked data over higher ranked data after carefully examining and comparing specific aspects of the data. For example, EPA may use a lower ranked data set that precisely matches the OES of interest over a higher ranked study that does not match the OES of interest as closely.
2. **Data Hierarchy:** EPA used both measured and modeled data to obtain accurate and representative estimates (*e.g.*, central-tendency, high-end) of the environmental releases and occupational exposures resulting directly from a specific source, medium, or product. If available, measured release and exposure data are given preference over modeled data, with the highest preference given to data that are both chemical-specific and directly representative of the OES/exposure source.

EPA considered both data quality and data hierarchy when determining evidence integration strategies. For example, EPA may use high quality modeled data that is directly applicable to a given OES over low quality measurement data that is not specific to the OES. The final integration of the environmental release and occupational exposure evidence combined decisions regarding the strength of the available information, including information on plausibility and coherence across each evidence stream.

EPA evaluated environmental releases based on reported release data and evaluated occupational exposures based on monitoring data and worker activity information from standard engineering sources and systematic review. EPA estimated OES-specific assessment approaches where supporting data existed and documented uncertainties where supporting data were only applicable for broader assessment approaches.

2.7 Estimating Number of Workers and Occupational Non-Users

This section provides a summary of the estimates for the total exposed workers and ONUs for each OES. To prepare these estimates, EPA first identified relevant North American Industrial Classification (NAICS) codes and Standard Occupational Classification (SOC) codes from the Bureau of Labor Statistics (BLS) (2023). The estimation process for the total number of workers and ONUs is described in Section 2.7.1 below. EPA also estimated the total number facilities associated with the relevant NAICS codes based on data from the U.S. Census Bureau (2015). To estimate the average number of potentially exposed workers and ONUs per site, the total number of workers and ONUs were divided by the total number of facilities. The following sections provide additional details on the approach and methodology for estimating the number of facilities using BBP and the number of potentially exposed workers and ONUs.

2.7.1 Number of Workers and Occupational Non-Users Estimation Methodology

Where available, EPA used CDR data to provide a basis to estimate the number of workers and ONUs. EPA supplemented the available CDR data with U.S. economic data using the following method:

1. Identify the NAICS codes for the industry sectors associated with these uses (
2. Table 2-2).
3. Estimate total employment by industry/occupation combination using the BLS's Occupational Employment Statistics data (BLS Data).
4. Refine the Occupational Employment Statistics estimates where they are not sufficiently granular by using the U.S. Census' SUSB data on total employment by 6-digit NAICS.
5. Use market penetration data to estimate the percentage of employees likely using BBP instead of other chemicals.
6. Where market penetration data are not available, use the estimated workers/ONUs per site in the 6-digit NAICS code and multiply by the number of sites estimated from CDR, TRI, DMR and/or NEI. In DMR data, sites report SIC codes rather than NAICS codes; therefore, EPA mapped each reported SIC code to a NAICS code for use in this analysis.
7. Combine the data generated in Steps 1 through 5 to produce an estimate of the number of employees using BBP in each industry/occupation combination and sum these to arrive at a total estimate of the number of employees with potential exposure within the OES.

Table 2-2 below contains the relevant NAICS codes and the calculated average number of workers and ONUs identified per site for each OES.

Table 2-2. NAICS Code Crosswalk and Number of Workers and ONUs for Each OES

Occupational Exposure Scenario (OES)	Relevant NAICS Codes	Exposed Workers per Site ^a	Exposed ONUs per Site ^a
Manufacturing	325199 – All Other Basic Chemical Manufacturing	39	18
Import and repackaging	325199 – All Other Basic Chemical Manufacturing 424690 – Other Chemical and Allied Products Merchant Wholesalers	20	9
Incorporation into adhesives	325520 – Adhesive Manufacturing	18	7

Occupational Exposure Scenario (OES)	Relevant NAICS Codes	Exposed Workers per Site^a	Exposed ONUs per Site^a
and sealants			
Incorporation into paints and coatings	325510 – Paint and Coating Manufacturing	14	5
Incorporation into other formulations, mixtures, and reaction products not covered elsewhere	325110 – Petrochemical Manufacturing 325199 – All Other Basic Chemical Manufacturing	51	24
PVC plastics compounding	325211 – Plastics Material and Resin Manufacturing	27	12
PVC plastics converting	326100 – Plastics Product Manufacturing	18	5
Non-PVC material compounding	325212 – Synthetic Rubber Manufacturing 326200 – Rubber Product Manufacturing 424690 – Other Chemical and Allied Products Merchant Wholesalers	23	6
Non-PVC material converting	325212 – Synthetic Rubber Manufacturing 326200 – Rubber Product Manufacturing 424690 – Other Chemical and Allied Products Merchant Wholesalers	23	6
Application of adhesives and sealants	322220 – Paper Bag and Coated and Treated Paper Manufacturing 334100 – Computer and Peripheral Equipment Manufacturing 334200 – Communications Equipment Manufacturing 334300 – Audio and Video Equipment Manufacturing 334400 – Semiconductor and Other Electronic Component Manufacturing 334500 – Navigational, Measuring, Electromedical, and Control Instruments Manufacturing 334600 – Manufacturing and Reproducing Magnetic and Optical Media 335100 – Electric Lighting Equipment Manufacturing 335200 – Household Appliance Manufacturing 335300 – Electrical Equipment Manufacturing 335900 – Other Electrical Equipment and Component Manufacturing 336100 – Motor Vehicle Manufacturing 336200 – Motor Vehicle Body and Trailer Manufacturing 336300 – Motor Vehicle Parts Manufacturing 336400 – Aerospace Product and Parts Manufacturing 336500 – Railroad Rolling Stock Manufacturing 336600 – Ship and Boat Building 336900 – Other Transportation Equipment Manufacturing	55	18
Application of paints and coatings	332431 – Metal Can Manufacturing 335931 – Current-Carrying Wiring Device Manufacturing 337110 – Wood Kitchen Cabinet and Countertop	12	5

Occupational Exposure Scenario (OES)	Relevant NAICS Codes	Exposed Workers per Site ^a	Exposed ONUs per Site ^a
	Manufacturing 337122 – Nonupholstered Wood Household Furniture Manufacturing 337124 – Metal Household Furniture Manufacturing 337127 – Institutional Furniture Manufacturing 337211 – Wood Office Furniture Manufacturing 337214 – Office Furniture (except Wood) Manufacturing 337215 – Showcase, Partition, Shelving, and Locker Manufacturing 811120 – Automotive Body, Paint, Interior, and Glass Repair		
Use of laboratory chemicals – liquid	541380 – Testing Laboratories 621511 – Medical Laboratories	1	4
Use of laboratory chemicals – solid	541380 – Testing Laboratories 621511 – Medical Laboratories	1	4
Fabrication of final products from articles	236100 – Residential Building Construction 236200 – Nonresidential Building Construction 237100 – Utility System Construction 237200 – Land Subdivision 237300 – Highway, Street, and Bridge Construction 237900 – Other Heavy and Civil Engineering Construction 337100 – Household and Institutional Furniture Manufacturing 337200 – Office Furniture (including Fixtures) Manufacturing	9	3
Use of lubricants and functional fluids	336100 – Motor Vehicle Manufacturing 336200 – Motor Vehicle Body and Trailer Manufacturing 336300 – Motor Vehicle Parts Manufacturing 336400 – Aerospace Product and Parts Manufacturing 336500 – Railroad Rolling Stock Manufacturing 336600 – Ship and Boat Building 336900 – Other Transportation Equipment Manufacturing 811100 – Automotive Repair and Maintenance	88	22
Recycling	562212 – Solid Waste Landfill 562213 – Solid Waste Combustors and Incinerators 562219 – Other Nonhazardous Waste Treatment and Disposal	6	4
Waste handling, treatment, and disposal	562212 – Solid Waste Landfill 562213 – Solid Waste Combustors and Incinerators 562219 – Other Nonhazardous Waste Treatment and Disposal	6	4
^a For cases where multiple NAICS codes were identified for an OES, an average was calculated for the number of workers and ONUs; this average was then applied to the OES.			

2.7.2 Summary of Number of Workers and ONUs

Table 2-3 summarizes the number of facilities and total number of exposed workers for all OESs. For scenarios in which the results are expressed as a range, the lower end of the range is based on the 50th percentile estimate of the number of sites and the upper end of the range is based on the 95th percentile estimate of the number of sites. For some OESs, the estimated number of facilities is based on the number of reporting sites to the 2020 CDR ([U.S. EPA, 2020a](#)), NEI ([U.S. EPA, 2023a](#)), DMR ([U.S. EPA, 2024b](#)), and TRI databases ([U.S. EPA, 2024e](#)).

Table 2-3. Summary of Total Number of Workers and ONUs Potentially Exposed to BBP per OES

OES	Total Exposed Workers	Total Exposed ONUs	Number of Facilities	Notes
Manufacturing	39	18	1	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on identified sites from CDR.
Import and repackaging	40	18	2	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on identified sites from CDR.
Incorporation into adhesives and sealants	252 (central tendency); 1,278 (high-end)	98 (central tendency); 497 (high-end)	14 (central tendency); 71 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on results from Monte Carlo modeling.
Incorporation into paints and coatings	14 (central tendency); 126 (high-end)	5 (central tendency); 45 (high-end)	1 (central tendency); 9 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on the minimum reportable range for number of sites in CDR.
Incorporation into other formulations, mixtures, and reaction products not covered elsewhere	51	24	1	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on the ESD on the Formulation of Waterborne Coatings (U.S. EPA, 2014a).
PVC plastics compounding	27	12	1	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on calculations via the Draft Generic Scenario for the Use of Additives in Plastic Compounding (U.S. EPA, 2021c).
PVC plastics converting	180 (central tendency); 432 (high-end)	50 (central tendency); 120 (high-end)	10 (central tendency); 24 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on identified downstream industrial sites from CDR.

OES	Total Exposed Workers	Total Exposed ONUs	Number of Facilities	Notes
Non-PVC material compounding	230 (central tendency); 552 (high-end)	60 (central tendency); 144 (high-end)	10 (central tendency); 24 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on identified downstream industrial sites from CDR.

Non-PVC material converting	230 (central tendency); 552 (high-end)	60 (central tendency); 144 (high-end)	10 (central tendency); 24 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on identified downstream industrial sites from CDR.
Application of adhesives and sealants	18,095 (central tendency); 2152,075 (high-end)	5,922 (central tendency); 49,770 (high-end)	329 (central tendency); 2,765 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on results from Monte Carlo modeling.
Application of paints and coatings	48 (central tendency); 384 (high-end)	20 (central tendency); 160 (high-end)	4 (central tendency); 32 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on results from Monte Carlo modeling.
Use of laboratory chemicals – liquid	14,597 (central tendency); 36,873 (high-end)	58,388 (central tendency); 147,492 (high-end)	14,597 (central tendency); 36,873 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on results from Monte Carlo modeling.
Use of laboratory chemicals – solid	36,873	147,492	36,873	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on results from Monte Carlo modeling.
Use of lubricants and functional fluids	10,296 (central tendency); 122,496 (high-end)	2,574 (central tendency); 30,624 (high-end)	117 (central tendency); 1,392 (high-end)	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on results from Monte Carlo modeling.
Fabrication of final products from articles	N/A			Number of sites data was unavailable for this OES.
Recycling	348	232	58	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimate based on industry data (ENF, 2024).
Waste handling, treatment, and disposal	168	112	28	Number of workers and ONU estimates based on the BLS and U.S. Census Bureau data (U.S. BLS, 2023 ; U.S. Census Bureau, 2015). Number of facilities estimated based

OES	Total Exposed Workers	Total Exposed ONUs	Number of Facilities	Notes
				on identified sites from DMR, which may be an underestimate.
BLS = Bureau of Labor Statistics; CDR = Chemical Data Reporting (rule); ONU = occupational non-user				

3 ENVIRONMENTAL RELEASE AND OCCUPATIONAL EXPOSURE ASSESSMENTS BY OES

3.1 Manufacturing

3.1.1 Process Description

At a typical manufacturing site, BBP is formed through the reaction of the monobutyl ester of phthalic acid with benzyl alcohol or by reaction with benzyl chloride in the presence of an acid catalyst. The monobutyl ester can be produced through reaction of phthalic anhydride with n-butyl alcohol, before reaction with benzyl chloride or benzyl alcohol to produce butyl benzyl phthalate ([CPSC, 2015](#)).

Similar to other phthalate manufacturing processes, the unreacted alcohols are recovered and reused, and the BBP mixture is purified by vacuum distillation. Manufacturers report BBP purities of 90 percent or greater ([U.S. EPA, 2020a](#); [ECJRC, 2008](#)). Based on manufacturing operations for similar phthalates, activities may also include filtrations and quality control sampling of the BBP product. Additionally, manufacturing operations include equipment cleaning/reconditioning and product transport to other areas of the manufacturing facility or offsite shipment for downstream processing or use. No changes to chemical composition are expected to occur during transportation ([ExxonMobil, 2022a](#)).

Figure 3-1 provides an illustration of the proposed manufacturing process based on identified process information ([ExxonMobil, 2022b](#); [CPSC, 2015](#)).

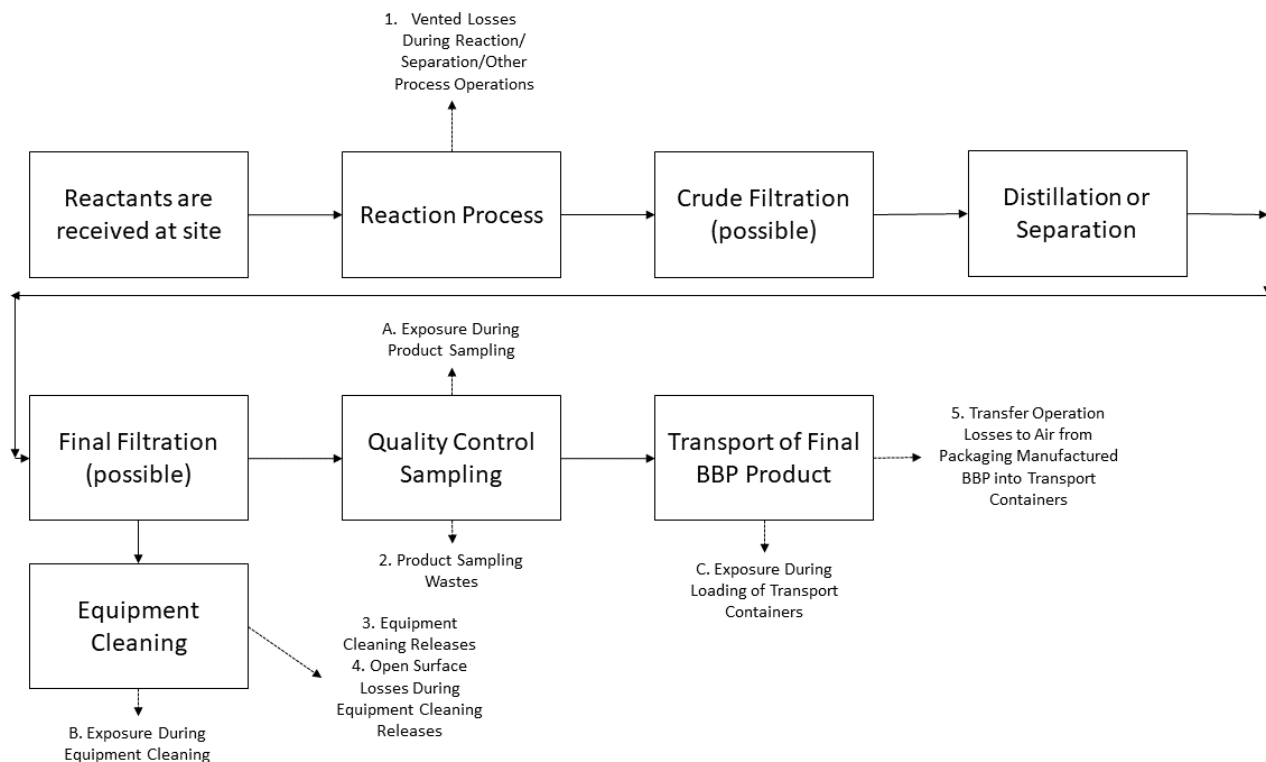


Figure 3-1. Manufacturing Flow Diagram

3.1.2 Facility Estimates

In the 2020 CDR, one site, Polymer Additives Inc., reported the manufacturing of BBP with a production volume (PV) that was claimed as CBI ([U.S. EPA, 2020a](#)). EPA did not identify other data on current manufacturing sites or production volumes from systematic review. For the manufacturing site from CDR, EPA estimated the PV with a uniform distribution with bounds calculated by subtracting the known import volumes from the estimated national aggregate BBP PV from CDR.

The 2020 CDR stated that the total national aggregate BBP PV was between 1,000,000 to less than 20,000,000 lb, this range was provided to protect the CBI of the reporter. EPA subtracted the combined known PV (611,115 lb) from importers (two sites reported importing BBP to the 2020 CDR) from each of these endpoints, resulting in a remaining import PV range of 388,885 to 19,388,885 lb; or 176,395 to 8,794,650 kg/year. EPA assumes that this range is the possible manufacturing throughput for the one site that indicated manufacturing operations in CDR. Review of preliminary 2024 CDR data shows that total production volumes for the years 2020 to 2023 are similar to the previously reported range from 2020 CDR. EPA used the range of production volumes as an input to the Monte Carlo modeling described in Section Appendix D to estimate releases. The production volume range is not used to calculate occupational exposures for BBP.

EPA did not identify information from systematic review for general site throughputs; site throughput information was estimated by dividing the site PV by the number of operating days. Based on the relatively large PV EPA assumed the number of operating days as 300 days/year with 6 day/week operations and two full weeks of downtime each operating year. CDR reporters indicated that BBP is manufactured in liquid form at a concentration of 90 to 100 percent ([U.S. EPA, 2020a](#)). Based on the estimated site daily throughput of 588 to 29,315 kg/site-day, EPA assumed that BBP may be packaged in drums or totes based on the ChemSTEER User Guide ([U.S. EPA, 2015](#)). The size of the container is an input to the Monte Carlo simulation to estimate releases but is not used to calculate occupational exposures for BBP.

3.1.3 Release Assessment

3.1.3.1 Environmental Release Points

One known site manufacturing BBP was identified in 2020 CDR Data: Polymer Additives, Inc. EPA expects stack air releases from vented losses during process operations. EPA expects fugitive air releases from equipment cleaning and from packaging manufactured BBP into transport containers. EPA expects wastewater, incineration, or landfill releases to only occur from sampling and equipment cleaning for this OES.

3.1.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the ESD on the Chemical Industry along with information from the ChemSTEER user guide and identified information on the manufacturing process for phthalates ([ExxonMobil, 2022b](#); [CPSC, 2015](#); [U.S. EPA, 2015](#); [OECD, 2011c](#)).

The model combines facility information (*e.g.*, production volume, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations used in the identified references to estimate releases from each source. The ESD presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were

available to do so, EPA modified the approaches described in the ESD to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the ESD are provided below:

- Release point 1 – Vented losses to air during reaction/separation/other process operations were assessed to stack air based on the ESD. The emission factors provided in the ESD were not representative of chemicals with relatively low vapor pressures like BBP. Because of this, EPA referenced the EU SpERC for the Manufacture of Substance – Industrial (solvent-borne) to estimate this release ([ESIG, 2012](#)). The SpERC document estimates a standard emission factor of 1.0×10^{-5} kg release / kg production volume for chemicals with VP < 1Pa (7.5×10^{-3} mmHg) ([OECD, 2011c](#)).
- Release point 2 – Sampling waste was assessed to water, land, or waste treatment using the *EPA/OPPT 2023 Methodology for Estimating Environmental Releases from Sampling Waste*. EPA modified this to include the distribution of loss fractions presented in the methodology document ([U.S. EPA, 2023b](#)).
- Release point 3 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model ([U.S. EPA, 2015](#)).
- Release point 4 – Volatile emissions generated during equipment cleaning were estimated to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 5 – Volatile emissions generated during container loading were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, drum volumes, and vapor correction factors based on various sources ([U.S. EPA, 2015](#); [Baldwin and Maynard, 1998](#)).

Other key assessment decisions and deviations from the ESD include the omission of volatilization releases from sampling the manufactured product since BBP has a low vapor pressure and EPA expects that release to be negligible relative to other volatilization releases. EPA assumed a uniform concentration distribution of 90 to 100 percent and a uniform production volume distribution of 176,395 to 8,794,650 kg/year based on information from the 2020 CDR ([U.S. EPA, 2020a](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.2.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount released may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for each facility identified in Section 3.1.2 for this OES. Table 3-1 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end

facility releases to each media, respectively.

Table 3-1. Summary of Modeled Environmental Releases for Manufacture of BBP

Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Stack Air	45	84	300		0.15	0.28
Fugitive Air	8.7E-04	1.5E-03			2.9E-06	4.9E-06
Wastewater, Incineration, or Landfill ^a	9.1E04	1.7E05			303	566

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.2. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.1.4 Occupational Exposure Assessment

3.1.4.1 Workers Activities

During manufacturing, worker exposures to BBP may occur via inhalation of vapors or dermal contact with liquid during product sampling, equipment cleaning, container cleaning, and packaging and loading of BBP into transport containers for shipment. EPA did not identify information on engineering controls or worker PPE used at BBP manufacturing facilities.

ONUs include employees (*e.g.*, supervisors, managers) that work at the manufacturing facility, but are not expected to directly handle BBP. EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. Nevertheless, potential exposures to ONUs through inhalation of vapor are assessed under the Manufacturing OES. Since ONUs are not expected to come into direct contact with the liquid form of the chemical, dermal exposures for ONUs were not assessed.

3.1.4.2 Occupational Inhalation Exposure Results

EPA identified personal inhalation monitoring data from two manufacturing sites, which consisted of five data sets on exposures to BBP during various activities of the manufacturing process. EPA used these data, which were provided in a risk evaluation conducted by the European Commission, Joint Research Centre (ECJRC), to estimate inhalation exposure for this OES ([ECJRC, 2007](#)). The ECJRC used these samples to develop a task-based exposure estimate for the production of BBP, including one exposure estimate each for the filling of truck tankers, drumming, and production. Most of the data points were presented as the mean of a range or as single data points. Two of the tanker truck loading measurements were for approximately an hour, but the study indicated that the site received and loaded 3 to 4 trucks per day, with each taking 60 to 90 minutes to fill. EPA built a worker 8-hour TWA exposure by assuming four truck fillings, a 90-minute fill time for each truck and no exposure for the remainder of the shift. This calculation is provided below.

Equation 3-1.

$$C_{BBP,8hr-TWA} = \frac{C_{BBP} \times N_{Loading} \times RateFill_{Truck}}{8 \text{ hrs}}$$

Where:

- $C_{BBP,8hr-TWA}$ = Contaminant concentration in air (8-hour TWA mg/m³)
- C_{BBP} = Sample contaminant concentration in air (mg/m³)
- $N_{Loading}$ = Number of truck loads per day (assumed 4 loads per day)
- $RateFill_{Truck}$ = Truck loading rate (assumed 90 minutes per load)

For a sample concentration of 0.61 mg/m³, the 8-hour TWA exposure estimate would be calculated as follows:

$$C_{BBP,8hr-TWA} = \frac{0.61 \frac{mg}{m^3} \times 4 \text{ truck loads} \times 90 \text{ mins} \times \frac{1 \text{ hr}}{60 \text{ mins}}}{8 \text{ hrs}}$$

$$C_{BBP,8hr-TWA} = 0.46 \frac{mg}{m^3}$$

With five data points, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency. Both the central tendency and high-end exposures use 250 days per year as the exposure frequency, which is the expected maximum for assessed exposure days.

Table 3-2 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during manufacture. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for inhalation of vapors containing BBP were assumed representative of ONU inhalation exposure. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-2. Summary of Estimated Worker Inhalation Exposures for Manufacturing of BBP

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.46
	Acute Dose (AD) (mg/kg-day)	1.3E-02	5.7E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.2E-03	4.2E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.6E-03	3.9E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.46
	Acute Dose (AD) (mg/kg-day)	1.4E-02	6.3E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	1.0E-02	4.6E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	9.5E-03	4.3E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.10
	Acute Dose (AD) (mg/kg-day)	1.3E-02	1.3E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.2E-03	9.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.6E-03	8.6E-03
^a EPA identified inhalation monitoring data from 1 source to estimate exposures for this OES (ECJRC, 2007). The source of monitoring data received a rating of medium from EPA's systematic review process. With 5 data points, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.			

3.1.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-3 are explained in Appendix A. ONU dermal exposures are not assessed for this OES as there are no activities expected to expose ONUs to BBP in liquid form. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP may lead to overestimation of dermal exposure. Table 3-3 summarizes the Acute Potential Dose Rate (APDR), AD, IADD, and ADD for average adult workers and female workers of reproductive age. No ONU dermal exposure is expected for this OES.

Table 3-3. Summary of Estimated Worker Dermal Exposures for the Manufacturing of BBP

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.023	0.045
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.022	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.042
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for two-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers).			

3.1.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-4. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-4. Summary of Estimated Worker Aggregate Exposures for Manufacture of BBP

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.046	0.12
	Intermediate (IADD, mg/kg-day)	0.033	0.091
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.031	0.085
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.044	0.12
	Intermediate (IADD, mg/kg-day)	0.032	0.091
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.030	0.085
ONU	Acute (AD, mg/kg-day)	1.3E-02	1.3E-02
	Intermediate (IADD, mg/kg-day)	9.2E-03	9.2E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	8.6E-03	8.6E-03
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.2 Import and Repackaging

3.2.1 Process Description

BBP may be imported into the United States in bulk via water, air, land, and intermodal shipments ([Tomer and Kane, 2015](#)). Based on the Chemical Repackaging Generic Scenario, import and repackaging sites unload import containers and transfer BBP into smaller containers (bags or supersacks) for downstream processing, use within the facility, or offsite use ([U.S. EPA, 2022](#)). Of the two known import sites, one site reported importing BBP as a liquid while the other site reported importing BBP as a solid. The physical forms and concentrations of BBP reported in the 2020 CDR are shown in Table 3-5 below. Liquid imports may include both neat or formulations containing BBP, and

solid imports are likely related to importing of plastic resins containing BBP. The liquid product arrives at the site in containers such as small containers, drums, and totes ranging in size from 1 to 1,000 gallons and at concentrations of 1 to 30 percent BBP. Solid product arrives at the site in containers ranging in size from 7 to 132 gallons. The size of the container is an input to the Monte Carlo simulation to estimate releases but is not used to calculate occupational exposures for BBP. Operations may include quality control sampling of BBP product and equipment cleaning. No changes to chemical composition occur during transportation ([U.S. EPA, 2022](#)). Figure 3-2 provides an illustration of the import and repackaging process based on information from the Chemical Repackaging Generic Scenario ([U.S. EPA, 2022](#)).

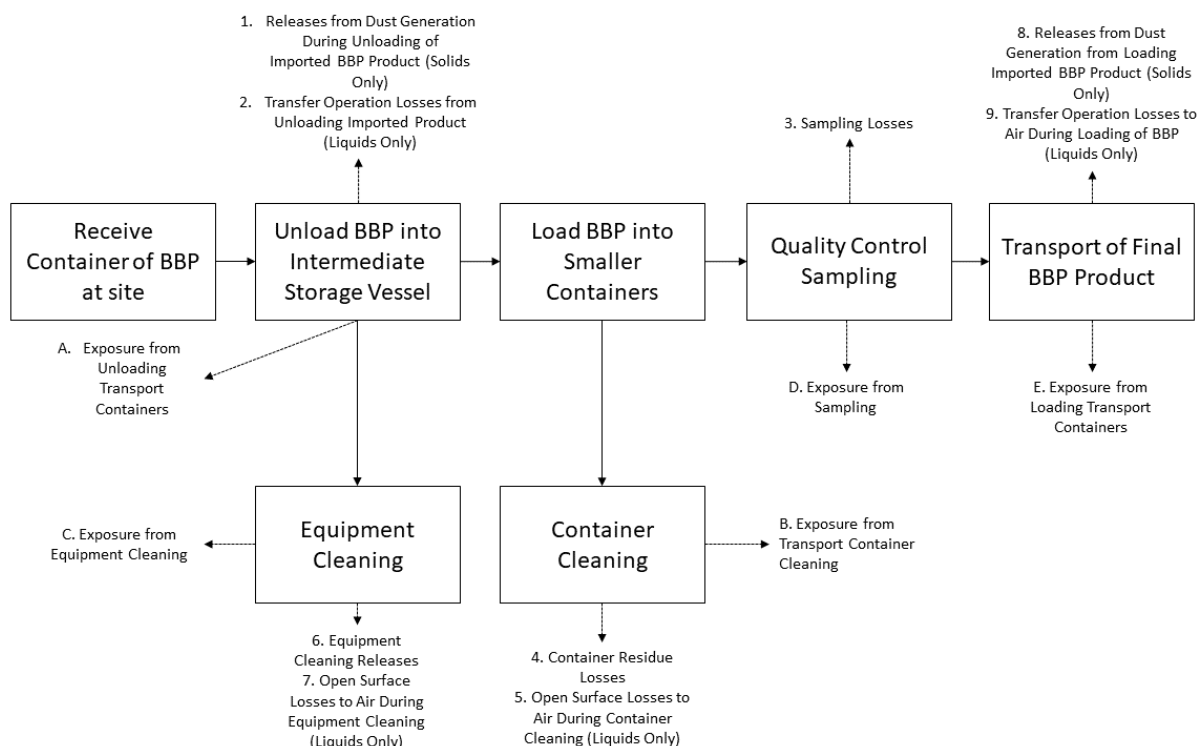


Figure 3-2. Import and Repackaging Flow Diagram

3.2.2 Facility Estimates

In the 2020 CDR, two sites reported import and repackaging of BBP CASRN 85-68-7. Both sites reported their production volumes ([U.S. EPA, 2020a](#)). Review of preliminary 2024 CDR data shows that total production volumes for the years 2020 to 2023 are similar to the previously reported range from 2020 CDR. Table 3-5 provides the location and reported production volume for BBP import sites.

Table 3-5. Production Volume of BBP Import and Repackaging Sites, 2020 CDR

BBP Import Site, Site Name	Site Location	2019 Reported Production Volume of BBP CASRN 85-68-7 (kg/site-year)	Physical Form	Reported Concentration ^a
M. Argueso & Co., Inc.	Muskegon, MI	2,678	Pellets or large crystals	1% to <30%
Tremco Incorporated	Beachwood, OH	274,520	Liquid	1% to <30%
^a Concentration is used in the dermal exposure and dust inhalation calculations where the highest concentration used to understand the greatest potential occupational exposure. It is also used to estimate the number of containers that could be used per site per day.				

There were no unknown sites; therefore, EPA based the total import production volume on the sum of these reported values, which is 277,198 kg/site-year (611,115 lb/site-year).

EPA did not identify information from systematic review for import site operating days; therefore, EPA assessed the total number of operating days for BBP import as 174 to 260 days per year based on the length of worker shifts described in the 2022 GS on Chemical Repackaging ([U.S. EPA, 2022](#)). Import and repackaging facilities typically operate 24 hours/day, 7 days/week (*i.e.*, multiple shifts). However, EPA capped the total number of operating days, so as not to exceed estimated site throughputs.

Based on CDR reports, BBP is imported as a liquid or dry powder with concentrations ranging from 1 to 30 percent BBP ([U.S. EPA, 2020a](#)). Based on CDR data, EPA assumes BBP is manufactured and imported in both solid and liquid form. EPA did not identify chemical- or site-specific information on site throughputs and estimated site throughputs by dividing the site PV by the number of operating days.

3.2.3 Release Assessment

3.2.3.1 Environmental Release Points

Two known sites importing BBP were identified in 2020 CDR Data: M. Argueso & Co., Inc. and Tremco Incorporated. Based on the 2022 Generic Scenario (GS) on Chemical Repackaging ([U.S. EPA, 2022](#)) release points include releases to wastewater, incineration, and landfill from sampling, container residue, and equipment cleaning. EPA expects fugitive air release from equipment and container cleaning. EPA also expects fugitive or stack air releases from loading and unloading of imported BBP into and out of transport containers.

3.2.3.2 Environmental Release Assessment Results

EPA identified releases from the 2017 to 2020 DMR database; however, this data is limited by infrequent samples and does not include release data for environmental media other than surface water and may not be representative of all releases from use sites. Therefore, EPA developed a probabilistic model to estimate air, land, and additional water releases for this OES using the approaches, model equations, and input parameters detailed in the 2022 GS on Chemical Repackaging ([U.S. EPA, 2022](#)).

The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source. The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter

variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Dust releases from unpacking and transferring solid BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2022, 2015](#)).
- Release point 2 – Volatile emissions generated during unloading containers with liquid BBP were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, drum volumes, and vapor correction factors based on various sources ([U.S. EPA, 2022, 2015](#); [Baldwin and Maynard, 1998](#))
- Release point 3 – Sampling waste was assessed to water, land, or waste treatment using the *EPA/OPPT 2023 Methodology for Estimating Environmental Releases from Sampling Waste*. EPA modified this to include the distribution of loss fractions presented in the methodology document ([U.S. EPA, 2023b](#)).
- Release point 4 – Waste from cleaning import containers was assessed to water, land, or waste treatment using the EPA/OPPT Bulk Transport Residual Model or the EPA/OPPT Solid Residuals in Transport Containers Model based on whether the model was run for liquid or solid releases respectively. EPA modified these models to include distributions for container size, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2022, 2015](#)).
- Release point 5 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2022, 2015](#); [Baldwin and Maynard, 1998](#))
- Release point 6 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Single Process Vessels Residual Model. This model assumes a standard loss fraction of 0.01 for each batch manufactured ([U.S. EPA, 2022, 2015](#)).
- Release point 7 – Volatile emissions generated during cleaning of equipment were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2022, 2015](#); [Baldwin and Maynard, 1998](#))
- Release point 8 – Dust releases from packing and transferring solid BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2022, 2015](#)).
- Release point 9 – Volatile emissions generated during loading containers with liquid BBP were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, and drum volumes based on various sources ([U.S. EPA, 2022, 2015](#); [Baldwin and Maynard, 1998](#)).

Other key assessment decisions and deviations from the GS include that EPA modeled multiple scenarios, one for each of the physical forms of BBP that are expected to be imported. EPA omitted

volatilization releases from sampling the manufactured product as BBP has a low vapor pressure and EPA expects that release to be much smaller than the release from the sampling or other volatilization releases. EPA also used a uniform concentration distribution of 1 to 30 percent based on information from the 2020 CDR ([U.S. EPA, 2020a](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.3.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for each facility identified in Section 3.2 for this OES. Table 3-6 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively. Additionally, EPA notes that Table 3-6 presents the release volumes for two independent cases, the first is where the BBP is received as a liquid and the second is for when BBP is received as a solid. As noted in earlier in this section, where the nine release points are listed, some of the release points specifically detail dust releases from operations involving solid BBP. When working with solid BBP, these dust releases result in a greater fraction of the BBP production volume to be released to the environment than compared to the releases from liquid BBP.

Table 3-6. Summary of Modeled Environmental Releases for Import and Repackaging of BBP

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
274,520 kg/year production volume (Liquid)	Fugitive Air	6.7E-05	1.8E-04	208	260	3.2E-07	8.6E-07
	Wastewater, incineration, or landfill ^a	3,820	4,140			18	23
2,678 kg/year production volume (Solid)	Stack air	12	49			0.058	0.24
	Wastewater, incineration, or landfill ^a	68	81			0.43	0.59
	Wastewater, incineration, or landfill ^a	15	65			0.073	0.33
	Incineration, or landfill ^a	20	67			0.091	0.32

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.3. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table 3-7 presents surface water discharges per year and per day based on the 2017 to 2022 DMR along with the number of release days per year, with medians and maxima presented from across the 6-year reporting range. If a facility has only one record in the identified range, then the median and maxima will be equivalent. According to the DMR data, three sites reported direct discharges to surface water for the Import and repackaging OES: Intercontinental Terminals Deer Park Terminal, Stolthaven New Orleans, LLC – Braithwaite Terminal, and TT Coatings LLC ([U.S. EPA, 2024a](#)). The modeled values of release to surface water are several orders of magnitude greater than those listed in DMR. There are uncertainties related to the DMR dataset, including the lack of context about why a particular chemical is being monitored (sites could be monitoring a specific chemical because of groundwater contamination or other non-TSCA purposes), EPA does not have a lot of information (NAICS and name) to use for determining which OES should be assigned to a site (creating uncertainty about the appropriateness of its inclusion in the OES), and low frequency of sampling (frequently once per year for chemical specific monitoring) that is directed by the NPDES permits for BBP monitoring (creating uncertainty if the annual load is truly representative for a chemical). Therefore, it is not known if these sites are representative of all sites in this OES. Therefore, modeling values in Table 3-6 were used as an upper bound for surface water concentrations in general population and environmental risk assessments, even though there are uncertainties present within the modeling parameters. The SACC agreed with the use of generic scenarios to generate release values in the absence of data. When EPA released the draft Risk Evaluation for BBP, EPA acknowledged the data gap for environmental release data for this OES and solicited alternative data sources from the public. However, no additional data sources were provided during the public comment period.

Table 3-7. Summary of Surface Water Discharges from DMR for Import and Repackaging

Site Identity	Median Annual Discharge (kg/year)	Median Average Daily Discharge (kg/day)	Maximum Annual Discharge (kg/year)	Maximum Average Daily Discharge (kg/day)	Annual Release Days (days/year)
Intercontinental Terminals Deer Park Terminal	5.10E-02	2.4E-04	8.1E-02	3.9E-04	208
Stolthaven New Orleans, LLC – Braithwaite Terminal	0.25	1.2E-03	0.25	1.2E-03	208
T T Coatings LLC	0.14	6.7E-04	0.14	6.7E-04	208

3.2.4 Occupational Exposure Assessment

3.2.4.1 Workers Activities

Import data from CDR ([U.S. EPA, 2020a](#)) indicate that BBP is imported as a liquid at one facility and as a solid in pellet or large crystal form at another facility. Therefore, workers may be exposed to liquids by vapor inhalation and dermal contact, as well as solids by inhalation of and dermal contact to dust generated from solid pellets and crystals abrading against each other. Specifically, worker inhalation and dermal exposures may occur when cleaning import vessels, loading and unloading BBP, sampling, and cleaning equipment. EPA did not find any information on the extent to which engineering controls and worker PPE are used at facilities that repackage BBP from import vessels into smaller containers.

ONUs include employees (*e.g.*, supervisors, managers) that work at the import site where repackaging occurs but do not directly handle BBP. Therefore, EPA expects ONUs to have lower inhalation

exposures and dermal exposures than workers. Nevertheless, potential exposures to ONUs through vapor inhalation for liquids and inhalation of dust and dermal contact with dust deposited on surfaces from solids are assessed under the Import and repackaging OES.

3.2.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for import and repackaging from systematic review of literature sources. BBP is imported as pellets/crystals or as a liquid, per CDR, and EPA assessed worker inhalation exposures to BBP dust for solids and BBP vapor for liquids during the unloading and loading processes.

For solid BBP, EPA did not identify monitoring data through the systematic review process, therefore, EPA developed a deterministic model to estimate inhalation exposures to respirable particulates for this OES using the approaches, model equations, and input parameters detailed in the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021b](#)). The model combines expected chemical concentrations at the facility with workplace TWA particulate samples compiled from the OSHA CEHD dataset. The model estimates an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Model approaches and parameters are described in Appendix D. The monitoring data in the GS is categorized by NAICS code groupings to refine estimates where data is available. EPA estimated the 450 TWA particulate samples associated with facilities having NAICS codes starting with 42 through 45 (Wholesale and Retail Trade) as most similar to this OES and used these to estimate BBP particulate concentrations in the air. Based on company reporting in the 2020 CDR, the highest expected BBP concentrations in imported solids containing BBP is 30 percent by mass. In the estimated exposures, EPA assumed that BBP is present in particulates at this fixed concentration throughout the work shift. EPA then used the model to calculate a central tendency BBP respirable particulate inhalation exposure dose using the 50th percentile of respirable PNOR samples and a high-end BBP respirable particulate inhalation exposure dose using the 95th percentile of respirable PNOR samples. Table 3-8 presents the central tendency and high-end facility exposure values estimated using the model.

For liquid BBP, EPA used the manufacturing inhalation exposure data as analogous to estimate vapor exposure to workers and ONUs. The manufacturing inhalation exposure data is from a risk evaluation conducted by the ECJRC ([2007](#)). See Section 3.1.4.2 for additional information on this data. EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.

EPA used the number of operating days estimated in the release assessment for this OES to estimate exposure frequency, which is the expected maximum number of working days. The high-end exposures use 250 days per year as the exposure frequency and central tendency exposures use 208 working days per year. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs.

Table 3-8 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during import and repackaging. Worker exposures were estimated for workers and for female workers of reproductive age using average body weights of the represented populations to estimate worker dose. Appendix A describes the approach for estimating AD, IADD, and ADD. The estimated exposures assume that the worker is exposed to BBP in either solid (particulates) or liquid (vapor) form does not account for scenarios where both might occur simultaneously.

Table 3-8. Summary of Estimated Worker Inhalation Exposures for Import and Repackaging of BBP

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker – Solid	8-hour TWA Exposure Concentration (mg/m ³)	6.6E–02	1.5
	Acute Dose (AD) (mg/kg-day)	8.3E–03	0.19
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.1E–03	0.14
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.7E–03	0.13
Female of Reproductive Age – Solid	8-hour TWA Exposure Concentration (mg/m ³)	6.6E–02	1.50
	Acute Dose (AD) (mg/kg-day)	9.1E–03	0.21
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.7E–03	0.15
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.2E–03	0.14
ONU – Solid	8-hour TWA Exposure Concentration (mg/m ³)	6.6E–02	6.6E–02
	Acute Dose (AD) (mg/kg-day)	8.3E–03	8.3E–03
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.1E–03	6.1E–03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.7E–03	5.7E–03
Average Adult Worker – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.46
	Acute Dose (AD) (mg/kg-day)	1.3E–02	5.7E–02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.2E–03	4.2E–02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	7.1E–03	3.9E–02
Female of Reproductive Age – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.46
	Acute Dose (AD) (mg/kg-day)	1.4E–02	6.3E–02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	1.0E–02	4.6E–02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	7.9E–03	4.3E–02
ONU – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.10
	Acute Dose (AD) (mg/kg-day)	1.3E–02	1.3E–02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.2E–03	9.2E–03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	7.1E–03	8.6E–03

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
^a EPA identified surrogate inhalation monitoring data from one source to estimate exposures for this OES (ECJRC, 2007). The source of monitoring data received a rating of medium from EPA’s systematic review process. With five data points, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency. For the PNOR model, EPA multiplied the concentration of BBP with the CT and HE estimates of the relevant NAICS code from the PNOR model to calculate the CT and HE estimates for this OES.			

3.2.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-9 are explained in Appendix A. For solid chemicals, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP may lead to overestimation of dermal exposure. Table 3-9 summarizes the APDR, the AD, the IADD, and the ADD for average adult workers, female workers of reproductive age, and ONUs. No ONU dermal exposure to liquid formulations of BBP is expected for this OES.

Table 3-9. Summary of Estimated Worker Dermal Exposures for Import and Repackaging of BBP

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker – Solid	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.4E-03	8.2E-03
Female of Reproductive Age – Solid	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.1E-03	7.5E-03
ONU – Solid	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg-day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	1.7E-03	2.0E-03
Average Adult Worker – Liquid	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.019	0.045

Modeled Scenario	Exposure Type	Central Tendency	High-End
Female of Reproductive Age – Liquid	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.019	0.045
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (i.e., 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (i.e., 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (i.e., 268 cm ²).			

3.2.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A to arrive at the aggregate worker and ONU exposure estimates in Table 3-10. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-10. Summary of Estimated Worker Aggregate Exposures for Import and Repackaging of BBP

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker – Solid	Acute (AD, mg/kg-day)	1.4E–02	0.20
	Intermediate (IADD, mg/kg-day)	1.0E–02	0.15
	Chronic, Non-Cancer (ADD, mg/kg-day)	8.1E–03	0.14
Female of Reproductive Age – Solid	Acute (AD, mg/kg-day)	1.5E–02	0.22
	Intermediate (IADD, mg/kg-day)	1.1E–02	0.16
	Chronic, Non-Cancer (ADD, mg/kg-day)	8.3E–03	0.15
ONU – Solid	Acute (AD, mg/kg-day)	1.1E–02	1.1E–02
	Intermediate (IADD, mg/kg-day)	8.2E–03	8.2E–03
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.4E–03	7.7E–03
Average Adult Worker – Liquid	Acute (AD, mg/kg-day)	0.046	0.12
	Intermediate (IADD, mg/kg-day)	0.033	0.091
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.026	0.085
Female of Reproductive Age – Liquid	Acute (AD, mg/kg-day)	0.044	0.12
	Intermediate (IADD, mg/kg-day)	0.032	0.091
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.025	0.085
ONU – Liquid	Acute (AD, mg/kg-day)	1.3E–02	1.3E–02
	Intermediate (IADD, mg/kg-day)	9.2E–03	9.2E–03
	Chronic, Non-Cancer (ADD, mg/kg-day)	7.1E–03	8.6E–03
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.3 Formulation of Adhesives and Sealants

3.3.1 Process Description

In the 2020 CDR two facilities reported use of BBP as a plasticizer and as a viscosity modifier in adhesive manufacturing. An additional site also reported the industrial use of BBP in adhesive manufacturing, but they did not specify the specific use of BBP in the formulation ([U.S. EPA, 2020a](#)). The identified industrial and commercial adhesive and sealant products for this OES include polymer sealants and industrial and commercial adhesives (see Appendix E for all EPA identified BBP-containing products for this OES). Based on the 2009 ESD on Adhesive Formulation ([OECD, 2009a](#)), a typical adhesive formulation site receives and unloads either a liquid or solid BBP into industrial mixing vessels and incorporates BBP into adhesive and sealant formulations using a batch blending or mixing process. EPA assumed that sites receive liquid BBP in drums and totes ranging in size from 20 to 1,000 gallons, and solid BBP in 25 kg bags to 500 kg gaylords based on manufacturing and import operations (see Section 3.1.2 and Section 3.2.2). The size of the container is an input to the Monte Carlo simulation to estimate releases but is not used to calculate occupational exposures for BBP. BBP is expected to be in concentrations between 1 to 100 percent upon receipt based on CDR ([U.S. EPA, 2020a](#)).

No reactions or chemical changes occur to the plasticizer (*i.e.*, BBP) during the mixing process ([OECD, 2009a](#)). Blending or mixing operations can take up to 8 hours a day. Process operations may also include quality control sampling. Formulation sites may dispose of off-specification product when the adhesive product does not meet quality or desired standards. Adhesive products containing BBP are expected to be in liquid form with the purpose of being mixed by the user into a solution or paste immediately before application. EPA expects that sites will load BBP-containing adhesive and sealant products into bottles, small containers, or drums depending on the product type ([OECD, 2009a](#)). For assessment purposes, EPA considered product container size data from container size ranges identified in the ChemSTEER User Guide ([U.S. EPA, 2015](#)) as well as technical data sheets for BBP-containing additive products, including those for adhesives/sealants, paints, and coatings. EPA assumed a range of container sizes from 0.1 gallons to an upper bound of 20 gallons, with a typical container size of one gallon. Figure 3-3 provides an illustration of the adhesive and sealant manufacturing process based on the above information ([OECD, 2009a](#)).

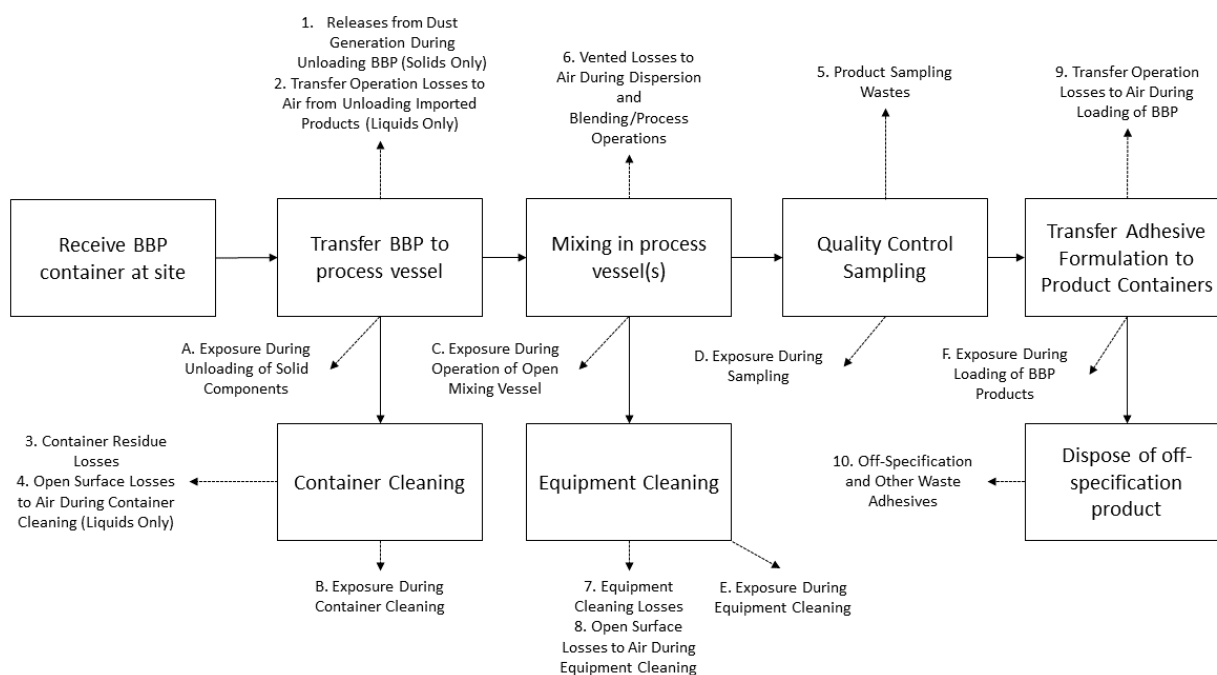


Figure 3-3. Formulation into Adhesives and Sealants Flow Diagram

3.3.2 Facility Estimates

This section primarily serves to explain the assumptions and calculations that EPA used to estimate the amount of BBP used in the formulation of adhesive and sealant products. EPA made this production volume estimate by using information from sites that reported to the 2020 CDR ([U.S. EPA, 2020a](#)). In CDR, three sites reported that they either manufacture or import BBP for use in adhesive manufacturing. One reporter, M. Argueso and Co., Inc., reported an overall PV of 2,678 kg/year (5,903 lb/year) for 2019 and stated that BBP was in the form of pellets/large crystals.

Another site, Polymer Additives, Inc., reported to CDR that 80 percent of the manufactured PV is used for the production of adhesives/sealants, with BBP used as a liquid in this process, but reported their overall site PV as CBI. As stated in Section 3.2.2, EPA used CDR to estimate this site's production volume. EPA estimated a total national aggregate BBP PV between 1,000,000 to less than 20,000,000 lb, using CBI that was reported to CDR. EPA subtracted the combined known PV from importers (611,115 lb) from each of these endpoints, resulting in a remaining import PV range of 388,885 to 19,388,885 lb; or 176,395 to 8,794,650 kg/year. EPA assumes that this range is the possible manufacturing throughput for the one site that indicated manufacturing operations in CDR.

The third site, Tremco Incorporated in Beachwood, Ohio, indicated an import volume of 605,212 lb of BBP in 2019. This site matched the name of a site in the Use Report for BBP that produced several products containing BBP, including both paints/coatings and adhesives. Therefore, EPA split the PV equally between this OES and the Application of adhesives and sealants OES, assuming a 302,606 lb (137,260 kg) PV for each OES.

Because there are different process activities that may result in releases that are dependent on the physical form of the chemical, EPA modeled the release of BBP for two different scenarios: the use of BBP in solid form, and the use of BBP in liquid form. The PV used for the assessment of BBP in solid formulation was 2,678 kg/year, the reported PV from the M. Argueso and Co., Inc facility. EPA

calculated that the overall PV for use of liquid formulations as the sum of the estimated production volumes of the other two sites:

Polymer Additives:	$80\% \times (388,885 - 19,388,885 \text{ lb/year}) = 311,108 \text{ to } 15,511,108 \text{ lb/year}$
Tremco Incorporated:	$50\% \times 605,212 \text{ lb/year} = 302,606 \text{ lb/year}$

Total PV for this OES: 613,714–15,813,714 lb/year (278,376–7,172,980 kg/year).

EPA used this overall production volume range but did not identify any BBP-specific information on batch sizes, operating days, or annual or daily throughputs for this OES. EPA assumed a 4,000 kg batch size and 250 batches per year based on the 2009 ESD on the Manufacture of Adhesives ([OECD, 2009a](#)). This is equivalent to a facility throughput of BBP of 1,000 to 700,000 kg-BBP/site-year based on a BBP concentration in the adhesive/sealant product of 0.1 to 70 percent, this concentration range was reported to CDR. This concentration range is based on two product SDSs that were identified for BBP (see Appendix E for EPA identified BBP-containing products for this OES) ([Smooth-On, 2023a](#); [Smooth-On Inc., 2018](#)). Using the PV range and dividing by the facility throughput range in EPA's Monte Carlo model for release estimates (discussed in more detail in Section 3.3.3) resulted in a central tendency (50th percentile) and high-end (95th percentile) estimate of 14 to 71 formulation sites that use liquid BBP in adhesives and sealants. EPA assumed just the one reporting site formulated adhesives using solid BBP. Additionally, EPA assumed the number of operating days was equivalent to the number of batches per year or 250 days/year of 24 hour/day, 7 day/week operations for the given site throughput scenario.

3.3.3 Release Assessment

3.3.3.1 Environmental Release Points

Because EPA did not identify any release data from TRI, DMR, or NEI for this OES, EPA assigned release points based on the 2009 ESD on the Manufacture of Adhesives ([OECD, 2009a](#)). EPA assigned a default model to quantify potential release from each release point. EPA expects releases to stack during process operations and fugitive air as well as wastewater, incineration, and landfill from unloading imported BBP through dust generation (solids) and transfer operations (liquids). EPA expects releases to fugitive air from container cleaning and equipment cleaning. EPA expects releases to wastewater, incineration, and landfill from sampling, equipment cleaning, container residue, and off-specification waste.

3.3.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process for this OES. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2009 ESD on the Manufacture of Adhesives ([OECD, 2009a](#)).

The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the ESD to estimate releases from each source. The ESD presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the ESD to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the ESD are provided below:

- Release point 1 – Dust releases from unpacking and transferring solid BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the ESD and the ChemSTEER User Guide ([U.S. EPA, 2015](#); [OECD, 2009a](#)).
- Release point 2 – Volatile emissions generated during unloading containers with liquid BBP were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, drum volumes, container opening diameters, and vapor correction factors based on various sources ([U.S. EPA, 2015](#); [OECD, 2009a](#); [Baldwin and Maynard, 1998](#)).
- Release point 3 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Drum Residual Model or the EPA/OPPT Solid Residuals in Transport Containers Model based on whether the model was run for liquid or solid releases respectively. EPA modified these models to include distributions for loss factor and container size, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2015](#); [OECD, 2009a](#)).
- Release point 4 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2015](#); [OECD, 2009a](#); [Baldwin and Maynard, 1998](#)).
- Release point 5 – Sampling waste was assessed to water, land, or waste treatment using the *EPA/OPPT 2023 Methodology for Estimating Environmental Releases from Sampling Waste*. EPA modified this to include the distribution of loss fractions presented in the methodology document ([U.S. EPA, 2023b](#)).
- Release point 6 – Emissions from dispersion and blending/process operations were assessed to stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, diameter of opening, and saturation factor based on various sources ([U.S. EPA, 2015](#); [OECD, 2009a](#); [Baldwin and Maynard, 1998](#)).
- Release point 7 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model. This model assumes a standard loss fraction of 0.02 for each batch manufactured ([U.S. EPA, 2015](#); [OECD, 2009a](#)).
- Release point 8 – Volatile emissions generated during cleaning of equipment were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2015](#); [OECD, 2009a](#); [Baldwin and Maynard, 1998](#)).
- Release point 9 – Volatile emissions generated during loading containers with liquid products containing BBP were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, drum volumes, and vapor correction factors based on various sources ([U.S. EPA, 2015](#); [OECD, 2009a](#); [Baldwin and Maynard, 1998](#)).

- Release point 10 – Dust releases from packing and transferring solid products containing BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2015](#); [OECD, 2009a](#)).

Other key assessment decisions and deviations from the ESD include that EPA modeled multiple scenarios, one for each of the physical forms of BBP that are expected to be used in the process. EPA omitted volatilization releases from sampling the manufactured product as BBP has a low vapor pressure and EPA expects that release to be much smaller than the release from the sampling or other volatilization releases. EPA also used a uniform concentration distribution of 1 to 100 percent for liquid raw materials and 1 to 30 percent for solid raw materials based on information from the 2020 CDR and a uniform concentration distribution of 0.1 to 70 percent for adhesive products based on identified product SDSs ([Smooth-On, 2023a](#); [U.S. EPA, 2020a](#); [Smooth-On Inc., 2018](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.4.1.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-11 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

It should be noted that releases to stack air for BBP in solid formulation were estimated to be much higher than stack air releases for liquids; this is due to the assessment of captured dust releases for the solid formulation scenario. BBP has a low volatility, which leads to very low estimates for fugitive air releases for both solid and liquid formulations, and low stack air releases for liquid formulations. For more information on the environmental medias assessed for modeled releases, see Section 2.3.4.

Table 3-11. Summary of Modeled Environmental Releases for Formulation into Adhesives and Sealants

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
2,678 kg/year production volume (Solids)	Stack air	6.0	25	250		2.4E-02	9.9E-02
	Fugitive air	1.4E-09	1.3E-08			5.4E-12	5.1E-11
	Incineration or landfill ^a	9.8	33			3.9E-02	0.13
	Wastewater, Incineration, or Landfill ^a	147	159			0.68	1.3

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	Fugitive air, wastewater, incineration, or landfill ^a	7.8	33			3.1E-02	0.13
278,376–7,172,980 kg/year production volume (Liquids)	Stack air	3.1E-09	2.5E-08	250		1.2E-11	9.8E-11
	Fugitive air	1.4E-09	1.3E-08			5.5E-12	5.2E-11
	Incineration or landfill ^a	788	4,036			3.2	16
	Wastewater, incineration, or landfill ^a	1.2E04	3.1E04			50	126
	Fugitive air, wastewater, incineration, or landfill ^a	630	3,826			2.5	15

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.4. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.3.4 Occupational Exposure Assessment

3.3.4.1 Workers Activities

During the formulation of adhesives and sealants containing BBP, workers are potentially exposed to BBP via inhalation of vapor or dust and dermal contact with liquids or solids when transferring BBP from transport containers into process vessels, taking quality control samples, and packaging formulated products into containers. Worker exposures may also occur when cleaning residuals from transport containers or process vessels ([OECD, 2009a](#)). EPA did not identify information on engineering controls or worker PPE used at BBP-containing adhesive and sealant formulation facilities.

For this OES, ONUs may include supervisors, managers, and other employees that formulation area but do not directly contact BBP that is received or work in the processed onsite or handle the formulated product. ONUs are potentially exposed via inhalation and dermal routes to airborne and settled dust while in the working area.

3.3.4.2 Occupational Inhalation Exposure Results

Based on reporting in CDR, BBP is incorporated into adhesives and sealants as a solid or liquid; therefore, EPA assessed worker inhalation exposures to BBP vapor from liquids and dust from solids ([U.S. EPA, 2020a](#)).

EPA identified vapor inhalation monitoring data for sealant manufacturing from data collated in the risk evaluation conducted by ECJRC ([2008](#)). The data assessed by the ECJRC consisted of four short-term samples taken from one sealant manufacturing site during the addition of BBP to the reaction vessel. All four samples, one PBZ and three Area measurements near various equipment in the processing line,

indicated an air concentration below 0.10 mg/m³, which EPA interpreted to be the LOD. EPA assessed the short-term PBZ sample as representative of the entire shift. With the sample at or below the LOD, EPA assessed inhalation exposures as a range from zero to the LOD. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint (*i.e.*, half the LOD or 0.05 mg/m³).

For solid BBP, EPA did not identify monitoring data through the systematic review process, therefore, EPA developed a deterministic model to estimate inhalation exposures to particulates for this OES using the approaches, model equations, and input parameters detailed in the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR ([U.S. EPA, 2021b](#)). The model combines expected chemical concentrations at the facility with workplace TWA particulate samples compiled from the OSHA CEHD dataset. The model estimates an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Model approaches and parameters are described in Appendix D. The monitoring data in the GS is categorized by NAICS code groupings to refine estimates where data is available. EPA estimated the 333 TWA particulate samples associated with facilities having NAICS codes starting with 325 (Chemical Manufacturing) as most similar to this OES and used these to estimate BBP particulate concentrations in the air. The highest expected BBP concentrations in imported solids containing BBP is 30 percent by mass based on company reporting in the 2020 CDR. In the estimated exposures, EPA assumed that BBP is present in particulates at this fixed concentration throughout the work shift. EPA then used the model to calculate a central tendency BBP particulate inhalation exposure dose using the 50th percentile and a high-end BBP particulate inhalation exposure dose using the 95th percentile. Table 3-12 presents the central tendency and high-end facility air concentrations of particulate and vapor estimated using the model.

Table 3-12 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during the formulation into adhesives and sealants. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The high-end and central tendency exposures use 250 days per year as the conservative estimate of exposure frequency since the 50th and 95th percentiles of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD. The estimated exposures assume that the worker is exposed to BBP in the form of either vapor or particulates, not both simultaneously.

Table 3-12. Summary of Estimated Worker Inhalation Exposures for Formulation into Adhesives and Sealants

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker – Solid	8-hour TWA Exposure Concentration (mg/m ³)	0.34	3.50
	Acute Dose (AD) (mg/kg-day)	4.2E-02	0.44
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	3.1E-02	0.32
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	2.9E-02	0.30
	8-hour TWA Exposure Concentration (mg/m ³)	0.34	3.50

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Female of Reproductive Age – Solid	Acute Dose (AD) (mg/kg-day)	4.6E-02	0.48
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	3.4E-02	0.35
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	3.2E-02	0.33
ONU – Solid	8-hour TWA Exposure Concentration (mg/m ³)	0.34	0.34
	Acute Dose (AD) (mg/kg-day)	4.2E-02	4.2E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	3.1E-02	3.1E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	2.9E-02	2.9E-02
Average Adult Worker – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.10
	Acute Dose (AD) (mg/kg-day)	6.3E-03	1.3E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	4.6E-03	9.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.3E-03	8.6E-03
Female of Reproductive Age – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.10
	Acute Dose (AD) (mg/kg-day)	6.9E-03	1.4E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	5.1E-03	1.0E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.7E-03	9.5E-03
ONU – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	5.0E-02
	Acute Dose (AD) (mg/kg-day)	6.3E-03	6.3E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	4.6E-03	4.6E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.3E-03	4.3E-03
^a EPA identified inhalation monitoring data from one source to estimate exposures for this OES (ECJRC, 2008). The source of monitoring data received a rating of medium from EPA's systematic review process. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint (<i>i.e.</i> , half the LOD or 0.05 mg/m ³). For the PNOR Model, EPA multiplied the concentration of BBP with the CT and HE estimates of the relevant NAICS code from the PNOR Model to calculate the CT and HE estimates for this OES.			

3.3.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-13 are explained in Appendix A. For solid chemicals, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper PPE or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP may lead to overestimation of dermal exposure. Table 3-13 summarizes the APDR, the AD, the IADD, and the ADD for average adult workers, female workers of reproductive age, and ONUs. No ONU dermal exposure to liquid formulations of BBP is expected for this OES.

Table 3-13. Summary of Estimated Worker Dermal Exposures for Formulation into Adhesives and Sealants

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker – Solid	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.1E-03	8.2E-03
Female of Reproductive Age – Solid	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.7E-03	7.5E-03
ONU – Solid	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg-day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	2.0E-03	2.0E-03
Average Adult Worker – Liquid	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.023	0.045
Female of Reproductive Age – Liquid	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.022	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.042
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (i.e., 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (i.e., 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (i.e., 268 cm ²).			

3.3.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-14. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-14. Summary of Estimated Worker Aggregate Exposures for Formulation into Adhesives and Sealants

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker – Solid	Acute (AD, mg/kg-day)	4.8E–02	0.45
	Intermediate (IADD, mg/kg-day)	3.5E–02	0.33
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.3E–02	0.31
Female of Reproductive Age – Solid	Acute (AD, mg/kg-day)	5.2E–02	0.49
	Intermediate (IADD, mg/kg-day)	3.8E–02	0.36
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.6E–02	0.34
ONU – Solid	Acute (AD, mg/kg-day)	4.5E–02	4.5E–02
	Intermediate (IADD, mg/kg-day)	3.3E–02	3.3E–02
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.1E–02	3.1E–02
Average Adult Worker – Liquid	Acute (AD, mg/kg-day)	0.039	0.079
	Intermediate (IADD, mg/kg-day)	0.029	0.058
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.027	0.054
Female of Reproductive Age – Liquid	Acute (AD, mg/kg-day)	0.037	0.075
	Intermediate (IADD, mg/kg-day)	0.027	0.055
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.026	0.051
ONU – Liquid	Acute (AD, mg/kg-day)	6.3E–03	6.3E–03
	Intermediate (IADD, mg/kg-day)	4.6E–03	4.6E–03
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.3E–03	4.3E–03
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.4 Formulation into Paints and Coatings

3.4.1 Process Description

The 2020 CDR and identified product data indicate that BBP is used as an additive in paint and coating manufacturing ([U.S. EPA, 2020a](#)). The 2020 CDR did not indicate the function of BBP in paints and coatings. EPA assumed it would be used as a plasticizer. See Appendix E for EPA-identified BBP-containing industrial and commercial products for this OES.

A typical formulation site receives and unloads BBP into industrial mixing vessels as a batch blending or mixing process, with no reactions or chemical changes occurring to the additive (*i.e.*, BBP) during the mixing process ([U.S. EPA, 2014a](#)). Based on CDR data for importers and manufacturers, EPA assumes that BBP arrives at formulation sites and is added to the formulation as a liquid. EPA assumed that formulation sites receive BBP in drums or totes with volumes between 20 gallons and 1,000 gallons with BBP concentrations of 1 to 60 percent, based on what was reported to CDR and estimated container sizes from the manufacturing and import operations (see Section 3.1.2 and Section 3.2.2) ([U.S. EPA, 2020a](#)). EPA assessed an upper bound concentration of 60% to account for identified coating products that listed a 60 percent concentration of BBP. EPA evaluated the SDSs for paint and coating products and assessed a lower bound of 0.1 percent, with a typical value of 1.75 percent (see Appendix E for EPA identified BBP-containing products for this OES). EPA considered container size data from technical data sheets for liquid BBP-containing additive products, including those for adhesives/sealants and paints and coatings, as well as container size ranges identified in the ChemSTEER User Guide ([U.S.](#)

[EPA, 2015](#)). EPA assessed a container size using a lower bound of 0.1 gallons, an upper bound of 100 gallons, with a typical value of one gallon (see Section D.5.9).

Blending or mixing operations can take up to 8 hours a day. Process operations may include quality control sampling. In the case of waterborne coatings, the formulator transfers the blended formulation through an in-line filter. Sites may dispose of off-specification products when the product does not meet quality or desired standards. Following formulation, formulation sites load BBP-containing products into bottles, small containers, or drums depending on the product type ([U.S. EPA, 2014a](#)). Figure 3-4 provides an illustration of the paint and coating manufacturing process based on information from the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)).

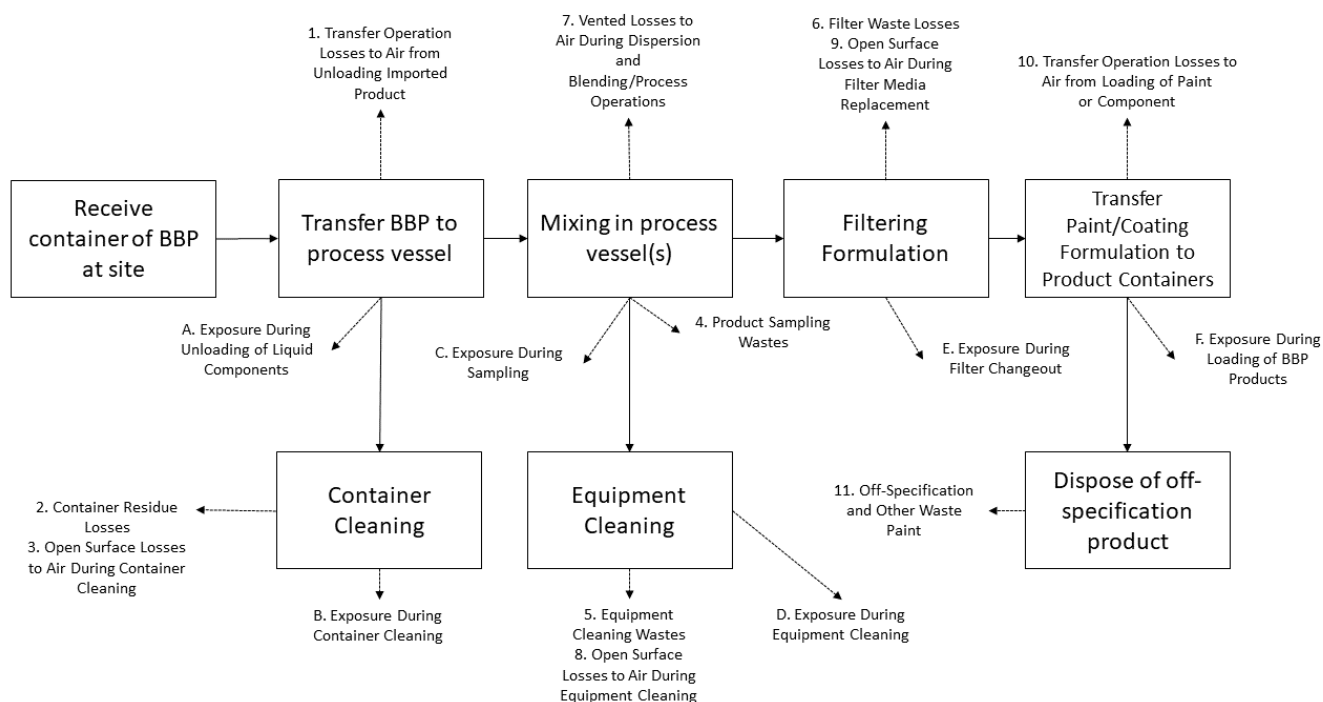


Figure 3-4. Formulation into Paints and Coatings Flow Diagram

3.4.2 Facility Estimates

In the 2020 CDR, one site, Tremco Incorporated in Beachwood, OH, indicated that it used BBP in paint and coating products and reported an import volume of 605,212 lb of BBP in 2019 ([U.S. EPA, 2020a](#)). This site matched the name of a site in the Use Report for BBP that produced several products containing BBP, including both paints/coatings and adhesives. Therefore, EPA assumed a 50/50 split of the PV between this OES and the Formulation of Adhesives and Sealants OES, which is 302,606 lb (137,260 kg) for each OES.

EPA used the 2020 CDR to estimate the number of paint and coating processing sites that use BBP. The one submitting site did not specify the number of downstream processing sites; however, it specified that less than 10 workers handled BBP. Based on this information, EPA assumed that 1 to 9 sites (the minimum reportable range for number of sites) incorporated BBP into paints and coatings.

EPA did not identify paint and coating site operating data (*i.e.*, batch size or number of batches per year), so EPA assumed 5,030 kg of paint or coating is produced per batch with 250 batches produced per year, based on the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)). EPA

assumed that the number of operating days was equivalent to the number of batches manufactured per year or 250 days/year for the given site throughput scenario. The annual throughput per facility was estimated by multiplying the daily throughput by the number of operating days.

3.4.3 Release Assessment

3.4.3.1 Environmental Release Points

One site reported using BBP in paint and coating products in 2020 CDR Data: Tremco, Incorporated. Based on the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)), EPA expects stack air releases from vented losses during dispersion and blending/process operations; fugitive air releases from transfer operations and equipment/container cleaning; releases to wastewater, incineration, or landfill from container residue, sampling wastes, equipment cleaning, and off-specification wastes; and releases to incineration or landfill from filter waste.

3.4.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)).

The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source. The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Volatile emissions generated during unloading containers with liquid BBP were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, drum volumes, and vapor correction factors based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 2 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Drum Residual Model or the EPA/OPPT Solid Residuals in Transport Containers Model based on whether the model was run for liquid or solid releases respectively. EPA modified these models to include distributions for container size and loss factor, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2015, 2014a](#)).
- Release point 3 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 4 – Sampling waste was assessed to water, land, or waste treatment using the EPA/OPPT 2023 Methodology for Estimating Environmental Releases from Sampling Waste. EPA modified this to include the distribution of loss fractions presented in the methodology document ([U.S. EPA, 2023b](#)).

- Release point 5 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model. This model assumes a standard loss fraction of 0.02 for each batch and was modified by EPA to include a distribution for equipment cleaning time ([U.S. EPA, 2015, 2014a](#)).
- Release point 6 – Releases from filter change-out waste was not assessed for this OES as there is no EPA/OPPT standard model or relevant industrial process data available to use in this calculation ([U.S. EPA, 2014a](#)).
- Release point 7 – Emissions from dispersion and blending/process operations were assessed to stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, diameter of opening, and saturation factor based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 8 – Volatile emissions generated during cleaning of equipment were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, equipment cleaning time, and saturation factor based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 9 – Volatile emissions from changing out filters in the process were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and operating time based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 10 – Volatile emissions generated during loading containers with liquid BBP products were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors and container volumes based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 11 – Releases from disposal of off-spec product were assessed for water, land, or waste treatment using a standard loss factor of 0.012 based on the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)).

Other key assessment decisions and deviations from the GS that EPA omitted volatilization releases from sampling the formulated product as BBP has a low vapor pressure and EPA expects that release to be much smaller than the release from the sampling or other volatilization releases. EPA also used a uniform concentration distribution of 1 to 60% for raw material based on information from the 2020 CDR and a uniform concentration distribution of 0.1 to 60% for paint/coating products based on identified product SDSs ([U.S. EPA, 2020a](#); [BJB Enterprises, 2019](#); [Multi-Tech Products Corp, 2015](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.5.1.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES.

Table 3-15 presents the 50th percentile and 95th percentile release volumes estimated by the model to

assess central tendency and high-end facility releases to each media, respectively.

Table 3-15. Summary of Modeled Environmental Releases for Formulation into Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
137,000 kg/year production volume	Stack Air	7.4E-05	4.9E-04	250		2.9E-07	2.0E-06
	Fugitive Air	7.8E-05	2.7E-04			3.1E--07	1.1E-06
	Wastewater, Incineration, or Landfill ^a	980	4,817			12	43

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.5. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.4.4 Occupational Exposure Assessment

3.4.4.1 Worker Activities

Worker inhalation exposures during the formulation of paints and coatings containing BBP may occur via inhalation of BBP vapors when handling liquid BBP. Dermal exposure to liquids may occur when unloading BBP, cleaning transport containers, product sampling, equipment cleaning, and during filter media change out ([U.S. EPA, 2014a](#)). EPA did not identify information on engineering controls or worker PPE used at BBP-containing paint and coating formulation sites.

For this OES, ONUs may include supervisors, managers, and other employees that work in the formulation area but do not directly contact BBP that is received or processed onsite or handle the formulated product. ONUs are potentially exposed via inhalation to BBP vapors and via dermal routes to settled dust while in the working area.

3.4.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the formulation of BBP into paints and coatings during systematic review. BBP is incorporated into paints and coatings as a liquid. EPA assessed worker inhalation exposures to BBP vapors during all work activities.

EPA used analogous monitoring data from formulation into adhesives and sealants to estimate worker vapor inhalation exposures to BBP for this OES. Inhalation exposures during the two formulation OES are expected to be comparable because they involve similar worker activities. The vapor inhalation monitoring data for formulation into adhesives and sealants is from the risk evaluation by ECJRC ([2008](#)). The data assessed by the ECJRC consisted of four short-term samples taken from one sealant manufacturing site during the addition of BBP to the reaction vessel. All four samples indicated an air concentration below 0.10 mg/m³, which EPA interpreted to be the LOD. With all samples at or below the LOD, EPA assessed inhalation exposures as a range from zero to the LOD. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint (*i.e.*, half the LOD or 0.05 mg/m³).

Table 3-16 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during the formulation into paints and coatings. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. EPA used the number of operating days estimated in the release assessment, which is 250 days/year, for this OES to estimate exposure frequency. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-16. Summary of Estimated Worker Inhalation Exposures for Formulation into Paints and Coatings

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.10
	Acute Dose (AD) (mg/kg-day)	6.3E-03	1.3E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	4.6E-03	9.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.3E-03	8.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.10
	Acute Dose (AD) (mg/kg-day)	6.9E-03	1.4E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	5.1E-03	1.0E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.7E-03	9.5E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	5.0E-02
	Acute Dose (AD) (mg/kg-day)	6.3E-03	6.3E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	4.6E-03	4.6E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.3E-03	4.3E-03

^a EPA identified surrogate inhalation monitoring data from one source to estimate exposures for this OES ([ECJRC, 2008](#)). The source of monitoring data received a rating of medium from EPA's systematic review process. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint (*i.e.*, half the LOD or 0.05 mg/m³).

3.4.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various "Exposure Concentration Types" from Table 3-17 are explained in Appendix A. ONU dermal exposures are not assessed for this OES as there are no activities expected to expose ONUs to BBP in liquid form. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP will likely lead to

overestimation of dermal exposure. Table 3-17 summarizes the Acute Potential Dose Rate (APDR), AD, IADD, and ADD for average adult workers and female workers of reproductive age. No ONU dermal exposure to liquid formulations of BBP is expected for this OES.

Table 3-17. Summary of Estimated Worker Dermal Exposures for Formulation into Paints and Coatings

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.023	0.045
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.022	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.042
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for two-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers).			

3.4.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates Table 3-18. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-18. Summary of Estimated Worker Aggregate Exposures for Formulation into Paints and Coatings

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.039	0.079
	Intermediate (IADD, mg/kg-day)	0.029	0.058
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.027	0.054
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.037	0.075
	Intermediate (IADD, mg/kg-day)	0.027	0.055
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.026	0.051
ONU	Acute (AD, mg/kg-day)	6.3E-03	6.3E-03
	Intermediate (IADD, mg/kg-day)	4.6E-03	4.6E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.3E-03	4.3E-03
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.5 Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere

3.5.1 Process Description

Incorporation into other formulations, mixtures, and reaction products refers to the process of mixing or blending several raw materials to obtain a single product or preparation. Exact process operations involved in the incorporation of BBP into a chemical formulation, mixture, or reaction products are dependent on the specific manufacturing process or processes involved. EPA expects that each individual formulation process will be similar batch mixing processes; therefore, EPA assessed releases and exposures for the incorporation of BBP into chemical formulations, mixtures, or reaction products as a group rather than individually.

While EPA identified limited information on the formulation of these types of products, EPA expects that formulation follows the same general processes regardless of end product type. Based on the 2014 GS on the Formulation of Waterborne Coatings, EPA expects that a typical site will unload BBP and incorporate it into other formulations, mixtures, and reaction products within industrial mixing vessels, using a batch blending or mixing process, with no reactions or chemical changes occurring to BBP during the mixing process ([U.S. EPA, 2014a](#)). EPA assumed container sizes were similar to those used for adhesives and sealants and paint and coating products. Specifically, EPA assumed BBP is received in drums or totes with volumes between 20 and 100 gallons, with BBP concentrations of 1 to 100 percent, based on CDR data and estimated container sizes from the manufacturing and import operations (see Section 3.1.2 and Section 3.2.2) ([U.S. EPA, 2020a](#)).

Blending or mixing operations can take up to 8 hours a day. Process operations may include quality control sampling and formulation sites may transfer the blended formulation through an in-line filter. Sites may dispose of off-specification product when the product does not meet quality or desired standards. EPA assumed the formulated products are produced in liquid form. Following formulation, sites load BBP-containing products into bottles, small containers, or drums depending on the product type ([U.S. EPA, 2014a](#)). EPA evaluated the SDSs for other formulation products and assessed the final product concentration with a lower bound of 0.1 percent, an upper bound of 100 percent, with a typical value of 0.65 percent (see Appendix E for EPA identified BBP-containing products for this OES). EPA assessed product container size using a lower bound of 0.1 gallons, an upper bound of 20 gallons, with a typical size of one gallon. Figure 3-5 provides an illustration of the other formulations manufacturing process based on information from the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)).

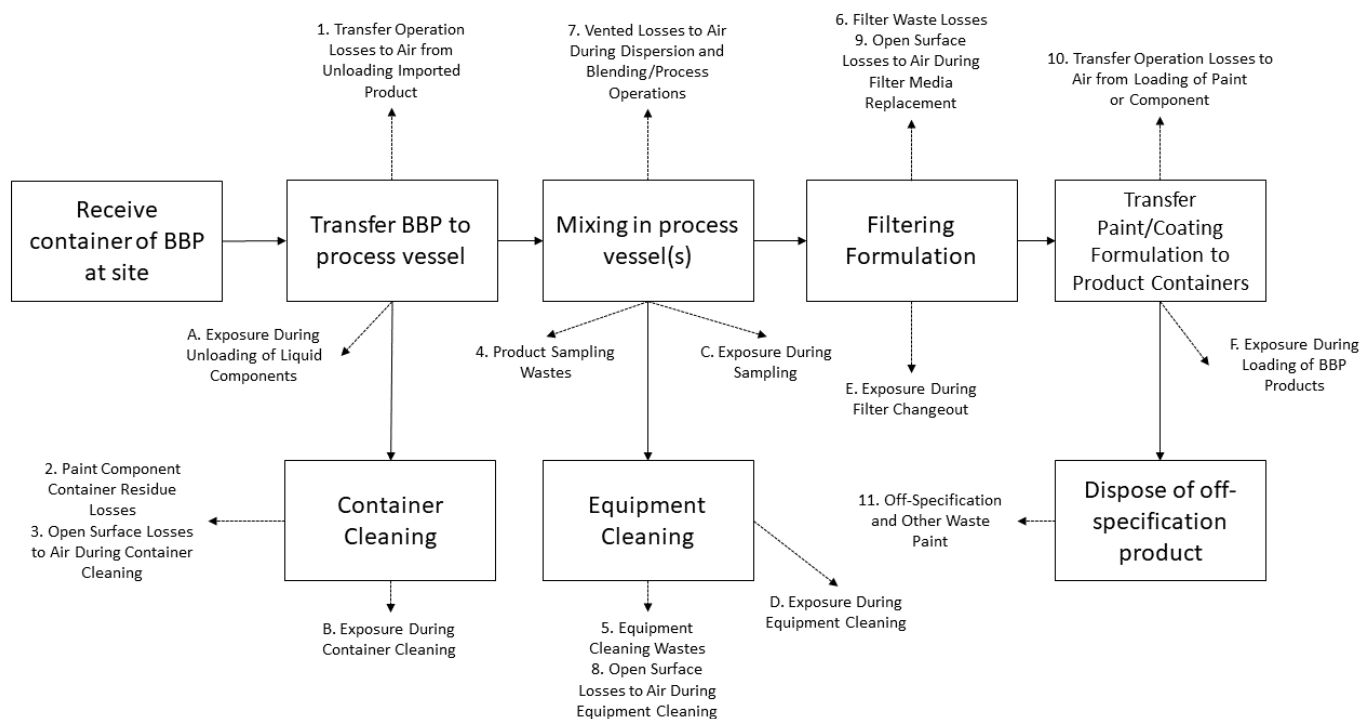


Figure 3-5. Incorporation into Other Formulations, Mixtures, and Reaction Products Flow Diagram

3.5.2 Facility Estimates

EPA did not identify any production volume information specific to this OES. EPA assumed that a portion of the BBP production volume from each CDR reporting site may be used for other formulations. Specifically, EPA estimated the total production volume of BBP used in other formulations using the CDR reporting threshold limits of either 25,000 pounds (11,340 kg) or 5 percent of a site's reported production volume, whichever value was smaller. EPA considered every site that reported using BBP to CDR, regardless of assigned OES. EPA assumed that sites that claimed their production volume as CBI produced 25,000 pounds of BBP-containing formulations annually. Table 3-19 lists the sites and associated production volumes that EPA considered in calculating the total production volume for this OES ([U.S. EPA, 2020a](#)). EPA estimated the total production volume for this OES as 50,295 lb/year or 22,813 kg/year.

Table 3-19. CDR Reported Site Information for Use in Calculation of Other Formulations, Mixtures, and Reaction Products Production Volume

Site Name	Reported Production Volume (lb/year)	Threshold Limit Used	Production Volume Added to Total (lb/year)
M. Argueso & Co., Inc.	5,903	5%	295
Polymer Additives, Inc.	CBI	25,000 lb	25,000
Tremco Incorporated	605,212	25,000 lb	25,000

EPA modeled the total number of sites that manufacture other formulations using throughput data from on the 2014 ESD on the Formulation of Waterborne Coatings (see Appendix D.6 for details) ([U.S. EPA, 2014a](#)). Using the assumptions in the ESD, formulation operations were estimated to occur at a single site; however, three facilities reported water releases to DMR. EPA used the ESD and Monte Carlo

modeling to estimate releases to air, incineration, and landfill for one generic site and assumed that those releases were comparable to releases from the three sites that reported to DMR.

EPA did not identify BBP-specific operating information (*i.e.*, batch size or number of batches per year) for this OES. Instead, EPA assessed 5,030 kg/batch of produced product and 250 batches/year based on the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)). Additionally, EPA assumed that the number of operating days was equivalent to the number of batches per year, or 250 days/year for the given site throughput scenario. EPA estimated the annual throughput per facility by multiplying the daily throughput by the number of operating days.

3.5.3 Release Assessment

3.5.3.1 Environmental Release Points

Based on the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) EPA assessed stack air releases from vented losses during dispersion and blending/process operations; fugitive air releases from container cleaning, equipment cleaning, filter media replacement, and transfer operations from unloading and loading; releases to wastewater, incineration, or landfill from container residue, sampling wastes, equipment cleaning, and off-specification wastes; and releases to incineration or landfill from filter waste losses.

3.5.3.2 Environmental Release Assessment Results

EPA identified surface water discharge data from DMR for this OES; however, this data did not include release data for environmental media other than surface water and may not be representative of all releases from use sites. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2014 GS on the Formulation of Waterborne Coatings, which EPA determined was the most applicable process to model releases for this OES ([U.S. EPA, 2014a](#)).

The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source. The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Volatile emissions generated during unloading containers with liquid BBP were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, drum volumes, and vapor correction factors based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 2 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Drum Residual Model. EPA modified this model to include distributions for container size and loss factor, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2015, 2014a](#)).
- Release point 3 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include

distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#))

- Release point 4 – Sampling waste was assessed to water, land, or waste treatment using the *EPA/OPPT 2023 Methodology for Estimating Environmental Releases from Sampling Waste*. EPA modified this to include the distribution of loss fractions presented in the methodology document ([U.S. EPA, 2023b](#)).
- Release point 5 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model. This model assumes a standard loss fraction of 0.02 for each batch ([U.S. EPA, 2015, 2014a](#)).
- Release point 6 – Releases from filter change-out waste was not assessed for this OES as there is no EPA/OPPT standard model or relevant industrial process data available to use in this calculation ([U.S. EPA, 2014a](#)).
- Release point 7 – Emissions from dispersion and blending/process operations were assessed to stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, diameter of opening, and saturation factor based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 8 – Volatile emissions generated during cleaning of equipment were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, equipment cleaning time, and saturation factor based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 9 – Volatile emissions from changing out filters in the process were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, operating time, and saturation factor based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 10 – Volatile emissions generated during loading containers with liquid BBP products were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors and container volumes based on various sources ([U.S. EPA, 2015, 2014a](#); [Baldwin and Maynard, 1998](#)).
- Release point 11 – Releases from disposal of off-spec product were assessed water, land, or waste treatment using a standard loss factor of 0.012 based on the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)).

Other key assessment decisions and deviations from the GS that EPA omitted volatilization releases from sampling the formulated product as BBP has a low vapor pressure and EPA expects that release to be much smaller than the release from the sampling or other volatilization releases. EPA also used a uniform concentration distribution of 1 to 100 percent for raw material based on information from the 2020 CDR and a triangular concentration distribution of 0.01 to 100 percent for formulated products based on identified product SDSs ([U.S. EPA, 2020a](#); [Bio SB Inc., 2019](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.6.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, and land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-20 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

Central tendency and high-end release estimates for non-air environmental media have little variation as EPA assessed a single static production volume for this OES rather than a range of volumes as used in other OES assessments. Therefore, variation in releases is solely dependent on the loss fraction distributions rather than both loss fraction and production volumes distributions and the latter tends to have a larger range of values and a bigger impact on releases quantities.

Table 3-20. Summary of Modeled Environmental Releases for Incorporation into Other Formulations, Mixtures, and Reaction Products

Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Stack Air	1.2E-04	8.0E-04	250		4.6E-07	3.2E-06
Fugitive Air	1.2E-04	4.3E-04			4.8E-07	1.7E-06
Wastewater, Incineration, or Landfill ^a	1,235	1,436			5.5	5.8
^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.						
^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.6. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively						

Table 3-21 presents surface water discharges per year and per day based on 2017 to 2022 DMR data along with the number of release days per year, with medians and maxima presented from across the six-year reporting range. If a facility has only one record in the identified range, then the median and maxima will be equivalent. According to the DMR data, three sites reported direct discharges to surface water for the this OES: Chemours - Chambers Works, Chevron Products, Co. - Hawaii Refinery, and Sochem Solutions Inc. - Sochem Naphthenic Acid Recovery Facility ([U.S. EPA, 2024a](#)). The modeled values of release to surface water are several orders of magnitude greater than those listed in DMR and may not be representative of true release to surface waters for this OES. However, the DMR data has several significant sources of uncertainty, including the lack of context about why a particular chemical is being monitored (sites could be monitoring a specific chemical because of groundwater contamination or other non-TSCA purposes), EPA does not have a lot of information (NAICS and name) to use for determining which OES should be assigned to a site (creating uncertainty about the appropriateness of its inclusion in the OES), and low frequency of sampling (frequently once per year for chemical specific monitoring) that is directed by the NPDES permits for BBP monitoring (creating uncertainty if the annual load is truly representative for a chemical). Therefore, it is not known if these sites are representative of all sites in this OES. Therefore, modeling values in Table 3-21 were used as an upper

bound for surface water concentrations in general population and environmental risk assessments, even though there are uncertainties present within the modeling parameters. The SACC agreed with the use of generic scenarios to generate release values in the absence of data. When EPA released the draft Risk Evaluation for BBP, EPA acknowledged the data gap for environmental release data for this OES and solicited alternative data sources from the public. However, no additional data sources were provided during the public comment period.

Table 3-21. Summary of Water Releases from DMR for Incorporation into Other Formulations, Mixtures, and Reaction Products

Site Identity	Median Annual Discharge (kg/year)	Median Average Daily Discharge (kg/day)	Maximum Annual Discharge (kg/year)	Maximum Average Daily Discharge (kg/day)	Annual Release Days (days/year)
Chemours-Chambers Works	2.68	1.1E-02	3.03	1.2E-02	250
Chevron Products Co – Hawaii Refinery	0.29	1.2E-03	0.29	1.2E-03	250
Sochem Solutions Inc – Sochem Naphthenic Acid Recovery Facility	1.9E-02	7.7E-05	7.6E-02	3.0E-04	250

3.5.4 Occupational Exposure Assessment

3.5.4.1 Worker Activities

During the incorporation of BBP into other formulations, mixtures or reaction products, workers are potentially exposed to BBP via inhalation of vapor and dermal contact with liquids when transferring BBP from transport containers into process vessels, taking QC samples, and packaging formulated products into containers. Worker exposures may also occur when cleaning residuals from transport containers or process vessels ([U.S. EPA, 2014a](#)). EPA did not identify information on engineering controls or worker PPE used at BBP-containing formulation facilities.

For this OES, ONUs may include supervisors, managers, and other employees that work in the formulation area but do not directly contact BBP that is received or processed onsite or handle the formulated product. ONUs are potentially exposed via inhalation routes to vapors while in the working area.

3.5.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the incorporation of BBP into other formulations, mixtures or reaction products during systematic review. BBP is incorporated into paints and coatings as a liquid based on the available manufactured and imported form data reported to CDR ([U.S. EPA, 2020a](#)). EPA assessed worker inhalation exposures to BBP vapors during all work activities.

EPA used analogous monitoring data from formulation into adhesives and sealants to estimate worker vapor inhalation exposures to BBP for this OES. Inhalation exposures during the two formulation activities are expected to be comparable. The vapor inhalation monitoring data is compiled in the risk evaluation conducted by ECJRC ([2008](#)). The data assessed by the ECJRC consisted of four short-term samples taken from one sealant manufacturing site during the addition of BBP to the reaction vessel. All four samples, 1 PBZ and 3 Area measurements near various equipment in the processing line, indicated

an air concentration below 0.10 mg/m³ which EPA interpreted to be the LOD. EPA assessed the short-term PBZ sample as representative of the entire shift. With the sample at or below the LOD, EPA assessed inhalation exposures as a range from 0 to the LOD. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint (*i.e.*, half the LOD).

Table 3-22 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during the incorporation into other formulations, mixtures, and reaction products. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The high-end and central tendency exposures use 250 days per year as the exposure frequency since the 95th and 50th percentiles of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-22. Summary of Estimated Worker Inhalation Exposures for Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.10
	Acute Dose (AD) (mg/kg-day)	6.3E-03	1.3E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	4.6E-03	9.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.3E-03	8.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.10
	Acute Dose (AD) (mg/kg-day)	6.9E-03	1.4E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	5.1E-03	1.0E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.7E-03	9.5E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	5.0E-02
	Acute Dose (AD) (mg/kg-day)	6.3E-03	6.3E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	4.6E-03	4.6E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.3E-03	4.3E-03
^a EPA identified surrogate inhalation monitoring data from one source to estimate exposures for this OES (ECJRC, 2008). The source of monitoring data received a rating of medium from EPA's systematic review process. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint (<i>i.e.</i> , half the LOD or 0.05 mg/m ³).			

3.5.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various "Exposure Concentration Types" from Table 3-17 are explained in Appendix A. ONU dermal exposures are not assessed for this OES as there are no activities expected to expose ONUs to BBP in liquid form. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8

hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP may lead to overestimation of dermal exposure. Table 3-23 summarizes the Acute Potential Dose Rate (APDR), AD, IADD, and ADD for average adult workers and female workers of reproductive age. No ONU dermal exposure to liquid formulations of BBP is expected for this OES.

Table 3-23. Summary of Estimated Worker Dermal Exposures for Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.023	0.045
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.022	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.042
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers).			

3.5.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-24. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-24. Summary of Estimated Worker Aggregate Exposures for Incorporation into Other Formulations, Mixtures, or Reaction Products Not Covered Elsewhere

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.039	0.079
	Intermediate (IADD, mg/kg-day)	0.029	0.058
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.027	0.054
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.037	0.075
	Intermediate (IADD, mg/kg-day)	0.027	0.055
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.026	0.051
ONU	Acute (AD, mg/kg-day)	6.3E-03	6.3E-03
	Intermediate (IADD, mg/kg-day)	4.6E-03	4.6E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.3E-03	4.3E-03
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.6 PVC Plastics Compounding

3.6.1 Process Description

PVC plastics compounding involves mixing the polymer with the plasticizer and other chemicals such as fillers and heat stabilizers ([NASA, 2020](#); [MEMA, 2019](#)). The plasticizer (*i.e.*, BBP) needs to be absorbed into the particle to impart flexibility to the polymer. For PVC plastics compounding scenarios, compounding occurs through mixing ingredients to produce a powder (dry blending) or a liquid (plastisol blending). The most common process for dry blending involves heating the ingredients in a high intensity mixer and transferring to a cold mixer. The plastisol blending is done at ambient temperature using specific mixers that allow for the breakdown of the agglomerates and the absorption of the plasticizer into the resin particle. The 2020 CDR reports use of BBP as a plasticizer in plastics (see Appendix E for EPA identified BBP-containing products for this OES) ([U.S. EPA, 2020a](#)).

BBP is assumed to primarily be received by plastics compounding sites as a liquid based on the information provided by the only 2020 CDR report that specified use in plastic products, Polymer Additives, Inc ([U.S. EPA, 2020a](#)). EPA expects that a typical compounding site receives BBP as a liquid in containers ranging in size from 20 to 1,000 gallons ([U.S. EPA, 2021c](#)). The site unloads and transfers BBP into mixing vessels to produce a compounded resin masterbatch. Following completion of the masterbatch, the site transfers the solid resin to an extruder that shapes and sizes the plastic and packages the final product for shipment to downstream conversion sites after cooling. Figure 3-6 provides an illustration of the plastic compounding process, developed based on information from the 2021 Draft Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)).

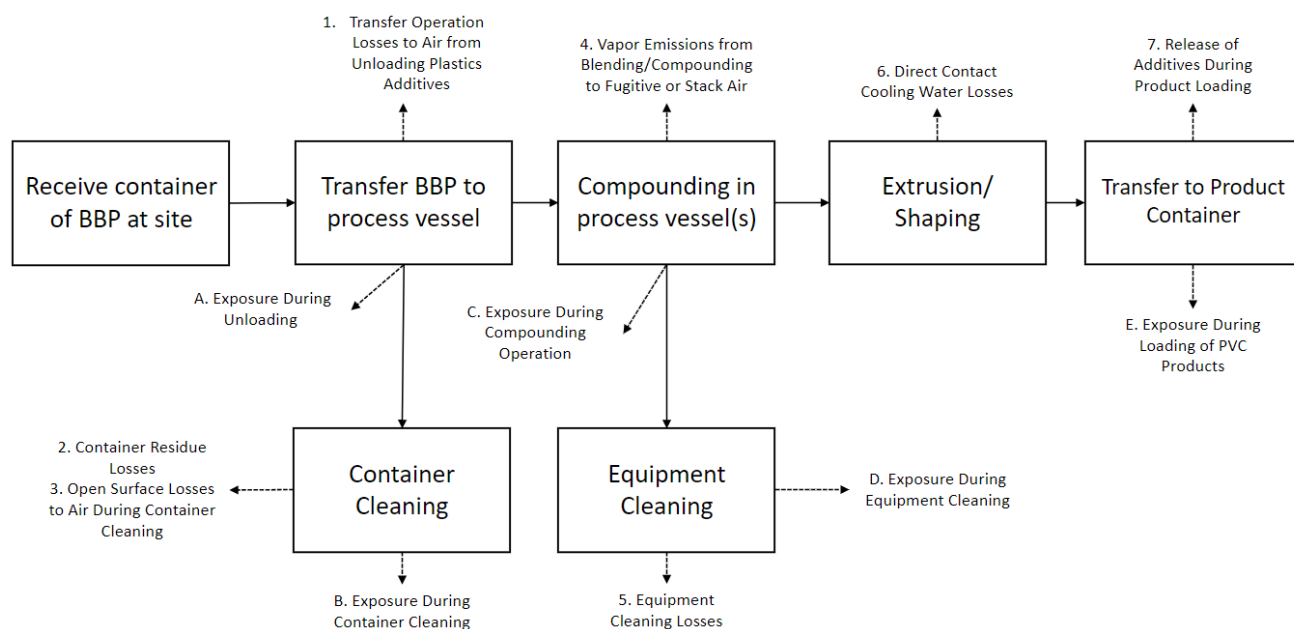


Figure 3-6. PVC Plastics Compounding Flow Diagram

3.6.2 Facility Estimates

In the 2020 CDR, one site, Polymer Additives, Inc. in Bridgeport, NJ, reported an industrial sector of “Plastics Product Manufacturing”. This site reported a CBI production volume in 2019 ([U.S. EPA, 2020a](#)). EPA estimated the potential PV for this site by taking the national aggregate BBP production volume range of 1,000,000 to 20,000,000 lb/year and subtracting the reported non-CBI PVs from all other sites (a total of 611,115 lb). Polymer Additives, Inc. reported to CDR that 20 percent of their PV

will be used in plastic product manufacturing, so the resulting number was multiplied by this 20 percent ([U.S. EPA, 2020a](#)). The total PV of BBP across this site was therefore estimated to be:
 $PV = 20\% * (388,855 - 19,388,885 \text{ lb}) = 77,777 \text{ to } 3,877,777 \text{ lb } (35,279 - 1,758,930 \text{ kg}).$

EPA did not identify site- or chemical-specific operating data for plastics compounding (*i.e.*, facility production rate, number of batches, or operating days). The 2021 Draft Generic Scenario for the Use of Additives in Plastic Compounding provides a range of 30 percent to 40 percent for the typical weight fraction of plasticizers in flexible PVC and an annual facility throughput of 4,319,048 kg/site-year for plastic additives ([U.S. EPA, 2021c](#)). EPA assessed the total number of operating days of based on the GS range of 148 to 264 days/year for the given site throughput scenario ([U.S. EPA, 2021c](#)). Additionally, EPA assumed the number of batches per site per year was equivalent to the number of operating days, or one batch per day. EPA estimated the number of sites by dividing the range of BBP production volume used in this OES by the estimated plastics additive throughput multiplied by the concentration of BBP in the plastic additives. EPA's Monte Carlo model for release estimates (discussed in more detail in Section 3.6.3) resulted in an estimate of just one PVC plastics compounding site at both the 50th and 95th percentile.

3.6.3 Release Assessment

3.6.3.1 Environmental Release Points

Based on the 2021 Draft Generic Scenario on Plastic Compounding ([U.S. EPA, 2021c](#)), EPA assessed fugitive or stack air releases from unloading transfer operations, container cleaning, and vapor emissions from blending/compounding; wastewater, incineration, or landfill releases from container residue and equipment cleaning; wastewater releases from direct contact cooling; stack air, fugitive air, wastewater, incineration, or landfill releases from dusts generated during loading the solid plastic resin.

Sites may utilize air capture and control technology for dusts releases ([U.S. EPA, 2021c](#)). If a site uses air capture and control technology, EPA expects captured and controlled dust releases from product loading to be released to disposal facilities for incineration or landfill. EPA expects that uncontrolled dust is released to stack air and any uncaptured dusts are released to fugitive air, wastewater, incineration, or landfill.

3.6.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2021 Draft Generic Scenario on Plastic Compounding ([U.S. EPA, 2021c](#)). The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source. The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Volatile emissions generated during container unloading were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, container volumes, and vapor correction factors based on various sources ([U.S. EPA, 2021c, 2015](#); [Baldwin and Maynard, 1998](#)).

- Release point 2 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Drum Residual Model. EPA modified this model to include distributions for container size and loss factor, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2021c, 2015](#)).
- Release point 3 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2021c, 2015](#); [Baldwin and Maynard, 1998](#))
- Release point 4 – Emissions from dispersion and blending/process operations were assessed to stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, diameter of opening, and saturation factor based on various sources ([U.S. EPA, 2021c, 2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 5 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model ([U.S. EPA, 2021c, 2015](#)).
- Release point 6 – Releases from cooling water were assessed to water and used a loss fraction from the 2021 Draft Generic Scenario on Plastic Compounding ([U.S. EPA, 2021c](#)).
- Release point 7 – Dust releases from loading compounded plastic containing BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2021c, 2015](#)).

Other key assessment decisions and deviations from the GS include using a uniform concentration distribution of 90 to 100 percent and a uniform production volume distribution of 35,279 to 1,758,930 kg/year based on information from the 2020 CDR ([U.S. EPA, 2020a](#)). A uniform concentration distribution of 30 to 45 percent was assumed for the compounded resin based on the GS ([U.S. EPA, 2021c](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.8.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-25 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

For some of the release estimates for this OES, the difference between the central tendency and high-end results do not seem to directly correspond with the difference between the low- and high-end of the overall production volume range (35,279–1,758,930 kg). This is true for fugitive or stack air releases and for releases to wastewater, incineration, and landfill. The releases that are assumed to be released to both of these media groups were calculated by multiplying a standard loss factor by the daily throughput rate of BBP, which itself was calculated using distributions for the overall production volume of BBP

and the number of operating days per site (which is provided by the GS). The calculated daily BBP throughput had a central tendency and high-end value of 4,067 to 7,999 kg/site-day; this smaller throughput range resulted in a smaller range of releases assessed to these medias.

Table 3-25. Summary of Modeled Environmental Releases for Plastics Compounding

Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Fugitive or Stack Air ^a	18	33	223	254	8.1E-02	0.16
Stack Air	249	7,112			1.2	33
Wastewater, Incineration, or Landfill ^a	2.0E04	4.1E04			90	203
Wastewater	8,911	1.7E04			41	80
Fugitive Air, Wastewater, Incineration, or Landfill ^a	2,111	1.3E04			9.7	60
Incineration or Landfill ^a	3,622	1.7E04			17	81

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.8. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively

3.6.4 Occupational Exposure Assessment

3.6.4.1 Worker Activities

Worker exposures to BBP during the compounding process may occur via inhalation of dusts. Worker exposures may also occur via dermal contact with liquids and inhalation of vapors during BBP unloading, transport container cleaning, and equipment cleaning ([U.S. EPA, 2021c](#)). EPA did not identify information on engineering controls or worker PPE used at plastics compounding sites.

For this OES, ONUs may include supervisors, managers, and other employees that work in the compounding area but do not directly contact BBP that is received or processed onsite or handle the compounded plastic product. ONUs are potentially exposed via inhalation and dermal routes to airborne and settled dust while in the working area.

3.6.4.2 Occupational Inhalation Exposure Results

EPA did not identify OES-specific inhalation monitoring data for BBP from systematic review of literature sources; however, EPA identified suitable analogous BBP monitoring data that was mapped to the PVC plastics converting OES. EPA identified two data sets with inhalation monitoring data; one risk evaluation conducted by the ECJRC that consists of 44 data points on vapor exposures to BBP during PVC plastics compounding and converting and four monitoring samples expected to be dust in OSHA'S CEHD database. Some of the monitoring data were for sites that did both compounding and converting, and EPA included them in this OES. The ECJRC used samples from literature to develop exposure estimates for the production of BBP based on individual worker titles, such as calendar operator, furnish mill operator, and mixer operator. Of the 44 data points, EPA determined that 20 were full-shift worker PBZ data ranging from 0.0022 to 0.61 mg/m³ and used these data to estimate vapor inhalation exposure for all potential exposed workers ([ECJRC, 2007](#)). With 20 datapoints, EPA characterized the data by

taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency, respectively.

The OSHA CEHD data entails four full-shift PBZ monitoring samples taken from a single manufacturing site owned by Tarkett, Inc – a manufacturer of vinyl, carpet, and other engineered flooring ([OSHA, 2020](#)). The CEHD dataset does not describe individual worker tasks for each sample, but all samples were collected over five to seven hours and EPA assumes represent worker exposure during a full 8-hour shift. With four data points available ranging from 0.15 to 4.2 mg/m³, EPA defined the high-end for the dataset as the maximum and central tendency as the median value. The sample method, and therefore media, is not known and EPA assumes the samples represent worker exposures to dust, though they may represent vapor or both. EPA assessed both vapor and dust datasets together, so there may be some duplication of vapor exposure, though dust is expected to be the predominant inhalation exposure type.

Table 3-26 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker and ONU exposures to BBP during the plastics compounding process. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum for working days. The central tendency exposures use 223 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-26. Summary of Estimated Worker Inhalation Exposures to Vapors and Dust for Plastics Compounding

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4
	Acute Dose (AD) (mg/kg-day)	8.8E-02	0.53
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	0.39
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.3E-02	0.36
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4
	Acute Dose (AD) (mg/kg-day)	9.7E-02	0.58
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	7.1E-02	0.43
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.9E-02	0.40
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.71	0.71
	Acute Dose (AD) (mg/kg-day)	8.8E-02	8.8E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	6.4E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.3E-02	6.0E-02

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
^a EPA identified surrogate inhalation monitoring data from two sources to estimate exposures for this OES (OSHA, 2020 ; ECJRC, 2007). The OSHA monitoring data and the ECJRC data received ratings of high and medium, respectively from EPA's systematic review process. With 20 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.			

3.6.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various "Exposure Concentration Types" from Table 3-27 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP will likely overestimate dermal exposure. Table 3-27 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-27. Summary of Estimated Worker Dermal Exposures for Plastics Compounding

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	3.1	6.3
	Acute (AD, mg/kg-day)	0.039	0.078
	Intermediate (IADD, mg/kg-day)	0.029	0.057
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.024	0.054
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.6	5.2
	Acute (AD, mg/kg-day)	0.036	0.072
	Intermediate (IADD, mg/kg-day)	0.026	0.053
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.022	0.049
ONU	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.8E-03	2.0E-03
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (i.e., 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (i.e., 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (i.e., 268 cm ²)			

3.6.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates Table 3-28. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-28. Summary of Estimated Worker Aggregate Exposures for Plastics Compounding

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.13	0.63
	Intermediate (IADD, mg/kg-day)	0.094	0.46
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.078	0.43
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.13	0.68
	Intermediate (IADD, mg/kg-day)	0.099	0.50
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.082	0.47
ONU	Acute (AD, mg/kg-day)	9.2E-02	9.2E-02
	Intermediate (IADD, mg/kg-day)	6.8E-02	6.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.6E-02	5.6E-02

Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

3.7 PVC Plastics Converting

3.7.1 Process Description

BBP is used as a plasticizer in plastics (see Appendix E for EPA-identified BBP-containing products for this OES). Plastic converting is the processing step directly following plastic compounding where compounded resins are processed into final plastic articles. EPA expects that BBP will arrive at a typical converting site as a solid in containers ranging in size from 5 to 1,000 gallons ([U.S. EPA, 2004a](#)). A typical converting site will unload BBP in solid form, as a masterbatch, from PVC plastic compounding sites. Following unloading, the converting site will transfer the masterbatch to a shaping unit operation such as an extruder, injection molding unit, or blow molding unit to achieve the final product shape. The converting site may trim excess material from the final plastic product after it cools. Figure 3-7 provides an illustration of the plastic converting process based on information from the 2021 Draft Generic Scenario for the Use of Additives in Plastics Converting ([U.S. EPA, 2021d](#)).

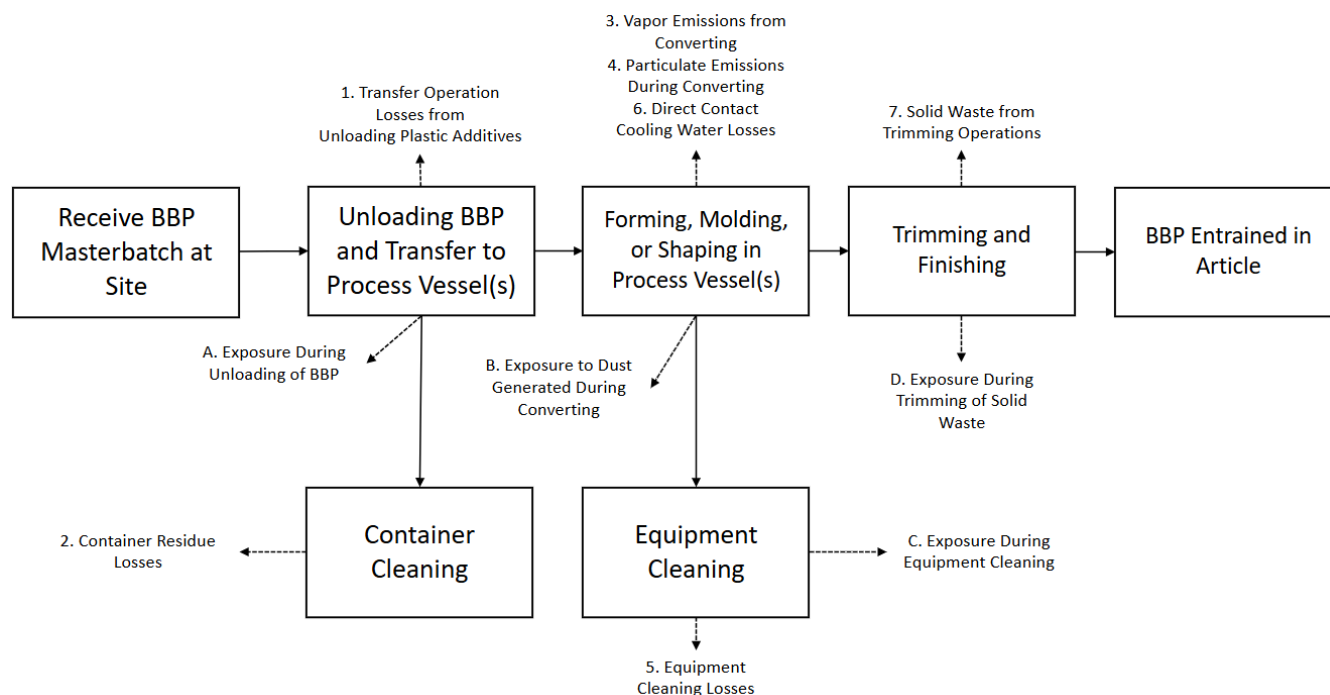


Figure 3-7. PVC Plastics Converting Flow Diagram

3.7.2 Facility Estimates

Since converting occurs immediately downstream of compounding, EPA expects the production volume for plastic converting to be identical to the production volume for the plastics compounding OES. The production volume of BBP for use in plastics compounding was 35,279 to 1,758,930 kg/year. EPA estimated the number of sites for converting based on BBP CDR data identified with the industrial sector, “Plastic Product Manufacturing”, which included one report that identified 10 to 24 sites. Based on this, EPA assumed a range of 10 to 24 converting sites ([U.S. EPA, 2020a](#)).

EPA did not identify BBP-specific plastic converting site operating data (*i.e.*, facility production rate, number of batches, or operating days). EPA assessed the total number of operating days as 137 to 254 days/year for the given site throughput scenario using information from the 2014 Use of Additives in the Thermoplastic Converting Industry Draft GS and the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d, 2014c](#)). Additionally, EPA assumed the number of batches completed per site per year was equivalent to the number of operating days, or one completed batch per day. EPA estimated a range of annual facility BBP throughput by dividing the range of annual production volume by the range of number of sites within the Monte Carlo model for release estimates (discussed in more detail in Section 3.7.3).

3.7.3 Release Assessment

3.7.3.1 Environmental Release Points

Based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), EPA assessed releases of dust to stack air, fugitive air, wastewater, incineration, or landfill from unloading plastic additives; releases of vapor emissions to fugitive or stack air during converting operations; particulate emissions to fugitive air, wastewater, incineration, or landfill during converting operations; releases to wastewater, incineration, or landfill from container residues and equipment

cleaning; releases to wastewater from direct contact cooling; and releases to incineration and landfill from solid waste trimming.

Sites may utilize air capture and control technology for dusts releases ([U.S. EPA, 2021d](#)). If a site uses air capture and control technology, EPA expects captured and controlled dust releases to be released to disposal facilities for incineration or landfill if filters are used or to wastewater if wet scrubbers are used. EPA expects that uncontrolled dust is released to stack air, and any uncaptured dusts are released to fugitive air, wastewater, incineration, or landfill.

3.7.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)). The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source.

The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Dust releases from unloading compounded plastic containing BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2021d, 2015](#)).
- Release point 2 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Solid Residuals in Transport Containers Model. EPA modified these models to include a distribution for container size, which was based on values in the ChemSTEER User Guide ([U.S. EPA, 2021d, 2015](#)).
- Release point 3 – Vapor emissions that occur during the converting process were assessed to uncertain air (fugitive or stack) and used an estimated loss fraction value from the GS ([U.S. EPA, 2021d](#)).
- Release point 4 – Particulate emissions that occur during the converting process were assessed to uncertain air (fugitive or stack), water, land, or waste treatment and used an estimated loss fraction value from the GS ([U.S. EPA, 2021d](#)).
- Release point 5 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model ([U.S. EPA, 2021c, 2015](#)).
- Release point 6 – Releases from cooling water were assessed to water and used a loss fraction from the GS ([U.S. EPA, 2021d](#)).
- Release point 7 – Waste from trimming the converted plastic was assessed to incineration or landfill and used a loss fraction from the GS ([U.S. EPA, 2021d](#)).

Other key assessment decisions and deviations from the GS include using a uniform concentration distribution of 90-100% and a uniform production volume distribution of 35,279 to 1,758,930 kg/year based on information from the 2020 CDR ([U.S. EPA, 2020a](#)). A uniform concentration distribution of 30 to 45 percent was assumed for the compounded resin based on the GS ([U.S. EPA, 2021d](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.8.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-29 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

For some of the release estimates for this OES, the difference between the central tendency and high-end results do not seem to directly correspond with the difference between the low- and high-end of the overall production volume range (35,279–1,758,930 kg). Process releases were generally calculated by multiplying a standard loss factor by the daily throughput rate of BBP, which itself was calculated using distributions for the overall production volume of BBP, the number of converting sites, and the number of operating days per site (which is provided by the GS). The calculated daily BBP throughput had a central tendency and high-end value of 246–606 kg/site-day; this smaller throughput range resulted in a smaller range of releases assessed to these medias.

Table 3-29. Summary of Modeled Environmental Releases for PVC Plastics Converting

Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Fugitive or stack Air ^a	1.9	11	219	251	8.8E-03	5.1E-02
Stack air	16	452			7.4E-02	2.1
Wastewater, incineration, or landfill ^a	1,581	3,753			7.4	18
Wastewater	527	1,251			2.5	6.1
Fugitive air, wastewater, incineration, or landfill ^a	131	836			0.62	4.0
Incineration or landfill ^a	1,610	3,972			7.5	19

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.8. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.7.4 Occupational Exposure Assessment

3.7.4.1 Worker Activities

Worker exposures to BBP during the converting process occur via inhalation of dust or dermal contact with dust during unloading and loading, transport container cleaning, equipment cleaning, and trimming of excess plastic ([U.S. EPA, 2021d](#)). EPA did not identify information on engineering controls or worker PPE used at BBP-containing PVC plastics converting sites.

ONUs include supervisors, managers, and other employees that work in the PVC converting area but do not directly contact the BBP-containing PVC material that is received, or handle the finished product or article. ONUs are potentially exposed to airborne and settled dust via inhalation and dermal routes while in the working area.

3.7.4.2 Occupational Inhalation Exposure Results

EPA identified two data sets with inhalation monitoring data; one risk evaluation conducted by the ECJRC that consists of 44 data points on vapor exposures to BBP during PVC plastics compounding and converting and four monitoring samples expected to be dust in OSHA's CEHD database. The OSHA inspection that yielded four monitoring samples included one non-detect sample, that EPA has excluded because EPA was not able to identify what test method was used by OSHA and thus unable to determine an LOD to use with the substitution method. Some of the monitoring data were for sites that did both compounding and converting, and EPA included them in this OES. The ECJRC used samples from literature to develop exposure estimates for the production of BBP based on individual worker titles, such as calendar operator, furnish mill operator, and mixer operator. Of the 44 data points, EPA determined that 20 were full-shift worker PBZ data ranging from 0.0022 to 0.61 mg/m³ and used these data to estimate vapor inhalation exposure for all potential exposed workers ([ECJRC, 2007](#)). With 20 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.

The OSHA CEHD data entails four full-shift PBZ monitoring samples taken from a single manufacturing site owned by Tarkett, Inc – a manufacturer of vinyl, carpet, and other engineered flooring ([OSHA, 2020](#)). The CEHD dataset does not describe individual worker tasks for each sample, but all samples were collected over five to seven hours and are expected to represent worker exposure during a full 8-hour shift. With four data points available ranging from 0.15 to 4.2 mg/m³, EPA defined the high-end for the dataset as the maximum and central tendency as the median value. The sample method, and therefore media, is not known and EPA assumes the samples represent worker exposures to dust, though they may also represent vapor. EPA assessed both vapor and dust datasets together, so there may be some duplication of vapor exposure, though dust is expected to be the predominant inhalation exposure type.

Table 3-30 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during PVC plastics converting. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. Therefore, worker central tendency exposure values were assumed representative of ONU inhalation exposure. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum for working days. The central tendency exposures use

219 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-30. Summary of Estimated Worker Inhalation Exposures to Vapors and Dust for PVC Plastics Converting

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4
	Acute Dose (AD) (mg/kg-day)	8.8E-02	0.53
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	0.39
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.3E-02	0.36
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4
	Acute Dose (AD) (mg/kg-day)	9.7E-02	0.58
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	7.1E-02	0.43
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.8E-02	0.40
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.71	0.71
	Acute Dose (AD) (mg/kg-day)	8.8E-02	8.8E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	6.4E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.3E-02	6.0E-02
^a EPA identified inhalation monitoring data from two sources to estimate exposures for this OES (OSHA, 2020 ; ECJRC, 2007). The OSHA monitoring data and the ECJRC data received ratings of high and medium, respectively from EPA's systematic review process. With 20 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.			

3.7.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various "Exposure Concentration Types" from Table 3-28 are explained in Appendix A. Since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-28 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-31. Summary of Estimated Worker Dermal Exposures for PVC Plastics Converting

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.6E-03	8.2E-03
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.3E-03	7.5E-03
ONU	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.8E-03	2.0E-03
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (<i>i.e.</i> , 268 cm ²)			

3.7.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-32. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-32. Summary of Estimated Worker Aggregate Exposures for PVC Plastics Converting

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	9.5E-02	0.56
	Intermediate (IADD, mg/kg-day)	7.0E-02	0.41
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.7E-02	0.39
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.10	0.62
	Intermediate (IADD, mg/kg-day)	7.6E-02	0.45
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.2E-02	0.42
ONU	Acute (AD, mg/kg-day)	9.2E-02	9.2E-02
	Intermediate (IADD, mg/kg-day)	6.8E-02	6.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.5E-02	6.3E-02
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.8 Non-PVC Material Compounding

3.8.1 Process Description

The 2020 CDR report indicates BBP use in non-PVC polymers, such as rubber ([U.S. EPA, 2020a](#)). However, EPA did not identify specific non-PVC polymer products that contain BBP from the data sources that underwent systematic review.

EPA expects that a typical non-PVC material compounding site operates similar to a plastic compounding site. Three out of four 2020 CDR industrial use reporters specified BBP's physical form as a liquid, with the fourth site reporting solid ([U.S. EPA, 2020a](#)). Therefore, both solid and liquid forms of BBP were assessed. EPA expects that a typical compounding site receives BBP as a liquid in drums ranging in size from 20 to 100 gallons or a solid in containers ranging from 7 to 132 gallons. Typical compounding sites receive and unload BBP and transfer it into mixing vessels to produce a compounded resin masterbatch. Following completion of the masterbatch, sites transfer the solid resin to extruders that shape and size the plastic and package the final product for shipment to downstream conversion sites after cooling ([U.S. EPA, 2021c](#)). Figure 3-8 provides an illustration of the plastic compounding process based on information from the 2021 Draft Generic Scenario on the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)).

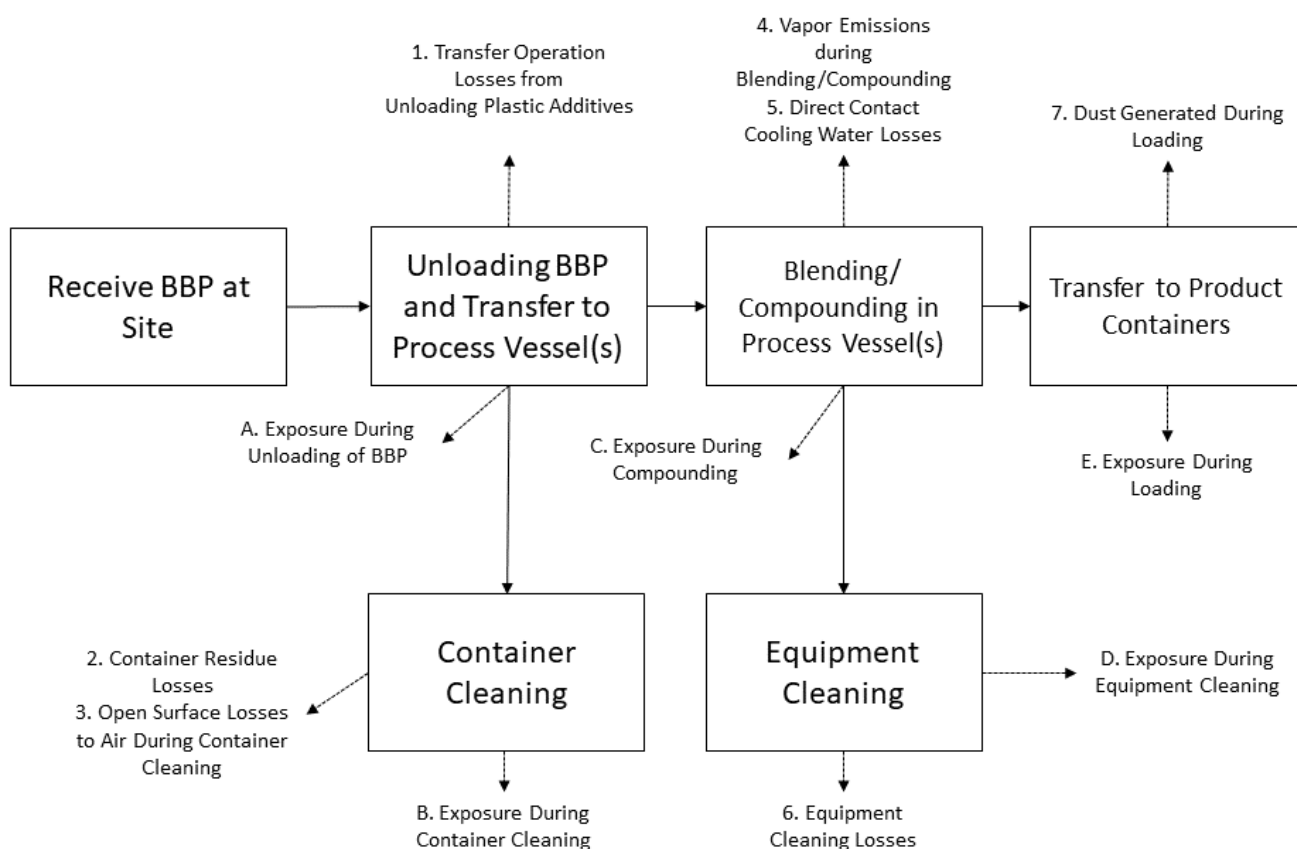


Figure 3-8. Non-PVC Material Compounding Flow Diagram

Note that some materials, such as rubber products, may be produced via a consolidated compounding and converting operation, as described in the SpERC Fact Sheet on Rubber Production and Processing.

However, the frequency at which consolidated operations are used for non-PVC materials is unknown; therefore, EPA assessed all formulations as separate compounding and converting steps. Figure 3-9 provides an illustration of the consolidated process based on information from the SpERC and 2004 ESD on Additives in the Rubber Industry ([ESIG, 2020](#); [OECD, 2004a](#)).

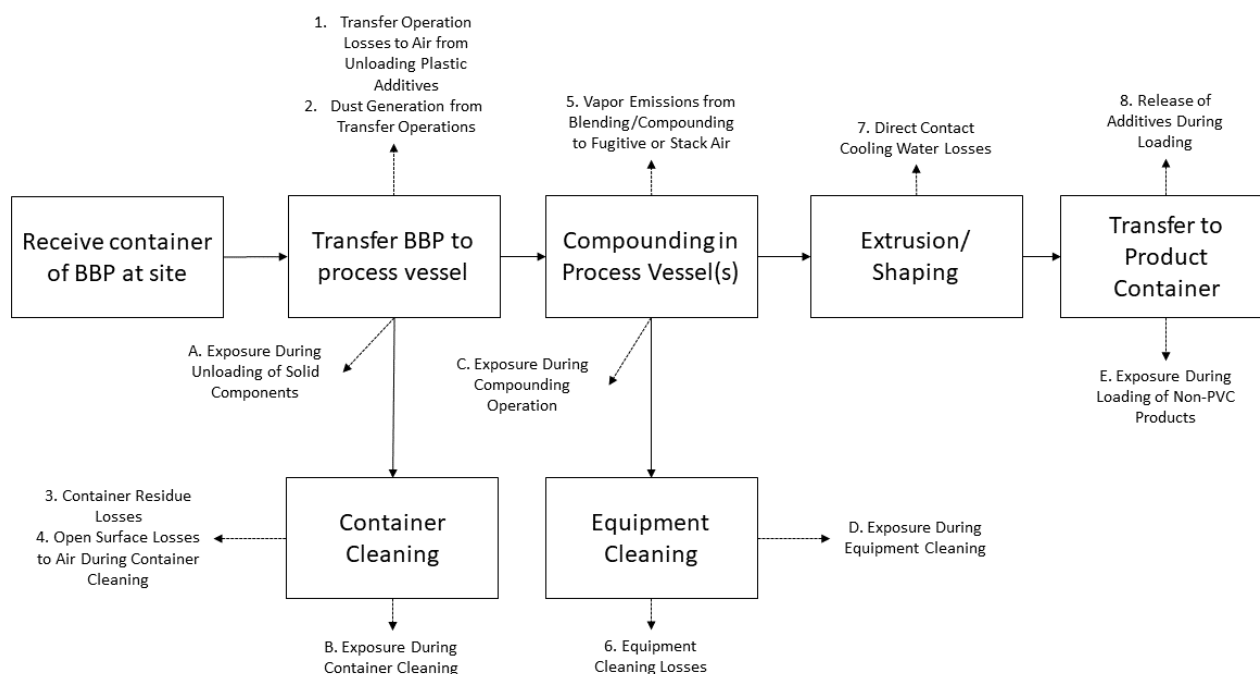


Figure 3-9. Consolidated Compounding and Converting Flow Diagram

3.8.2 Facility Estimates

EPA did not identify any production volume information specific to this OES. EPA estimated the total BBP production volume for non-PVC materials using CDR data and reporting thresholds for CDR reporters. CDR reports require a site to report processing and use for a chemical if the usage exceeds five percent of its reported PV or if the use exceeds 25,000 lb per year (whichever is smaller). No sites reporting to CDR listed the manufacture of rubber as a downstream use for BBP; therefore, EPA assumed that all unique sites reporting to CDR manufactured or imported BBP for rubber end-uses up to the reporting threshold limit. Using these volume estimates, EPA calculated the total BBP production volume for non-PVC materials at 50,295 lb/year (22,813 kg/year). See Table 3-19 for a list of the identified sites and production volumes.

EPA did not identify site- or BBP-specific non-PVC material compounding operating data (*i.e.*, facility production rate, number of batches, or operating days). EPA assessed non-PVC material compounding operating data based on plastics compounding operating data, as the operations are expected to be similar. EPA estimated the number of sites for non-PVC material compounding as a uniform distribution of 10 to 24 sites based on the number of downstream industrial sites reported under the “Plastics Product Manufacturing” industrial sector in CDR for BBP ([U.S. EPA, 2020a](#)).

EPA based the estimated number of operating days on the 2021 Generic Scenario on the Use of Additives in Plastic Compounding. EPA also considered the 2004 ESD on Additives in the Rubber Industry but determined the plastics compound GS to be more representative of the whole OES ([OECD, 2004a](#)). The GS estimated the total number of operating days as 148 to 300 days/year for the given site

throughput scenario. The number of batches completed per site year was equivalent to the number of operating days, or one batch per day ([U.S. EPA, 2021c](#)). EPA estimated a range of annual facility BBP throughput by dividing the annual production volume by the range of number of sites within the Monte Carlo model for release estimates (discussed in more detail in Section 3.8.3).

3.8.3 Release Assessment

3.8.3.1 Environmental Release Points

Based on the 2021 Generic Scenario on Plastic Compounding ([U.S. EPA, 2021c](#)), EPA assessed fugitive or stack air releases from unloading transfer operations, container cleaning, and vapor emissions from blending/compounding; wastewater, incineration, or landfill releases from container residue and equipment cleaning; wastewater releases from direct contact cooling; dust releases to stack air, fugitive air, wastewater, incineration, or landfill releases from transfer operations during unloading and loading.

Sites may utilize air capture and control technology for dusts releases ([U.S. EPA, 2021c](#)). If a site uses air capture and control technology, EPA expects captured and controlled dust releases to be released to disposal facilities for incineration or landfill if filters are used or to wastewater if wet scrubbers are used. EPA expects that uncontrolled dust is released to stack air and any uncaptured dusts are released to fugitive air, wastewater, incineration, or landfill.

3.8.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2021 Draft Generic Scenario on Plastic Compounding as it was determined to contain the most representative process information for this OES ([U.S. EPA, 2021c](#)). The model combines facility information (e.g., throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source. The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Volatile emissions generated during container unloading were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, container volumes, and vapor correction factors based on various sources ([U.S. EPA, 2021c, 2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 2 – Dust releases from unloading solid BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2021c, 2015](#)).
- Release point 3 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Drum Residual Model or the EPA/OPPT Solid Residuals in Transport Containers Model based on whether the model was run for liquid or solid releases respectively. EPA modified these models to include distributions for container size and loss factor, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2021c, 2015](#)).

- Release point 4 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2021c, 2015](#); [Baldwin and Maynard, 1998](#))
- Release point 5 – Emissions from dispersion and blending/process operations were assessed to stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, diameter of opening, and saturation factor based on various sources ([U.S. EPA, 2021c, 2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 6 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model ([U.S. EPA, 2021c, 2015](#)).
- Release point 7 – Releases from cooling water were assessed to water and used a loss fraction from the 2021 Draft Generic Scenario on Plastic Compounding ([U.S. EPA, 2021c](#)).
- Release point 8 – Dust releases from loading compounded material containing BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2021c, 2015](#)).

Other key assessment decisions and deviations from the GS include that EPA modeled two scenarios, one for each physical form of BBP that is expected to be used in the process. EPA used a uniform concentration distribution of 1 to 100 percent for raw material based on information from the 2020 CDR and a uniform concentration distribution of 1 to 20 percent for compounded resin based on the 2004 ESD on Additives in the Rubber Industry ([U.S. EPA, 2020a](#); [OECD, 2004a](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.7.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES.

Table 3-33 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

Table 3-33. Summary of Modeled Environmental Releases for Non-PVC Materials Compounding

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
22,813 kg/year production volume (Liquid)	Fugitive or stack air ^a	1.4E-07	2.7E-07	234	280	1.2E-04	2.0E-04
	Stack Air	0.47	10			2.1E-03	4.6E-02
	Wastewater, incineration, or landfill ^a	53	92			2.2	6.1
	Wastewater	13	23			5.9E-02	0.10
	Fugitive air, wastewater, incineration, or landfill ^a	4.0	18			1.8E-02	8.1E-02
	Landfill or Incineration ^a	6.7	24			0.11	2.9E-02
22,813 kg/year production volume (Solid)	Fugitive or stack Air ^a	1.4E-09	3.3E-09	234	280	1.2E-04	2.0E-04
	Stack air	0.94	21			4.2E-03	9.2E-02
	Wastewater, incineration, or landfill ^a	40	68			0.34	0.93
	Wastewater	13	23			5.9E-02	0.10
	Fugitive air, wastewater, incineration, or landfill ^a	8.0	36			3.5E-02	0.16
	Landfill or incineration ^a	14	47			5.9E-02	0.21

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.7. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.8.4 Occupational Exposure Assessment

3.8.4.1 Worker Activities

Worker exposures during the compounding process may occur via inhalation of BBP-containing dusts. Worker exposures may also occur via dermal contact with liquids and inhalation of vapors during BBP unloading, transport container cleaning, and equipment cleaning ([U.S. EPA, 2021c](#)). EPA did not identify site-specific information on engineering controls or worker PPE used at BBP-containing non-PVC material compounding sites.

ONUs may include supervisors, managers, and other employees that work in the compounding area but do not directly contact BBP that is received or processed onsite or handle compounded product. ONUs

are potentially exposed via inhalation and dermal routes to airborne and settled dust while in the working area.

3.8.4.2 Occupational Inhalation Exposure Results

EPA did not identify OES-specific inhalation monitoring data for BBP from systematic review of literature sources; however, EPA identified suitable analogous BBP monitoring data from PVC plastics converting, which is expected to have similar exposure profiles due to similar activities. This dataset is the same as used in previous compounding and converting OES for BBP and includes two data sets with inhalation monitoring data; one risk evaluation conducted by the ECJRC that consists of 44 data points on vapor exposures to BBP during PVC plastics compounding and converting and four monitoring samples expected to be dust in OSHA’S CEHD database. Some of the monitoring data were for sites that did both compounding and converting, and EPA included them in this OES. The ECJRC used samples from literature to develop exposure estimates for the production of BBP based on individual worker titles, such as calendar operator, furnish mill operator, and mixer operator. Of the 44 data points, EPA determined that 20 were full-shift worker PBZ data ranging from 0.0022 to 0.61 mg/m³ and used these data to estimate vapor inhalation exposure for all potential exposed workers ([ECJRC, 2007](#)). With 20 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.

The OSHA CEHD data entails four full-shift PBZ monitoring samples taken from a single manufacturing site owned by Tarkett, Inc – a manufacturer of vinyl, carpet, and other engineered flooring ([OSHA, 2020](#)). The CEHD dataset does not describe individual worker tasks for each sample, but all samples were collected over five to seven hours and are expected to represent worker exposure during a full 8-hour shift. With four data points available ranging from 0.15 to 4.2 mg/m³, EPA defined the high-end for the dataset as the maximum and central tendency as the median value. The sample method, and therefore media, is not known and EPA assumes the samples represent worker exposures to dust, though they may also represent vapor. EPA assessed both vapor and dust datasets together, so there may be some duplication of vapor exposure, though dust is expected to be the predominant inhalation exposure type.

Table 3-34 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during non-PVC material compounding. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum for working days. The central tendency exposures use 234 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-34. Summary of Estimated Worker Inhalation Exposures to Vapors and Dust for Non-PVC Material Compounding

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Acute Dose (AD) (mg/kg-day)	8.8E-02	0.53
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	0.39
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.6E-02	0.36
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4
	Acute Dose (AD) (mg/kg-day)	9.7E-02	0.58
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	7.1E-02	0.43
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	6.2E-02	0.40
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.71	0.71
	Acute Dose (AD) (mg/kg-day)	8.8E-02	8.8E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	6.4E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.6E-02	6.0E-02
^a EPA identified surrogate inhalation monitoring data from 2 sources to estimate exposures for this OES (OSHA, 2020 ; ECJRC, 2007). The OSHA monitoring data and the ECJRC data received ratings of high and medium, respectively from EPA's systematic review process. With 20 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.			

3.8.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-35 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-35 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-35. Summary of Estimated Worker Dermal Exposures for Non-PVC Material Compounding

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	3.1	6.3
	Acute (AD, mg/kg-day)	0.039	0.078
	Intermediate (IADD, mg/kg-day)	0.029	0.057
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.025	0.054
	Dose Rate (APDR, mg/day)	2.6	5.2

Modeled Scenario	Exposure Type	Central Tendency	High-End
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.036	0.072
	Intermediate (IADD, mg/kg-day)	0.025	0.053
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.023	0.049
ONU	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.9E-03	2.0E-03
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (<i>i.e.</i> , 268 cm ²)			

3.8.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-36. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-36. Summary of Estimated Worker Aggregate Exposures for Non-PVC Material Compounding

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.13	0.63
	Intermediate (IADD, mg/kg-day)	0.094	0.46
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.082	0.43
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.13	0.68
	Intermediate (IADD, mg/kg-day)	0.099	0.50
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.086	0.47
ONU	Acute (AD, mg/kg-day)	9.2E-02	9.2E-02
	Intermediate (IADD, mg/kg-day)	6.8E-02	6.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.9E-02	5.9E-02
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.9 Non-PVC Material Converting

3.9.1 Process Description

The 2020 CDR indicates BBP use in non-PVC materials such as rubber (see Appendix E for EPA-identified BBP-containing products for this OES) ([U.S. EPA, 2020a, c](#)); however, EPA did not identify specific BBP-containing products through systematic review.

Plastic converting is the processing step directly following plastic compounding where compounded resins are processed into final plastic articles. EPA expects that a typical non-PVC material converting site operates similar to a plastic converting site. A typical converting site receives and unloads BBP in solid form, as a masterbatch, from compounding sites. The converting sites then transfer the masterbatch to a shaping unit operation such as an extruder, injection molding unit, or blow molding unit to achieve the final product shape ([U.S. EPA, 2021c](#)). The converting site may trim excess material from the final product after it cools. Figure 3-10 provides an illustration of the non-PVC material converting process based on information from the 2021 Draft Generic Scenario on the Use of Additives in Plastic Converting ([U.S. EPA, 2021c](#)).

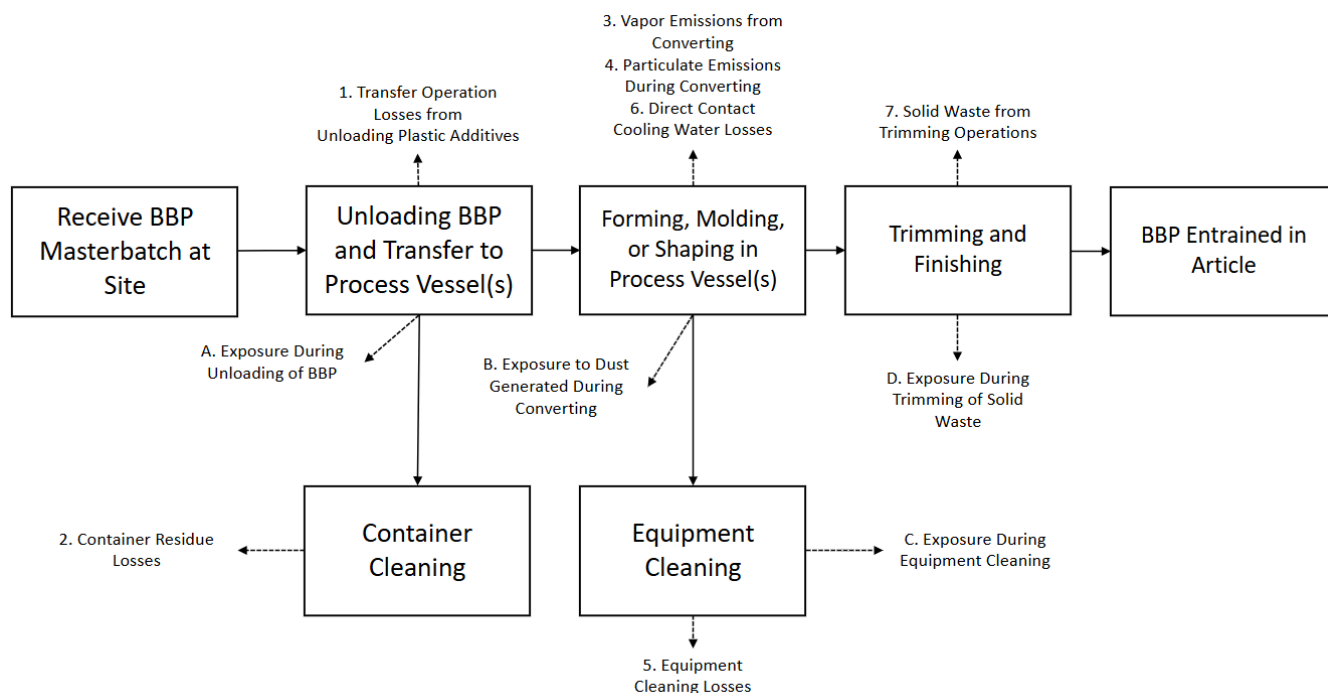


Figure 3-10. Non-PVC Material Converting Flow Diagram

3.9.2 Facility Estimates

Since converting occurs immediately downstream of compounding, EPA expects the production volume for non-PVC material converting to be identical to the production volume for the non-PVC material compounding OES. The production volume of BBP for use in non-PVC material converting was estimated as 22,813 kg/year. EPA estimated the number of non-PVC material converting sites as a uniform distribution of 10 to 24 sites based on the number of downstream industrial sites reported under the “Plastics Product Manufacturing” industrial sector in CDR for BBP ([U.S. EPA, 2020a](#)).

EPA did not identify site- or chemical- specific plastic converting operating data (*i.e.*, facility production rate, number of batches, or operating days). The 2021 Draft Generic Scenario on the Use of Additives in Plastic Converting estimated the total number of operating days as 137 to 254 days/year for the given site throughput scenario. EPA assumed that the number of batches per site year was equivalent to the number of operating days, or one batch per day ([U.S. EPA, 2021c](#)). EPA estimated a range of annual facility BBP throughput by dividing the annual production volume by the range of number of sites within the Monte Carlo model for release estimates (discussed in more detail in Section 3.9.3).

3.9.3 Release Assessment

3.9.3.1 Environmental Release Points

Based on the 2021 Draft Generic Scenario on the Use of Additives in Plastic Converting ([U.S. EPA, 2021c](#)), EPA assessed vapor emissions from converting operations to fugitive or stack air; particulate emissions from converting operations to fugitive air, wastewater, incineration, or landfill; releases to wastewater, incineration, or landfill from container residues and equipment cleaning wastes; releases to wastewater from direct contact cooling; releases to fugitive air, wastewater, incineration, or landfill from

unloading plastic additives; and releases to landfill or incineration from solid waste generated during trimming operations.

Sites may utilize air capture and control technology for dusts releases ([U.S. EPA, 2021c](#)). If a site uses air capture and control technology, EPA expects captured and controlled dust releases to be released to disposal facilities for incineration or landfill if filters are used or to wastewater if wet scrubbers are used. EPA expects that uncontrolled dust is released to stack air, and any uncaptured dusts are released to fugitive air, wastewater, incineration, or landfill.

3.9.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2021 Use of Additives in Plastics Converting Draft Generic Scenario as it was assumed to be the most relevant GS for this OES ([U.S. EPA, 2021d](#)). The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source.

The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Dust releases from unloading compounded plastic containing BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2021d, 2015](#)).
- Release point 2 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Solid Residuals in Transport Containers Model. EPA modified these models to include a distribution for container size, which was based on values in the ChemSTEER User Guide ([U.S. EPA, 2021d, 2015](#)).
- Release point 3 – Vapor emissions that occur during the converting process were assessed to uncertain air (fugitive or stack) and used an estimated loss fraction value from the GS ([U.S. EPA, 2021d](#)).
- Release point 4 – Particulate emissions that occur during the converting process were assessed to uncertain air (fugitive or stack), water, land, or waste treatment and used an estimated loss fraction value from the GS ([U.S. EPA, 2021d](#)).
- Release point 5 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model ([U.S. EPA, 2021c, 2015](#)).
- Release point 6 – Releases from cooling water were assessed to water and used a loss fraction from the GS ([U.S. EPA, 2021d](#)).
- Release point 7 – Waste from trimming the converted plastic was assessed to incineration or landfill and used a loss fraction from the GS ([U.S. EPA, 2021d](#)).

Other key assessment decisions and deviations from the GS include that EPA modeled two scenarios, one for each physical form of BBP that is expected to be used in the process. EPA used a uniform concentration distribution of 1 to 20 percent for compounded resin based on the 2004 ESD on Additives in the Rubber Industry ([U.S. EPA, 2020a](#); [OECD, 2004a](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.7.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-37 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

Table 3-37. Summary of Modeled Environmental Releases for Non-PVC Material Converting

Table D-57. Summary of Modeled Environmental Releases for Non PVC Material Conveying							
Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
22,813 kg/year production volume	Fugitive or stack air ^a	4.6E-02	0.21	219	251	3.3E-04	9.8E-04
	Stack air	0.48	10			2.3E-03	4.8E-02
	Wastewater, incineration, or landfill ^a	40	68			0.38	0.77
	Wastewater	13	23			6.4E-02	0.11
	Fugitive air, wastewater, incineration, or landfill ^a	4.1	18			1.9E-02	8.8E-02
	Incineration or landfill ^a	42	72			0.20	0.36
^a When multiple environmental media are addressed together, releases may go all to 1 media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.							
^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.7. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.							

3.9.4 Occupational Exposure Assessment

3.9.4.1 Worker Activities

Worker exposures to BBP during the converting process may occur via inhalation of dust or dermal contact with dust during unloading and loading, transport container cleaning, equipment cleaning, and trimming of excess plastic ([U.S. EPA, 2021d](#)). EPA did not identify site-specific information on engineering controls or worker PPE used at BBP-containing, non-PVC material converting sites.

ONUs include supervisors, managers, and other employees that may work in the process area but do not directly contact BBP that is received or processed onsite or handle the finished converted product. ONUs are potentially exposed to airborne and settled dust via inhalation and dermal routes while in the working area.

3.9.4.2 Occupational Inhalation Exposure Results

EPA did not identify OES-specific inhalation monitoring data for BBP from systematic review of literature sources; however, EPA identified suitable analogous BBP monitoring data from PVC plastics converting. This dataset is the same as used in previous compounding and converting OES for BBP and includes two data sets with inhalation monitoring data; one risk evaluation conducted by the ECJRC that consists of 44 data points on vapor exposures to BBP during PVC plastics compounding and converting and four monitoring samples expected to be dust in OSHA'S CEHD database. Some of the monitoring data were for sites that did both compounding and converting, and EPA included them in this OES. The ECJRC used samples from literature to develop exposure estimates for the production of BBP based on individual worker titles, such as calendar operator, furnish mill operator, and mixer operator. Of the 44 data points, EPA determined that 20 were full-shift worker PBZ data ranging from 0.0022 to 0.61 mg/m³ and used these data to estimate vapor inhalation exposure for all potential exposed workers ([ECJRC, 2007](#)). With 20 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.

The OSHA CEHD data entails four full-shift PBZ monitoring samples taken from a single manufacturing site owned by Tarkett, Inc.—a manufacturer of vinyl, carpet, and other engineered flooring ([OSHA, 2020](#)). The CEHD dataset does not describe individual worker tasks for each sample, but all samples were collected over 5 to 7 hours and are expected to represent worker exposure during a full 8-hour shift. With four data points available ranging from 0.15 to 4.2 mg/m³, EPA defined the high-end for the dataset as the maximum and central tendency as the median value. The sample method, and therefore media, is not known and EPA assumes the samples represent worker exposures to dust, though they may also represent vapor. EPA assessed both vapor and dust datasets together, so there may be some duplication of vapor exposure, though dust is expected to be the predominant inhalation exposure type.

Table 3-38 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during non-PVC material converting. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. EPA used the number of operating days estimated in the release assessment for this OES to estimate exposure frequency, which is the expected maximum number of working days. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum for working days. The central tendency exposures use 219 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-38. Summary of Estimated Worker Inhalation Exposures to Vapors and Dust for Non-PVC Material Converting

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4
	Acute Dose (AD) (mg/kg-day)	8.8E-02	0.53
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	0.39
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.3E-02	0.36
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.71	4.4
	Acute Dose (AD) (mg/kg-day)	9.7E-02	0.58
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	7.1E-02	0.43
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.8E-02	0.40
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.71	0.71
	Acute Dose (AD) (mg/kg-day)	8.8E-02	8.8E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	6.4E-02	6.4E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.3E-02	6.0E-02

^a EPA identified surrogate inhalation monitoring data from two sources to estimate exposures for this OES ([OSHA, 2020](#); [ECJRC, 2007](#)). The OSHA monitoring data and the ECJRC data received ratings of high and medium, respectively from EPA's systematic review process. With 20 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.

3.9.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various "Exposure Concentration Types" from Table 3-39 are explained in Appendix A. Since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-39 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-39. Summary of Estimated Worker Dermal Exposures for Non-PVC Material Converting

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.6E-03	8.2E-03
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.3E-03	7.5E-03
ONU	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.8E-03	2.0E-03
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (<i>i.e.</i> , 268 cm ²)			

3.9.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-40. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-40. Summary of Estimated Worker Aggregate Exposures for Non-PVC Material Converting

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	9.5E-02	0.56
	Intermediate (IADD, mg/kg-day)	7.0E-02	0.41
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.7E-02	0.39
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.10	0.62
	Intermediate (IADD, mg/kg-day)	7.6E-02	0.45
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.2E-02	0.42
ONU	Acute (AD, mg/kg-day)	9.2E-02	9.2E-02
	Intermediate (IADD, mg/kg-day)	6.8E-02	6.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.5E-02	6.3E-02
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.10 Application of Adhesives and Sealants

3.10.1 Process Description

BBP is used as a plasticizer in the manufacture of industrial and commercial liquid adhesives and sealant products, including polymer sealants and industrial adhesives ([U.S. EPA, 2020a](#)). BBP is also used as a component of two-part adhesive systems. Two-part systems are adhesives where reactive components are kept separate until being mixed upon application to initiate the curing/crosslinking reaction ([OECD, 2015](#)).

The liquid adhesive product arrives at the application sites in containers ranging in size from 0.1 to 100 gallons and at concentrations of 0.1 to 70 percent BBP (see Appendix E for EPA identified-BBP-containing products for this OES). EPA did not identify BBP-specific application methods through systematic review; however, EPA assumed adhesives and sealants to be applied at the end-use site using application equipment such as a caulk gun, syringe, or similar device and then cured to form a solid final product ([OECD, 2015](#)). Application may occur over the course of an 8-hour workday at a given site, accounting for drying or curing times and additional coats where necessary. The site may trim excess adhesive/sealant from the applied substrate area. Figure 3-11 provides an illustration of the process of applying adhesives and sealants based on information from the 2015 ESD on the Use of Adhesives ([OECD, 2015](#)).

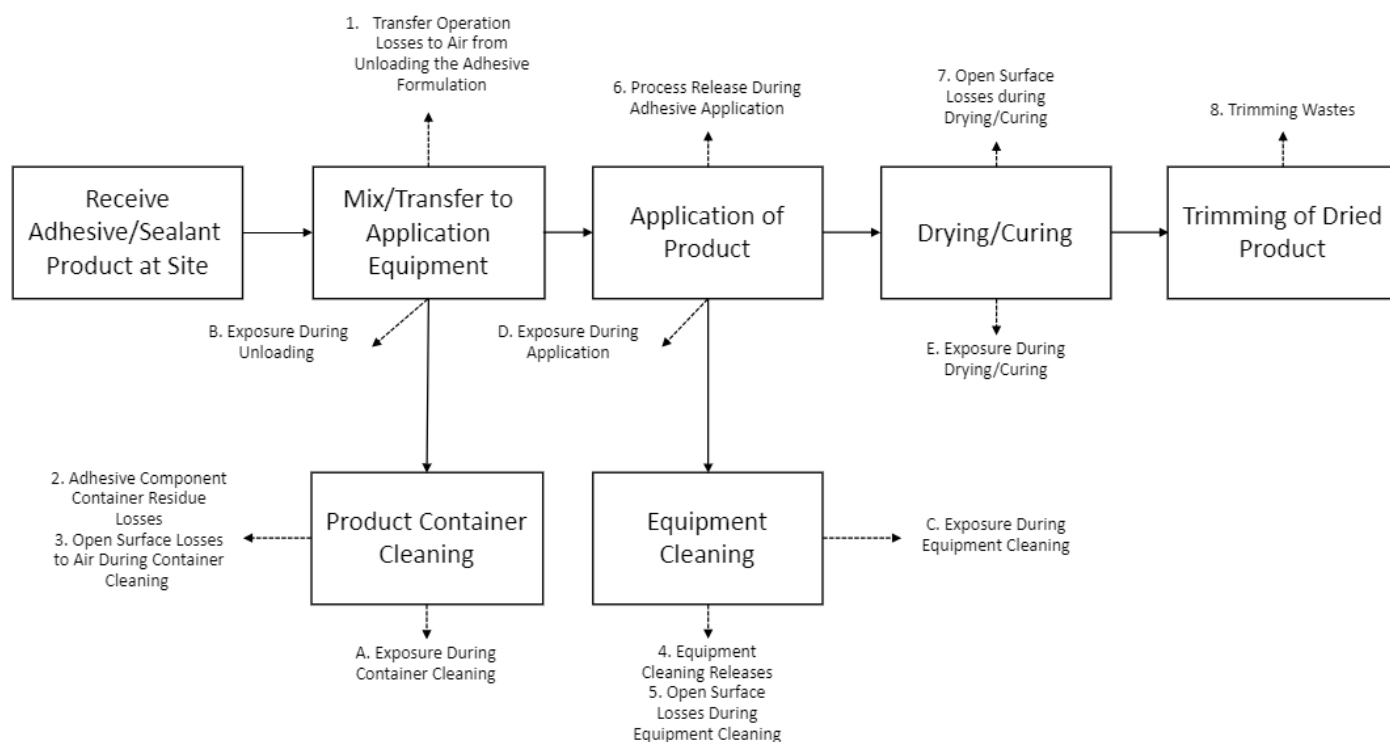


Figure 3-11. Application of Adhesives and Sealants Flow Diagram

3.10.2 Facility Estimates

Since the application of adhesives and sealants occurs immediately downstream of formulation into adhesive and sealants, EPA expects the same production volume for the two OESs. The production volume for adhesives and sealants formulation was estimated as 278,376 to 7,172,980 kg/year.

EPA did not identify site- or chemical-specific adhesive and sealant application operating data (*i.e.*, facility use rates, operating days). However, the 2015 ESD on the Use of Adhesives estimated an adhesive use rate of 1,500 to 141,498 kg/site-year across multiple application industry sectors. BBP-containing adhesives may be applied in multiple industries; therefore, EPA assessed the full range of adhesive use rates for BBP. Based on BBP concentration in the liquid adhesive product of 0.1 to 70 percent, EPA estimated a BBP use rate of 1.5 to 99,049 kg/site-year. EPA did not identify BBP-specific information on operating days through systematic review. Therefore, EPA used data from the ESD which estimated the number of operating days for a typical application site as 50 to 365 days/year ([OECD, 2015](#)). EPA did not identify estimates on the number of sites that may apply adhesive and sealant products containing BBP. Therefore, EPA estimated the total number of application sites that use BBP-containing adhesives and sealants using the BBP production volume range and dividing by the facility throughput range in EPA's Monte Carlo model for release estimates (discussed in more detail in Section 3.10.3). This resulted in a central tendency (50th percentile) and high-end (95th percentile) estimate of 329 to 2,765 application sites.

3.10.3 Release Assessment

3.10.3.1 Environmental Release Points

Based on the 2015 ESD on the Use of Adhesives ([OECD, 2015](#)), EPA assessed fugitive air releases from unloading of adhesive products, container cleaning, equipment cleaning, and drying or curing processes; releases to wastewater, incineration, or landfill from equipment cleaning waste; and releases to incineration or landfill from container residue and trimming wastes.

3.10.3.2 Environmental Release Assessment Results

EPA identified surface water discharge data from one site in DMR for this OES; however, this data did not include release data for environmental media other than surface water and may not be representative of all releases from use sites. Therefore, EPA developed a probabilistic model to estimate air, land, and water releases for this OES using the approaches, model equations, and input parameters detailed in the 2015 ESD on the Use of Adhesives ([OECD, 2015](#)). The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the ESD to estimate releases from each source. The ESD presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the ESD to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the ESD are provided below:

- Release point 1 – Volatile emissions generated during container unloading were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, container volumes, and vapor correction factors based on various sources ([OECD, 2015](#); [U.S. EPA, 2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 2 – Waste from cleaning transport containers was assessed to land or waste treatment using the EPA/OPPT Small Container Residual Model and the EPA/OPPT Drum Residual Model. EPA modified these models to include distributions for container size and loss factor, which were based on values in the ChemSTEER User Guide ([OECD, 2015](#); [U.S. EPA, 2015](#)).

- Release point 3 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([OECD, 2015](#); [U.S. EPA, 2015](#); [Baldwin and Maynard, 1998](#))
- Release point 4 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model using a loss fraction from the ChemSTEER User Guide ([OECD, 2015](#); [U.S. EPA, 2015](#)).
- Release point 5 – Volatile emissions generated during cleaning of process equipment were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([OECD, 2015](#); [U.S. EPA, 2015](#); [Baldwin and Maynard, 1998](#))
- Release point 8 – Releases from trimming waste were assessed to land or waste treatment and used a loss fraction from the ESD ([OECD, 2015](#)).

Other key assessment decisions and deviations from the ESD include the omission of releases from application and curing/drying of the adhesive (release points 6 and 7) due to lack of surface substrate surface area data, curing duration data, temperature, and vapor generation rate of the adhesive product. These releases are assumed to be low relative to other estimated releases due to BBP's low vapor pressure. In addition, EPA used a uniform concentration distribution of 0.1 to 70 percent for adhesive products based on identified product SDSs ([Smooth-On, 2023a](#); [U.S. EPA, 2020a](#); [Smooth-On Inc., 2018](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.9.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-41 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

Table 3-41. Summary of Modeled Environmental Releases for Application of Adhesives and Sealants

Scenarios

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
281,054–7,175,658 kg/year production volume	Fugitive air	7.9E–05	2.6E–04	232	325	3.7E–07	1.1E–06
	Incineration, or landfill ^a	471	2,057			2.7	11
	Wastewater, incineration, or landfill ^a	198	808			0.92	4.2

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.9. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table 3-42 presents surface water discharges per year and per day based on the 2017 through 2022 DMR database along with the number of release days per year, with medians and maxima presented from across the six-year reporting range. According to the DMR data, one site reported direct discharges to surface water for the Application of adhesives and sealants OES: Owens-Brockway Glass Container Inc. ([U.S. EPA, 2024a](#)). The modeled values of release to surface water are several orders of magnitude greater than those listed in DMR and may not be representative of true release to surface waters for this OES. However, the DMR data has several significant sources of uncertainty, including the lack of context about why a particular chemical is being monitored (sites could be monitoring a specific chemical because of groundwater contamination or other non-TSCA purposes), EPA does not have a lot of information (NAICS and name) to use for determining which OES should be assigned to a site (creating uncertainty about the appropriateness of its inclusion in the OES), and low frequency of sampling (frequently once per year for chemical specific monitoring) that is directed by the NPDES permits for BBP monitoring (creating uncertainty if the annual load is truly representative for a chemical). Subsequent investigation into this NPDES permit indicates this discharge only contains stormwater which further decreases the likelihood that it is representative of discharges for this OES. Therefore, it is not known if this site is representative of all sites in this OES. Modeling values in Table 3-41 were used as an upper bound for surface water concentrations in general population and environmental risk assessments, even though there are uncertainties present within the modeling parameters. The SACC agreed with the use of generic scenarios to generate release values in the absence of data. When EPA released the draft Risk Evaluation for BBP, EPA acknowledged the data gap for environmental release data for this OES and solicited alternative data sources from the public. However, no additional data sources were provided during the public comment period.

Table 3-42. Summary of Water Releases from DMR for Application of Adhesives and Sealants

Site Identity	Median Annual Discharge (kg/year)	Median Average Daily Discharge (kg/day)	Maximum Annual Discharge (kg/year)	Maximum Average Daily Discharge (kg/day)	Annual Release Days (days/year)
Owens-Brockway Glass Container Inc.	6.7E-02	2.9E-04	7.9E-02	3.4E-04	232

3.10.4 Occupational Exposure Assessment

3.10.4.1 Worker Activities

During the use of adhesives and sealants containing BBP, worker inhalation and dermal exposures to BBP in adhesives and sealants may occur while unloading, mixing, applying, container cleaning, and application equipment cleaning ([OECD, 2015](#)). EPA did not identify information on engineering controls or worker PPE used at BBP-containing adhesive and sealant use sites.

ONUs include supervisors, managers, and other employees that work in the application area but do not directly contact adhesives or sealants or handle or apply products. ONUs are potentially exposed via vapor inhalation while present in the adhesives or sealant mixing area.

3.10.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the use of adhesives and sealants during systematic review of literature sources; however, EPA identified suitable analogous BBP monitoring data from the Application of paints and coatings OES. Specifically, EPA used data from the risk evaluation conducted by ECJRC for the mixing process of raw materials in a PVC float scenario as analogous for this OES ([ECJRC, 2007](#)). The data from the ECJRC consisted of monitoring data from one site where all samples were below 0.005 mg/m³, which EPA expects is the limit of detection. Therefore, EPA could not create a full distribution of monitoring results. To estimate high-end exposures to workers exposures, EPA used the LOD of 0.005 mg/m³. To estimate central tendency worker exposure, EPA used half this value. EPA used these data as analogous because it represents the handling of liquid BBP products in a similar manner expected for this OES (*e.g.*, no spray or other activity that may generate mists, aerosols, or particulates). Therefore, this data is expected to be representative of two-part sealants and adhesives in a paste or liquid form that is applied by hand. Literature and product data do not indicate the potential for spray coating and, therefore, EPA did not assess mist exposures.

Table 3-43 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during the use of adhesives and sealants. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum for working days. The central tendency exposures use 223 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-43. Summary of Estimated Worker Inhalation Exposures for Application of Adhesives and Sealants

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	2.5E-03	5.0E-03
	Acute Dose (AD) (mg/kg-day)	3.1E-04	6.3E-04
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	2.3E-04	4.6E-04
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	2.0E-04	4.3E-04
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	2.5E-03	5.0E-03
	Acute Dose (AD) (mg/kg-day)	3.5E-04	6.9E-04
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	2.5E-04	5.1E-04
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	2.2E-04	4.7E-04
ONU	8-hour TWA Exposure Concentration (mg/m ³)	2.5E-03	2.5E-03
	Acute Dose (AD) (mg/kg-day)	3.1E-04	3.1E-04
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	2.3E-04	2.3E-04
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	2.0E-04	2.1E-04
^a EPA identified surrogate inhalation monitoring data from one source to estimate exposures for this OES (ECJRC, 2007). The source of monitoring data received a rating of medium from EPA's systematic review process. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint.			

3.10.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-44 are explained in Appendix A. ONU dermal exposures are not assessed for this OES as there are no activities expected to expose ONUs to BBP in liquid form. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper PPE or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-44 summarizes the APDR, AD, IADD, and ADD for average adult workers and female workers of reproductive age. No ONU dermal exposure to liquid formulations of BBP is expected for this OES.

Table 3-44. Summary of Estimated Worker Dermal Exposures for Application of Adhesives and Sealants

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.045
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.022	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.019	0.042
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (i.e., 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (i.e., 535 cm ² for male workers and 445 cm ² for female workers).			

3.10.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-45. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-45. Summary of Estimated Worker Aggregate Exposures for Application of Adhesives and Sealants

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.033	0.067
	Intermediate (IADD, mg/kg-day)	0.025	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.046
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.031	0.062
	Intermediate (IADD, mg/kg-day)	0.023	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.020	0.042
ONU	Acute (AD, mg/kg-day)	3.1E-04	3.1E-04
	Intermediate (IADD, mg/kg-day)	2.3E-04	2.3E-04
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-04	2.1E-04
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.11 Application of Paints and Coatings

3.11.1 Process Description

BBP is a plasticizer in paint and coating products for industrial and commercial use, including paints and colorant products ([U.S. EPA, 2020a](#)). The formulated paints and coatings containing BBP include standard liquid paints/coatings/inks, as well as components of two-part coating systems. Two-part

systems are adhesives where reactive components are kept separate until being mixed upon application to initiate the curing/crosslinking reaction ([OECD, 2015](#)).

EPA assumed the liquid product arrives at the application sites in containers ranging in size from 0.1 to 100 gallons and at concentrations of 0.1 to 60 percent BBP (see Appendix E for EPA identified BBP-containing products for this OES). EPA notes that the product containing 60 percent BBP was a pigment which would reduce the BBP concentration in the coating product, therefore the highest concentration of BBP in a coating product was listed as 50 percent BBP. EPA did not identify BBP-specific application site processes through systematic review. However, EPA assumes the application site directly transfers the liquid product to the application equipment to apply the coating to the substrate ([OECD, 2015](#)). EPA assumed that application methods for BBP-containing paints and coatings may include spray, brush/roller, and/or trowel coating. EPA did not identify information on the prevalence of these various application methods for BBP.

Manual spray equipment includes air (*e.g.*, low volume/high pressure), air-assisted, and airless spray systems ([OECD, 2011a](#), [2009c](#); [U.S. EPA, 2004d](#)). End use sites may utilize spray booth capture technologies when performing spray applications ([OECD, 2011a](#)). Brush and trowel application involve manual application by workers using a handheld tool (*i.e.*, brush, roller, trowel, etc.). EPA only assessed spray applications as EPA expects potential releases and exposures from other application methods to be lower than spray coating releases. EPA assumes BBP will remain in the dried/cured coating following application to the substrate. Applications may occur over the course of a worker's 8-hour workday at a given site and may include multiple coats and time for drying or curing ([OECD, 2011b](#)). Figure 3-12 provides an illustration of the spray application of paints and coatings based on the above information ([OECD, 2011a, b, 2009c](#); [U.S. EPA, 2004d](#)).

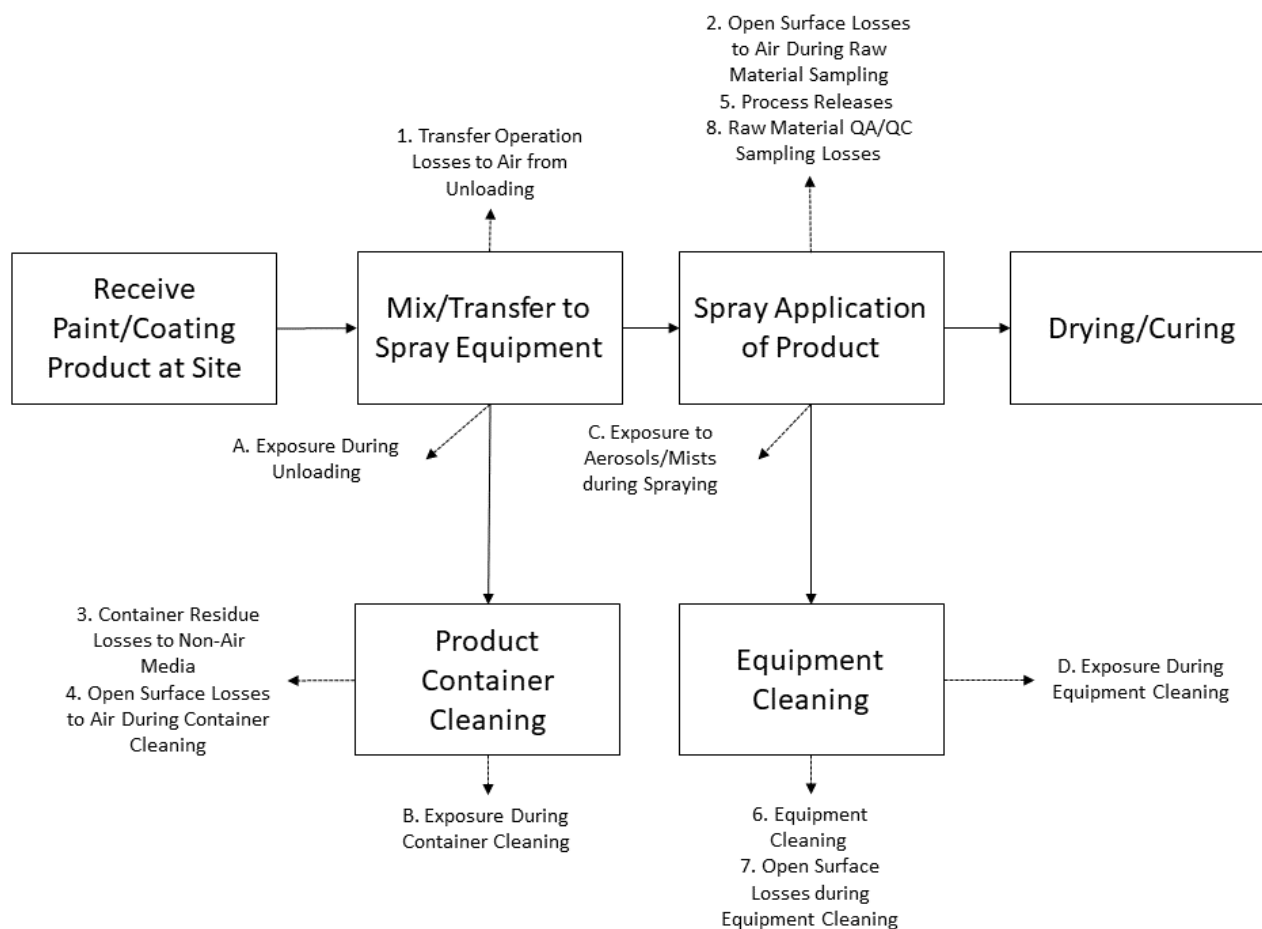


Figure 3-12. Application of Paints and Coatings Flow Diagram

3.11.2 Facility Estimates

Since the application of paints and coatings occurs immediately downstream of formulation into paints and coatings, EPA expects these OES to have the same production volume. The production volume for paint and coating formulation was estimated as 137,260 kg/year.

EPA did not identify site- or BBP-specific paint and coating use operating data (*e.g.*, facility use rates, operating days). Therefore, EPA based the facility use rate on the 2011 ESD on Radiation Curable Coatings, Inks and Adhesives, the 2011 ESD on Coating Application via Spray-Painting in the Automotive Finishing Industry, the 2004 GS on Spray Coatings in the Furniture Industry, and the European Council of the Paint, Printing Ink, and Artist's Colours Industry (CEPE) SpERC Factsheet for Industrial Application of Coatings and Inks by Spraying ([CEPE, 2020](#); [OECD, 2011a, b](#); [U.S. EPA, 2004c](#)). The ESDs, GS, and SpERC estimated coating use rates of 12,684 to 446,600 kg/site-year. Based on a BBP concentration in liquid paints and coatings of 0.1 to 60 percent, EPA estimated a BBP use rate of 12.7 to 267,960 kg/site-year. Additionally, the ESDs, GS, and SpERC estimated the number of operating days as 225 to 300 days/year with 8 hour/day operations ([CEPE, 2020](#); [OECD, 2011a, b](#); [U.S. EPA, 2004c](#)). EPA did not identify estimates of the number of sites that may apply paint and coating products containing BBP. Therefore, EPA estimated the total number of application sites that use BBP-containing paints and coatings using a Monte Carlo model (see Appendix D.10 for details). The 50th to 95th modeled percentile range of the number of sites was 4 to 32.

3.11.3 Release Assessment

3.11.3.1 Environmental Release Points

Based on the 2011 ESD on Radiation Curable Coatings, Inks and Adhesives ([OECD, 2011b](#)), EPA assessed fugitive air releases from transfer operations, raw material sampling, container cleaning and equipment cleaning; releases to wastewater, incineration, or landfill from container residue losses and sampling; releases to incineration or landfill from equipment cleaning; and releases to fugitive air, wastewater, incineration, or landfill from process releases during application.

EPA assessed releases for this OES using Monte Carlo modeling and site-specific batch parameters provided by the 2011 ESD on Radiation Curable Coatings, Inks and Adhesives ([OECD, 2011b](#)). EPA did not identify information on whether sites using BBP-containing adhesives would use overspray control technologies when using spray applications. Therefore, EPA assessed two scenarios, one where application sites use overspray control technologies and one where no controls are used. If a site uses overspray control technology, EPA assessed stack air releases of approximately 10 percent of the application related losses with the remaining 90 percent of application losses to wastewater, landfill, or incineration ([OECD, 2011b](#)). If the site does not use control technology, EPA expects the site to release all application related losses to fugitive air, wastewater, incineration, or landfill in unknown percentages ([OECD, 2011b](#)).

3.11.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2011 ESD on Radiation Curable Coatings, Inks and Adhesives ([OECD, 2011b](#)). The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the ESD to estimate releases from each source. The ESD presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the ESD to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the ESD are provided below:

- Release point 1 – Volatile emissions generated during container unloading were estimated to fugitive air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, container volumes, and vapor correction factors based on various sources ([U.S. EPA, 2015](#); [OECD, 2011b](#); [Baldwin and Maynard, 1998](#)).
- Release point 2 – Volatile emissions generated during sampling activities were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, diameter of opening, and saturation factor based on various sources ([U.S. EPA, 2015](#); [OECD, 2011b](#); [Baldwin and Maynard, 1998](#)).
- Release point 3 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Drum Residual Model. EPA modified this model to include distributions for container size and loss factor, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2015](#); [OECD, 2011b](#)).

- Release point 4 – Volatile emissions generated during container cleaning were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2015](#); [OECD, 2011b](#); [Baldwin and Maynard, 1998](#))
- Release point 5 – Releases from spray application of the paint/coating product were assessed using the EPA/OPPT Automobile OEM Overspray Loss Model to fugitive or stack air, water, land, or waste treatment. EPA modified this model to include a distribution for the transfer efficiency of the application method, which was sourced from the ESD ([OECD, 2011b](#)).
- Release point 6 – Equipment cleaning waste was assessed to land or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model ([U.S. EPA, 2015](#); [OECD, 2011b](#)).
- Release point 7 – Volatile emissions generated during cleaning of process equipment were assessed to fugitive air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2015](#); [OECD, 2011b](#); [Baldwin and Maynard, 1998](#))
- Release point 8 – Sampling waste was assessed to water, land, or waste treatment using the *EPA/OPPT 2023 Methodology for Estimating Environmental Releases from Sampling Waste*. EPA modified this to include distributions of loss fractions based on data in the methodology document ([U.S. EPA, 2023b](#)).

Other key assessment decisions and deviations from the ESD include the assessment of application losses only from spray applications as EPA expects spray applications to result in the largest releases and be protective of other application methods. EPA also assessed a uniform concentration distribution of 0.1 to 60 percent for paint/coating products based on identified product SDSs listed in Appendix E. The upper bound of this distribution (60%) was based on a pigment, which EPA acknowledges may over estimate BBP concentration within paints and coatings. A coating product with 50 percent BBP is the product with the next highest concentration, which is more representative of a reasonable upper bound of exposure for this OES. Finally, EPA ran the model twice—once with the assumption that engineering controls were in place to control spray application releases and once with the assumption that no spray controls were in place. For more details on model equations, input parameters, parameter distributions, and EPA’s rationale for selecting each see Appendix D.9.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-46 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

It should be noted that stack air and incineration/landfill releases appear larger for the control technology scenario compared to the no control technology scenario. However, this is only a result of how spray application losses are partitioned to the various environmental media. The total releases for both scenarios are approximately equal as the loss fractions distributions are the same for both scenarios. However, in the scenario with control technologies overspray are captured and sent through control

equipment where they are ultimately incinerated or landfilled with uncontrolled overspray sent through stack air and in the no control scenario the overspray losses are to fugitive air, wastewater, incineration, or landfill with unknown partitioning between media. The use of control technology impacts the relative partitioning across media of release, but does not change the total environmental release.

Table 3-46. Summary of Modeled Environmental Releases for Application of Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Spray Application with Control Technology	Fugitive air	7.5E-05	2.4E-04	257	287	2.9E-07	9.1E-07
	Stack air	1,563	5,956			6.1	23
	Incineration or landfill ^a	1.5E04	5.6E04			57	218
	Wastewater, incineration, or landfill ^a	553	3,003			2.2	12
Spray Application with No Control Technology	Fugitive air	7.5E-05	2.4E-04	257	287	2.9E-07	9.1E-07
	Incineration or landfill ^a	736	2,489			2.9	9.7
	Wastewater, incineration, or landfill ^a	553	2,985			2.2	12
	Unknown (air, wastewater, incineration, or landfill ^a)	1.6E04	6.0E04			61	231

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.10. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively

3.11.4 Occupational Exposure Assessment

3.11.4.1 Worker Activities

During the use of BBP-containing paints and coatings, workers may experience dermal or inhalation exposure to BBP when unloading or mixing a multi-component product that includes BBP in a concentrated form. Workers are potentially exposed to BBP from overspray inhalation during spray coating. Workers may be exposed via dermal contact to liquids containing BBP during product unloading into application equipment, brush and trowel applications, raw material sampling, and container and equipment cleaning ([OECD, 2011b](#)). EPA did not find information on the extent to which engineering controls and worker PPE are used at facilities that use BBP-containing paints and coatings. EPA expects the types of PPE and controls used at each site to be based on the hazards present; therefore, the common PPE/controls presented in the GS/ESD may or may not apply when BBP is being used.

For this OES, ONUs would include supervisors, managers, and other employees that do not directly handle paint or coating equipment but may be present in the application area. ONUs are potentially exposed through the inhalation of mist and dermal contact with surfaces where mist has been deposited.

3.11.4.2 Occupational Inhalation Exposure Results

EPA did not identify BBP-specific inhalation monitoring data for the use of paints and coatings during systematic review, except for two non-detect samples from OSHA CEHD. EPA was not able to identify what test method was used by OSHA and thus unable to determine an LOD to use with the substitution method. EPA identified analogous vapor inhalation monitoring data for the application of plastisol during systematic review of literature sources ([ECJRC, 2007](#)). EPA determined that this data was generally relevant to the application of paint and coating products because plastisols can be manually spread on a substrate similar to a paint or coating with comparable BBP concentrations. The data from the ECJRC consisted of 13 PBZ inhalation monitoring data points from three sites. With 13 datapoints, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency. EPA also estimated inhalation exposures to mist for this OES using the Automotive Refinishing Spray Coating Mist Inhalation Model from the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry ([OECD, 2011a](#)).

Although paints and coatings can be applied in a variety of ways, EPA assessed exposures during spray application to encompass high-end exposures during this OES. EPA used the Automotive Refinishing Spray Coating Mist Inhalation Model which estimates worker inhalation exposure based on the concentration of the chemical of interest in the nonvolatile portion of the sprayed product and the concentration of over sprayed mist/particles ([OECD, 2011a](#)). The model is based on PBZ monitoring data for mists during automotive refinishing. EPA used the 50th and 95th percentile mist concentration along with the concentration of BBP in the paint from identified products (max of 50%) to estimate the central tendency and high-end inhalation exposures, respectively. For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.14. EPA selected this model as the most appropriate method to estimate occupational exposure to BBP through the spray application of paints and coatings.

Table 3-47 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP mist and vapors from the use of paints and coatings. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The central tendency and high-end exposures use 250 days per year as the exposure frequency since the 50th and 95th percentiles of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-47. Summary of Estimated Worker Inhalation Exposures to Mist and Vapor for Application of Paints and Coatings

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	1.7	22
	Acute Dose (AD) (mg/kg-day)	0.21	2.8
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	0.16	2.0
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	0.15	1.9
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	1.7	22
	Acute Dose (AD) (mg/kg-day)	0.23	3.1
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	0.17	2.2
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	0.16	2.1
ONU	8-hour TWA Exposure Concentration (mg/m ³)	1.7	1.7
	Acute Dose (AD) (mg/kg-day)	0.21	0.21
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	0.16	0.16
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	0.15	0.15

^a EPA identified surrogate inhalation monitoring data from 1 source to estimate exposures for this OES ([ECJRC, 2007](#)). The source of monitoring data received a rating of medium from EPA's systematic review process.

3.11.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various "Exposure Concentration Types" from Table 3-48 are explained in Appendix A. ONU dermal exposures are not assessed for this OES as there are no activities expected to expose ONUs to BBP in liquid form. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper PPE or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Since there may be mist deposited on surfaces from this OES, dermal exposure to ONUs from contact with mist on surfaces was assessed. Table 3-48 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-48. Summary of Estimated Worker Dermal Exposures for Application of Paints and Coatings

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.023	0.045
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.022	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.042
ONU	Dose Rate (APDR, mg/day)	1.33	1.33
	Acute Dose (AD) (mg/kg/day)	0.017	0.017
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	0.012	0.012
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	0.011	0.011
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (i.e., 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (i.e., 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (i.e., 268 cm ²)			

3.11.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-49. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-49. Summary of Estimated Worker Aggregate Exposures for Application of Paints and Coatings

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.25	2.8
	Intermediate (IADD, mg/kg-day)	0.18	2.1
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.17	1.9
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.27	3.1
	Intermediate (IADD, mg/kg-day)	0.19	2.3
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.18	2.1
ONU	Acute (AD, mg/kg-day)	0.23	0.23
	Intermediate (IADD, mg/kg-day)	0.17	0.17
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.16	0.16
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.12 Use of Laboratory Chemicals

3.12.1 Process Description

EPA identified multiple products for BBP in laboratory chemicals, in both liquid and solid forms. The relevant SDS indicate laboratory chemicals contain BBP in a concentration of 0.1 to 1 percent for liquid products and concentrations from 0.1 to 0.3 percent for solids (see Appendix E for EPA identified BBP-containing products for this OES). Laboratory chemicals containing BBP arrive at end use sites in containers ranging in size from 0.5 to 1 gallon for liquid chemicals or 0.5 to 1 kg for solids. The end use site transfers the chemical to labware and lab equipment for analyses. After analysis, laboratory sites clean containers, labware, and lab equipment and dispose of laboratory waste and unreacted BBP-containing laboratory chemicals ([U.S. EPA, 2023c](#)). Figure 3-13 provides an illustration of the use of laboratory chemicals based on information from the 2023 GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)).

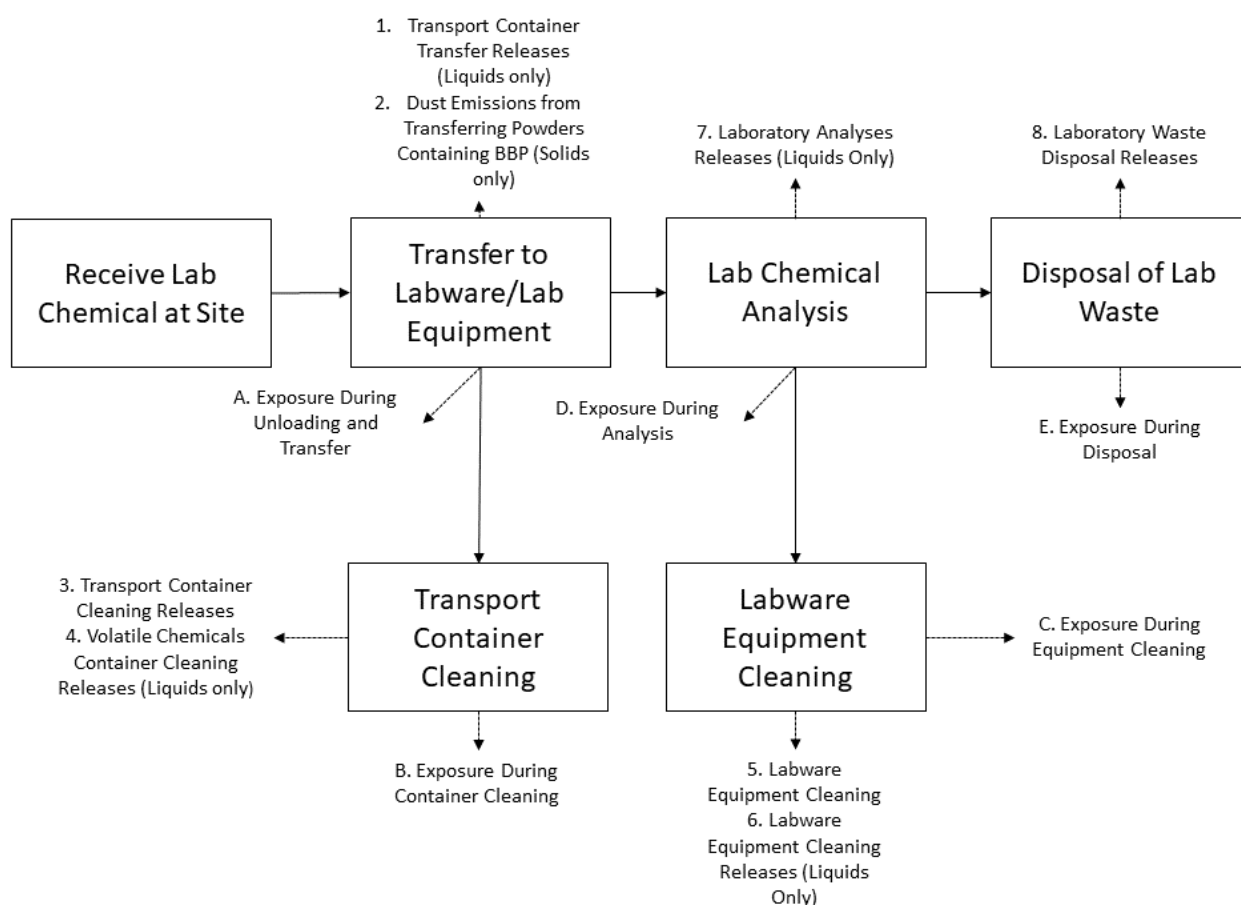


Figure 3-13. Use of Laboratory Chemicals Flow Diagram

3.12.2 Facility Estimates

No sites reported the use of BBP-containing laboratory chemicals in the 2020 CDR. Instead, EPA assumed that a portion of the BBP production volume from each CDR reporting site may be used in laboratory chemicals. Specifically, EPA estimated the total production volume of BBP in laboratory chemicals using the CDR reporting threshold limits of either 25,000 pounds (11,340 kg) or five percent of a site's reported production volume, whichever value was smaller. EPA considered every site that reported using BBP to CDR. For sites that claimed their production volume as CBI, EPA assumed 25,000 pounds of BBP-containing laboratory chemicals annually ([U.S. EPA, 2020a](#)). The total

production volume estimated for this OES was 22,813 kg/year. See Table 3-19 for a list of the identified sites and production volumes.

EPA did not identify site- or chemical-specific operating data for laboratory use of BBP (*i.e.*, facility throughput, operating days, number of sites). For solid products, the 2023 GS on The Use of Laboratory Chemicals provides an estimated throughput of 0.33 kg/site-day for solid laboratory chemicals ([U.S. EPA, 2023c](#)). Based on the concentration of BBP in solid laboratory chemicals of 0.1 to 0.3 percent, EPA estimated a daily facility use rate using Monte Carlo modeling, resulting in a 50th to 95th percentile range of 2.6×10^{-3} to 3.2×10^{-3} kg/site-day. For liquid products, the 2023 GS provided an estimated throughput of 0.5 to 4,000 mL/site-day for liquid laboratory chemicals ([U.S. EPA, 2023c](#)). Based on the concentration of BBP in liquid laboratory chemicals of 0.1 to 1 percent and the BBP density of 1.38 kg/L, EPA estimated a daily facility use rate of laboratory chemicals using Monte Carlo modeling, resulting in a 50th to 95th percentile range of 6.8×10^{-3} to 2.5×10^{-2} kg/site-day. Additionally, the GS estimated the number of operating days as 174 to 260 days/year, with 8 hour/day operations ([U.S. EPA, 2023c](#)).

EPA did not identify estimates of the number of sites that use laboratory chemicals containing BBP. Therefore, EPA estimated the total number of sites that use BBP-containing laboratory chemicals using a Monte Carlo model (see Appendix D.10.3 for details). For liquid use, the 50th to 95th percentile range of the number of sites was 14,597 to 36,873. Both the 50th and 95th percentile results for the number of sites were the bounding estimate of 36,873 sites for the solid use case.

3.12.3 Release Assessment

3.12.3.1 Environmental Release Points

Laboratory sites may use a combination of solid and liquid laboratory chemicals each with different release points and associated release media. For release assessment, EPA assumed each site used either the liquid or solid form (not both simultaneously) of the BBP-containing laboratory chemical. Based on the 2023 GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)), liquid laboratory chemical uses have fugitive or stack air releases from transferring chemicals from transport containers, cleaning containers, labware cleaning, and laboratory analysis. For solid laboratory chemical uses the GS indicates releases from dust emissions during transferring powders to stack or fugitive air, wastewater, incineration, or landfill ([U.S. EPA, 2023c](#)). For both liquids and solids, the GS indicates wastewater, incineration, or landfill releases from container cleaning wastes, labware equipment cleaning wastes, and laboratory waste disposal ([U.S. EPA, 2023c](#)).

Sites may utilize air capture and control technology for dusts releases ([U.S. EPA, 2023c](#)). If a site uses air capture and control technology, EPA expects captured and controlled dust releases to be released to disposal facilities for incineration or landfill. EPA expects that uncontrolled dust is released to stack air, and any uncaptured dusts are released to fugitive air, wastewater, incineration, or landfill.

3.12.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2023 GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)). The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each

source. The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Volatile emissions generated during container unloading of liquid BBP were estimated to fugitive or stack air using the EPA/OAQPS AP-42 Loading Model which EPA modified to include distributions for saturation factors, container volumes, and vapor correction factors based on various sources ([U.S. EPA, 2023c](#), [2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 2 – Dust releases from unloading solid laboratory chemicals containing BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation, engineering control capture and control efficiencies, and container size. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2023c](#), [2015](#)).
- Release point 3 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Small Container Residual Model or the EPA/OPPT Solid Residuals in Transport Containers Model based on whether the model was run for liquid or solid releases respectively. EPA modified these models to include distributions for container size and loss factor, which were based on values in the ChemSTEER User Guide ([U.S. EPA, 2023c](#), [2015](#)).
- Release point 4 – Volatile emissions generated during container cleaning of liquid BBP containers were assessed to fugitive or stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2023c](#), [2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 5 – Equipment cleaning waste was assessed to water, land, or waste treatment using either the EPA/OPPT Multiple Process Vessels Residual Model or the EPA/OPPT Solid Residuals in Transport Containers Model depending on if the model was run for liquids or solids respectively ([U.S. EPA, 2023c](#), [2015](#)).
- Release point 6 – Volatile emissions generated during cleaning of liquid BBP process equipment were assessed to fugitive or stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed and saturation factor based on various sources ([U.S. EPA, 2023c](#), [2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 7 – Volatile emissions generated during use of liquid BBP were assessed to fugitive or stack air using a combination of the EPA/OPPT Penetration Model and the EPA/OPPT Mass Transfer Coefficient Model. EPA modified these to include distributions for air speed, diameter of opening, and saturation factor based on various sources ([U.S. EPA, 2023c](#), [2015](#); [Baldwin and Maynard, 1998](#)).
- Release point 8 – Releases from disposal of BBP used in the lab was estimated as the amount of BBP remaining after accounting for all previous releases (release of all BBP each day was assumed). This release was assessed to water, land, or waste treatment.

Other key assessment decisions and deviations from the GS include that EPA modeled two scenarios, one for each physical form of BBP that is expected to be used in the process. EPA used a triangular

concentration distribution of 0.1 to 1 percent for liquid lab chemicals and a uniform distribution of 0.1 to 0.3 percent BBP for solid lab chemicals based on identified SDSs for products containing BBP ([Bio SB Inc., 2019](#); [Phenova, 2018](#)). For more details on model equations, input parameters, parameter distributions, and EPA’s rationale for selecting each see Appendix D.11.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-50 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

Table 3-50. Summary of Modeled Environmental Releases for Use of Laboratory Chemicals

Modeled Scenario	Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
		Central Tendency	High-End	Central Tendency		Central Tendency	High-End
Liquid Laboratory Chemicals	Fugitive or stack air ^a	1.9E-08	5.4E-08	235	258	2.3E-10	8.3 E-11
	Wastewater, incineration, or landfill ^a	1.6	5.7			6.8E-03	2.4E-02
Solid Laboratory Chemicals	Stack air	1.0E-03	5.3E-03	235	258	4.5E-06	2.3E-05
	Unknown media (air, wastewater, incineration, or landfill ^a)	1.8E-03	7.6E-03			8.0E-06	3.3E-05
	Wastewater, incineration, or landfill ^a	0.61	0.62			2.6E-03	3.2E-03
	Incineration or landfill ^a	2.5E-03	8.4E-03			1.1E-05	3.7E-05

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.11. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.12.4 Occupational Exposure Assessment

3.12.4.1 Worker Activities

Worker exposures to BBP may occur through the inhalation of vapors or solid powders while unloading and transferring laboratory chemicals and during laboratory analysis. Dermal exposure to liquid and

solid chemicals may occur during laboratory chemical unloading, container cleaning, labware equipment cleaning, laboratory analysis, and disposal of laboratory wastes ([U.S. EPA, 2023c](#)). EPA did not find information on the extent to which laboratories that use BBP-containing chemicals also use engineering controls and worker PPE.

ONUs include supervisors, managers, and other employees that do not directly handle the laboratory chemical or laboratory equipment but may be present in the laboratory or analysis area. ONUs are potentially exposed through the inhalation route while in the laboratory area from vapor and airborne dust and through the dermal route from contact with surfaces where dust has been deposited.

3.12.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the use of laboratory chemicals during systematic review. BBP is present in solid and liquid laboratory chemicals based on identified BBP-containing lab products in Appendix E. EPA assessed potential for worker and ONU inhalation to vapor from liquid and dust from solid laboratory chemicals. Due to no relevant vapor inhalation exposure data for this OES, EPA assesses the manufacturing vapor exposure as a bounding limit as EPA expects the manufacturing OES to be the most representative for this OES because worker activities in the manufacturing OES include sampling and testing. The manufacturing inhalation exposure data is from a risk evaluation conducted by the ECJRC ([2007](#)). See Section 3.1.4.2 for additional information on this data. EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency.

For solid BBP, EPA did not identify monitoring data through the systematic review process, therefore, EPA developed a deterministic model to estimate inhalation exposures to particulates for this OES using the approaches, model equations, and input parameters detailed in the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021b](#)). The model combines expected chemical concentrations at the facility with workplace TWA particulate samples compiled from the OSHA CEHD dataset. The model estimates an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Model approaches and parameters are described in Appendix D.2. The monitoring data in the GS is categorized by NAICS code groupings to refine estimates where data is available. EPA estimated the 32 TWA particulate samples associated with facilities having NAICS codes starting with 54 (Professional, Scientific, and Technical Services) as most similar to this OES and used these to estimate BBP particulate concentrations in the air. For this OES, 0.3 percent by mass was the highest identified lab-grade solid material in Appendix E. In the estimated exposures, EPA assumed that BBP is present in particulates at this fixed concentration throughout the work shift. EPA then used the model to calculate a central tendency BBP particulate inhalation exposure dose using the 50th percentile and a high-end BBP particulate inhalation exposure dose using the 95th percentile. While there are uncertainties in estimates for particulate matter from PNOR, during the August 2025 SACC peer review of high-priority phthalates, the use of an upper bound exposure estimate was recommended in the absence of direct measurements of phthalates within particulates or facility specific data. Therefore, these modeled values were utilized in the occupational exposure assessment for BBP.

Table 3-51 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during the use of solid laboratory chemicals. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA

assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. EPA used the number of operating days estimated in the release assessment for this OES to estimate exposure frequency, which is the expected maximum number of working days. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum for working days. The central tendency exposures use 235 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD. The estimated exposures to solids assume that the worker is exposed to BBP in the form of particulates and does not account for other potential inhalation exposure routes (*i.e.*, vapor).

Table 3-51. Summary of Estimated Worker Inhalation Exposures for Use of Laboratory Chemicals

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker – Solid	8-hour TWA Exposure Concentration (mg/m ³)	5.7E–04	8.1E–03
	Acute Dose (AD) (mg/kg-day)	7.1E–05	1.0E–03
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	5.2E–05	7.4E–04
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.6E–05	6.9E–04
Female of Reproductive Age – Solid	8-hour TWA Exposure Concentration (mg/m ³)	5.7E–04	8.1E–03
	Acute Dose (AD) (mg/kg-day)	7.9E–05	1.1E–03
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	5.8E–05	8.2E–04
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	5.1E–05	7.7E–04
ONU – Solid	8-hour TWA Exposure Concentration (mg/m ³)	5.7E–04	5.7E–04
	Acute Dose (AD) (mg/kg-day)	7.1E–05	7.1E–05
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	5.2E–05	5.2E–05
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	4.6E–05	4.9E–05
Average Adult Worker – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.46
	Acute Dose (AD) (mg/kg-day)	1.3E–02	5.7E–02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.2E–03	4.2E–02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.0E–03	3.9E–02
Female of Reproductive Age – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.46
	Acute Dose (AD) (mg/kg-day)	1.4E–02	6.3E–02

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	1.0E-02	4.6E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.9E-03	4.3E-02
ONU – Liquid	8-hour TWA Exposure Concentration (mg/m ³)	0.10	0.10
	Acute Dose (AD) (mg/kg-day)	1.3E-02	1.3E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.2E-03	9.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.0E-03	8.6E-03

^a EPA identified surrogate inhalation monitoring data from one source to estimate exposures for this OES ([ECJRC, 2007](#)). The source of monitoring data received a rating of medium from EPA’s systematic review process. With 5 data points, EPA characterized the data by taking the 95th percentile and the 50th percentile of the combined dataset to represent the high-end and central tendency. For the PNOR Model, EPA multiplied the concentration of BBP with the CT and HE estimates of the relevant NAICS code from the PNOR Model to calculate the CT and HE estimates for this OES.

3.12.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-9 are explained in Appendix A. For solid chemicals, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-52 summarizes the APDR, the AD, the IADD, and the ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-52. Summary of Estimated Worker Dermal Exposures for Use of Laboratory Chemicals

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker – Solid	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.8E-03	8.2E-03
Female of Reproductive Age – Solid	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.5E-03	7.5E-03
ONU – Solid	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.9E-03	2.0E-03
Average Adult Worker – Liquid	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.024	0.049
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.021	0.045
Female of Reproductive Age – Liquid	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.022	0.045
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.020	0.042
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (<i>i.e.</i> , 268 cm ²)			

3.12.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-53. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-53. Summary of Estimated Worker Aggregate Exposures for Use of Laboratory Chemicals

Worker Population	Exposure Type	Central Tendency	High-End
Average Adult Worker – Solid	Acute (AD, mg/kg-day)	6.0E–03	1.3E–02
	Intermediate (IADD, mg/kg-day)	4.4E–03	9.5E–03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.9E–03	8.9E–03
Female of Reproductive Age – Solid	Acute (AD, mg/kg-day)	5.6E–03	1.2E–02
	Intermediate (IADD, mg/kg-day)	4.1E–03	8.8E–03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.6E–03	8.3E–03
ONU – Solid	Acute (AD, mg/kg-day)	3.1E–03	3.1E–03
	Intermediate (IADD, mg/kg-day)	2.2E–03	2.2E–03
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E–03	2.1E–03
Average Adult Worker – Liquid	Acute (AD, mg/kg-day)	0.046	0.12
	Intermediate (IADD, mg/kg-day)	0.033	0.091
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.029	0.085
Female of Reproductive Age – Liquid	Acute (AD, mg/kg-day)	0.044	0.12
	Intermediate (IADD, mg/kg-day)	0.033	0.091
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.029	0.085
ONU – Liquid	Acute (AD, mg/kg-day)	1.3E–02	1.3E–02
	Intermediate (IADD, mg/kg-day)	9.2E–03	9.2E–03
	Chronic, Non-Cancer (ADD, mg/kg-day)	8.0E–03	8.6E–03
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.13 Use of Lubricants and Functional Fluids

3.13.1 Process Description

A comment from the Department of Defense indicated the use of BBP in hydraulic fluids ([EPA-HQ-OPPT-2018-0501-0044](#)); however, EPA was unable to identify any lubricant/hydraulic fluid products that contained BBP. Based on the 2004 ESD on Lubricants and Lubricant Additives, EPA assumed a typical end use site unloads the lubricant/functional fluid when ready for changeout ([OECD, 2004b](#)). Sites incorporate the product into the system with a frequency ranging from once every three months to once every five years. After changeout, sites clean the transport containers and equipment and dispose of the used fluid. Figure 3-14 provides an illustration of the expected use of lubricants and functional fluids process based on information from the ESD ([OECD, 2004b](#)).

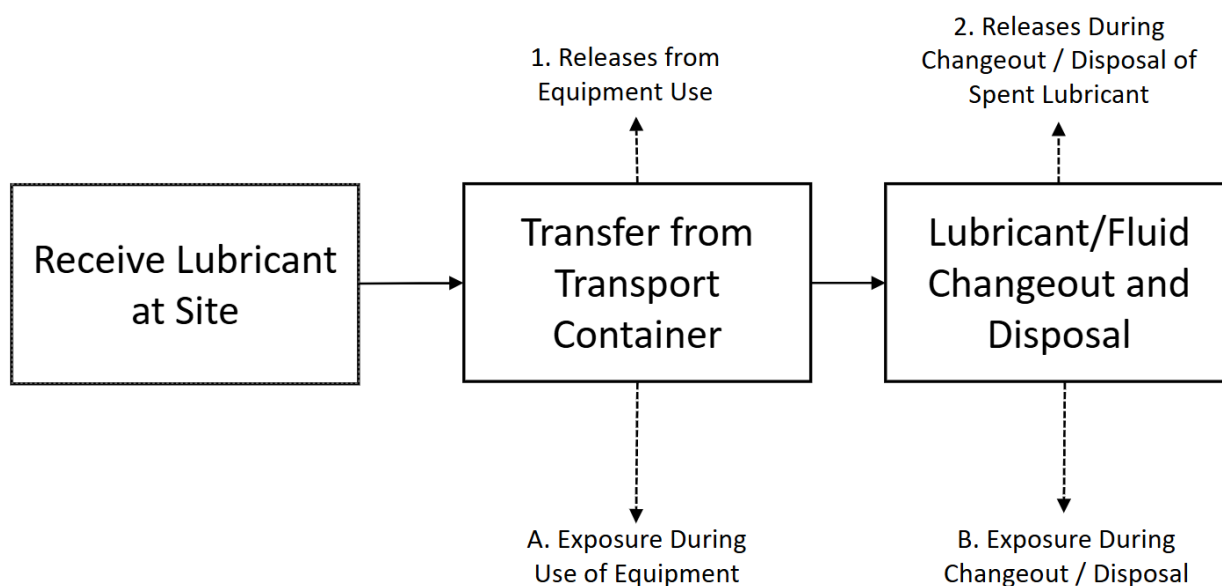


Figure 3-14. Use of Lubricants and Functional Fluids Flow Diagram

3.13.2 Facility Estimates

No sites reported the use of BBP-containing lubricants or functional fluids to the 2020 CDR ([U.S. EPA, 2020a](#)). Therefore, EPA estimated production volume for this OES assuming production volumes were below CDR reporting thresholds. Specifically, EPA estimated the total production volume of BBP in lubricants and functional fluids using the CDR reporting threshold limits of either 25,000 pounds (11,340 kg) or 5 percent of a site's reported production volume, whichever value was smaller. EPA considered every site that reported using BBP to CDR, regardless of assigned OES. For sites that claimed their production volume as CBI, EPA assumed 25,000 lb of BBP-containing lubricants/functional fluids annually. The total production volume estimated for this OES was 22,813 kg/year. See Table 3-19 for a list of the identified sites and production volumes.

EPA did not identify site- or BBP-specific lubricant and functional fluid use operating data (*e.g.*, facility use rates, operating days). However, based on the 2004 ESD on Lubricants and Lubricant Additives, EPA assumed a product throughput equivalent to one container per lubricant/functional fluid changeout ([OECD, 2004b](#)). The ESD provides an estimate of one to four changeouts per year for different types of hydraulic fluids, and EPA assumed each changeout occurs over the course of 1 day. Based on this relationship, the EPA assessed one to four operating days per year. Based on this operating day distribution, the 50th to 95th percentile range of the resulting product use rate was 195 to 913 kg/site-year. EPA did not identify any estimates of the number of sites that may use lubricants/functional fluids containing BBP. Therefore, EPA estimated the total number of sites that use BBP-containing lubricants/functional fluids by dividing the estimated production volume by the range of annual site throughput within the Monte Carlo analysis (see Appendix D.12.3 for details). The 50th to 95th percentile range of the number of sites was 117 to 1,392 sites.

3.13.3 Release Assessment

3.13.3.1 Environmental Release Points

Based on the 2004 ESD on Lubricants and Lubricant Additives ([OECD, 2004b](#)), EPA assessed releases to wastewater or landfill from the use of equipment for fluid changeouts; and releases to wastewater, recycling, landfill, and incineration from fluid disposal.

3.13.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate water and land releases for this OES using the approaches, model equations, and input parameters detailed in the 2004 ESD on Lubricants and Lubricant Additives ([OECD, 2004b](#)). The model combines facility information (*e.g.*, throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the ESD to estimate releases from each source. The ESD presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the ESD to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the ESD are provided below:

- Release point 1 – Releases that occur during use of equipment were assessed to land and water using loss fractions provided by the ESD ([OECD, 2004b](#)).
- Release point 2 – Release during changeout and disposal of spent lubricant were assessed to fuel blending (incineration), water, land, recycling, or waste treatment using loss fractions provided by the ESD ([OECD, 2004b](#)).

Another key assessment decision and deviation from the ESD was that EPA used a triangular distribution to model lubricant density based on analogous lubricant chemicals containing other phthalates. For this OES, the sum of releases from points 1 and 2 is equal to 100% of the production volume as EPA assumes that all functional fluids that were not released during their use are released during periodic changeout. For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.12.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to water and land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental media for a generic facility for this OES. Table 3-54 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

Where the environmental media is stated to "wastewater" it indicates the amount sent to wastewater treatment and not the amount ultimately discharged to surface water. Removal efficiencies and the subsequent discharge to surface water are considered when estimating final environmental concentrations. Similarly, where the environmental media is stated to "incineration" it indicates the amount going to the incinerator prior to any destruction of the chemical. Destruction efficiencies and the subsequent air emissions are considered when estimating final environmental concentrations. See Appendix D.12 for more details.

Table 3-54. Summary of Modeled Environmental Releases for Use of Lubricants and Functional Fluids

Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^a (kg/site-day)	
	Central Tendency	High- End	Central Tendency	High- End	Central Tendency	High- End
Wastewater	98	489	2	4	46	171
Landfill	42	235			20	84
Recycling	1.5	11			0.70	4.1
Fuel blending (incineration)	33	250			16	92

^a The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.12. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.13.4 Occupational Exposure Assessment

3.13.4.1 Worker Activities

Workers are potentially exposed to BBP from lubricant and functional fluid use when unloading lubricants and functional fluids from transport containers, during changeout and removal of used lubricants and functional fluids, and during any associated equipment or container cleaning activities. Workers may be exposed via inhalation of BBP vapors or dermal contact with liquids containing BBP. EPA did not identify chemical-specific information for engineering controls and worker PPE used at facilities that perform changeouts of lubricants or functional fluids.

ONUs include supervisors, managers, and other employees that may be in the area when changeouts occur but do not perform changeout tasks. ONUs are potentially exposed via inhalation to vapors in the area but have no expected dermal exposure.

3.13.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for use of lubricants and functional fluids during systematic review of literature sources. However, EPA estimated inhalation exposures for this OES using monitoring data for BBP exposures during the application of adhesives and sealants as analogous. EPA expects that inhalation exposures during the application of adhesives and sealants are similar to inhalation exposures expected during use of lubricants and functional fluids because BBP is handled similarly between the OES (*e.g.*, as a liquid formulation handled in a way that does not generate mists, particulates, or aerosols). Specifically, unloading and equipment cleaning is driving the exposure for both OESs.

EPA used analogous monitoring data provided in a risk evaluation conducted by ECJRC (2008). The data assessed by the ECJRC consisted of monitoring data from one site where all samples were below 0.005 mg/m³, which EPA expects is the LOD. EPA could not create a full distribution of monitoring results. To estimate high-end exposures to workers exposures, EPA used the 0.005 mg/m³ value reported in the study. To estimate central tendency worker exposure, EPA used half of the level of detection to represent central tendency exposure. Literature and product data do not indicate the potential for aerosol spraying; therefore, EPA did not assess mist exposures.

Table 3-55 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during use of lubricants and functional fluids. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The high-end exposures use four days per year as the exposure frequency based on the 95th percentile of operating days from the release assessment. The central tendency exposures use two days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-55. Summary of Estimated Worker Inhalation Exposures for Use of Lubricants and Functional Fluids

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	2.5E-03	5.0E-03
	Acute Dose (AD) (mg/kg-day)	3.1E-04	6.3E-04
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	2.1E-05	8.3E-05
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	1.7E-06	6.8E-06
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	2.5E-03	5.0E-03
	Acute Dose (AD) (mg/kg-day)	3.5E-04	6.9E-04
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	2.3E-05	9.2E-05
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	1.9E-06	7.6E-06
ONU	8-hour TWA Exposure Concentration (mg/m ³)	2.5E-03	2.5E-03
	Acute Dose (AD) (mg/kg-day)	3.1E-04	3.1E-04
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	2.1E-05	4.2E-05
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	1.7E-06	3.4E-06
^a EPA identified surrogate inhalation monitoring data from one source to estimate exposures for this OES (ECJRC, 2008). The source of monitoring data received a rating of medium from EPA's systematic review process. EPA estimated the high-end exposure as equal to the LOD and the central tendency as the midpoint.			

3.13.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various "Exposure Concentration Types" from Table 3-56 are explained in Appendix A. ONU dermal exposures are not assessed for this OES as there are no activities expected to expose ONUs to BBP in liquid form. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper PPE or washes their hands after contact

with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-56 summarizes the APDR, AD, IADD, and ADD for average adult workers and female workers of reproductive age. No ONU dermal exposure to liquid formulations of BBP is expected for this OES.

Table 3-56. Summary of Estimated Worker Dermal Exposures for Use of Lubricants and Functional Fluids

Worker Population	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.7	5.3
	Acute (AD, mg/kg-day)	0.033	0.066
	Intermediate (IADD, mg/kg-day)	0.0022	0.0088
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.00018	0.00067
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.2	4.4
	Acute (AD, mg/kg-day)	0.030	0.061
	Intermediate (IADD, mg/kg-day)	0.0020	0.0081
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.00017	0.00067
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers).			

3.13.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-57. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-57. Summary of Estimated Worker Aggregate Exposures for Use of Lubricants and Functional Fluids

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	0.033	0.067
	Intermediate (IADD, mg/kg-day)	0.0022	0.0089
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.00018	0.00073
Female of Reproductive Age	Acute (AD, mg/kg-day)	0.031	0.062
	Intermediate (IADD, mg/kg-day)	0.0021	0.0082
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.00017	0.00068
ONU	Acute (AD, mg/kg-day)	3.1E-04	3.1E-04
	Intermediate (IADD, mg/kg-day)	2.1E-05	4.2E-05
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.7E-06	3.4E-06
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.14 Fabrication of Final Product from Articles

3.14.1 Process Description

EPA anticipates that BBP may be present in a wide array of different final articles that are used both commercially and industrially. BBP is used to increase the flexibility of industrial and commercial plastic and rubber products. Based on uses for similar phthalate chemicals, this may include use of products such as vinyl floor tiles, vinyl wallpaper, and products used in transportation equipment manufacturing ([DAP Products, 2024](#); [NASA, 2020](#); [NLM, 2015](#)). EPA did not identify any specific product data to support these uses; the only source that indicated these potential uses was the 2020 CDR report, which provides minimal information on the specific uses ([U.S. EPA, 2020a](#)). EPA was unable to identify products for the fabrication and final use of products or articles OES. Per the above discussion, EPA assumes that most products used under this OES are plastics and used the estimated concentration from the plastic compounding/converting OESs to represent this scenario, with BBP at a concentration ranging from 30 to 45 percent ([U.S. EPA, 2021c](#)).

3.14.2 Facility Estimates

EPA did not identify representative site- or chemical-specific operating data for this OES (*i.e.*, facility throughput, number of sites, total production volume, operating days, product concentration), as BBP-containing article use occurs at many disparate industrial and commercial sites, with different operating conditions. Due to a lack of readily available information for this OES, the number of industrial or commercial use sites is unquantifiable and unknown. The total production volume for this OES is also unquantifiable, and EPA assumed that each end use site utilizes a small number of finished articles containing BBP. EPA assumed the number of operating days was 250 days/year with 5 day/week operations and two full weeks of downtime each operating year.

3.14.3 Release Assessment

EPA did not quantitatively assess environmental releases for this OES due to the lack of readily available process-specific and BBP-specific data; however, EPA assumes releases from this OES to be small and disperse in comparison to other upstream OES, as EPA assumes BBP to be present in smaller amounts and predominantly remain entrained in the final article, limiting the potential for release. Table 3-58 describes the expected fabrication and use activities that may potentially generate releases. All releases are non-quantifiable due to a lack of identified process- and product- specific data.

Table 3-58. Release Activities for Fabrication/Use of Final Articles Containing BBP

Release Point	Release Behavior	Release Media
Cutting, Grinding, Shaping, Drilling, Abrading, and Similar Activities	Dust Generation	Fugitive or stack air, wastewater, incineration, or landfill
Heating/Plastic Welding Activities	Vapor Generation	Fugitive or stack air

3.14.4 Occupational Exposure Assessment

3.14.4.1 Worker Activities

During fabrication and final use of products or articles, worker exposures to BBP may occur via dermal contact while handling and shaping articles containing BBP additives. Worker exposures may also occur via particulate inhalation during activities such as cutting, grinding, shaping, drilling, and/or abrasive actions that generate particulates from the product. EPA did not identify chemical-specific information on engineering controls and worker PPE used at final product or article fabrication or use sites.

ONUs include supervisors, managers, and other employees that may be in manufacturing or use areas but do not directly handle BBP-containing materials or articles. ONU inhalation exposures may occur when ONUs are present in the manufacturing area during dust generating activities. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.14.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data to assess exposures to BBP during fabrication and final use of products or articles containing BBP. Based on the presence of BBP as an additive in articles ([CPSC, 2015](#)), EPA assessed worker inhalation exposures to BBP as an exposure to particulates of final products. Therefore, EPA developed a deterministic model to estimate inhalation exposures to particulates for this OES using the approaches, model equations, and input parameters detailed in the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021b](#)). The model combines expected chemical concentrations at the facility with workplace TWA particulate samples compiled from the OSHA CEHD dataset. The model estimates an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Model approaches and parameters are described in 4.2Appendix D.

The monitoring data in the GS is categorized by NAICS code groupings to refine estimates where data is available. EPA estimated the 162 TWA particulate samples associated with facilities having NAICS codes starting with 337 (Furniture and Related Product Manufacturing) as most similar to this OES and used these to estimate BBP particulate concentrations in the air. For this OES, EPA identified 45 percent by mass as the highest expected BBP concentration based on the estimated plasticizer concentrations in relevant products given by the Use of Additives in Plastic Compounding Generic Scenario ([U.S. EPA, 2021c](#)). In the estimated exposures, EPA assumed that BBP is present in particulates at this fixed concentration throughout the work shift. EPA then used the model to calculate a central tendency BBP particulate inhalation exposure dose using the 50th percentile and a high-end BBP particulate inhalation exposure dose using the 95th percentile.

Table 3-59 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposure to BBP during fabrication and final use of products. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the

represented populations to estimate worker dose. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The high-end and central tendency exposures both use 250 days per year as the exposure frequency based on 5 day/week operations and two full weeks of downtime each operating year. Appendix A describes the approach for estimating AD, IADD, and ADD.

Table 3-59. Summary of Estimated Worker Inhalation Exposures for Fabrication and Final Use of Products or Articles

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	9.0E-02	0.81
	Acute Dose (AD) (mg/kg-day)	1.1E-02	0.10
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	8.3E-03	7.4E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	7.7E-03	6.9E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	9.0E-02	0.81
	Acute Dose (AD) (mg/kg-day)	1.2E-02	0.11
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.1E-03	8.2E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.5E-03	7.7E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	9.0E-02	9.0E-02
	Acute Dose (AD) (mg/kg-day)	1.1E-02	1.1E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	8.3E-03	8.3E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	7.7E-03	7.7E-03
^a Using the PNOR Model, EPA multiplied the concentration of BBP with the CT and HE estimates of the relevant NAICS code from the PNOR to calculate the CT and HE estimates for this OES.			

3.14.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-60 are explained in Appendix A. Since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate an estimate of exposure. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day (CEB, 1991). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-60 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-60. Summary of Estimated Worker Dermal Exposures for Fabrication and Final Use of Products or Articles

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.1E-03	8.2E-03
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.7E-03	7.5E-03
ONU	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	63.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	2.0E-03	2.0E-03
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (<i>i.e.</i> , 268 cm ²).			

3.14.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-61. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-61. Summary of Estimated Worker Aggregate Exposures for Fabrication and Final Use of Products or Articles

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.7E-02	0.11
	Intermediate (IADD, mg/kg-day)	1.3E-02	8.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.2E-02	7.8E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.8E-02	0.12
	Intermediate (IADD, mg/kg-day)	1.3E-02	9.0E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.2E-02	8.4E-02
ONU	Acute (AD, mg/kg-day)	1.4E-02	1.4E-02
	Intermediate (IADD, mg/kg-day)	1.0E-02	1.0E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	9.7E-03	9.7E-03
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.15 Recycling

3.15.1 Process Description

EPA did not identify information specific to the recycling of products containing BBP during the systematic review process and instead used the same assumptions as the assessments for recycling products containing DIDP/DINP ([U.S. EPA, 2024c](#)). EPA assumed that BBP is primarily recycled industrially in the form of BBP-containing PVC/plastic waste streams. Based on a report by Sika Corporation, PVC recycling is completed using mechanical recycling technology, in the form of scrap regrinding and recycling ([Irwin, 2022](#)). While chemical/feedstock recycling is possible, EPA did not identify any market share data indicating chemical/feedstock recycling processes for BBP-containing waste streams.

The Association of Plastic Recyclers reported recycled PVC arrives at a typical recycling site tightly baled as crushed finished articles ranging from 240 to 453 kg ([APR, 2023](#)). The bales are unloaded into process vessels, where the plastic material is ground and the PVC fraction is separated from non-PVC fractions using electrostatic separation, washing/floatation, or air/jet separation. Following cooling of ground PVC, the site transfers the product to feedstock storage for use in the plastics compounding or converting line or loads it into containers for shipment to downstream use sites. Figure 3-15 provides an illustration of the PVC recycling process based on the above information ([Irwin, 2022](#); [U.S. EPA, 2021c](#)).

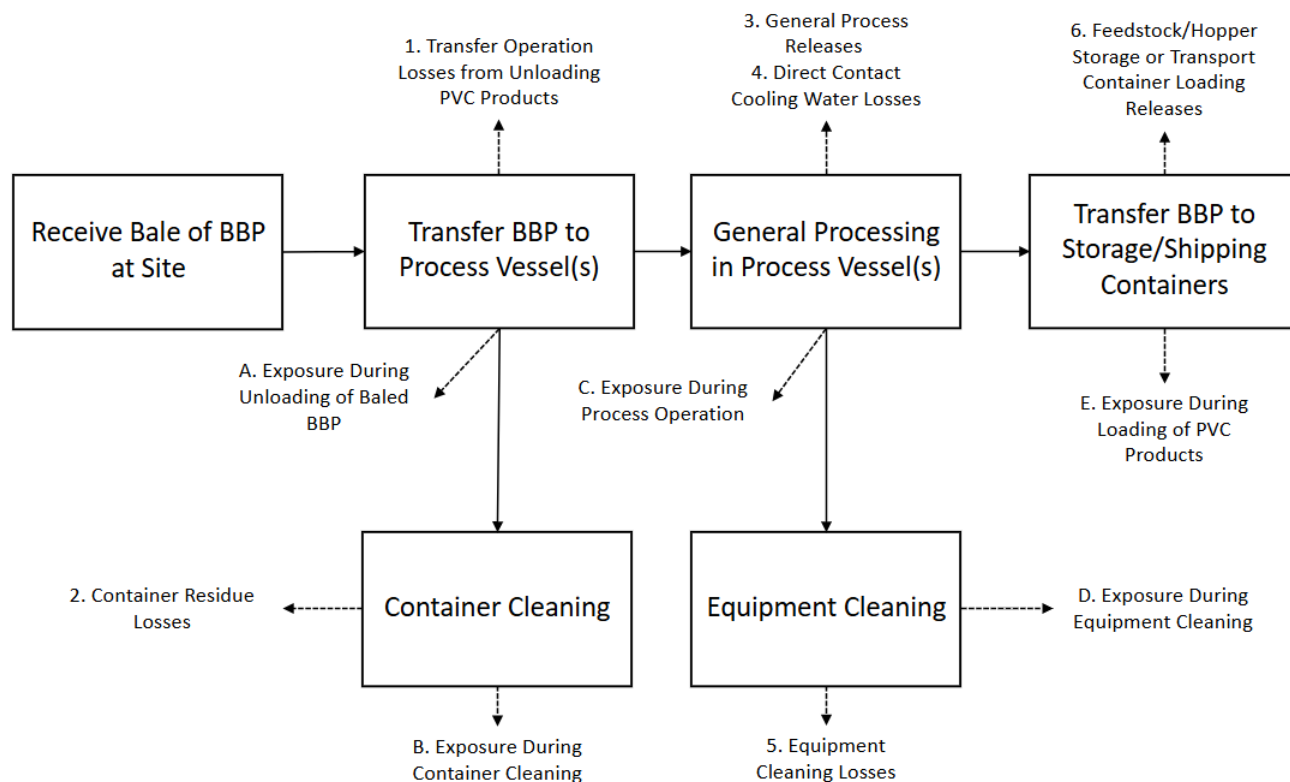


Figure 3-15. BBP-Containing PVC Recycling Flow Diagram

3.15.2 Facility Estimates

ENF Recycling ([ENF, 2024](#)) estimated a total of 228 plastics recyclers currently operating in the United States, 58 of which accept PVC wastes for recycling. It is unclear if the total number of sites includes some or all circular recycling sites; that is, facilities where new PVC can be manufactured from recycled and virgin materials at the same site. Such sites would be identified primarily by the manufactured product; however, EPA used compounding site parameters and release estimates based on generic values specified in the 2021 Generic Scenario on Plastics Compounding, which would incorporate all PVC material streams whether from recycled or virgin production ([U.S. EPA, 2021c](#)).

EPA was unable to identify a quantifiable recyclable volume of BBP-containing PVC. EPA based BBP volume estimates on data for PVC waste that contained the phthalates DINP and DIDP, and scaled these estimates based on overall production volumes for these chemicals used in plastic products. The “Quantification and Evaluation of Plastic Waste in the United States” journal article estimated that, of the 699 kilotons of PVC waste was managed in 2019, three percent (20,970,000 kg PVC) was recycled ([Milbrandt et al., 2022](#)). The 2010 technical report, “Evaluation of New Scientific Evidence Concerning DINP and DIDP”, estimated that the fractions of DIDP-containing PVC and DINP-containing PVC that were used in the overall PVC market as 9.78 and 18.3 percent, respectively ([ECHA, 2010](#)). As a result, EPA calculated the use rate of recycled PVC plastics containing DIDP as 9.78 percent of the yearly recycled production volume of PVC, which is equivalent to 2,050,866 kg/year. For DINP the use rate was calculated as 18.3 percent of the yearly recycled production volume of PVC which is equivalent to 3,846,801 kg/year. Then EPA related the DINP and DIDP use rates to the production volume of BBP used in plastic products to develop scaling factors for recyclable PVC volumes (see Table 3-62).

Table 3-62. Production Volumes Used to Develop Recycling Estimates

Chemical	Production Volume of Plastic Products (kg/year)	Source
BBP	35,279–1,758,930	See Section 3.7.2
DINP	64,568,873–473,505,075	(U.S. EPA, 2025f)
DIDP	43,859,857–434,749,009	(U.S. EPA, 2024d)

EPA divided the end points of the PV range for BBP by the endpoints for the ranges of the other two phthalates to develop scaling factors:

- Low-end scaling factor with DINP data: $35,279/473,505,075 = 7.45 \times 10^{-5}$
- High-end scaling factor with DINP data: $1,758,930/64,568,873 = 2.72 \times 10^{-2}$
- Low-end scaling factor with DIDP data: $35,279/434,749,009 = 8.11 \times 10^{-5}$
- High-end scaling factor with DIDP data: $1,758,930/43,859,857 = 4.01 \times 10^{-2}$

EPA then multiplied these scaling factors by the market percentages of the two phthalates in order to estimate a proportional market percentage range for BBP:

- DINP: $0.183 \times (7.45 \times 10^{-5} - 2.72 \times 10^{-2}) = 1.34 \times 10^{-5}$ to 4.90×10^{-3}
- DIDP: $0.098 \times (8.11 \times 10^{-5} - 4.01 \times 10^{-2}) = 7.95 \times 10^{-6}$ to 3.93×10^{-3}
- Overall range of scaling factors: 7.95×10^{-6} to 4.90×10^{-3}

Based on the 2021 Generic Scenario on Plastics Compounding, EPA estimated that the mass fraction of BBP used as a plasticizer in plastics was 30 to 45 percent ([U.S. EPA, 2021c](#)). EPA multiplied the estimated overall PVC waste volume estimate of 20,970,000 kg-PVC by the estimated PVC market share for BBP and the fraction of BBP assumed to be used in plastic products. This resulted in a range of 50 to 46,271 kg of BBP recycled per year. The GS estimated the total number of operating days of 148 to 264 days/year, with 24 hour/day, 7 day/week operations for the given site throughput scenario ([U.S. EPA, 2021c](#)).

3.15.3 Release Assessment

3.15.3.1 Environmental Release Points

EPA did not identify BBP- or industry-specific information on release points during recycling. Therefore, EPA assumed recycling sites would operate similar to plastic compounding sites for virgin plastics. Based on the 2021 Generic Scenario on Plastic Compounding ([U.S. EPA, 2021c](#)), EPA assessed fugitive air, wastewater, incineration, or landfill releases from unloading of recycled plastic, compounding processes, and transfers of compounded material containing the recycled plastic; releases to wastewater, incineration, or landfill from container residue losses and equipment cleaning; and wastewater releases from direct contact cooling water.

Sites may utilize air capture and control technology for dusts releases ([U.S. EPA, 2021c](#)). If a site uses air capture and control technology, EPA expects captured and controlled dust releases from product loading to be released to disposal facilities for incineration or landfill. EPA expects that uncontrolled dust is released to stack air, and any uncaptured dusts are released to fugitive air, wastewater, incineration, or landfill.

3.15.3.2 Environmental Release Assessment Results

EPA did not identify release data through the systematic review process. Therefore, EPA developed a probabilistic model to estimate air, water, and land releases for this OES using the approaches, model

equations, and input parameters detailed in the 2021 Draft Generic Scenario on Plastic Compounding as this was assumed to be the GS/ESD that was most representative of the recycling process ([U.S. EPA, 2021c](#)). The model combines facility information (e.g., throughputs, operating days, chemical concentrations, container types, number of facilities) with information on release sources, industry release and waste management practices, and model equations in the GS to estimate releases from each source. The GS presents generic industry information and typically provides a single recommended value for input parameters. Therefore, as needed and where data were available to do so, EPA modified the approaches described in the GS to incorporate chemical-specific information or to address input parameter variability. A summary of the release sources assessed, the associated EPA model used to develop the estimates, and any deviations from the approach in the GS are provided below:

- Release point 1 – Dust releases from unloading plastic containing BBP were assessed to fugitive air, water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include a distribution for dust generation, which was from the ChemSTEER User Guide ([U.S. EPA, 2015](#)). This release assumed no dust capture/control technologies and used a loss estimate based on values provided in the GS ([U.S. EPA, 2021c](#)).
- Release point 2 – Waste from cleaning transport containers was assessed to water, land, or waste treatment using the EPA/OPPT Solid Residuals in Transport Containers Model. EPA modified this model to include a distribution for bale size, which were based on information from the Association of Plastic Recyclers ([APR, 2023](#); [U.S. EPA, 2021c, 2015](#)).
- Release point 3 – Emissions from general processing operations were assessed to fugitive air, water, land, or waste treatment using a loss fraction provided by industry. This replaced the blending/dispersion release to fugitive or stack air that is described by the GS ([Lewandowski and Skórczewska, 2022](#); [U.S. EPA, 2021c](#)).
- Release point 4 – Releases from cooling water were assessed to water and used a loss fraction from the 2021 Draft Generic Scenario on Plastic Compounding ([U.S. EPA, 2021c](#)).
- Release point 5 – Equipment cleaning waste was assessed to water, land, or waste treatment using the EPA/OPPT Multiple Process Vessels Residual Model ([U.S. EPA, 2021c, 2015](#)).
- Release point 6 – Dust releases from loading processed material containing BBP were assessed to uncertain air (fugitive or stack), water, land, or waste treatment using the EPA/OPPT Dust Emissions from Transferring Solids Model. EPA modified this model to include distributions for dust generation and engineering control capture and control efficiencies. These were based on values provided in the GS and the ChemSTEER User Guide ([U.S. EPA, 2021c, 2015](#)).

Other key assessment decisions and deviations from the GS include the assumption of no dust capture or control technologies during the unloading process, a uniform production volume distribution of 167 to 102,824 kg/year of plastic that contains BBP based on estimates using industry data ([Milbrandt et al., 2022](#); [ECHA, 2010](#)). A uniform concentration distribution of 30 to 45% was assumed for the compounded resin based on the GS ([U.S. EPA, 2021c](#)). For more details on model equations, input parameters, parameter distributions, and EPA's rationale for selecting each see Appendix D.8.

EPA then performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model releases to air, water, land. Where releases are identified as going to one or more media, the amount release may be entirely to one of the identified media or partitioned across the media; however, this partitioning is unknown. The model calculates a release volume from each release source using the defined inputs and associated distributions and then sums volumes from sources with the same media of release to generate a total daily and annual release volume to each environmental

media for a generic facility for this OES. Table 3-63 presents the 50th percentile and 95th percentile release volumes estimated by the model to assess central tendency and high-end facility releases to each media, respectively.

Table 3-63 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. Where the environmental media is stated to “wastewater” it indicates the amount sent to wastewater treatment and not the amount ultimately discharged to surface water. Removal efficiencies and the subsequent discharge to surface water are considered when estimating final environmental concentrations. Similarly, where the environmental media is stated to “incineration” it indicates the amount going to the incinerator prior to any destruction of the chemical. Destruction efficiencies and the subsequent air emissions are considered when estimating final environmental concentrations.

Table 3-63. Summary of Modeled Environmental Releases for Recycling

Environmental Media	Annual Release (kg/site-year)		Number of Release Days		Daily Release ^b (kg/site-day)	
	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Stack air	0.60	3.6	223	254	2.8E-03	1.7E-02
Fugitive air, wastewater, incineration, or landfill ^a	4.4	14			2.0E-02	6.5E-02
Wastewater	3.3	6.6			1.5E-02	3.1E-02
Wastewater, incineration, or landfill ^a	11	23			1.3	1.8

^a When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation, using the input parameter distributions detailed in Appendix D.8. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.15.4 Occupational Exposure Assessment

3.15.4.1 Worker Activities

At PVC recycling sites, worker exposures from dermal contact with solids and inhalation of dust may occur during the unloading of bailed PVC or loading of PVC onto compounding or converting lines or into transport containers, processing of recycled PVC, and equipment cleaning ([U.S. EPA, 2004a](#)). EPA did not identify information on engineering controls or workers PPE used at recycling sites.

ONUs include supervisors, managers, and other employees that work in the processing area but do not directly handle BBP-containing PVC to be recycled or the recycled compounded product. ONUs are potentially exposed through the inhalation route while in the working area. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.15.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data to assess exposures to BBP during recycling processes, except for one non-detect sample from OSHA CEHD. EPA was not able to identify what test method was used by OSHA and thus unable to determine an LOD to use with the substitution method. Based on the presence of BBP as an additive in plastics ([CPSC, 2015](#)), EPA assessed worker inhalation exposures to BBP in particulates of recycled plastic materials. Therefore, EPA developed a deterministic model to estimate inhalation exposures to particulates for this OES using the approaches, model equations, and input parameters detailed in the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR ([U.S. EPA, 2021b](#)). The model combines expected chemical concentrations at the facility with workplace TWA particulate samples compiled from the OSHA CEHD dataset. The model estimates an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Model approaches and parameters are described in Appendix D.

The monitoring data in the GS is categorized by NAICS code groupings to refine estimates where data is available. EPA estimated the 108 TWA particulate samples associated with facilities having NAICS codes starting with 56 (Administrative and Support and Waste Management and Remediation Services) as most similar to this OES and used these to estimate BBP particulate concentrations in the air. For this OES, EPA identified 45 percent by mass as the highest expected BBP concentration based on the estimated plasticizer concentrations in relevant products given by the Use of Additives in Plastic Compounding Generic Scenario ([U.S. EPA, 2021c](#)). In the estimated exposures, EPA assumed that BBP is present in particulates at this fixed concentration throughout the work shift. EPA then used the model to calculate a central tendency BBP particulate inhalation exposure dose using the 50th percentile and a high-end BBP particulate inhalation exposure dose using the 95th percentile.

EPA used the number of operating days estimated in the release assessment for this OES to estimate exposure frequency. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum for working days. The central tendency exposures use 223 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. In absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs.

Table 3-64 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during recycling. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. Appendix A describes the approach for estimating AD, IADD, and ADD. The estimated exposures assume that the worker is exposed to BBP in the form of plastic particulates and does not account for other potential inhalation exposure routes, such as from the inhalation of vapors which are unlikely to form during recycling operations.

Table 3-64. Summary of Estimated Worker Inhalation Exposures for Recycling

Modeled Scenario	Exposure Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	0.11	1.6
	Acute Dose (AD) (mg/kg-day)	1.4E-02	0.20
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.9E-03	0.14
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.2E-03	0.13
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.11	1.6
	Acute Dose (AD) (mg/kg-day)	1.5E-02	0.22
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	1.1E-02	0.16
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	9.1E-03	0.15
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.11	0.11
	Acute Dose (AD) (mg/kg-day)	1.4E-02	1.4E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.9E-03	9.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	8.2E-03	9.2E-03
^a Using the PNOR Model, EPA multiplied the concentration of BBP with the CT and HE estimates of the relevant NAICS code from the PNOR to calculate the CT and HE estimates for this OES.			

3.15.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-65 are explained in Appendix A. Since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate an estimate of exposure. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day (CEB, 1991). However, if a worker uses proper PPE or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP likely leads to overestimation of dermal exposure. Table 3-65 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-65. Summary of Estimated Worker Dermal Exposures for Recycling

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.6E-03	8.2E-03
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.3E-03	7.5E-03
ONU	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.8E-03	2.0E-03
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (<i>i.e.</i> , 268 cm ²).			

3.15.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-66. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-66. Summary of Estimated Worker Aggregate Exposures for Recycling

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.9E-02	0.21
	Intermediate (IADD, mg/kg-day)	1.4E-02	0.15
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.2E-02	0.14
Female of Reproductive Age	Acute (AD, mg/kg-day)	2.0E-02	0.23
	Intermediate (IADD, mg/kg-day)	1.5E-02	0.17
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.2E-02	0.16
ONU	Acute (AD, mg/kg-day)	1.6E-02	1.6E-02
	Intermediate (IADD, mg/kg-day)	1.2E-02	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.0E-02	1.1E-02
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.16 Waste Handling, Treatment, and Disposal

3.16.1 Process Description

Each of the conditions of use of BBP may generate waste streams of the chemical that are collected and transported to third-party sites for disposal, treatment, or recycling. These waste streams may include the following:

- **Wastewater:** BBP may be contained in wastewater discharged to POTW or other, non-public treatment works for treatment. Industrial wastewater containing BBP discharged to a POTW may be subject to EPA or authorized NPDES state pretreatment programs. The assessment of wastewater discharges to POTWs and non-public treatment works of BBP is included in each of the condition of use assessments in Sections 3.1 through 3.15.
- **Solid Wastes:** Solid wastes are defined under RCRA as any material that is discarded by being; abandoned; inherently waste-like; a discarded military munition; or recycled in certain ways (certain instances of the generation and legitimate reclamation of secondary materials are exempted as solid wastes under RCRA). Solid wastes may subsequently meet RCRA's definition of hazardous waste by either being listed as a waste at 40 CFR 261.30 to 261.35 or by meeting waste-like characteristics as defined at 40 CFR 261.20 to 261.24. Solid wastes that are hazardous wastes are regulated under the more stringent requirements of Subtitle C of RCRA, whereas non-hazardous solid wastes are regulated under the less stringent requirements of Subtitle D of RCRA. BBP is not listed as a toxic chemical as specified in Subtitle C of RCRA, and not subject to hazardous waste regulation. However, solid wastes containing BBP may require regulation if the waste leaches constituents, specified in the toxicity characteristic leaching procedure (TCLP), in excess of the regulatory limit. This could include toxins such as lead and cadmium, which are used as stabilizers in PVC. The assessment of solid waste discharges of BBP is included in each of the condition of use assessments in Sections 3.1 through 3.15.

Off-site transfers of BBP and BBP-containing wastes to land disposal, wastewater treatment, incineration, and recycling facilities are expected based on industry supplied data, and published EPA and OECD emission documentation such as Generic Scenarios and Emission Scenario Documents. Off-site transfers are incinerated, sent to land disposal, sent to wastewater treatment, are recycled off-site, and or are sent to other or unknown off-site disposal/treatment. See Figure 3-16.

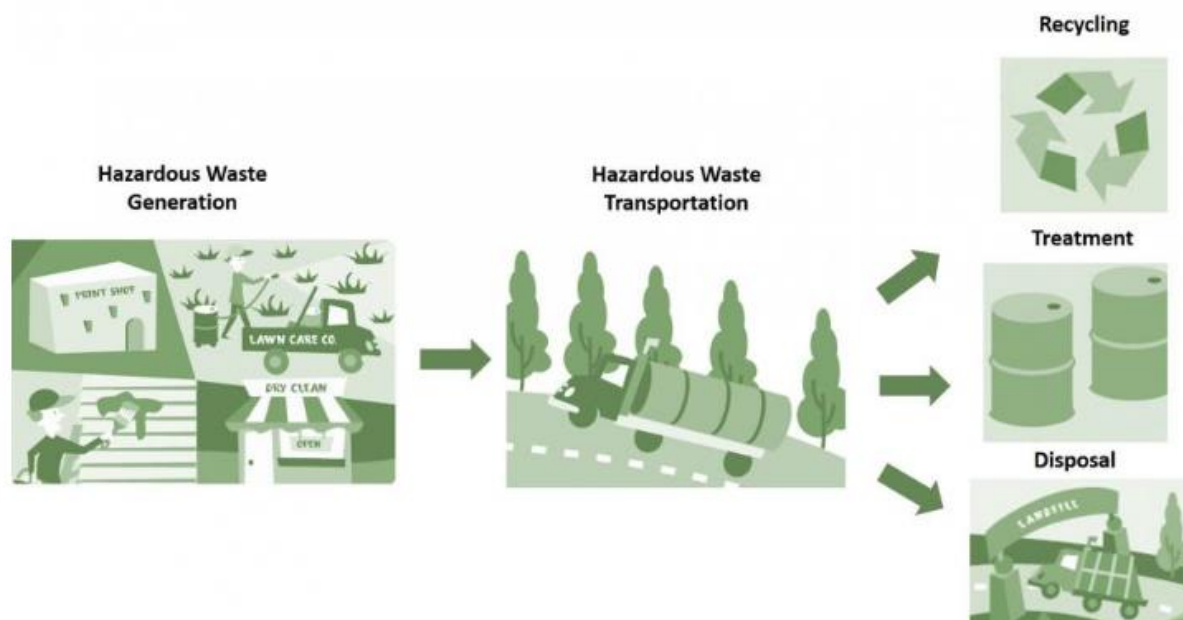


Figure 3-16. General Process for Typical Waste Disposal

Source: ([U.S. EPA, 2019](https://www.epa.gov/landfill))

Municipal Waste Incineration

Municipal waste combustors (MWCs) that recover energy are generally located at large facilities and comprised of an enclosed tipping floor and a deep waste storage pit. Typical large MWCs may range in capacity from 250 to over 1,000 tons per day. At facilities of this scale, waste materials are not generally handled directly by workers. Trucks may dump the waste directly into the pit, or waste may be tipped to the floor and later pushed into the pit by a worker operating a front-end loader. A large grapple from an overhead crane is used to grab waste from the pit and drop it into a hopper, where hydraulic rams feed the material continuously into the combustion unit at a controlled rate. The crane operator also uses the grapple to mix the waste within the pit, to provide a fuel consistent in composition and heating value, and to pick out hazardous or problematic waste.

Facilities burning refuse-derived fuel (RDF) conduct on-site sorting, shredding, and inspection of the waste prior to incineration to recover recyclables and remove hazardous waste or other unwanted materials. Sorting is usually an automated process that uses mechanical separation methods, such as trommel screens, disk screens, and magnetic separators. Once processed, the waste material may be transferred to a storage pit, or it may be conveyed directly to the hopper for combustion.

Tipping floor operations may generate dust. Air from the enclosed tipping floor, however, is continuously drawn into the combustion unit via one or more forced air fans to serve as the primary combustion air and minimize odors. Dust and lint present in the air is typically captured in filters or other cleaning devices to prevent the clogging of steam coils, which are used to heat the combustion air and help dry higher-moisture inputs ([Kitto and Stultz, 1992](#)).

Municipal Waste Landfill

Municipal solid waste landfills are discrete areas of land or excavated sites that receive household wastes and other types of non-hazardous wastes (*e.g.*, industrial and commercial solid wastes). Standards and requirements for municipal waste landfills include location restrictions, composite liner requirements, leachate collection and removal systems, operating practices, groundwater monitoring requirements, corrective action provisions, and closure-and post-closure care requirements that include financial assurance. Non-hazardous solid wastes are regulated under RCRA Subtitle D, but states may impose more stringent requirements.

Municipal solid wastes may be first unloaded at waste transfer stations for temporary storage, prior to being transported to the landfill or other treatment or disposal facilities.

Hazardous Waste Landfill

Hazardous waste landfills are excavated or engineered sites specifically designed for the final disposal of non-liquid hazardous wastes. Design standards for these landfills require double liner, double leachate collection and removal systems, leak detection systems, runoff and wind dispersal controls, and construction quality assurance program.² There are also requirements for closure and post-closure, such as the addition of a final cover over the landfill and continued monitoring and maintenance. These standards and requirements prevent potential contamination of groundwater and nearby surface water resources. Hazardous waste landfills are regulated under 40 CFR 264/265, Subpart N.

3.16.2 Facility Estimates

The concentration of BBP in waste materials varies depending on the type of product and the characteristics of that product. EPA did not identify representative site- or chemical-specific operating data for this OES (*i.e.*, facility throughput, number of sites, total production volume, operating days, product concentration), as BBP-containing wastes occur at all levels of the BBP life cycle. EPA expects disposal routes to include POTW and non-publicly owned treatment works; municipal and hazardous waste incineration; and municipal and hazardous waste landfill. Due to a lack of readily available information for this OES, the number of industrial or commercial use sites is unquantifiable and unknown; however, the available DMR data indicates at least 28 sites that manage waste containing BBP. Total production volume for this OES is also unquantifiable. EPA assumed the number of operating days was 250 days/year with 5 day/week operations and two full weeks of downtime each operating year.

3.16.3 Release Assessment

3.16.3.1 Environmental Release

EPA did not identify process-specific and BBP-specific data for this OES; however, disposal releases are quantified in upstream OESs as release indicated to wastewater, incineration, or landfill (or any combination of the three) may include both on-site and off-site treatment/disposal. The latter of which would be applicable to this OES. Therefore, additional assessment of such releases is not included here to avoid double counting. EPA did provide release estimates to surface water based on DMR data for waste management sites (primarily wastewater treatment facilities).

3.16.3.2 Environmental Release Assessment Results

Table 3-67 presents surface water discharges per year and per day based on the 2017 through 2022 DMR database along with the release days per year, with medians and maxima presented from across the six-year reporting range. If a facility has only one record in the identified range, then the median and

² <https://www.epa.gov/hwpermitting/hazardous-waste-management-facilities-and-units> (accessed December 15, 2025).

maxima will be equivalent. According to the DMR data, 28 sites reported direct discharges to surface water for the Waste handling, disposal, and treatment OES ([U.S. EPA, 2024a](#)).

Table 3-67. Summary of Water Releases from DMR for Waste Handling, Disposal, and Treatment

Site Identity	Median Annual Discharge (kg/year)	Median Average Daily Discharge (kg/day)	Maximum Annual Discharge (kg/year)	Maximum Average Daily Discharge (kg/day)	Annual Release Days (days/year)
Anderson Wastewater Treatment Plant	0.18	7.1E-04	0.18	7.1E-04	250
Barbourville STP	18	7.1E-02	18	7.1E-02	250
Brawley Wastewater Treatment Plant	3.4E-02	1.4E-04	3.4E-02	1.4E-04	250
Burlingame WWTP	10	4.1E-02	20	8.1E-02	250
Calipatria WWTP	7.1E-02	2.8E-04	7.1E-02	2.8E-04	250
Camarillo Sanitary Dist Water Reclamation Plant	0.21	8.3E-04	0.21	8.3E-04	250
Chino	5.25	2.1E-02	5.25	2.1E-02	250
City Of Red Bluff Wastewater Reclamation Plant	3.7E-02	1.5E-04	0.34	1.4E-03	250
City Of Safford – Gila Resources WRP	5.67	2.3E-02	5.67	2.3E-02	250
Clear Creek WWTP	2.94	1.2E-02	2.94	1.2E-02	250
Coastal Tank Cleaning, LLC	0.64	2.6E-03	0.64	2.6E-03	250
Colusa WWTP	0.15	6.0E-04	0.15	6.0E-04	250
Deer Park Terminal	0.16	6.4E-04	0.45	1.8E-03	250
Manteca WWQCF	0.64	2.6E-03	0.64	2.6E-03	250
Merced WWTF	0.46	1.9E-03	0.46	1.9E-03	250
Monterey Regional WWTP	14	5.7E-02	14	5.7E-02	250
Neewc Seawater Desalination Test Facility	0.29	1.2E-03	0.29	1.2E-03	250
Northern Edge Casino	0.28	1.1E-03	0.28	1.1E-03	250
Northern Madison County Sanitation District	1.39	5.5E-03	1.39	5.5E-03	250
Pismo Beach WWTF	8.32	3.3E-02	8.39	3.4E-02	250
Portola WWTP	1.68	6.7E-03	1.68	6.7E-03	250
Redding Stillwater Wastewater Treatment Plant	0.26	1.1E-03	0.26	1.1E-03	250
Richmond Otter Creek STP	69	0.28	69	0.28	250
Richmond Silver Creek STP	6.40	2.6E-02	13	5.2E-02	250
San Jacinto River And Rail	14	5.6E-02	28	0.11	250
Santa Cruz Wastewater Treatment Plant	11	4.3E-02	11	4.3E-02	250
South Louisiana Ethanol LLC	0.56	2.2E-03	2.23	8.9E-03	250
Stolthaven Houston, Inc.	0.31	1.3E-03	0.68	2.7E-03	250
STP = sewage treatment plant; WRP = water reclamation plant; WWTF = wastewater treatment facility; WWTP = wastewater treatment plant; WWQCF = wastewater quality control facility					

3.16.4 Occupational Exposure Assessment

3.16.4.1 Worker Activities

At waste disposal sites, workers are potentially exposed via dermal contact with waste containing BBP or via inhalation of BBP vapor or dust. Depending on the concentration of BBP in the waste stream, the route and level of exposure may be similar to that associated with container unloading activities.

Municipal Waste Incineration

At municipal waste incineration facilities, there may be one or more technicians present on the tipping floor to oversee operations, direct trucks, inspect incoming waste, or perform other tasks as warranted by individual facility practices. These workers may wear protective gear such as gloves, safety glasses, or dust masks. Specific worker protocols are largely up to individual companies, although state or local regulations may require certain worker safety standards be met. Federal operator training requirements pertain more to the operation of the regulated combustion unit rather than operator health and safety.

Workers are potentially exposed via inhalation to vapors and dust while working on the tipping floor. Potentially exposed workers include workers stationed on the tipping floor, including front-end loader and crane operators, as well as truck drivers. The potential for dermal exposures is minimized by the use of trucks and cranes to handle the wastes.

Hazardous Waste Incineration

More information is needed to determine the potential for worker exposures during hazardous waste incineration and any requirements for personal protective equipment. There is likely a greater potential for worker exposures for smaller scale incinerators that involve more direct handling of the wastes.

Municipal and Hazardous Waste Landfill

At landfills, typical worker activities may include operating refuse vehicles to weigh and unload the waste materials, operating bulldozers to spread and compact wastes, and monitoring, inspecting, and surveying and landfill site.³

3.16.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data to assess exposures to BBP during disposal processes. Based on the presence of BBP as an additive in plastics ([CPSC, 2015](#)), EPA assessed worker inhalation exposures to BBP as an exposure to particulates of discarded plastic materials. Therefore, EPA developed a deterministic model to estimate inhalation exposures to particulates for this OES using the approaches, model equations, and input parameters detailed in the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR ([U.S. EPA, 2021b](#)). The model combines expected chemical concentrations at the facility with workplace TWA particulate samples compiled from the OSHA CEHD dataset. The model estimates an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Model approaches and parameters are described in Appendix D.

The monitoring data in the GS is categorized by NAICS code groupings to refine estimates where data is available. EPA estimated the 108 TWA particulate samples associated with facilities having NAICS codes starting with 56 (Administrative and Support and Waste Management and Remediation Services) as most similar to this OES and used these to estimate BBP particulate concentrations in the air. For this OES, EPA identified 45 percent by mass as the highest expected BBP concentration based on the

³ <http://www.calrecycle.ca.gov/SWfacilities/landfills/needfor/Operations.htm> (accessed December 8, 2025).

estimated plasticizer concentrations in relevant products given by the Use of Additives in Plastic Compounding Generic Scenario ([U.S. EPA, 2021c](#)). In the estimated exposures, EPA assumed that BBP is present in particulates at this fixed concentration throughout the work shift. EPA then used the model to calculate a central tendency BBP particulate inhalation exposure dose using the 50th percentile and a high-end BBP particulate inhalation exposure dose using the 95th percentile.

Due to expected process similarities, EPA used the number of operating days estimated in the release assessment for the recycling OES to estimate exposure frequency. The high-end and central tendency exposures use 250 days per year, based on 5 day/week operations and two full weeks of downtime each operating year.

Table 3-68 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to BBP during disposal. Worker exposures were estimated for average workers and for average female workers of reproductive age using average body weights of the represented populations to estimate worker dose. Appendix A describes the approach for estimating AD, IADD, and ADD. The estimated exposures assume that the worker is exposed to BBP in the form of plastic particulates and does not account for other potential inhalation exposure routes, such as from the inhalation of vapors.

Table 3-68. Summary of Estimated Worker Inhalation Exposures for Disposal

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	0.11	1.6
	Acute Dose (AD) (mg/kg-day)	1.4E-02	0.20
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.9E-03	0.14
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	9.2E-03	0.13
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.11	1.6
	Acute Dose (AD) (mg/kg-day)	1.5E-02	0.22
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	1.1E-02	0.16
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	1.0E-02	0.15
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.11	0.11
	Acute Dose (AD) (mg/kg-day)	1.4E-02	1.4E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/kg-day)	9.9E-03	9.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg-day)	9.2E-03	9.2E-03
^a Using the PNOR Model, EPA multiplied the concentration of BBP with the CT and HE estimates of the relevant NAICS code from the PNOR model to calculate the CT and HE estimates for this OES.			

3.16.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal approach outlined in Section 2.4.3 and Appendix C. The various “Exposure Concentration Types” from Table 3-69 are explained in Appendix A. Since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. In the absence of data specific to ONU exposure, EPA

assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate an estimate of exposure. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. So, in absence of exposure duration data, EPA has assumed that absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day ([CEB, 1991](#)). However, if a worker uses proper PPE or washes their hands after contact with BBP or BBP-containing materials dermal exposure will be reduced. Therefore, the assumption of an 8-hour exposure duration for BBP may lead to overestimation of dermal exposure. Table 3-69 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs.

Table 3-69. Summary of Estimated Worker Dermal Exposures for Disposal

Modeled Scenario	Exposure Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	0.48	0.95
	Acute (AD, mg/kg-day)	6.0E-03	1.2E-02
	Intermediate (IADD, mg/kg-day)	4.4E-03	8.7E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.1E-03	8.2E-03
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.40	0.79
	Acute (AD, mg/kg-day)	5.5E-03	1.1E-02
	Intermediate (IADD, mg/kg-day)	4.0E-03	8.0E-03
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.7E-03	7.5E-03
ONU	Dose Rate (APDR, mg/day)	0.24	0.24
	Acute Dose (AD) (mg/kg/day)	3.0E-03	3.0E-03
	Intermediate Average Daily Dose, Non-Cancer Exposures (IADD) (mg/m ³)	2.2E-03	2.2E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	2.0E-03	2.0E-03
Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for 2-hand surface areas (<i>i.e.</i> , 1,070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for 2-hand surface areas (<i>i.e.</i> , 535 cm ² for male workers and 445 cm ² for female workers). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for 1 palm of an adult male (<i>i.e.</i> , 268 cm ²).			

3.16.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-70. The assumption behind this approach is that an individual worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.

Table 3-70. Summary of Estimated Worker Aggregate Exposures for Recycling

Modeled Scenario	Exposure Type (mg/kg-day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.9E-02	0.21
	Intermediate (IADD, mg/kg-day)	1.4E-02	0.15
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.3E-02	0.14
Female of Reproductive Age	Acute (AD, mg/kg-day)	2.0E-02	0.23
	Intermediate (IADD, mg/kg-day)	1.5E-02	0.17
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.4E-02	0.16
ONU	Acute (AD, mg/kg-day)	1.6E-02	1.6E-02
	Intermediate (IADD, mg/kg-day)	1.2E-02	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.1E-02	1.1E-02
Note: A worker could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.17 Distribution in Commerce

3.17.1 Process Description

Distribution in commerce involves loading and unloading (throughout various life cycle stages), transit, temporary storage, warehousing, and spill cleanup of BBP. EPA generally considers loading and unloading activities as part of distribution in commerce; however, the releases and exposures resulting from these activities are covered within each individual OES where the activity occurs (*i.e.*, unloading of imported BBP is covered under the import OES). Similarly, tank cleaning activities, which occur after unloading of BBP, are also assessed as part of the individual OES where the activity occurs.

Some worker activities associated with distribution in commerce (*e.g.*, loading and unloading) are expected to be similar to other OESs such as manufacturing or import; however, it is also expected that workers involved in distribution in commerce spend less time exposed to BBP than workers in manufacturing or import facilities since only part of the workday is spent in an area with potential exposure. In conclusion, occupational exposures associated with the distribution in commerce OES are expected to be less than other OESs including manufacturing and import.

4 WEIGHT OF SCIENTIFIC EVIDENCE CONCLUSIONS

4.1 Environmental Releases

For each OES, EPA considered the assessment approach; the quality of the data and models; and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine a weight of the scientific evidence rating. EPA considered factors that increase or decrease the strength of the evidence supporting the release estimate (*e.g.*, quality of the data/information), the applicability of the release or exposure data to the OES (*e.g.*, temporal relevance, locational relevance), and the representativeness of the estimate for the whole industry. EPA used the descriptors of robust, moderate, slight, or indeterminant to categorize the available scientific evidence using its best professional judgment, according to EPA's *Draft systematic review protocol supporting TSCA risk evaluations for chemical substances, Version 1.0* ([U.S. EPA, 2021a](#)). EPA used slight to describe limited information that does not sufficiently cover all sites within the OES, and for which the assumptions and uncertainties are not fully known or documented. See EPA's *Draft systematic review protocol supporting TSCA risk evaluations for chemical substances, Version 1.0* ([U.S. EPA, 2021a](#)) for additional information on weight of the scientific evidence conclusions.

Table 4-1 and Table 4-2 provide a summary of EPA's overall confidence in its environmental release estimates for each OES.

Table 4-1. Summary of the Data Sources Used for Environmental Releases by OES

OES	Release Media	Reported Data ^a	Data Quality Ratings for Reported Data ^b	Modeling	Data Quality Ratings for Modeling ^c	Weight of Scientific Evidence Conclusion
Manufacturing	Fugitive air	×	N/A	✓	M	Moderate
	Stack air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
Import and repackaging (liquids)	Surface water	✓	M	×	N/A	Moderate
	Fugitive air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
Import and repackaging (solids)	Surface water	✓	M	×	N/A	Moderate
	Stack air	×	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
Formulation into adhesives and sealants (solids and liquids)	Fugitive air	×	N/A	✓	M	Moderate
	Stack air	×	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
Formulation into paints and coatings	Fugitive air	×	N/A	✓	M	Moderate
	Stack air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Surface water	✓	M	✓	M	Moderate
	Fugitive air	×	N/A	✓	M	

OES	Release Media	Reported Data ^a	Data Quality Ratings for Reported Data ^b	Modeling	Data Quality Ratings for Modeling ^c	Weight of Scientific Evidence Conclusion
Incorporation into formulation, mixture, or reaction product	Stack air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Fugitive air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
PVC plastic compounding	Waste water	×	N/A	✓	M	Moderate
	Fugitive or stack air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	×	N/A	✓	M	
PVC plastic converting	Surface water	×	N/A	✓	M	Moderate
	Fugitive or stack air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
Non-PVC compounding (liquids)	Waste water	×	N/A	✓	M	Moderate
	Fugitive or Stack air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	

OES	Release Media	Reported Data ^a	Data Quality Ratings for Reported Data ^b	Modeling	Data Quality Ratings for Modeling ^c	Weight of Scientific Evidence Conclusion
	Incineration or landfill	×	N/A	✓	M	
Non-PVC compounding (solids)	Waste water	×	N/A	✓	M	Moderate
	Fugitive or Stack air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
Non-PVC plastic converting	Waste water	×	N/A	✓	M	Moderate
	Fugitive or Stack air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
Application of adhesives and sealants	Waste water	✓	M	✓	M	Moderate
	Fugitive air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
Application of paints and coatings – no spray controls	Waste water	×	N/A	✓	M	Moderate
	Fugitive air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Unknown (air, water, incineration, or landfill)	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	

OES	Release Media	Reported Data ^a	Data Quality Ratings for Reported Data ^b	Modeling	Data Quality Ratings for Modeling ^c	Weight of Scientific Evidence Conclusion
	Incineration or landfill	×	N/A	✓	M	
Application of paints and coatings – spray controls	Waste water	×	N/A	✓	M	Moderate
	Fugitive air	×	N/A	✓	M	
	Stack air	×	N/A	✓	M	
	Water, incineration, or landfill	×	N/A	✓	M	
	Unknown (air, water, incineration, or landfill)	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
Use of laboratory chemicals (liquids)	Fugitive or stack air	×	N/A	✓	M	Moderate
	Water, incineration, or landfill	×	N/A	✓	M	
Use of laboratory chemicals (solids)	Stack air	×	N/A	✓	M	Moderate
	Water, Incineration, or Landfill	×	N/A	✓	M	
	Incineration or landfill	×	N/A	✓	M	
	Unknown (air, water, incineration, or landfill)	×	N/A	✓	M	
Use of lubricants and functional fluids	Waste water	×	N/A	✓	M	Moderate
	Land	×	N/A	✓	M	
	Recycling	×	N/A	✓	M	
	Fuel blending (incineration)	×	N/A	✓	M	
Fabrication and final use of products from articles	No data were available to estimate releases for this OES and there were no suitable surrogate or analogous release data or models. This release is described qualitatively.					
Recycling	Stack air	×	N/A	✓	M	Moderate
	Water, incineration, or landfill	×	N/A	✓	M	

OES	Release Media	Reported Data ^a	Data Quality Ratings for Reported Data ^b	Modeling	Data Quality Ratings for Modeling ^c	Weight of Scientific Evidence Conclusion
	Wastewater	✗	N/A	✓	M	
	Fugitive air, water, incineration, or landfill	✗	N/A	✓	M	
Waste handling, treatment, and disposal	Surface water	✓	M	✗	N/A	Moderate
Distribution in commerce	These releases are assessed as part of individual OESs where the relevant activities occur.					
^a Reported data includes data obtained from EPA databases (<i>i.e.</i> , DMR).						
^b Data quality ratings for reported data are based on EPA systematic review and include ratings Low (L), Medium (M), and High (H)						
^c Data quality ratings for models include ratings of underlying literature sources used to select model approaches and input values/distributions such as a GS/ESD used in tandem with Monte Carlo modeling.						

Table 4-2. Summary of Assumptions, Uncertainty, and Overall Confidence in Release Estimates by OES

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
Manufacturing	EPA found limited chemical specific data for the Manufacturing OES and assessed environmental releases using models and model parameters derived from CDR, the 2023 Methodology for Estimating Environmental Releases from Sampling Wastes (U.S. EPA, 2023b), and sources identified through systematic review (including surrogate, industry supplied data for DINP and DIDP). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, with media of release assessed using assumptions from EPA/OPPT models and industry supplied data. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Additionally, Monte Carlo modeling uses a large number of data points (simulation runs) and considers the full distributions of input parameters. EPA used facility-specific BBP manufacturing volumes for all facilities that reported this information to CDR and non-BBP-specific operating parameters derived using data from a current U.S. DIDP/DINP manufacturing site that is assumed to be similar to a BBP manufacturing site. This information was assumed to be more accurate than the generic values provided by the EPA/OPPT models. These strengths increase the weight of evidence. The primary limitation of EPA’s approach is the uncertainty in the representativeness of release estimates toward the true distribution of potential releases. In addition, one BBP manufacturing site claimed their BBP production volume as CBI for the purpose of CDR reporting; therefore, BBP throughput estimates for this site are based on the national aggregate PV and other sites’ reported import volumes. Additional limitations include uncertainties in the representativeness of the surrogate, industry-provided operating

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	parameters for DIDP and DINP and the generic EPA/OPPT models for BBP manufacturing sites. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Import and repackaging (Liquids and Solids)	EPA found limited chemical specific data for liquid and solid DBP for the Import and repackaging OES. EPA assessed water releases using releases reported to the 2017 to 2022 DMR, which has a medium overall data quality determination from the systematic review process. EPA modeled releases for other media using assumptions and values from the Chemical Repackaging Generic Scenario (U.S. EPA, 2022), which the systematic review process rated high for data quality. EPA also referenced the 2023 Methodology for Estimating Environmental Releases from Sampling Wastes (U.S. EPA, 2023b). Specifically, EPA used EPA/OPPT models and the GS combined with Monte Carlo modeling to estimate releases to the environment for other media. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Additionally, Monte Carlo modeling considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. For water releases based on DMR data, the primary limitation is that the assessment is based on three reporting sites; EPA did not have additional sources to estimate water releases from this OES. For the modeled releases to other media, because the default values in the GS are generic, there is uncertainty in the representativeness of these generic site estimates in characterizing actual releases from real-world sites that import and repack BBP. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Formulation into adhesives and sealants	EPA found limited chemical specific data for the Formulation into adhesives and sealants OES and assessed releases to the environment using the ESD on the Formulation of Adhesives (OECD, 2009a), which has a high data quality rating based on the systematic review process. EPA based the estimated production volume and number of processing sites on CDR reporting data. EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using assumptions from the ESD and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used BBP-specific data on concentrations in adhesive and sealant products, which are more accurate than the generic values provided by the ESD. The safety and product data sheets that EPA obtained these values from have medium to high data quality ratings based on the systematic review process. These strengths increase the weight of evidence.

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the default values in the ESD may not be representative of actual releases from real-world sites that incorporate BBP into adhesives and sealants. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Formulation into paints and coatings	EPA found limited chemical specific data for the Formulation into paints and coatings OES and assessed releases to the environment using the Draft GS for the Formulation of Waterborne Coatings (U.S. EPA, 2014a), which has a medium data quality rating based on systematic review. EPA based the estimated production volume and the estimate for number of processing sites on CDR reporting data. EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using assumptions from the GS and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used BBP-specific data on concentrations in paint and coating products to provide more accurate estimates of BBP concentrations than the generic values provided by the GS. The safety and product data sheets that EPA obtained these values from have medium to high data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS are specific to waterborne coatings and may not be representative of releases from real-world sites that incorporate BBP into paints and coatings, particularly for sites formulating other coating types (<i>e.g.</i>, solvent-borne coatings). These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Incorporation into other formulations, mixtures, and reaction products	EPA found limited chemical specific data for the Incorporation into other formulations, mixtures, and reaction products not covered elsewhere OES. EPA assessed water releases using releases reported to the 2017 to 2022 DMR (U.S. EPA, 2024a), which has a medium overall data quality determination from the systematic review process. EPA modeled releases to other media using the Draft GS for the Formulation of Waterborne Coatings (U.S. EPA, 2014a), which has a medium data quality rating based on the systematic review process. EPA used EPA/OPPT models and the GS combined with Monte Carlo modeling to estimate releases for other medias, which were determined using assumptions from the GS and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allows for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used BBP-specific data on concentrations in other formulation, mixture, and reaction products, which are more accurate than the generic values provided in the GS. The safety and product data sheets that EPA obtained these values from have medium to high data quality ratings based on the systematic review process. These strengths increase the weight of evidence.

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. For water releases based on DMR data, the primary limitation is that the assessment is based on three reporting sites; EPA did not have additional sources to estimate water releases from this OES. For modeled releases for other media, the generic default values in the GS are based on the formulation of paints and coatings and may not represent releases from real-world sites that incorporate BBP into other formulations, mixtures, or reaction products. Additionally, no CDR entries indicated a use relevant to this formulation OES and there were no other sources to estimate the volume of BBP used in this OES. As a result, EPA developed a high-end bounding estimate for production volume based on the CDR reporting threshold of 25,000 lb or five percent of total product volume for a given use, which by definition is expected to over-estimate the average release case. For BBP facility throughputs, EPA used a range of generic default values in the GS. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
PVC plastics compounding	EPA found limited chemical specific data for the PVC plastics compounding OES and assessed releases to the environment using the Revised Draft GS for the Use of Additives in Plastic Compounding (U.S. EPA, 2021c), which has a medium data quality rating based on systematic review. EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. The generic default values in the GS consider all types of plastic compounding and may not represent releases from real-world sites that use BBP to compound specific types of PVC plastic materials. In addition, EPA lacks data on BBP-specific facility production volume and number of compounding sites; therefore, EPA estimated throughput and production volume based on CDR which has a reporting threshold of 25,000 lb. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
PVC plastics converting	EPA found limited chemical specific data for the PVC plastics converting OES and assessed releases to the environment using the Revised Draft GS on the Use of Additives in the Thermoplastics Converting Industry, which has a medium data quality rating based on systematic review (U.S. EPA, 2021d). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD are based on all types of thermoplastics converting sites and processes and may not represent actual releases from real-world sites that convert BBP-containing raw material into plastic articles. In addition, EPA lacks data on BBP-specific facility production volume and number of converting sites; therefore, EPA estimated throughput based on CDR, which has a reporting threshold of 25,000 lb, an annual national aggregate production volume range for BBP, and production volume ranges of downstream sites. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Non-PVC material compounding	EPA found limited chemical specific data for liquid and solid DBP for the Non-PVC material compounding OES and assessed releases to the environment using the Revised Draft GS for the Use of Additives in Plastic Compounding and the ESD on Additives in the Rubber Industry (U.S. EPA, 2021c; OECD, 2004a). Both sources have a medium data quality rating based on the systematic review process. EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS, ESD, and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, there was a lack of concentration data for specific products that contained BBP; EPA relied on the GS and ESD to generate concentration estimates. These values may not be representative of actual values from real-world sites that use BBP in non-PVC material compounding. Additionally, no entries in CDR indicated a use relevant to the compounding or converting non-PVC material and there were no other sources to estimate the volume of BBP used in this OES. As a result, EPA developed a high-end bounding estimate based on the CDR reporting threshold of 25,000 lb or five percent of total product volume for a given use, which by definition is expected to over-estimate the average release case. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Non-PVC material converting	EPA found limited chemical specific data for the Non-PVC material converting OES and assessed releases to the environment using the Revised Draft GS on the Use of Additives in the Thermoplastics Converting Industry and the ESD on Additives in the Rubber Industry (U.S. EPA, 2021d; OECD, 2004a). Both documents have a medium data quality rating based on systematic review. EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	assumptions from the GS, ESD, and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, there was a lack of concentration data for specific products that contained BBP; EPA relied on the GS and ESD to generate concentration estimates. These values may not be representative of actual values from real-world sites that convert BBP into non-PVC articles. Additionally, no entries in CDR indicated a use relevant to non-PVC material compounding or converting and there were no other sources to estimate the volume of BBP or number of sites used in this OES. As a result, EPA developed a range of high-end bounding estimates based on the CDR reporting thresholds or 25,000 lb of five percent of total product volume for a given use, which by definition is expected to over-estimate the average release case. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Application of adhesives and sealants	EPA found limited chemical specific data for the Application of adhesives and sealants OES. EPA assessed water releases using releases reported to the 2017 to 2022 DMR (U.S. EPA, 2024a), which has a medium overall data quality determination from the systematic review process. EPA modeled releases to other media using the ESD on the Use of Adhesives (OECD, 2015), which has a medium data quality rating based on systematic review. EPA used EPA/OPPT models and the ESD combined with Monte Carlo modeling to estimate releases for other media, which were determined using assumptions from the GS and EPA/OPPT models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used BBP-specific data on concentration and application methods for different BBP-containing adhesives and sealant products. These data are more accurate than the generic values provided by the ESD. The safety and product data sheets from which these values were obtained have medium to high data quality ratings from the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. For water releases based on DMR data, the primary limitation is that the assessment is based on one reporting site; EPA did not have additional sources to estimate water releases from this OES. For the modeled releases to other media, the generic default values in the ESD may not represent releases from real-world sites that incorporate BBP into adhesives and sealants. The overall production volume of BBP for this OES was based on CDR data using the same assumptions as the Formulation into adhesives and sealants OES. EPA lacks data on BBP-specific facility use volume and number of use sites; therefore, EPA based facility throughput estimates and number of sites on industry-specific default throughputs from the ESD, BBP product concentrations, and the overall production volume range from CDR data, which has a reporting threshold of 25,000 lb. These limitations decrease the weight of evidence.

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of reasonably available data.
Application of paints and coatings	EPA found limited chemical specific data for the Application of paints and coatings OES and assessed releases to the environment using the ESD on the Application of Radiation Curable Coatings, Inks and Adhesives and the GS on Coating Application via Spray Painting in the Automotive Refinishing Industry (OECD, 2011a, b). These documents have a medium data quality rating based on the systematic review process. EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment. EPA assessed media of release using assumptions from the ESD, GS, and EPA/OPPT models and a default assumption that all paints and coatings are spray applied. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used BBP-specific concentration data for different paints and coatings in the analysis. These data are more accurate than the generic values provided by the GS and ESD. The safety and product data sheets that EPA obtained these values from have medium to high data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS and ESD may not represent releases from real-world sites that incorporate BBP into paints and coatings. Additionally, EPA assumes spray applications of the coatings, which may not be representative of other coating application methods. In addition, EPA lacks data on BBP-specific facility use volumes and number of use sites; therefore, EPA based throughput estimates on values from ESD, GS, and CDR data, which has a reporting threshold of 25,000 lb, and an annual BBP production volume range. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of reasonably available data.
Use of laboratory chemicals (Liquids and Solids)	EPA found limited chemical specific data for liquid and solid DBP for the Use of laboratory chemicals OES and assessed releases to the environment using the Draft GS on the Use of Laboratory Chemicals (U.S. EPA, 2023c), which has a high data quality rating based on systematic review. EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models for solid and liquid BBP materials. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allows for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. EPA used SDSs from BBP-containing laboratory products to inform product concentrations and material states, which have medium to high data quality ratings from the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. EPA lacks data on BBP-specific laboratory chemical throughput and number

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	of laboratories; therefore, EPA based the number of laboratories and throughput estimates on stock solution throughputs from the Draft GS on the Use of Laboratory Chemicals and on CDR reporting thresholds. Additionally, no entries in CDR indicate laboratory use and there were no other sources to estimate the volume of BBP used in this OES. As a result, EPA developed a high-end bounding estimate based on the CDR reporting threshold of 25,000 lb or five percent of total product volume for a given use, which by definition is expected to over-estimate the average release case. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of reasonably available data.
Use of lubricants and functional fluids	EPA found limited chemical specific data for the Use of lubricants and functional fluids OES and assessed releases to the environment using the ESD on Lubricants and Lubricant Additives, which has a medium data quality rating based on systematic review (OECD, 2004b). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, with the media of release based on information from the ESD and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. EPA did not identify any lubricant or functional fluid products that contained BBP but identified one DINP-containing functional fluid for use in the Monte Carlo analysis for the Risk Evaluation for that chemical. Therefore, EPA used products containing DINP as surrogate for concentration and use data in this analysis. EPA believes that this data provides more accurate estimates than the generic values provided by the ESD. The safety and product data sheets that EPA used to obtain these values have high data quality ratings based on systematic review. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the use of DINP-specific surrogate data and its uncertainty in the representativeness of estimated release values toward the true distribution of potential BBP releases at all sites in this OES. Additionally, the generic default values in the ESD may not represent releases from real-world sites using BBP-containing lubricants and functional fluids. In addition, EPA lacks information on the specific facility use rate of BBP-containing products and number of use sites; therefore, EPA estimated the number of sites and throughputs based on CDR, which has a reporting threshold of 25,000 lb and an annual BBP production volume. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of reasonably available data.
Fabrication and final use of products or articles	No data were available to estimate releases for this OES and there were no suitable surrogate or analogous release data or models. This release is described qualitatively.
Recycling	EPA found limited chemical specific data for the Recycling OES. EPA assessed releases to the environment from recycling activities using the Revised Draft GS for the Use of Additives in Plastic Compounding (U.S. EPA, 2021c) as analogous for the recycling process. The GS has a medium data quality rating based on systematic review. EPA/OPPT models were combined with Monte Carlo modeling to estimate releases to the environment. EPA believes the strength of the Monte Carlo modeling approach is that variation in

OES	Weight of the Scientific Evidence Conclusion in Release Estimates
	model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. EPA referenced the Quantification and Evaluation of Plastic Waste in the United States, which has a medium quality rating based on systematic review (Milbrandt et al., 2022), to estimate the rate of PVC recycling in the U.S. Additionally, EPA estimated the BBP PVC market share (based on the surrogate market shares from DINP and DIDP) to define an approximate recycling volume of PVC containing BBP. These strengths increase the weight of evidence. The primary limitation of EPA’s approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values and release points in the GS represent all types of plastic compounding sites and may not represent sites that recycle PVC products containing BBP. In addition, EPA lacks BBP-specific PVC recycling rates and facility production volume data; therefore, EPA based throughput estimates on U.S. PVC recycling rates and market share values based on surrogate DINP and DIDP values adjusted for BBP’s smaller overall volume, which may not accurately reflect current U.S. recycling volume. BBP may also be present in non-PVC plastics that are recycled; however, EPA was unable to identify information on these recycling practices. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of the scientific evidence for this assessment is moderate, considering the strengths and limitations of the reasonably available data.
Waste handling, treatment, and disposal	No data were available to estimate air and land releases for this OES and there were no suitable surrogate release data or models. Releases to air and land were described qualitatively. EPA assessed water releases for POTW, non-POTW, and remediation sites using releases reported to the 2017 to 2022 DMR, which has a medium overall data quality determination from the systematic review process (U.S. EPA, 2024a). There were a total of 28 DMR reported releases of DBP to water. A strength of using DMR data is that the Pollutant Loading Tool used to pull the DMR data calculates an annual pollutant load by integrating monitoring period release reports provided to the EPA and extrapolating over the course of the year. However, this approach assumes that the average quantities, concentrations, and hydrologic flows for a given period are representative of other times of the year. Based on this information, for water releases, EPA has concluded that the weight of the scientific evidence for this assessment is moderate to robust, considering the strengths and limitations of reasonably available data.

4.2 Occupational Exposures

For each OES, EPA considered the assessment approach, the quality of the data and models, and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine a weight of the scientific evidence rating. EPA considered factors that increase or decrease the strength of the evidence supporting the occupational exposure estimate—including quality of the data/information, applicability of the exposure data to the OES (including considerations of temporal relevance, locational relevance) and the representativeness of the estimate for the whole industry. The best professional judgment is summarized using the descriptors of robust, moderate, slight, or indeterminant, according to EPA’s 2021 System Review Protocol ([U.S. EPA, 2021a](#)). For example, a conclusion of moderate is appropriate where exposure data is generated from a generic model with high data quality and some chemical-specific or industry-specific inputs such that the exposure estimate is a reasonable representation of potential sites within the OES. A conclusion of slight is appropriate where there is limited information that does not sufficiently cover all sites within the OES, and the assumptions and uncertainties are not fully known or documented. See the Protocol ([U.S. EPA, 2021a](#)) for additional information on weight of the scientific evidence conclusions.

Table 4-3 provides a summary of EPA’s overall confidence in its inhalation and dermal exposure estimates for each OES.

Table 4-3. Summary of Assumptions, Uncertainty, and Overall Confidence in Inhalation Exposure Estimates by OES

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
Manufacturing	EPA used a risk evaluation completed by the ECJRC with worker inhalation exposure data from manufacturing (ECJRC, 2007). The primary strength of this approach is the use of directly applicable monitoring data, which is preferable to other assessment approaches, such as modeling or the use of occupational exposure limits (OELs). EPA used PBZ air concentration data pulled from the risk evaluation, which has a medium data quality rating from the systematic review process (ECJRC, 2007). These data were BBP-specific from two different BBP manufacturing facilities. These strengths increase the weight of evidence. The primary limitations of these data include the uncertainty of the representativeness of these data toward the true distribution of inhalation concentrations for this scenario. The ECJRC source provided four datasets focused on loading into various containers and only one data point on BBP production from two facilities and it is uncertain whether the measured concentrations and activities accurately represent the entire industry. EPA also assumed 8 exposure hours per day and 250 exposure days per year based on continuous BBP exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Import and repackaging	Due to no relevant OES-specific data availability on import and repackaging inhalation exposures, EPA used analogous monitoring data for manufacturing from an ECJRC risk evaluation (ECJRC, 2007) for BBP to estimate worker inhalation exposure to vapors. The primary strength of this approach is the use of monitoring data, which are preferable to other assessment approaches, such as modeling or the use of OELs. EPA used PBZ air concentration data pulled from the risk evaluation, which has a medium data quality rating from the systematic review process (ECJRC, 2007). These data were BBP-specific from two different BBP manufacturing facilities. EPA utilized the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR (U.S. EPA, 2021b) to estimate worker inhalation exposure to solid particulate. The respirable particulate concentrations used by the generic model were rated high for data quality from the systematic review process, and the model data is based on OSHA CEHD data (OSHA, 2020). EPA used a subset of the respirable particulate data from the generic model identified with the Wholesale and Retail Trade NAICS codes (NAICS codes 42 through 45) to assess this OES, which EPA expects to be the most representative subset of the particulate data in the absence of chemical-specific data. EPA estimated the highest expected concentration of BBP in particulates during import and repackaging using BBP concentration information from CDR reporters, which was also rated high for data quality in the systematic review process (U.S. EPA, 2020a). These strengths increase the weight of evidence. The primary limitation of this approach is uncertainty in the representativeness of the vapor monitoring data and the PNOR model in capturing the true distribution of inhalation concentrations for this OES. The vapor monitoring data is from one source and only represents two facilities and it is uncertain if the activities represented by the data reflect the import and repackaging industry. EPA additionally lacks facility-specific particulate concentrations in air, and the representativeness of the data set used in the model towards sites that handle BBP is uncertain. Further, the model lacks metadata on worker activities. Finally, EPA assumed 8 exposure hours per day and 208 to 250 exposure days per year based on continuous BBP exposure during each working day for a typical worker schedule with the exposure days representing the 50th to 95th percentile of the exposure day distribution. It is uncertain

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Formulation into adhesives and sealants	EPA used monitoring data from a sealant processing site to assess inhalation exposures to vapor. The primary strength of this approach is the use of monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. For the vapor exposure, EPA used personal breathing zone air concentration data found from one source with medium data quality rating from the systematic review process to assess inhalation exposures to vapor (ECJRC, 2008). This data was BBP-specific and from a BBP -containing sealant processing facility. EPA incorporated the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR into the assessment to estimate worker inhalation exposures to solid particulate. The respirable particulate concentrations used by the generic model were rated high for data quality from the systematic review process, and the model data is based on OSHA CEHD data (OSHA, 2020). EPA used a subset of the respirable particulate data from the generic model identified with the Chemical Manufacturing NAICS code (NAICS code 325) to assess this OES, which EPA expects to be the most representative subset of the particulate data for chemical product manufacturing in the absence of BBP-specific data. EPA estimated the highest expected concentration of BBP in particulates during adhesive and sealant manufacturing using BBP concentration information from CDR reporters, which was also rated high for data quality in the systematic review process (U.S. EPA, 2020a). These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of sealant processing vapor data and PNOR model in capturing the true distribution of inhalation concentrations for this OES. The vapor data is from one source and is one data point, therefore there is uncertainty in the true distribution of inhalation vapor concentrations for this OES. The sample point is also below the LOD, and the actual exposure concentration is unknown, so EPA used the LOD as an upper limit of exposure. EPA additionally lacks facility-specific particulate concentrations in air, and the representativeness of the data set used in the model towards sites that handle BBP is uncertain. Further, the model lacks metadata on worker activities. EPA also assumed 8 exposure hours per day and 250 exposure days per year based on continuous BBP exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Formulation into paints and coatings	Due to no relevant OES-specific data, EPA used analogous monitoring data from Formulation into adhesives and sealants to assess worker inhalation exposures to vapor. The primary strength of this approach is the use of monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. EPA used personal breathing zone air concentration data found from one source with medium data quality rating from the systematic review process to assess inhalation exposures to vapor (ECJRC, 2008). This data was BBP-specific and from a formulation site that is expected to be similar to a site that formulates paints and coatings. EPA incorporated the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR into the assessment to estimate worker inhalation exposures to solid particulate. The respirable particulate concentrations used by the

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	generic model were rated high for data quality from the systematic review process, and the model data is based on OSHA CEHD data (OSHA, 2020). EPA used a subset of the respirable particulate data from the generic model identified with the Chemical Manufacturing NAICS code (NAICS code 325) to assess this OES, which EPA expects to be the most representative subset of the particulate data for chemical product manufacturing in the absence of BBP-specific data. EPA estimated the highest expected concentration of BBP in particulates during paint and coating manufacturing using BBP concentration information from CDR reporters, which was also rated high for data quality in the systematic review process (U.S. EPA, 2020a). These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of sealant processing vapor data and PNOR model in capturing the true distribution of inhalation concentrations for this OES. The vapor data is from one source and is one data point for the formulation into adhesives and sealants, therefore there is uncertainty in the true distribution of inhalation vapor concentrations for this OES. The sample point is also below the LOD, and the actual exposure concentration is unknown, so EPA used the LOD as an upper limit of exposure. EPA additionally lacks facility-specific particulate concentrations in air, and the representativeness of the data set used in the model towards sites that handle BBP is uncertain. Further, the model lacks metadata on worker activities. EPA also assumed 8 exposure hours per day and 250 exposure days per year based on continuous BBP exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Incorporation into other formulations, mixtures, and reaction products not covered elsewhere	Due to no relevant OES-specific data, EPA used analogous monitoring data from Formulation into adhesives and sealants to assess worker inhalation exposures to vapor. The primary strength of this approach is the use of monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. EPA used personal breathing zone air concentration data found from one source with medium data quality rating from the systematic review process to assess inhalation exposures to vapor (ECJRC, 2008). This data was BBP-specific and from a formulation site that is expected to be similar to a site that formulates other products. EPA incorporated the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) into the assessment to estimate worker inhalation exposures to solid particulate. The respirable particulate concentrations used by the generic model were rated high for data quality from the systematic review process, and the model data is based on OSHA CEHD data (OSHA, 2020). EPA used a subset of the respirable particulate data from the generic model identified with the Chemical Manufacturing NAICS code (NAICS code 325) to assess this OES, which EPA expects to be the most representative subset of the particulate data for chemical product manufacturing in the absence of BBP-specific data. EPA estimated the highest expected concentration of BBP in particulates during other incorporative activities using BBP concentration information from CDR reporters, which was also rated high for data quality in the systematic review process (U.S. EPA, 2020a). These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of sealant processing vapor data and PNOR model in capturing the true distribution of inhalation concentrations for this OES. The vapor data is from one source and is one data point

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	for the formulation into adhesives and sealants, therefore there is uncertainty in the true distribution of inhalation vapor concentrations for this OES. The sample point is also below the LOD, and the actual exposure concentration is unknown, so EPA used the LOD as an upper limit of exposure. EPA additionally lacks facility-specific particulate concentrations in air, and the representativeness of the data set used in the model towards sites that handle BBP is uncertain. Further, the model lacks metadata on worker activities. EPA also assumed 8 exposure hours per day and 250 exposure days per year based on continuous BBP exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
PVC plastics compounding	EPA used PVC plastics compounding and converting monitoring data from the OSHA CEHD dataset to assess dust exposures and from a BBP risk evaluation completed by the ECJRC to estimate vapor exposures. The primary strength of this approach is the use of monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. The ECJRC BBP risk evaluation, which has a medium data quality rating, provided PBZ worker exposures to vapor from five different datasets from different plastics compounding and converting facilities (ECJRC, 2007). EPA used PBZ air concentration data from the OSHA CEHD, which has a medium data quality rating from the systematic review process, to assess worker inhalation exposure to dust (OSHA, 2019). Collectively the two datasets contain 24 datapoints and are well characterized. These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of the monitoring data in capturing the true distribution of inhalation concentrations for this OES. Various process and facility data, such as the concentration of BBP in the plastic material and the specific compounding or converting process are not known. In some instances, the data is assumed to be for PVC but could represent other plastic materials. Finally, EPA assumed 8 exposure hours per day and 223 to 250 exposure days per year based on continuous BBP exposure during each working day for a typical worker schedule with the exposure days representing the 50th to 95th percentile of the exposure day distribution. It is uncertain whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is robust.
PVC plastics converting	EPA used PVC plastics compounding and converting monitoring data from the OSHA CEHD dataset to assess dust exposures and from a BBP risk evaluation completed by the ECJRC to estimate vapor exposures. The primary strength of this approach is the use of monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. The ECJRC BBP risk evaluation, which has a medium data quality rating, provided PBZ worker exposures to vapor from five different datasets from different plastics compounding and converting facilities (ECJRC, 2007). EPA used PBZ air concentration data from the OSHA CEHD, which has a medium data quality rating from the systematic review process, to assess worker inhalation exposure to dust (OSHA, 2019). Collectively the two datasets contain 24 datapoints and are well characterized. These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of the monitoring data in capturing the true distribution of inhalation concentrations for this OES. Various process and facility data, such as the concentration of BBP in the

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	plastic material and the specific compounding or converting process are not known. In some instances, the data is assumed to be for PVC but could represent other plastic materials. Finally, EPA assumed 8 exposure hours per day and 219 to 250 exposure days per year based on continuous BBP exposure during each working day for a typical worker schedule with the exposure days representing the 50th to 95th percentile of the exposure day distribution. It is uncertain whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is robust.
Non-PVC materials compounding	Due to no relevant OES-specific data, EPA used analogous PVC plastics compounding and converting monitoring data from the OSHA CEHD dataset to assess dust exposures and from a BBP risk evaluation completed by the ECJRC to estimate vapor exposures. The primary strength of this approach is the use of monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. The ECJRC BBP risk evaluation, which has a medium data quality rating, provided PBZ worker exposures to vapor from five different datasets from different plastics compounding and converting facilities (ECJRC, 2007). EPA used PBZ air concentration data from the OSHA CEHD, which has a medium data quality rating from the systematic review process, to assess worker inhalation exposure to dust (OSHA, 2019). Collectively the two datasets contain 24 datapoints and are well characterized. These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of the monitoring data in capturing the true distribution of inhalation concentrations for this OES. Various process and facility data, such as the concentration of BBP in the plastic material and the specific compounding or converting process are not known. In some instances, the data is assumed to be for PVC but could represent other plastic materials. Finally, EPA assumed 8 exposure hours per day and 234 to 250 exposure days per year based on continuous BBP exposure during each working day for a typical worker schedule with the exposure days representing the 50th to 95th percentile of the exposure day distribution. It is uncertain whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is robust.
Non-PVC material converting	Due to no relevant OES-specific data, EPA used analogous PVC plastics compounding and converting monitoring data from the OSHA CEHD dataset to assess dust exposures and from a BBP risk evaluation completed by the ECJRC to estimate vapor exposures. The primary strength of this approach is the use of monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. The ECJRC BBP risk evaluation, which has a medium data quality rating, provided PBZ worker exposures to vapor from five different datasets from different plastics compounding and converting facilities (ECJRC, 2007). EPA used PBZ air concentration data from the OSHA CEHD, which has a medium data quality rating from the systematic review process, to assess worker inhalation exposure to dust (OSHA, 2019). Collectively the two datasets contain 24 datapoints and are well characterized. These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of the monitoring data in capturing the true distribution of inhalation concentrations for this OES. Various process and facility data, such as the concentration of BBP in the plastic material and the specific compounding or converting process are not known. In some instances, the data is assumed to be for PVC but could represent other plastic materials. Finally, EPA assumed 8 exposure hours per day and 219 to 250 exposure days per

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	year based on continuous BBP exposure during each working day for a typical worker schedule with the exposure days representing the 50th to 95th percentile of the exposure day distribution. It is uncertain whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is robust.
Application of adhesives and sealants	EPA used monitoring data from a BBP risk evaluation completed by the ECJRC to estimate worker inhalation exposures during the application of adhesives and sealants. The primary strength of this approach is the use of directly applicable monitoring data, which is preferable to other assessment approaches, such as modeling or the use of OELs. EPA used PBZ air concentration data from this source, which has a medium data quality rating from the systematic review process, to assess inhalation exposures (ECJRC, 2007). These strengths increase the weight of evidence. The primary limitations of these data include uncertainty in the representativeness of the vapor monitoring data in capturing the true distribution of inhalation concentrations for this OES, as the dataset only represents sealants and is a single sample. Additionally, the one sample is below the LOD, so EPA used the LOD as the upper limit of exposure. Finally, EPA assumed 8 exposure hours per day and 232 to 250 exposure days per year based on continuous BBP exposure during each working day for a typical worker schedule with the exposure days representing the 50th to 95th percentile of the exposure day distribution. It is uncertain whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Application of paints and coatings	Due to no relevant OES-specific data, EPA used analogous monitoring data for plastisol coating from a BBP risk evaluation completed by the ECJRC to estimate worker inhalation exposures to vapor and analogous monitoring data from the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry, to estimate inhalation exposures to mists. The primary strength of this approach is the use of monitoring data from a similar activity, which is preferable to other assessment approaches, such as modeling or the use of OELs. To assess worker inhalation exposure to vapor, EPA used thirteen PBZ air concentration measurements from three use facilities representing BBP use in the application of plastisols from the ECJRC risk evaluation, which has a medium data quality rating from the systematic review process (ECJRC, 2007). To assess worker inhalation exposure to mists, EPA used mist data from the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry, which has a medium data quality rating from the systematic review process (OECD, 2011a). EPA used SDSs and product data sheets from identified BBP-containing products, which have medium to high data quality ratings, to identify product concentrations to apply to the mist data to estimate BBP mist exposures. These strengths increase the weight of evidence. The primary limitation is the lack of BBP-specific mist monitoring data, with the ESD serving as an analogous source of monitoring data representing the level of exposure that could be expected at a typical work site for the given spray application method. EPA assumes spray applications of the coatings, so the estimates may not be representative of exposure during other coating application methods. Additionally, it is uncertain whether the substrates coated, and products used to generate the analogous data are representative of those associated with BBP-containing coatings. EPA assessed vapor and mist exposures to BBP over a full 8-hour work shift to estimate the level of exposure, though other activities may result in exposures other than vapor and mist and application duration may be variable depending on the job site. Finally, EPA assumed 8 exposure hours per day and 250 exposure days per year

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	based on continuous BBP exposure during each working day for a typical worker schedule. It is uncertain whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Use of laboratory chemicals	Due to no relevant OES-specific data availability, EPA used analogous monitoring data from the BBP Manufacturing OES to estimate worker vapor inhalation exposures to liquids. The primary strength of this approach is the use of monitoring data, which are preferable to other assessment approaches, such as modeling or the use of OELs. EPA used PBZ air concentration data from this source, which has a medium data quality rating, to assess inhalation exposures to vapor (ECJRC, 2007). EPA used the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) to estimate worker inhalation exposures to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the Professional, Scientific, and Technical Services NAICS code (NAICS code 54). EPA expects this NAICS code to be the most representative subset of the particulate data for use of laboratory chemicals in the absence of BBP-specific data. EPA estimated the highest expected concentration of BBP in particulates during laboratory use using SDSs and product data sheets from identified lab-grade chemicals, which have medium to high data quality ratings. These strengths increase the weight of evidence. The primary limitation of this approach is uncertainty in the representativeness of the manufacturing vapor monitoring data and the PNOR model in capturing the true distribution of inhalation concentrations for this OES. Further, the OSHA CEHD dataset used in the PNOR model is not specific to BBP. Finally, EPA assumed 8 exposure hours per day and 235 to 250 exposure days per year based on continuous BBP exposure during each working day for a typical worker schedule with the exposure days representing the 50th to 95th percentile of the exposure day distribution. It is uncertain whether this assumption captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Use of lubricants and functional fluids	Due to no relevant OES-specific data availability, EPA used analogous monitoring data for the Application of adhesives and sealants from a BBP risk evaluation completed by the ECJRC to estimate worker inhalation exposures to vapor, which is an uncertainty. The primary strength of this approach is the use of monitoring data, which are preferable to other assessment approaches, such as modeling or the use of OELs. EPA used PBZ air concentration data from this source, which has a medium data quality rating from the systematic review process, to assess inhalation exposures (ECJRC, 2007). These strengths increase the weight of evidence. The primary limitation of this approach is uncertainty in the representativeness of the Application of adhesives and sealants vapor monitoring data in capturing the true distribution of inhalation concentrations for this OES. Additionally, the vapor monitoring data comes from one source and 100% of the data were below the LOD; therefore, the actual exposure concentration is unknown with the LOD used as an upper limit of exposure. EPA also assumed 8 exposure hours per day and 2 to 4 exposure days per year based on a typical equipment maintenance schedule; it is uncertain whether this captures actual worker schedules and exposures. These limitations decrease the weight of evidence.

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
Fabrication or use of final products and articles	Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate. EPA utilized the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021b) to estimate worker inhalation exposure to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the furniture and related product manufacturing NAICS code (NAICS 337), and the resulting dataset contains 272 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of BBP in plastic using industry provided data on BBP concentrations in PVC plastics, which has a high for data quality from the systematic review process. These strengths increase the weight of evidence. The primary limitation of this approach is uncertainty in the representativeness of these data towards the true distribution of potential inhalation exposures. Additionally, the representativeness of the CEHD dataset and the identified BBP concentrations in plastics for the fabrication and final use of products or articles is uncertain. EPA lacks facility and BBP-containing product fabrication and use rates, methods, and operating times; therefore, EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous BBP exposure each working day for a typical worker schedule. It is uncertain whether this captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Recycling	EPA utilized the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021b) to estimate worker inhalation exposure to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the Administrative and Support and Waste management and Remediation Services NAICS code (NAICS 56) and the resulting dataset contains 130 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of BBP in plastic using industry provided data on BBP concentration in PVC plastic, which has a high data quality rating from the systematic review process. These strengths increase the weight of evidence. The primary limitation of this approach is uncertainty in the representativeness of the data toward the true distribution of potential inhalation exposures. Additionally, the representativeness of the CEHD dataset and the identified BBP concentrations in plastics for the fabrication and final use of products or articles is uncertain. EPA lacks facility- and BBP-specific product recycling rates, methods, and operating times; therefore, EPA assumed 8 exposure hours per day and 223 to 250 exposure days per year based on continuous BBP exposure each working day for a typical worker schedule. It is uncertain whether this captures actual worker schedules and exposures. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Waste handling, treatment, and disposal	EPA utilized the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021b) to estimate worker inhalation exposure to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the Administrative and Support and Waste management and Remediation Services NAICS code (NAICS 56) and the resulting dataset contains 130 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	concentration of BBP in plastic using industry provided data on BBP concentration in PVC plastic, which have a high data quality rating from the systematic review process. These strengths increase the weight of evidence. The primary limitation of this approach is uncertainty in the representativeness of the data toward the true distribution of potential inhalation exposures. Additionally, the representativeness of the CEHD dataset and the identified BBP concentrations in plastics towards all waste handling, treatment, and disposal is uncertain. EPA lacks facility- and BBP-specific product disposal rates, methods, and operating times; therefore, EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous BBP exposure each working day for a typical worker schedule. It is uncertain whether this captures actual worker schedules and exposures. The exposure days represent the 50th-95th percentile range of the distribution of exposure days per year. These limitations decrease the weight of evidence. Based on these strengths and limitations, EPA concluded that the weight of scientific evidence for this assessment is moderate.
Dermal – liquids	EPA used dermal absorption data for BBP formulations to estimate occupational dermal exposures to workers (Sugino et al., 2017), which EPA’s systematic review process deemed to be acceptable. The tests were performed <i>in vitro</i> on human skin samples over an 8-hour duration to a neat solution. It is acknowledged that variations in chemical concentration and co-formulant components affect the rate of dermal absorption. However, it is assumed that absorption of the neat chemical serves as a reasonable upper bound across chemical compositions and the data received a study quality rating of Medium during systematic review. The rate of dermal absorption was significantly higher than that predicted by EPA’s RAGS model based on the physical/chemical properties of BBP. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and that the chemical is contacted at least once per day. Because BBP has low volatility and relatively low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. Therefore, absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day (CEB, 1991), which likely overestimates potential exposure since 1) it is assumed that exposure happens daily at the beginning of a shift and 2) general housekeeping at facilities includes handwashing before and after breaks. For average adult workers, the surface area of contact was assumed equal to the area of one hand (<i>i.e.</i>, 535 cm²), or two hands (<i>i.e.</i>, 1,070cm²), for central tendency exposures, or high-end exposures, respectively (U.S. EPA, 2011). The standard sources for exposure duration and area of contact received high ratings through EPA’s systematic review process. The occupational dermal exposure assessment for contact with liquid materials containing BBP was based on dermal absorption data for BBP, as well as standard occupational inputs for exposure duration and area of contact, as described above. Based on the strengths and limitations of these inputs, EPA has concluded that the weight of scientific evidence for this assessment is moderate and likely provides an overestimate of occupational dermal exposures.
Dermal – solids	EPA used dermal absorption data from an <i>in vitro</i> absorption study using human skin samples and BBP contained within film (DuPont, 2006a) to estimate occupational dermal exposures of workers and ONUs to solid materials as described in Appendix C.2.1.2. EPA’s systematic review process deemed this data to be acceptable. It is acknowledged that variations in chemical concentration and co-formulant components affect the rate of dermal absorption. The Dupont <i>et al.</i> (2006a) study received a study quality rating of Medium during systematic review.

OES	Weight of the Scientific Evidence Conclusion in Exposure Estimates
	For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and that the chemical is contacted at least once per day. Because BBP has low volatility and low absorption, it is possible that the chemical remains on the surface of the skin after dermal contact until the skin is washed. Therefore, absorption of BBP from occupational dermal contact with materials containing BBP may extend up to 8 hours per day (CEB, 1991), which likely overestimates potential exposure since 1) it is assumed that exposure happens daily at the beginning of a shift and 2) general housekeeping at facilities includes handwashing before and after breaks.. EPA used the 8-hour steady-state absorptive flux from Dupont et al. to estimate occupational exposures (DuPont, 2006a). Because this duration agrees with the occupational exposure duration, EPA expects the use of the steady-state absorptive flux data from Dupont et al. to be representative of the duration of dermal exposures in occupational settings (DuPont, 2006a). For average adult workers, the surface area of contact was assumed equal to the area of one hand (<i>i.e.</i>, 535 cm²), or two hands (<i>i.e.</i>, 1,070cm²), for central tendency exposures, or high-end exposures, respectively (U.S. EPA, 2011). The standard sources for exposure duration and area of contact received high ratings through EPA's systematic review process. The occupational dermal exposure assessment for contact with solid materials containing BBP was based on <i>in vitro</i> dermal absorption data using human skin samples to a neat solution, as well as standard occupational inputs for exposure duration and area of contact, as described above. Based on the strengths and limitations of these inputs, EPA has concluded that the weight of scientific evidence for this assessment for workers is moderate and for ONUs is slight to moderate and likely provides an overestimate of occupational dermal exposures.

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APPENDICES

Appendix A EQUATIONS FOR CALCULATING ACUTE, INTERMEDIATE, AND CHRONIC (NON-CANCER) INHALATION AND DERMAL EXPOSURES

This report assesses BBP inhalation exposures to workers in occupational settings, presented as 8-hour time-weighted average (TWA). The full-shift TWA exposures are then used to calculate acute doses (AD), intermediate average daily doses (IADD), and average daily doses (ADD) for chronic non-cancer risks. This report also assesses BBP dermal exposures to workers in occupational settings, presented as a dermal acute potential dose rate (APDR). The APDRs are then used to calculate the AD, IADD, and ADD. This appendix presents the equations and input parameter values used to estimate each exposure metric.

A.1 Equations for Calculating Acute, Intermediate, and Chronic (Non-Cancer) Inhalation Exposure

EPA used AD to estimate acute risks (*i.e.*, risks occurring as a result of exposure for <1 day) from workplace inhalation exposures for, per equation below:

Equation_Apx A-1.

$$AD = \frac{C \times ED \times BR}{BW}$$

Where:

<i>AD</i>	=	Acute dose (mg/kg-day)
<i>C</i>	=	Contaminant concentration in air (TWA mg/m ³)
<i>ED</i>	=	Exposure duration (h/day)
<i>BR</i>	=	Breathing rate (m ³ /h)
<i>BW</i>	=	Body weight (kg)

EPA used IADD to estimate intermediate risks from workplace exposures as follows:

Equation_Apx A-2.

$$IADD = \frac{C \times ED \times EF_{int} \times BR}{BW \times ID}$$

Where:

<i>IADD</i>	=	Intermediate average daily dose (mg/kg-day)
<i>EF_{int}</i>	=	Intermediate exposure frequency (day)
<i>ID</i>	=	Days for intermediate duration (day)

EPA used ADD to estimate chronic non-cancer risks from workplace exposures. EPA estimated ADD as follows:

Equation_Apx A-3.

$$ADD = \frac{C \times ED \times EF \times WY \times BR}{BW \times 365 \frac{\text{days}}{\text{yr}} \times WY}$$

Where:

<i>ADD</i>	=	Average daily dose for chronic non-cancer risk calculations
<i>EF</i>	=	Exposure frequency (day/year)
<i>WY</i>	=	Working years per lifetime (yr) – used in the denominator for ADD

A.2 Equations for Calculating Acute, Intermediate, and Chronic (Non-Cancer) Dermal Exposures

EPA used AD to estimate acute risks from workplace dermal exposures using Equation_Apx A-4.

Equation_Apx A-4.

$$AD = \frac{APDR}{BW}$$

Where:

<i>AD</i>	=	Acute retained dose (mg/kg-day)
<i>APDR</i>	=	Acute potential dose rate (mg/day)
<i>BW</i>	=	Body weight (kg)

EPA used IADD to estimate intermediate risks from workplace dermal exposures using Equation_Apx A-5.

Equation_Apx A-5.

$$IADD = \frac{APDR \times EF_{int}}{BW \times ID}$$

Where:

<i>IADD</i>	=	Intermediate average daily dose (mg/kg-day)
<i>EF_{int}</i>	=	Intermediate exposure frequency (day)
<i>ID</i>	=	Days for intermediate duration (day)

EPA used ADD to estimate chronic non-cancer risks from workplace dermal exposures using Equation_Apx A-6.

Equation_Apx A-6.

$$ADD = \frac{APDR \times EF \times WY}{BW \times 365 \frac{days}{yr} \times WY}$$

Where:

<i>ADD</i>	=	Average daily dose for chronic non-cancer risk calculations
<i>EF</i>	=	Exposure frequency (day/year)
<i>WY</i>	=	Working years per lifetime (yr)

A.3 Calculating Aggregate Exposure

EPA combined the expected dermal and inhalation exposures for each OES and worker type into a single aggregate exposure to reflect the potential total dose from both exposure routes.

Equation_Apx A-7.

$$AD_{aggregate} = AD_{dermal} + AD_{inhalation}$$

Where:

<i>AD_{Aggregate}</i>	=	Aggregated acute retained does (mg/kg-day)
<i>AD_{Dermal}</i>	=	Dermal exposure acute retained dose (mg/kg-day)

$$AD_{Inhalation} = \text{Inhalation exposure acute retained dose (mg/kg-day)}$$

IADD and ADD also follow the same approach for defining aggregate exposures.

A.4 Acute, Intermediate, and Chronic (Non-Cancer) Equation Inputs

EPA used the input parameter values in Table_Apx A-1 to calculate acute, intermediate, and chronic inhalation exposure risks. The EF used for each OES can differ, and the appropriate sections of this report describe these values and their selection. This section describes the values that EPA used in the equations in Appendix A.1 and A.2 and summarizes them in the table below.

Table_Apx A-1. Parameter Values for Calculating Inhalation Exposure Estimates

Parameter Name	Symbol	Value	Unit
Exposure Duration	ED	8	hours/day
Breathing Rate	BR	1.25	m ³ /h
Exposure Frequency	EF	2–250 ^a	days/year
Exposure Frequency, Intermediate	EF _{int}	22	days
Days for Duration, Intermediate	ID	30	days
Working Years	WY	31 (50th percentile) 40 (95th percentile)	years
Body Weight	BW	80 (average adult worker) 72.4 (female of reproductive age)	kg

^a Depending on OES.

A.4.1 Exposure Duration (ED)

EPA generally used an exposure duration of 8 hours per day for averaging full-shift exposures.

A.4.2 Breathing Rate

EPA used a breathing rate, based on average worker breathing rates. The breathing rate accounts for the amount of air a worker breathes during the exposure period. The typical worker breathes about 10 m³ of air in 8 hours or 1.25 m³/h ([CEB, 1991](#)).

A.4.3 Exposure Frequency (EF)

EPA generally used a maximum exposure frequency of 250 days per year EPA generally used a maximum exposure frequency of 250 days per year based on the assumptions of daily exposure during each working day, 5 workdays per week, and 2 weeks of vacation per year. However, for some OES where a range of exposure frequencies were possible, EPA used probabilistic modeling to estimate exposures and the associated exposure frequencies, resulting in exposure frequencies below 250 days per year. The relevant sections of this report describe EPA's estimation of exposure frequency and the associated distributions for each OES.

EF is expressed as the number of days per year a worker is exposed to the chemical being assessed. In some cases, it may be reasonable to assume a worker is exposed to the chemical on each working day. In other cases, it may be more appropriate to assume a worker's exposure to the chemical occurs during a subset of the worker's annual working days. The relationship between exposure frequency and annual working days can be described mathematically as follows:

Equation_Apx A-8.

$$EF = AWD \times f$$

Where:

EF	=	Exposure frequency, the number of days per year a worker is exposed to the chemical (days/year)
AWD	=	Annual working days, the number of working days per year for an individual worker(days/year)
f	=	Fractional number of annual working days during which a worker is exposed to the chemical (unitless)

BLS provides data on the total number of work hours and total number of employees by each industry NAICS code. BLS provides these data from the 3- to 6-digit NAICS level (where 3-digit NAICS are less granular and 6-digit NAICS are the most granular). Dividing the total, annual hours worked by the number of employees yields the average number of hours worked per employee per year for each NAICS.

EPA identified approximately 140 NAICS codes applicable to the multiple conditions of use for the first 10 chemicals that underwent risk evaluation. For each NAICS code of interest, EPA looked up the average hours worked per employee per year at the most granular NAICS level available (*i.e.*, 4-, 5-, or 6-digit). EPA converted the working hours per employee to working days per year per employee assuming employees work an average of 8 hours per day. The average number of working days per year, or AWD, ranges from 169 to 282 days per year, with a 50th percentile value of 250 days per year. EPA repeated this analysis for all NAICS codes at the 4-digit level. The average AWD for all 4-digit NAICS codes ranges from 111 to 282 days per year, with a 50th percentile value of 228 days per year. 250 days per year is approximately the 75th percentile of the distribution AWD for the 4-digit NAICS codes. In the absence of industry- and BBP-specific data, EPA assumed the parameter, f , is equal to one for all OES.

A.4.4 Intermediate Exposure Frequency (EF_{int})

For BBP, the ID was set at 30 days. EPA estimated the maximum number of working days within the ID, using the following equation and assuming 5 working days/wk:

Equation_Apx A-9.

$$EF_{int(max)} = 5 \frac{\text{working days}}{wk} \times \frac{30 \text{ total days}}{7 \frac{\text{total days}}{wk}} = 21.4 \text{ days, rounded up to 22 days}$$

A.4.5 Intermediate Duration (ID)

EPA assessed an intermediate duration of 30 days based on the available health data.

A.4.6 Working Years (WY)

EPA developed a triangular distribution for number of lifetime working years using the following parameters:

- **Minimum value:** BLS CPS tenure data with current employer as a low-end estimate of the number of lifetime working years: 10.4 years;

- **Mode value:** The 50th percentile of the tenure data with all employers from SIPP as a mode value for the number of lifetime working years: 36 years; and
- **Maximum value:** The maximum of the average tenure data with all employers from SIPP as a high-end estimate on the number of lifetime working years: 44 years.

This triangular distribution has a 50th percentile value of 31 years and a 95th percentile value of 40 years. EPA uses these values to represent the central tendency and high-end number of working years in the ADD calculations.

The U.S. BLS ([2014](#)) provides information on employee tenure with *current employer* obtained from the Current Population Survey (CPS). CPS is a monthly sample survey of about 60,000 households that provides information on the labor force status of the civilian non-institutional population age 16 and over. BLS releases CPS data every 2 years. The data are available by demographic characteristics and by generic industry sectors, but not by NAICS codes.

The U.S. Census Bureau ([2016](#)) Survey of Income and Program Participation (SIPP) provides information on *lifetime tenure with all employers*. SIPP is a household survey that collects data on income, labor force participation, social program participation and eligibility, and general demographic characteristics through a continuous series of national panel surveys of between 14,000 and 52,000 households ([U.S. BLS, 2016](#)). EPA analyzed the 2008 SIPP Panel Wave 1, a panel that began in 2008 and covers the interview months of September 2008 through December 2008 ([U.S. BLS, 2016](#)). For this panel, lifetime tenure data are available by Census Industry Codes, which can be cross walked with NAICS codes.

SIPP data include fields for the industry in which each surveyed, employed individual workers (TJBIND1); worker age (TAGE); and years of work experience *with all employers* over the surveyed individual's lifetime⁴ Census household surveys use different industry codes than the NAICS codes, so EPA converted these industry codes to NAICS using a published crosswalk ([U.S. Census Bureau, 2012](#)). EPA calculated the average tenure for the following age groups: (1) workers aged 50 and older; (2) workers aged 60 and older; and (3) workers of all ages employed at time of survey. EPA used tenure data for age group "50 and older" to determine the high-end lifetime working years, because the sample size in this age group is often substantially higher than the sample size for age group "60 and older". For some industries, the number of workers surveyed, or the *sample size*, was too small to provide a reliable representation of the worker tenure in that industry. Therefore, EPA excluded data where the sample size is less than five from the analysis.

Table_Apx A-2 summarizes the average tenure for workers aged 50 and older from SIPP data. Although the tenure may differ for any given industry sector, there is no significant variability between the 50th and 95th percentile values of average tenure across manufacturing and non-manufacturing sectors.

⁴ To calculate the number of years of work experience EPA took the difference between the year first worked (TMAKMNYR) and the current data year (*i.e.*, 2008). EPA then subtracted any intervening months when not working (ETIMEOFF).

Table_Apx A-2. Overview of Average Worker Tenure from U.S. Census SIPP (Age Group 50+)

Industry Sectors	Working Years			
	Average	50th Percentile	95th Percentile	Maximum
Manufacturing sectors (NAICS 31–33)	35.7	36	39	40
Non-manufacturing sectors (NAICS 42–81)	36.1	36	39	44
Source: (U.S. BLS, 2016)				
Note: Industries where sample size is less than five are excluded from this analysis.				

BLS CPS data provide the median years of tenure that wage and salary workers had been with their current employer. Table_Apx A-3 presents CPS data for all demographics (men and women) by age group from 2008 to 2012. To estimate the low-end value for number of working years, EPA used the most recent (2014) CPS data for workers aged 55 to 64 years, which indicates a median tenure of 10.4 years with their current employer. The use of this low-end value represents a scenario where workers are only exposed to the chemical of interest for a portion of their lifetime working years, as they may change jobs or move from one industry to another throughout their career.

Table_Apx A-3. Median Years of Tenure with Current Employer by Age Group

Age	January 2008	January 2010	January 2012	January 2014
16 years and over	4.1	4.4	4.6	4.6
16–17 years	0.7	0.7	0.7	0.7
18–19 years	0.8	1.0	0.8	0.8
20–24 years	1.3	1.5	1.3	1.3
25 years and over	5.1	5.2	5.4	5.5
25–34 years	2.7	3.1	3.2	3.0
35–44 years	4.9	5.1	5.3	5.2
45–54 years	7.6	7.8	7.8	7.9
55–64 years	9.9	10.0	10.3	10.4
65 years and over	10.2	9.9	10.3	10.3
Source: (U.S. BLS, 2014)				

A.4.7 Body Weight (BW)

EPA assumes a BW of 80 kg for average adult workers. EPA assumed a BW of 72.4 kg for females of reproductive age, per Chapter 8 of the *Exposure Factors Handbook* ([U.S. EPA, 2011](#)).

Appendix B SAMPLE CALCULATIONS FOR CALCULATING ACUTE, INTERMEDIATE, AND CHRONIC (NON-CANCER) OCCUPATIONAL EXPOSURES

Sample calculations for high-end and central tendency acute, intermediate, and chronic (non-cancer) doses for one condition of use, PVC plastics compounding, are demonstrated below for an average adult worker. The explanation of the equations and parameters used is provided in Appendix A.

B.1 Inhalation Exposures

B.1.1 Example High-End AD, IADD, and ADD Calculations

Calculating AD_{HE} :

$$AD_{HE} = \frac{C_{HE} \times ED \times BR}{BW}$$
$$AD_{HE} = \frac{4.2 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr}}{80 kg} = 0.53 \frac{mg}{kg day}$$

Calculating $IADD_{HE}$:

$$IADD = \frac{C_{HE} \times ED \times BR \times EF_{int}}{BW \times ID}$$
$$IADD_{HE} = \frac{4.2 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr} \times 22 \frac{days}{year}}{80 kg \times 30 \frac{days}{year}} = 0.39 \frac{mg}{kg day}$$

Calculating ADD_{HE} :

$$ADD_{HE} = \frac{C_{HE} \times ED \times BR \times EF \times WY}{BW \times 365 \frac{days}{year} \times WY}$$
$$ADD_{HE} = \frac{4.7 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr} \times 250 \frac{days}{year} \times 40 years}{80 kg \times 365 \frac{days}{year} \times 40 years} = 0.36 \frac{mg}{kg day}$$

B.1.2 Example Central Tendency AD, IADD, and ADD Calculations

Calculating AD_{CT} :

$$AD_{CT} = \frac{C_{CT} \times ED \times BR}{BW}$$

$$AD_{CT} = \frac{0.70 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr}}{80 kg} = 8.8 \times 10^{-2} \frac{mg}{kg \cdot day}$$

Calculating IADD_{CT}:

$$IADD_{CT} = \frac{C_{CT} \times ED \times BR \times EF_{int}}{BW \times ID}$$

$$IADD_{CT} = \frac{0.70 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr} \times 22 \frac{days}{year}}{80 kg \times 30 \frac{days}{year}} = 6.4 \times 10^{-2} \frac{mg}{kg \cdot day}$$

Calculating ADD_{CT}:

$$ADD_{CT} = \frac{C_{CT} \times ED \times BR \times EF \times WY}{BW \times 365 \frac{days}{year} \times WY}$$

$$ADD_{CT} = \frac{0.70 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr} \times 223 \frac{days}{year} \times 31 years}{80 kg \times 365 \frac{days}{year} \times 31 years} = 5.3 \times 10^{-2} \frac{mg}{kg \cdot day}$$

B.2 Dermal Exposures

B.2.1 Example High-End AD, IADD, and ADD Calculations

Calculating AD_{HE}:

$$AD_{HE} = \frac{APDR}{BW}$$

$$AD_{HE} = \frac{0.36 \frac{mg}{day}}{80 kg} = 4.5 \times 10^{-3} \frac{mg}{kg \cdot day}$$

Calculate IADD_{HE}:

$$IADD_{HE} = \frac{APDR \times EF_{int}}{BW \times ID}$$

$$IADD_{HE} = \frac{0.36 \frac{mg}{day} \times 22 \frac{day}{yr}}{80 kg \times 30 \frac{day}{yr}} = 3.3 \times 10^{-3} \frac{mg}{kg \cdot day}$$

Calculate ADD_{HE} (non-cancer):

$$ADD_{HE} = \frac{APDR \times EF \times WY}{BW \times 365 \frac{\text{day}}{\text{yr}} \times WY}$$

$$ADD_{HE} = \frac{0.36 \frac{\text{mg}}{\text{day}} \times 250 \frac{\text{day}}{\text{yr}} \times 40 \text{ years}}{80 \text{ kg} \times 365 \frac{\text{day}}{\text{yr}} \times 40 \text{ years}} = 3.1 \times 10^{-3} \frac{\text{mg}}{\text{kg-day}}$$

B.2.2 Example Central Tendency AD, IADD, and ADD Calculations

Calculating AD_{CT}:

$$AD_{CT} = \frac{APDR}{BW}$$

$$AD_{CT} = \frac{0.18 \frac{\text{mg}}{\text{day}}}{80 \text{ kg}} = 2.3 \times 10^{-3} \frac{\text{mg}}{\text{kg-day}}$$

Calculating IADD_{CT}:

$$IADD_{CT} = \frac{APDR \times EF_{int}}{BW \times ID}$$

$$IADD_{CT} = \frac{0.18 \frac{\text{mg}}{\text{day}} \times 22 \frac{\text{days}}{\text{yr}}}{80 \text{ kg} \times 30 \frac{\text{days}}{\text{yr}}} = 1.7 \times 10^{-3} \frac{\text{mg}}{\text{kg-day}}$$

Calculate ADD_{CT} (non-cancer):

$$ADD_{CT} = \frac{APDR \times EF \times WY}{BW \times AT}$$

$$ADD_{CT} = \frac{0.18 \frac{\text{mg}}{\text{day}} \times 223 \frac{\text{days}}{\text{yr}} \times 31 \text{ years}}{80 \text{ kg} \times 365 \frac{\text{day}}{\text{yr}} \times 31 \text{ years}} = 1.4 \times 10^{-3} \frac{\text{mg}}{\text{kg-day}}$$

Appendix C DERMAL EXPOSURE ASSESSMENT METHOD

C.1 Dermal Dose Equation

As described in Section 2.4.3, occupational dermal exposures to BBP are characterized using a flux-based approach to dermal exposure estimation. EPA capped the dermal dose based on typical dermal loading values (Q). Therefore, EPA used the lesser of the equations below to estimate the acute potential dose rate (APDR) from occupational dermal exposures. The APDR (units of mg/day) characterizes the quantity of chemical that is potentially absorbed by a worker on a given workday.

Equation_Apx C-1.

$$APDR = \frac{J \times S \times t_{abs}}{PF}$$

Where:

J	=	Average absorptive flux through and into skin (mg/cm ² /h);
S	=	Surface area of skin in contact with the chemical formulation (cm ²);
t_{abs}	=	Duration of absorption (hr/day)
PF	=	Glove protection factor (unitless, $PF \geq 1$)

Equation_Apx C-2.

$$APDR = \frac{Q \times F_w \times S}{PF}$$

Where:

Q	=	Dermal loading of liquid or solid formulation (mg/cm ²);
F_w	=	Weight fraction of BBP in the liquid or solid formulation (unitless);

The inputs to the dermal dose equation are described in Appendix C.2.

C.2 Parameters of the Dermal Dose Equation

Table_Apx C-1 summarizes the dermal dose equation parameters and their values for estimating dermal exposures. Additional explanations of EPA's selection of the inputs for each parameter are provided in the subsections after this table.

Table_Apx C-1. Summary of Dermal Dose Equation Values

Input Parameter	Symbol	Value	Unit	Rationale
Absorptive Flux	<i>J</i>	Dermal Contact with Liquids: 3.23E-02 Dermal Contact with Solids: 1.113E-04	mg/cm ² /h	See Appendix C.2.1
Surface Area	<i>S</i>	Workers: 535 (central tendency) 1,070 (high-end) Females of reproductive age: 445 (central tendency) 890 (high-end)	cm ²	See Appendix C.2.2
Absorption Time	<i>t_{abs}</i>	8	hr	See Appendix C.2.3
Dermal Loading	<i>Q</i>	Liquid Contact: 1.4 (central tendency) 2.1 (high-end) Liquid Immersion: 3.8 (central tendency) 10.3 (high-end) Solids Contact: 900 (central tendency) 3,100 (high-end) Solid contact with container surfaces/solders/pastes: 450 (central tendency) 1,100 (high-end)	mg/cm ² (liquids) mg/day (solids)	See Appendix C.2.4
BBP Weight Fraction	<i>F_w</i>	OES-specific	Unitless	See Appendix C.2.5
Glove Protection Factor	<i>PF</i>	1; 5; 10; or 20	unitless	See Appendix C.2.6

C.2.1 Absorptive Flux

Dermal data were sufficient to characterize occupational dermal exposures to liquids or formulations containing BBP, as well as solids containing BBP. 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.

C.2.1.1 Dermal Contact with Liquids or Formulations Containing BBP

As described in Section 2.4.3.2, Elsis (1989) estimated the steady-state flux of neat BBP as 1.93×10^{-2} mg/cm²/h, Dupont (2006b) estimated the steady-state flux of neat BBP as 3.23×10^{-2} mg/cm²/h, and EPA estimated the steady-state flux that was occurring in Sugino et al. as 6.4×10^{-4} mg/cm²/h (Sugino et al., 2017). Assuming that the flux of the neat material is representative across exposure conditions, EPA has chosen the value of flux 6.4×10^{-4} mg/cm²/h as the representative value for occupational dermal exposure assessment of the contact with liquids or formulations containing BBP.

C.2.1.2 Dermal Contact with Solids or Articles Containing BBP

As described in Section 2.4.3 for solid products, EPA estimated the steady-state flux of BBP using 8-hour dermal exposure information from Dupont (2006a). The steady-state flux of neat BBP is estimated

as 1.113×10^{-4} mg/cm²/h. EPA assumes this is a representative value for dermal exposures to solids or articles containing BBP.

C.2.2 Surface Area

Regarding surface area of occupational dermal exposure, EPA assumed a high-end value of 1,070 cm² for male workers and 890 cm² for female workers. These high-end occupational dermal exposure surface area values are based on the mean two-hand surface area for adults of age 21 or older from Chapter 7 of EPA's *Exposure Factors Handbook* ([U.S. EPA, 2011](#)). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or 1 side of 2 hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm² for male workers and 445 cm² for female workers).

It should be noted that while the surface area of exposed skin is derived from data for hand surface area, EPA did not assume that only the workers hands may be exposed to the chemical. Nor did EPA assume that the entirety of the hands is exposed for all activities. Rather, EPA assumed that dermal exposures occur to some portion of the hands plus some portion of other body parts (*e.g.*, arms) such that the total exposed surface area is approximately equal to the surface area of one or two hands for the central tendency and high-end exposure scenario, respectively.

C.2.3 Absorption Time

Although a splash or contact-related transfer of material onto the skin may occur instantaneously, the material may remain on the skin surface until the skin is washed. Because BBP does not rapidly absorb or evaporate, and the worker may contact the material multiple times throughout the workday, EPA assumes that absorption of BBP in occupational settings may occur throughout the entirety of an 8-hour work shift ([CEB, 1991](#)).

C.2.4 Dermal Loading

C.2.4.1 Liquid Dermal Loading

For contact with liquids in occupational settings, EPA assumes a range of dermal loading of 0.7 to 2.1 mg/cm² ([U.S. EPA, 1992b](#)) for tasks such as product sampling, loading/unloading, and cleaning as shown in the ChemSTEER Manual ([U.S. EPA, 2015](#)). More specifically, EPA has utilized the raw data of the ([U.S. EPA, 1992b](#)) study to determine a central tendency (50th percentile) dermal loading value of 1.4 mg/cm² and a high-end (95th percentile) dermal loading value of 2.1 mg/cm² for dermal exposure to liquids. For scenarios where liquid immersion occurs, EPA assumes a range of dermal loading of 1.3 to 10.3 mg/cm² ([U.S. EPA, 1992b](#)) for tasks such as spray coating as shown in the ChemSTEER Manual ([U.S. EPA, 2015](#)). More specifically, EPA has utilized the raw data of the ([U.S. EPA, 1992b](#)) study to determine a central tendency (50th percentile) value of 3.8 mg/cm² and a high-end (95th percentile) value of 10.3 mg/cm² for scenarios aligned with dermal immersion in liquids.

The average absorptive flux of BBP for an 8-hour absorption period, as determined from ([Sugino et al., 2017](#)), would result in maximum absorption of 5.0×10^{-3} mg/cm² over an 8-hour period (5.3 mg/day for high-end worker exposures and 2.7 mg/day for central tendency worker exposures). Therefore, for OES with lower concentrations of BBP in the liquid, it is possible that the estimated amount absorbed using the flux value would exceed the amount of BBP available in the dermal load. In these cases, EPA capped the amount absorbed to the maximum amount of BBP in the liquid (*i.e.*, the product of the dermal load and the weight fraction of BBP).

C.2.4.2 Solid Dermal Loading

For contact with solids or powders in occupational settings, EPA generally assumes a range of dermal loading of 900 to 3,100 mg/day (50th–95th percentile from Lansink *et al.* (1996)) as shown in the ChemSTEER manual (U.S. EPA, 2015). For contact with materials such as solder/pastes in occupational settings, EPA assumes a range of dermal loading of 450 to 1,100 mg/day (50th–95th percentile from Lansink *et al.* (1996)) as shown in the ChemSTEER Manual (U.S. EPA, 2015).

C.2.5 DBP Weight Fraction

Due to uncertainties around how different formulations of BBP may impact the overall dermal absorption, EPA used the maximum weight fraction of BBP in each OES to provide the most protective dermal exposure assessment. The details of the range of expected weight fractions of BBP in each OES are described for each OES in Section 3. Table Apx C-2 presents the weight fraction of BBP used for the dermal exposure of each OES.

Table Apx C-2. Summary of DBP Weight Fractions for Dermal Exposure Estimates

OES	Physical Form	Weight Fraction
Manufacturing	Liquid	1
Import and repackaging	Liquid	0.3
	Solid	0.3
Formulation into adhesives and sealants	Liquid	1
	Solid	0.3
Formulation into paints and coatings	Liquid	0.6
Incorporation into other formulations, mixtures, reaction products	Liquid	1
PVC plastics compounding	Liquid	1
	Solid	0.45
PVC plastics converting	Solid	0.45
Non-PVC material compounding	Liquid	1
	Solid	0.2
Non-PVC material converting	Solid	0.2
Application of adhesives and sealants	Liquid	0.7
Application of paints and coatings	Liquid	0.6
Use of laboratory chemicals	Liquid	0.01
	Solid	0.003
Use of lubricants and functional fluids	Liquid	0.5
Fabrication of final product from articles	Solid	0.45
Recycling	Solid	0.45
Waste handling, treatment, and disposal	Solid	0.45

C.2.6 Glove Protection Factors

Gloves may mitigate dermal exposures, if used correctly and consistently. However, data about the frequency of effective glove use (*i.e.*, the proper use of effective gloves) is very limited in industrial settings. Initial literature review suggests that there is unlikely to be sufficient data to justify a specific

probability distribution for effective glove use for a chemical or industry. Instead, the impact of effective glove use should be explored by considering different percentages of effectiveness (*e.g.*, 25 vs. 50% percent effectiveness).

Gloves only offer barrier protection until the chemical breaks through the glove material. Using a conceptual model, Cherrie *et al.* (2004) proposed a glove workplace protection factor – the ratio of estimated uptake through the hands without gloves to the estimated uptake through the hands while wearing gloves; this protection factor is driven by flux, and thus varies with time. The ECETOC TRA Model represents the protection factor of gloves as a fixed, APF equal to 5, 10, or 20 (Marquart *et al.*, 2017). Where, similar to the APR for respiratory protection, the inverse of the protection factor is the fraction of the chemical that penetrates the glove.

Given the limited state of knowledge about the protection afforded by gloves in the workplace, it is reasonable to utilize the PF values of the ECETOC TRA Model (Marquart *et al.*, 2017), rather than attempt to derive new values.

Table_Apx C-3 presents the PF values from ECETOC TRA Model (Version 3). In the exposure data used to evaluate the ECETOC TRA model, (Marquart *et al.*, 2017) reported that the observed glove protection factor was 34, compared to PF values of 5 or 10 used in the model.

Table_Apx C-3. Exposure Control Efficiencies and Protection Factors for Different Dermal Protection Strategies from ECETOC TRA v3

Dermal Protection Characteristics	Affected User Group	Indicated Efficiency (%)	Protection Factor (PF)
Any glove / gauntlet without permeation data and without employee training	Both industrial and professional users	0	1
Gloves with available permeation data indicating that the material of construction offers good protection for the substance		80	5
Chemically resistant gloves (<i>i.e.</i> , as b above) with “basic” employee training		90	10
Chemically resistant gloves in combination with specific activity training (<i>e.g.</i> , procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur	Industrial users only	95	20

Appendix D MODEL APPROACHES AND PARAMETERS

This appendix section presents the modeling approach and model equations used in estimating environmental releases and occupational exposures for each of the applicable OESs. The models were developed through review of the literature and consideration of existing EPA/OPPT models, ESDs, and/or GSs. An individual model input parameter could either have a discrete value or a distribution of values. EPA assigned statistical distributions based on reasonably available literature data. In most cases, a Monte Carlo simulation (a type of stochastic simulation) was conducted to capture variability in the model input parameters. Simulations were conducted using the Latin hypercube sampling method in @Risk Industrial Edition, Version 8.0 (Palisade, 2022). The Latin hypercube sampling method generates a sample of possible values from a multi-dimensional distribution and is considered a stratified method, meaning the generated samples are representative of the probability density function (variability) defined in the model. EPA performed models at 100,000 iterations to capture a broad range of possible input values, including values with low probability of occurrence.

EPA used the 95th and 50th percentile Monte Carlo simulation model result values for assessment, and similarly a high-end and central tendency value for models that did not utilize Monte Carlo simulation. The 95th percentile value represents the high-end release amount or exposure level, whereas the 50th percentile value represents the typical release amount or exposure level. The following subsections detail the model design equations and parameters for each of the OESs.

D.1 EPA/OPPT Standard Models

This appendix section discusses the standard models used by EPA to estimate environmental releases of chemicals and occupational inhalation exposures. All the models presented in this section are models that were previously developed by EPA and are not the result of any new model development work for this risk evaluation. Therefore, this appendix does not provide the details of the derivation of the model equations which have been provided in other documents such as the ChemSTEER User Guide (U.S. EPA, 2015), *Chemical Engineering Branch Manual for the Preparation of Engineering Assessments, Volume 1* (CEB, 1991), *Evaporation of pure liquids from open surfaces* (Arnold and Engel, 2001), *Evaluation of the Mass Balance Model Used by the References Environmental Protection Agency for Estimating Inhalation Exposure to New Chemical Substances* (Fehrenbacher and Hummel, 1996), and *Releases During Cleaning of Equipment* (PEI Associates, 1988). The models include loss fraction models as well as models for estimating chemical vapor generation rates used in subsequent model equations to estimate the volatile releases to air and occupational inhalation exposure concentrations. The parameters in the equations of this appendix section are specific to calculating environmental releases and occupational inhalation exposures to BBP.

The EPA/OPPT Penetration Model (U.S. EPA, 2015) estimates releases to air from evaporation of a chemical from an open, exposed liquid surface. This model is appropriate for determining volatile releases from activities that are performed indoors or when air velocities are expected to be less than or equal to 100 feet per minute. The EPA/OPPT Penetration Model calculates the average vapor generation rate of the chemical from the exposed liquid surface using the following equation:

Equation_Apx D-1.

$$G_{activity} = \frac{(8.24 \times 10^{-8}) * (MW_{BBP}^{0.835}) * F_{correction\_factor} * VP * \sqrt{Rate_{air\_speed}} * (0.25\pi D_{opening}^2)^4 \sqrt{\frac{1}{29} + \frac{1}{MW_{BBP}}}}{T^{0.05} * \sqrt{D_{opening}} * \sqrt{P}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
MW_{BBP}	=	BBP molecular weight (g/mol)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	BBP vapor pressure (torr)
$Rate_{air\_speed}$	=	Air speed (cm/s)
$D_{opening}$	=	Diameter of opening (cm)
T	=	Temperature (K)
P	=	Pressure (torr)

The EPA/OPPT Mass Transfer Coefficient Model estimates releases to air from the evaporation of a chemical from an open, exposed liquid surface ([U.S. EPA, 2015](#)). This model is appropriate for determining this type of volatile release from activities that are performed outdoors or when air velocities are expected to be greater than 100 feet per minute. The EPA/OPPT Mass Transfer Coefficient Model calculates the average vapor generation rate of the chemical from the exposed liquid surface using the following equation:

Equation_Apx D-2.

$$G_{activity} = \frac{(1.93 \times 10^{-7}) * (MW_{BBP}^{0.78}) * F_{correction\_factor} * VP * Rate_{air\_speed}^{0.78} * (0.25\pi D_{opening}^2)^3 \sqrt{\frac{1}{29} + \frac{1}{MW_{BBP}}}}{T^{0.4} D_{opening}^{0.11} (\sqrt{T} - 5.87)^{2/3}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
MW_{BBP}	=	BBP molecular weight (g/mol)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	BBP vapor pressure (torr)
$Rate_{air\_speed}$	=	Air speed (cm/s)
$D_{opening}$	=	Diameter of opening (cm)
T	=	Temperature (K)

The EPA's Office of Air Quality Planning and Standards (OAQPS) AP-42 Loading Model estimates releases to air from the displacement of air containing chemical vapor as a container/vessel is filled with a liquid ([U.S. EPA, 2015](#)). This model assumes that the rate of evaporation is negligible compared to the vapor loss from the displacement and is used as the default for estimating volatile air releases during both loading activities and unloading activities. This model is used for unloading activities because it is assumed while one vessel is being unloaded another is assumed to be loaded. The EPA/OAQPS AP-42 Loading Model calculates the average vapor generation rate from loading or unloading using the following equation:

Equation_Apx D-3.

$$G_{activity} = \frac{F_{saturation\_factor} * MW_{BBP} * V_{container} * 3785.4 \frac{cm^3}{gal} * F_{correction\_factor} * VP * \frac{RATE_{fill} \frac{s}{hr}}{3600 \frac{s}{hr}}}{R * T}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)

$F_{saturation\_factor}$	=	Saturation factor (unitless)
MW_{BBP}	=	BBP molecular weight (g/mol)
$V_{container}$	=	Volume of container (gal/container)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	BBP vapor pressure (torr)
$RATE_{fill}$	=	Fill rate of container (containers/h)
R	=	Universal gas constant [(torr/mol-K)]
T	=	Temperature (K)

For each of the vapor generation rate models, the vapor pressure correction factor ($F_{correction\_factor}$) can be estimated using Raoult's Law and the mole fraction of BBP in the liquid of interest. However, in most cases, EPA did not have data on the molecular weights of other components in the liquid formulations; therefore, EPA approximated the mole fraction using the mass fraction of BBP in the liquid of interest. Using the mass fraction of BBP to estimate mole fraction does create uncertainty in the vapor generation rate model. If other components in the liquid of interest have similar molecular weights as BBP, then mass fraction is a reasonable approximation of mole fraction. However, if other components in the liquid of interest have much lower molecular weights than BBP, the mass fraction of BBP will be an overestimate of the mole fraction. If other components in the liquid of interest have much higher molecular weights than BBP, the mass fraction of BBP will underestimate the mole fraction.

If calculating an environmental release, the vapor generation rate calculated from one of the above models (Equation_Apx D-1, Equation_Apx D-2, and Equation_Apx D-3) is then used along with an operating time to calculate the release amount:

Equation_Apx D-4.

$$Release\_Year_{activity} = Time_{activity} * G_{activity} * 3600 \frac{s}{hr} * 0.001 \frac{kg}{g}$$

Where:

$Release\_Year_{activity}$	=	BBP released for activity per site-year (kg/site-year)
$Time_{activity}$	=	Operating time for activity (h/site-year)
$G_{activity}$	=	Vapor generation rate for activity (g/s)

In addition to the vapor generation rate models, EPA uses various loss fraction models to calculate environmental releases, including the following:

- EPA/OPPT Small Container Residual Model
- EPA/OPPT Drum Residual Model
- EPA/OPPT Bulk Transport Residual Model
- EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders
- EPA/OPPT Multiple Process Vessel Residual Model
- EPA/OPPT Single Process Vessel Residual Model
- EPA/OPPT Solid Residuals in Transport Containers Model
- March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

The loss fraction models apply a given loss fraction to the overall throughput of BBP for the given process. More information for each model can be found in the ChemSTEER User Guide ([U.S. EPA](#),

[2015](#)). The loss fraction value or distribution of values differs for each model; however, each model follows the same general equation based on the approaches described for each OES:

Equation_Apx D-5.

$$Release\_Year_{activity} = PV * F_{activity\_loss}$$

Where:

$Release\_Year_{activity}$	=	BBP released for activity per site-year (kg/site-year)
PV	=	Production volume throughput of BBP for the activity (kg/site-year)
$F_{activity\_loss}$	=	Loss fraction for activity (unitless)

The EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders estimates a loss fraction of dust that may be generated during the transferring/unloading of solid powders. This model can be used to estimate a loss fraction of dust both when the facility does not employ capture technology (*i.e.*, local exhaust ventilation, hoods) or dust control/removal technology (*i.e.*, cyclones, electrostatic precipitators, scrubbers, or filters), and when the facility does employ capture and/or control/removal technology. The model explains that when dust is uncaptured, the release media is uncertain (*i.e.*, fugitive air, water, incineration, or landfill). When dust is captured but uncontrolled, the release media is to stack air. When dust is captured and controlled, the release media is to incineration or landfill. The EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders calculates the amount of dust not captured, captured but not controlled, and both captured and controlled, using the following equations ([U.S. EPA, 2021b](#)):

Equation_Apx D-6.

$$Elocal_{dust\_not\_captured} = Elocal_{dust\_generation} * (1 - F_{dust\_capture})$$

Where:

$Elocal_{dust\_not\_captured}$	=	Daily amount emitted from transfers/unloading that is not captured (kg not captured/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg generated/site-day)
$F_{dust\_capture}$	=	Capture technology efficiency (kg captured/kg generated)

Equation_Apx D-7.

$$Elocal_{dust\_cap\_uncontrol} = Elocal_{dust\_generation} * F_{dust\_capture} * (1 - F_{dust\_control})$$

Where:

$Elocal_{dust\_cap\_uncontrol}$	=	Daily amount emitted from control technology from transfers/unloading (kg not controlled/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg generated/site-day)
$F_{dust\_capture}$	=	Capture technology efficiency (kg captured/kg generated)
$F_{dust\_control}$	=	Control technology removal efficiency (kg controlled/kg captured)

Equation_Apx D-8.

$$Elocal_{dust\_cap\_control} = Elocal_{dust\_generation} * F_{dust\_capture} * F_{dust\_control}$$

Where:

$Elocal_{dust\_cap\_control}$	=	Daily amount captured and removed by control technology from transfers/unloading (kg controlled/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg generated/site-day)
$F_{dust\_capture}$	=	Capture technology efficiency (kg captured/kg generated)
$F_{dust\_control}$	=	Control technology removal efficiency (kg controlled/kg captured)

D.2 Manufacturing Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Manufacturing OES. This approach utilizes CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on BBP's physical properties and a virtual tour of the manufacturing processes for other phthalates (DIDP and DINP) ([ExxonMobil, 2022b](#)), EPA identified the following potential release sources from manufacturing operations:

- Release source 1: Vented Losses to Air During Reaction/Separations/Other Process Operations
- Release source 2: Product Sampling Wastes
- Release source 3: Equipment Cleaning Wastes
- Release source 4: Open Surface Losses to Air During Equipment Cleaning
- Release source 5: Transfer Operation Losses to Air from Packaging Manufactured BBP into Transport Containers

Environmental releases for BBP during manufacturing are a function of BBP's physical properties, container size, mass fractions, and other model parameters. Although physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: BBP concentration, production volume, air speed, diameter of openings, saturation factor, container size, and loss fractions. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts and exposure concentrations for this OES.

D.2.1 Model Equations

Table_Apx D-1 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Manufacturing OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.1. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-1. Models and Variables Applied for Release Sources in the Manufacturing OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Vented Losses to Air During Reaction/Separations/Other Process Operations	See Equation_Apx D-9	$Q_{BBP\_day}; F_{BBP\_SPERC}$
Release source 2: Product Sampling Wastes	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix D.1)	$Q_{BBP\_day}; LF_{sampling}$
Release source 3: Equipment Cleaning Wastes	EPA/OPPT Multiple Process Vessel Residual Model (Appendix D.1)	$Q_{BBP\_day}; LF_{equip\_clean}$
Release source 4: Open Surface Losses to Air During Equipment Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: $F_{BBP}; MW; VP;$ $RATE_{air\_speed}; D_{equip\_clean}; T; P$ Operating Time: OH_{equip_clean}
Release source 5: Transfer Operation Losses to Air from Packaging Manufactured BBP into Transport Containers	EPA/OAQPS AP-42 Loading Model (Appendix D.1)	Vapor Generation Rate: $F_{BBP}; VP; f_{sat}; MW; R;$ $T; RATE_{fill\_drum}$ Operating Time: $N_{cont\_load\_year};$ $RATE_{fill\_drum}; OD$

Release source 1 daily release (Vented Losses to Air During Reaction/Separations/Other Process Operations) is calculated using the following equation:

Equation_Apx D-9.

$$Release\_perDay_{RP1} = Q_{BBP\_day} * F_{BBP\_SPERC}$$

Where:

$$\begin{aligned}
 Release\_perDay_{RP1} &= \text{BBP released for release source 1 (kg/site-day)} \\
 Q_{BBP\_day} &= \text{Facility throughput of BBP (kg/site-day)} \\
 F_{BBP\_SPERC} &= \text{Loss fraction for unit operations (unitless)}
 \end{aligned}$$

D.2.2 Model Input Parameters

Table_Apx D-2 summarizes the model parameters and their values for the Manufacturing Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-2. Summary of Parameter Values and Distributions Used in the Manufacturing Models

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Number of Sites	Ns	sites	1	–	–	–	–	See Section D.2.3
Facility Production Rate – Known Site	PV	kg/site-year	8,794,650	176,395	8,794,650	–	Uniform	See Section D.2.4
Manufactured BBP Concentration	F _{BBP}	kg/kg	1.0	0.90	1.0	–	Uniform	See Section D.2.7
Air Speed	RATE _{air_speed}	ft/min	19.7	2.56	398	–	Lognormal	See Section D.2.8
Diameter of Sampling Opening	D _{sampling}	cm	2.5	2.5	10	2.5	Triangular	See Section D.2.9
Diameter of Equipment Opening	D _{equip_clean}	cm	92	–	–	–	–	See Section D.2.9
Saturation Factor	f _{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.2.10
Drum Size	V _{drum}	gal	100	20	1000	100	Triangular	See Section D.2.11
Fraction of BBP Lost During Sampling – 1 (Q _{BBP_day} < 50 kg/site-day)	F _{sampling_1}	kg/kg	2.0E–02	2.0E–03	2.0E–02	2.0E–02	Triangular	See Section D.2.12
Fraction of BBP Lost During Sampling – 2 (Q _{BBP_day} 50–200 kg/site-day)	F _{sampling_2}	kg/kg	5.0E–03	6.0E–04	5.0E–03	5.0E–03	Triangular	See Section D.2.12
Fraction of BBP Lost During Sampling – 3 (Q _{BBP_day} 200–5,000 kg/site-day)	F _{sampling_3}	kg/kg	4.0E–03	5.0E–04	4.0E–03	4.0E–03	Triangular	See Section D.2.12

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Fraction of BBP Lost During Sampling – 4 ($Q_{BBP\_day} > 5,000$ kg/site-day)	F _{sampling_4}	kg/kg	4.0E–04	8.0E–05	4.0E–04	4.0E–04	Triangular	See Section D.2.12
Operating Days	OD	days/year	300	–	–	–	–	See Section D.2.13
Vapor Pressure at 25 °C	VP	mmHg	8.25E–06	–	–	–	–	Physical property
Vapor Pressure at 140 °F	VP ₁₄₀	mmHg	2.08E–03	–	–	–	–	Physical property
Vapor Pressure at 250 °F	VP ₂₅₀	mmHg	0.303	–	–	–	–	Physical property
Vapor Pressure at 375 °F	VP ₃₇₅	mmHg	17.8	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	312.37	–	–	–	–	Physical property
Density of BBP	RHO	kg/L	1.119	–	–	–	–	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	–	–	–	–	Universal constant
Process Operation Emission Factor	F _{BBP_SPERC}	kg/kg	1.0E–05	–	–	–	–	See Section D.2.14
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1.0	–	–	–	–	Process parameter
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	0.02	–	–	–	–	See Section D.2.15
Drum Fill Rate	RATE _{fill_drum}	drums/h	20	–	–	–	–	See Section D.2.16

D.2.3 Number of Sites

EPA used 2020 CDR data ([U.S. EPA, 2020a](#)) to identify the number of sites that manufacture BBP. In CDR, one site reported domestic manufacturing of BBP, Polymer Additives, Inc. located in Bridgeport, NJ.

D.2.4 Throughput Parameters

The one manufacturing site reported in CDR a production volume that was CBI ([U.S. EPA, 2020a](#)). For the manufacturing site, EPA estimated the PV with a uniform distribution with bounds calculated by subtracting the known import volumes from the estimated national aggregate BBP PV from CDR.

CDR estimated a total national aggregate BBP PV between 1,000,000 and less than 20,000,000 lb. EPA subtracted the combined known PV from importers (611,115 lb) from each of these endpoints, resulting in a remaining import PV range of 388,885 to 19,388,885 lb; or 176,395 to 8,794,650 kg/year.

The daily throughput of BBP is calculated using Equation_Apx D-10 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section D.2.13.

Equation_Apx D-10.

$$Q_{BBP\_day} = \frac{PV}{OD}$$

Where:

Q_{BBP_day}	=	Facility throughput of BBP (kg/site-day)
PV	=	Annual production volume (kg/site-year)
OD	=	Operating days (see Section D.2.13) (days/year)

D.2.5 Number of Containers Per Year

The number of manufactured BBP product containers filled by a site per year is calculated using the following equation:

Equation_Apx D-11.

$$N_{cont\_load\_year} = \frac{PV}{V_{drum}}$$

Where:

$N_{cont\_load\_year}$	=	Annual number of product containers (container/site-year)
V_{drum}	=	Product container volume (see Section D.2.11) (gal/container)
PV	=	Facility production rate (see Section D.2.4) (kg/site-year)

D.2.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) and/or through calculation from other parameters. Release points with operating hours provided from the ChemSTEER User Guide include equipment cleaning.

The operating hours for loading of BBP into transport containers (release point 5) is calculated based on the number of product containers filled at the site and the fill rate using the following equation:

Equation_Apx D-12.

$$Time_{RP5} = \frac{N_{cont\_load\_year}}{RATE_{fill\_drum} * OD}$$

Where:

$Time_{RP5}$	=	Operating time for release point 5 (h/site-day)
$RATE_{fill\_drum}$	=	Fill rate of container (see Section D.2.16) (containers/h)
$N_{cont\_load\_year}$	=	Annual number of product containers (see Section D.2.5) (containers/site-year)
OD	=	Operating days (see Section D.2.13) (days/site-year)

D.2.7 Manufactured BBP Concentration

EPA used the manufactured concentration range reported in CDR for the known site ([U.S. EPA, 2020a](#)) to make a uniform distribution of 90 to 100 percent BBP.

D.2.8 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.2.9 Diameters of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities ([U.S. EPA, 2015](#)). For equipment cleaning operations, the ChemSTEER User Guide indicates a single default value of 92 cm ([U.S. EPA, 2015](#)).

For sampling activities, the ChemSTEER User Guide indicates that the typical diameter of opening for vaporization of the liquid is 2.5 cm ([U.S. EPA, 2015](#)). Additionally, the ChemSTEER User Guide

provides 10 cm as a high-end value for the diameter of opening during sampling ([U.S. EPA, 2015](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the estimated lower bound, upper bound, and mode of the parameter. EPA assigned the value of 2.5 cm as a lower bound for the parameter and 10 cm as the upper bound based on the values provided in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA also assigned 2.5 cm as the mode diameter value for sampling liquids based on the typical value described in ChemSTEER User Guide ([U.S. EPA, 2015](#)).

D.2.10 Saturation Factor

The Chemical Engineering Branch Manual for the Preparation of Engineering Assessments, Volume 1 [CEB Manual] indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([CEB, 1991](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.2.11 Container Size

The manufacturing site identified that BBP is manufactured as a liquid. Based on the larger PV range of 176,395 to 8,794,650 kg/year, EPA assumed that BBP may be packaged in drums or totes. According to the ChemSTEER User Guide, drums are defined as containing between 20 and 100 gallons of liquid, with a default of 55 gallons while totes are defined as containing between 100 and 1,000 gallons, with a default of 550 gallons ([U.S. EPA, 2015](#)). Therefore, EPA modeled packaged container size using a triangular distribution with a lower bound of 20 gallons, an upper bound of 1,000 gallons, and a mode of 100 gallons (the maximum for drums and minimum for totes).

D.2.12 Sampling Loss Fraction

Sampling loss fractions were estimated using the March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes ([U.S. EPA, 2023b](#)). In this methodology, EPA completed a search of over 300 Initial Review Engineering Report (IRERs) completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both Pre-Manufacture Notices (PMNs) and Low Volume Exemptions (LVEs). Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites ($\approx 75\%$ of IRERs), were obtained. The data points were analyzed as a function of the chemical daily throughput and industry type. This analysis showed that the sampling loss fraction generally decreased as the chemical daily throughput increased. Therefore, the methodology provides guidance for selecting a loss fraction based on chemical daily throughput. Table_Apx D-3 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-3. Sampling Loss Fraction Data from the March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

Chemical Daily Throughput (kg/site-day) ($Q_{chem\_site\_day}$)	Number of Data Points	Sampled Quantity (kg chemical/day)		Sampling Loss Fraction ($LF_{sampling}$)	
		50th Percentile	95th Percentile	50th Percentile	95th Percentile
<50	13	0.03	0.20	0.002	0.02
50 to <200	10	0.10	0.64	0.0006	0.005
200 to <5,000	25	0.37	3.80	0.0005	0.004
≥5,000	10	1.36	6.00	0.00008	0.0004
All	58	0.20	5.15	0.0005	0.008

For each range of daily throughputs, EPA estimated sampling loss fractions using a triangular distribution of the 50th percentile value as the lower bound, and the 95th percentile value as the upper bound and mode. The sampling loss fraction distribution was chosen based on the calculation of daily throughput, as shown in Section D.2.4.

D.2.13 Operating Days

EPA was unable to identify specific information for operating days for the manufacturing of BBP. Therefore, EPA assumes a constant value of 300 days/year, which assumes the production sites operate 6 days per week and 50 weeks per year, with 2 weeks down for turnaround.

D.2.14 Process Operations Emission Factor

In order to estimate releases from reactions, separations, and other process operations, EPA used an emission factor from the European Solvents Industry Group (ESIG). According to the ESD on Plastic Additives, the processing temperature during manufacture of plasticizers is 375 °F ([OECD, 2009b](#)). However, the rate of release is expected to be limited by the ambient temperature of the manufacturing facility. At room temperature, the vapor pressure of BBP is less than 1 Pa. The ESIG Specific Environmental Release Category for Industrial Substance Manufacturing (solvent-borne) states that a chemical with a vapor pressure of less than 1 Pa will have an emission factor of 0.00001 ([ESIG, 2012](#)). Therefore, EPA used this emission factor as a constant value for process operation releases.

D.2.15 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. That model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of 2 percent from equipment cleaning.

D.2.16 Container Fill Rates

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical fill rate of 20 containers per hour for containers with 20 to 1,000 gallons of material.

D.3 Import and Repackaging Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Import and repackaging OES. This approach utilizes the Generic Scenario for Chemical Repackaging ([U.S. EPA, 2022](#)) and CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the GS, EPA identified the following release sources from import and repackaging operations:

- Release source 1: Dust Generation from Unloading Imported Product (solids only)
- Release source 2: Transfer Operation Losses to Air from Unpacking Imported BBP from Transport Containers (liquids only)
- Release source 3: Sampling Wastes
- Release source 4: Import Container Residue Losses
- Release source 5: Open Surface Losses to Air During Container Cleaning (liquids only)
- Release source 6: Equipment Cleaning Losses
- Release source 7: Open Surface Losses to Air During Equipment Cleaning (liquids only)
- Release source 8: Dust Generation from Loading Imported Product (solids only)
- Release source 9: Transfer Operation Losses to Air During Loading of BBP (liquids only)

Environmental releases for BBP during import and repackaging are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production rate, operating days, BBP concentration, air speed, saturation factor, container size, and loss fractions. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.3.1 Model Equations

Table_Apx D-4 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Import and repackaging OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.3.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-4. Models and Variables Applied for Release Sources in the Repackaging OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Dust Generation from Unloading Imported Product (solids only)	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix D.1)	Q_{BBP_day} ; $F_{dust\_generation}$; $F_{dust\_capture}$; $F_{dust\_control}$; OD
Release source 2: Transfer Operation Losses to Air from Unpacking Imported BBP from Transport Containers (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	F_{BBP} ; MW ; VP ; $RATE_{fill\_tote}$; V_{tote} ; OH_{unload_tote} ; T ; f_{sat} ; OD
Release source 3: Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix D.1)	Q_{BBP_day} ; $LF_{sampling}$; OD

Release Source	Model(s) Applied	Variables Used
Release source 4: Import Container Residue Losses	EPA/OPPT Bulk Transport Residual Model (Appendix D.1)	$Q_{BBP\_day}; LF_{bulk}; LF_{cont}; N_{cont\_unload\_year}; OD$
Release source 5: Open Surface Losses to Air during Container Cleaning. (Liquids Only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: $F_{BBP}; MW; VP;$ $RATE_{air\_speed}; D_{cont\_clean}; T; P$ Operating Time: $N_{cont\_unload\_year};$ $RATE_{fill\_bulk}; OD$
Release source 6: Equipment Cleaning Losses	EPA/OPPT Single Process Vessel Residual Model (Appendix D.1)	$Q_{BBP\_day}; LF_{equip\_clean}; OD$
Release source 7: Open Surface Losses to Air during Equipment Cleaning (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: $F_{BBP}; MW; VP;$ $RATE_{air\_speed}; D_{equip\_clean}; T; P$ Operating Time: OH_{equip_clean}
Release source 8: Dust Generation from Loading Imported Product (solids only)	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix D.1)	$Q_{BBP\_day}; F_{dust\_generation}; F_{dust\_capture};$ $F_{dust\_control}; OD$
Release source 9: Transfer Operation Losses to Air during Loading of BBP (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: $F_{BBP}; f_{sat}; V_{drum}; MW;$ $VP; RATE_{fill\_drum}; D_{equip\_clean}; T$ Operating Time: OH_{load_drum}

D.3.2 Model Input Parameters

Table_Apx D-5 summarizes the model parameters and their values for the Import and Repackaging Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-5. Summary of Parameter Values and Distributions Used in the Import and Repackaging Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Facility Production Rate	PV1(liquid)	kg/site-year	2,678	–	–	–	–	See Appendix D.3.4
	PV2 (solid)	kg/site-year	274,520	–	–	–	–	See Appendix D.3.4
Operating Hours for Equipment Cleaning	OH _{equip_clean}	h/day	1.0	–	–	–	–	See Appendix D.3.6
Operating Days	OD	days/year	208	174	260	–	Discrete	See Appendix D.3.7
Imported BBP Concentration	F _{BBP}	kg/kg	0.3	1.0E–02	0.3	–	Uniform	See Appendix D.3.8
Air Speed	RATE _{air_speed}	cm/s	10	1.3	202	–	Lognormal	See Appendix D.3.9
Saturation Factor	f _{sat}	Dimension-less	0.5	0.5	1.5	0.5	Triangular	See Appendix D.3.10
Drum Size	V _{drum}	gal	55	20	100	55	Triangular	See Appendix D.3.11
Tote Size	V _{tote}	gal	550	100	1000	550	Triangular	See Appendix D.3.11
Bulk Container Loss Fraction	LF _{bulk}	kg/kg	7.0E–04	2.0E–04	2.0E–03	7.0E–04	Triangular	See Appendix D.3.12
Fraction of BBP Lost During Sampling – 1 (Q _{BBP_day} < 50 kg/site-day)	F _{sampling_1}	kg/kg	2.0E–02	2.0E–03	2.0E–02	2.0E–02	Triangular	See Appendix D.3.13
Fraction of BBP Lost During Sampling – 2 (Q _{BBP_day} 50–200 kg/site-day)	F _{sampling_2}	kg/kg	5.0E–03	6.0E–04	5.0E–03	5.0E–03	Triangular	See Appendix D.3.13
Fraction of BBP Lost During Sampling – 3 (Q _{BBP_day} 200–5,000 kg/site-day)	F _{sampling_3}	kg/kg	4.0E–03	5.0E–04	4.0E–03	4.0E–03	Triangular	See Appendix D.3.13
Fraction of BBP Lost During Sampling – 4 (Q _{BBP_day} > 5,000 kg/site-day)	F _{sampling_4}	kg/kg	4.0E–04	8.0E–05	4.0E–04	4.0E–04	Triangular	See Appendix D.3.13

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Fraction of Chemical Lost During Transfer of Solid Powders	F _{dust_generation}	kg/kg	5.0E-03	1.0E-03	3.0E-02	5.0E-03	Triangular	See Appendix D.3.16
Capture Efficiency for Dust Capture Methods	F _{dust_capture}	kg/kg	0.96	0	1	0.96	Triangular	See Appendix D.3.16
Control Efficiency for Dust Capture Methods	F _{dust_control}	kg/kg	0.79	0	1	0.79	Triangular	See Appendix D.3.16
Vapor Pressure at 25 °C	VP	mmHg	8.25E-06	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	312	–	–	–	–	Physical property
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	1.0E-02	–	–	–	–	See Appendix D.3.14
Bulk Solid Container Size	V _{bulk}	kg	227	–	–	–	–	See Appendix D.3.11
Small Container Fill Rate	RATE _{fill_cont}	cont/h	60	–	–	–	–	See Appendix D.3.15
Drum Fill Rate	RATE _{fill_drum}	drums/h	20	–	–	–	–	See Appendix D.3.15
Bulk Container Fill Rate	RATE _{fill_bulk}	totes/h	20	–	–	–	–	See Appendix D.3.15
Solid Container Loss Fraction	LF _{cont}	kg/kg	1.0E-02	–	–	–	–	See Appendix D.3.18
Diameter of Opening, Container Cleaning	D _{cont_clean}	cm	5.08	–	–	–	–	See Appendix D.3.17
Diameter of Opening, Equipment Cleaning	D _{equip_clean}	cm	92.0	–	–	–	–	See Appendix D.3.17
Density of BBP	RHO	kg/L	1.1190	–	–	–	–	Physical property

D.3.3 Number of Sites

EPA used 2020 CDR data ([U.S. EPA, 2020a](#)) to identify the number of sites that import BBP. In CDR, two sites reported importing BBP. Table_Apx D-6 presents the names and locations of these sites.

Table_Apx D-6. Sites Reporting to CDR for Import of BBP

Facility Name	Facility Location
M. Argueso & Co., Inc.	Muskegon, MI
Tremco Incorporated	Beachwood, OH

D.3.4 Throughput Parameters

EPA used 2020 CDR data ([U.S. EPA, 2020a](#)) to identify annual facility PV for each site. Out of the two sites that reported importing of BBP in CDR, both provided a non-CBI production volume. M. Argueso & Co., Inc. reported a production volume of 5,903 lb/site-year (2,678 kg/site-year) of imported BBP. Tremco Incorporated reported a production volume of 605,212 lb/site-year (274,520 kg/site-year) of imported BBP. There were no unknown sites, therefore the total production volume is based on the sum of these reported values which is 611,115 lb/site-year (277,198 kg/site-year).

The daily throughput of BBP is calculated using Equation_Apx D-13 by dividing the annual facility production volume by the number of operating days. The number of operating days is determined according to Appendix D.3.7.

Equation_Apx D-13.

$$Q_{BBP\_day} = \frac{PV}{OD}$$

Where:

Q_{BBP_day}	=	Facility throughput of BBP (kg/site-day)
PV	=	Annual overall production volume (kg/site-year)
OD	=	Operating days (see Appendix D.3.7) (days/year)

D.3.5 Number of Containers per Year

The number of imported BBP containers for liquids unloaded by a site per year is calculated using the following equation:

Equation_Apx D-14.

$$N_{cont\_unload\_year} = \frac{PV}{V_{drum} * 3.79 \frac{L}{gal} * RHO}$$

Where:

V_{drum}	=	Drum size (see Appendix D.3.2) (gal)
PV	=	Annual overall production volume (kg/site-year)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (containers/site-year)
RHO	=	Density of BBP (g/L)

The number of imported BBP containers for solids unloaded by a site per year is calculated using the following equation:

Equation_Apx D-15.

$$N_{cont\_unload\_year} = \frac{PV}{V_{bulk}}$$

Where:

V_{bulk}	=	Bulk solid container size (see Appendix D.3.11) (kg)
PV	=	Annual overall production volume (kg/site-year)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (containers/site-year)

The number of BBP containers for liquids loaded by a site per year is calculated using the following equation:

Equation_Apx D-16.

$$N_{cont\_load\_year} = \frac{Q_{BBP\_year}}{V_{drum} * 3.79 \frac{L}{gal} * RHO}$$

Where:

Q_{BBP_year}	=	Facility throughput (kg/site-year)
V_{drum}	=	Drum size (see Appendix E.10) (gal)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (containers/site-year)
RHO	=	Density of BBP (g/L)

The number of BBP containers for solids loaded by a site per year is calculated using the following equation:

Equation_Apx D-17.

$$N_{cont\_load\_year} = \frac{Q_{BBP\_year}}{V_{cont}}$$

Where:

Q_{BBP_year}	=	Facility throughput (kg/site-year)
V_{cont}	=	Solid container size (see Appendix D.3.11) (kg)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (containers/site-year)

D.3.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) and/or through calculation from other parameters. Release points with operating hours provided from the ChemSTEER User Guide include unloading and loading transport containers.

For unloading (release point 1), the operating hours are calculated based on the number of imported bulk containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-18.

$$OH_{unload\_cont} = \frac{N_{cont\_unload\_year}}{RATE_{fill\_bulk} * OD}$$

Where:

OH_{unload_cont}	=	Daily operating hours for unloading containers (h/site-day)

$RATE_{fill\_bulk}$	=	Fill rate of bulk container, dependent on volume (see Appendix D.3.15) (containers/h)
$N_{cont\_unload\_year}$	=	Number of containers used per year (see Appendix D.3.5) (containers/site-year)
OD	=	Operating days (see Appendix D.3.7) (days/site-year)

For loading into transport containers (release point 8), the operating hours are calculated based on number of product containers filled per year, or on remaining time after accounting for container unloading. The operating hours for liquids and solids (with solid container sizes between 1–20 gallons) are calculated using the following equation:

Equation_Apx D-19.

$$OH_{load} = \frac{N_{cont\_load\_day}}{RATE_{fill\_cont}}$$

Where:

OH_{load}	=	Daily operating hours for loading (h/site-day)
$RATE_{fill\_cont}$	=	Container fill rate (containers/h)
$N_{cont\_load\_day}$	=	Number of containers loaded per day (containers/site-day)

The operating hours for solids (with solid container sizes between 20–1000 gallons) are calculated using the following equation:

Equation_Apx D-20.

$$OH_{load} = \frac{N_{cont\_load\_day}}{RATE_{fill\_drum\_tote}}$$

Where:

OH_{load}	=	Daily operating hours for loading (h/site-day)
$RATE_{fill\_drum\_tote}$	=	Drum or tote fill rate (drums/h)
$N_{cont\_load\_day}$	=	Number of containers loaded per day (containers/site-day)

D.3.7 Operating Days

EPA assessed the number of operating days associated with import and repackaging using employment data obtained through the U.S. BLS Occupational Employment Statistics ([U.S. BLS, 2016](#)). Per the U.S. BLS website, operating duration for each NAICS code is assumed as a ‘year-round, full-time’ hours figure of 2,080 hours ([U.S. BLS, 2016](#)). Assuming a working duration of 8 to 12 hours/day yields a number of operating days between 174 and 260 days/year. To account for differences in operating days, EPA assumed three types of shift durations with corresponding operating days per year: 8-, 10-, and 12-hour shifts. These shift durations correspond to 260, 208, and 174 operating days per year, respectively. Therefore, EPA used a discrete distribution with equal probability for each shift length/operating days combination to model this parameter.

D.3.8 Imported BBP Concentration

EPA used the imported concentration ranges reported in CDR ([U.S. EPA, 2020a](#)) to make a uniform distribution of 1 to 30 percent BBP.

D.3.9 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.3.10 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([CEB, 1991](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.3.11 Container Size

One CDR reporter indicated that BBP is imported as a solid while the other importer indicated import of BBP as a liquid ([U.S. EPA, 2020a](#)). For repackaging of BBP in solid form, EPA assumed a default solid container size of 500 lb (227 kg) for bulk solid containers of raw material unloaded based on the Generic Scenario for Chemical Repackaging. EPA modeled the container size of repackaged material containers using a triangular distribution with a lower bound and mode of 25 kg and upper bound of 500 kg. This is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), which states that compounded plastics in pellet form are routinely shipped in containers ranging from 25 kg bags to 500 kg gaylords. EPA assumes that shipping manufactured BBP in powder/pellet form may occur in similarly sized containers. EPA converted the mass of the container to volume assuming a density of 1 kg/L. The volumetric distribution contains a lower bound and mode of 7 gallons, and an upper bound of 132 gallons.

For importing BBP in liquid form, drums were assumed to be used in the model based on the expected import PV of BBP. According to the ChemSTEER User Guide, drums are defined as containing between 20 and 100 gallons of liquid, and the default drum size is 55 gallons ([U.S. EPA, 2015](#)). Therefore, EPA modeled drum size using a triangular distribution with a lower bound of 20 gallons, an upper bound of 100 gallons, and a mode of 55 gallons.

For the packaged container size for liquid materials, EPA assumed BBP may be packaged into bottles or other small containers and modeled the size range based on values from the ChemSTEER User Guide ([U.S. EPA, 2015](#)). The ChemSTEER User Guide provides default values of 1 to 20 gallons for bottles and small containers. EPA estimated the size of packaged containers using a triangular distribution with a lower bound of 1 gallon, an upper bound of 20 gallons, and a mode of 1 gallon.

D.3.12 Bulk Container Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying tanks by gravity-draining was aligned with the default central tendency and high-end values from the EPA/OPPT Bulk Transport Residual Model. For unloading tanks by gravity-draining in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.02 percent to 0.19 percent and an average of 0.06 percent ([PEI Associates, 1988](#)). The EPA/OPPT Bulk Transport Residual Model from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) recommends a default central tendency loss fraction of 0.07 percent and a high-end loss fraction of 0.2 percent.

The underlying distribution of the loss fraction parameter for bulk containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Bulk Transport Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study for emptying tanks by gravity-draining ([PEI Associates, 1988](#)).

D.3.13 Sampling Loss Fraction

Sampling loss fractions were estimated using the March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes ([U.S. EPA, 2023b](#)). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and LVEs. Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites (~75 percent of IRERs), were obtained. The data points were analyzed as a function of the chemical daily throughput and industry type. This analysis showed that the sampling loss fraction generally decreased as the chemical daily throughput increased. Therefore, the methodology provides guidance for selecting a loss fraction based on chemical daily throughput. Table_Apx D-7 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-7. Sampling Loss Fraction Data from the March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

Chemical Daily Throughput (kg/site-day) (Q _{chem_site_day})	Number of Data Points	Sampled Quantity (kg chemical/day)		Sampling Loss Fraction (LF _{sampling})	
		50th Percentile	95th Percentile	50th Percentile	95th Percentile
<50	13	0.03	0.20	0.002	0.02
50 to <200	10	0.10	0.64	0.0006	0.005
200 to <5,000	25	0.37	3.80	0.0005	0.004
≥5,000	10	1.36	6.00	0.00008	0.0004
All	58	0.20	5.15	0.0005	0.008

For each range of daily throughputs, EPA estimated sampling loss fractions using a triangular distribution of the 50th percentile value as the lower bound, and the 95th percentile value as the upper bound and mode. The sampling loss fraction distribution was chosen based on the calculation of daily throughput, as shown in Appendix D.3.4.

D.3.14 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Single Process Residual Model to estimate the releases from equipment cleaning. That model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of 1 percent from equipment cleaning.

D.3.15 Container Fill Rates

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical fill rate of 60 containers per hour for containers with 1 to 20 gallons of material and 20 containers per hour for containers with 20 to 1,000 gallons of material.

D.3.16 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Dust Release Model) compiled data for loss fractions of solids from various sources in addition to the capture and removal efficiencies for control technologies in order to estimate releases of dust to the environment. Dust releases estimated from the model are based on three different parameters: the initial loss fraction, the fraction captured by the capture technology, and the fraction removed/controlled by the control technology. The underlying distributions for each of these parameters is not known; therefore, EPA assigned triangular distributions, since triangular distribution requires least assumptions and is completely defined by range and mode of a parameter.

EPA assigned the range and mode for each of the three parameters using the data presented in the Dust Release Model. For the initial loss fraction, EPA assigned a range of 1.0×10^{-3} to 3.0×10^{-2} with a mode of 5.0×10^{-3} by mass. EPA assigned the mode based on the recommended default value for the parameter in the Dust Release Model. The range of initial loss fraction values comes from the range of values compiled from various sources and considered in the development of the Dust Release Model ([U.S. EPA, 2021b](#)).

For the fraction captured, EPA assigned a range of 0 to 1.0 with a mode of 0.963 by mass. EPA assigned the range for the fraction captured based on the minimum and maximum estimated capture efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction captured

based on the average of all lower bound estimated capture efficiency values for all capture technologies presented in the model.

For the fraction removed/controlled, EPA assigned a range of 0 to 1.0 with a mode of 0.79 by mass. EPA assigned the range for the fraction controlled based on the minimum and maximum estimated control efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction controlled based on the average of all lower bound estimated control efficiency values for all control technologies presented in the model.

D.3.17 Diameters of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities ([U.S. EPA, 2015](#)). For equipment cleaning operations, the ChemSTEER User Guide indicates a single default value of 92 cm ([U.S. EPA, 2015](#)). For container cleaning activities, the Guide indicates a single default value of 5.08 cm for containers less than 5,000 gallons ([U.S. EPA, 2015](#)).

D.3.18 Solid Container Loss Fraction

EPA used the EPA/OPPT Solid Residuals in Transport Containers Model to estimate residual releases from solid container cleaning. The EPA/OPPT Solid Residuals in Transport Containers Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of one percent from container cleaning.

D.4 Formulation into Adhesives and Sealants Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Formulation into adhesives and sealants OES. This approach utilizes the Emission Scenario Document on Adhesive Formulation ([OECD, 2009a](#)) and CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD, EPA identified the following release sources from formulation into adhesives and sealants:

- Release source 1: Dust Generation from Unloading Imported Product (solids only)
- Release source 2: Transfer Operations Losses to Air from Unloading Imported Product (liquids only)
- Release source 3: Container Residue Losses
- Release source 4: Open Surface Losses to Air During Container Cleaning (liquids only)
- Release source 5: Sampling Losses
- Release source 6: Vented Losses to Air During Dispersion and Blending/Process Operations
- Release source 7: Equipment Cleaning Waste
- Release source 8: Open Surface Losses to Air During Equipment Cleaning
- Release source 9: Transfer Operation Losses to Air During Loading
- Release source 10: Off-Specification and Other Waste Adhesive

Environmental releases for BBP during formulation into adhesives and sealants are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production volume, BBP concentrations, air speed, saturation factor, container size, loss fractions, and operating durations. EPA used the outputs

from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.4.1 Model Equations

Table_Apx D-8 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Formulation into adhesives and sealants OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.4.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-8. Models and Variables Applied for Release Sources in the Formulation into Adhesives and Sealants OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Dust Generation from Unloading Imported Product (SOLIDS ONLY)	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix D.1)	Q_{BBP_day} ; $F_{dust\_generation}$; $F_{dust\_capture}$; $F_{dust\_control}$
Release source 2: Transfer Operations Losses to Air from Unloading Imported Product (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	OH_{unload_tote} ; f_{sat} ; V_{tote} ; $RATE_{fill\_tote}$; VP ; T ; F_{BBP} ; MW
Release source 3: Container Residue Losses	EPA/OPPT Solid Residuals in Transport Containers Model (Appendix D.1)	Q_{BBP_day} ; LF_{cont} ; V_{cont} ; F_{BBP_import} ; $N_{cont\_unload\_year}$
Release source 4: Open Surface Losses to Air During Container Cleaning (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	OH_{unload_cont} ; F_{BBP_import} ; $RATE_{air\_speed}$; D_{cont_clean} ; MW ; VP ; T ; P
Release source 5: Sampling Losses	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix D.1)	Q_{BBP_day} ; $LF_{sampling}$
Release source 6: Vented Losses to Air During Dispersion and Blending/Process Operations	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	OH_{blend} ; F_{BBP_final} ; $RATE_{air\_speed}$; D_{blend} ; MW ; VP ; T ; P
Release source 7: Equipment Cleaning Waste	EPA/OPPT Multiple Process Vessel Residual Model (Appendix D.1)	Q_{BBP_day} ; LF_{equip_clean}
Release source 8: Open Surface Losses to Air During Equipment Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	OH_{equip_clean} ; F_{BBP_final} ; $RATE_{air\_speed}$; D_{equip_clean} ; MW ; VP ; T ; P

Release Source	Model(s) Applied	Variables Used
Release source 9: Transfer Operation Losses to Air During Loading	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix D.1)	$OH_{load_{cont_{adjusted}}}$; f_{sat} ; $V_{cont_{packaged}}$; MW_{VP} ; T ; $RATE_{fill_{adjusted}}$; $F_{BBP_{final}}$
Release source 10: Off-Specification and Other Waste Adhesive	See Equation_Apx D-21	$Q_{BBP_{day}}$; $LF_{offspec}$

Release source 10 daily release (off-spec and other waste adhesive) is calculated using the following equation:

Equation_Apx D-21.

$$Release\_perDay_{RP10} = Q_{BBP\_day} * LF_{offspec}$$

Where:

$Release\_perDay_{RP10}$	=	BBP released for release source 10 (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (kg/site-day)
$LF_{offspec}$	=	Loss fraction for off-spec and waste adhesive (unitless)

D.4.2 Model Input Parameters

Table_Apx D-9 summarizes the model parameters and their values for the Formulation into Adhesives and Sealants Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-9. Summary of Parameter Values and Distributions Used in the Formulation into Adhesives and Sealants Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Total PV of BBP at All Sites	PV _{total}	kg/year	7,172,980	278,376	7,172,980	–	Uniform	See Appendix D.4.4
Initial BBP Concentration (Run 1-Solids)	F _{BBP_initial_1}	kg/kg	0.30	1.0E–02	0.30	–	Uniform	See Appendix D.4.7
Initial BBP Concentration (Run 2-Liquids)	F _{BBP_initial_2}	kg/kg	1.0	1.0E–02	1.0	–	Uniform	See Appendix D.4.7
Final BBP Concentration	F _{BBP_final}	kg/kg	0.10	1.0E–03	0.70	0.1	Uniform	See Appendix D.4.8
Solid Container Size	V _{cont}	kg	25	25	499	25	Triangular	See Appendix D.4.9
Initial Container Size	V _{tote}	gal	100	20	1000	100	Triangular	See Appendix D.4.9
Packaged Container Size	V _{cont_packaged}	gal	55	0.10	100	55	Triangular	See Appendix D.4.9
Saturation Factor	f _{sat}	dimensionless	0.50	0.50	1.5	0.50	Triangular	See Appendix D.4.11
Fraction of Chemical Lost During Transfer of Solid Powders	F _{dust_generation}	kg/kg	5.0E–03	1.0E–03	3.0E–02	5.0E–03	Triangular	See Appendix D.4.15
Capture Efficiency for Dust Capture Methods	F _{dust_capture}	kg/kg	0.96	0	1	0.96	Triangular	See Appendix D.4.15
Control Efficiency for Dust Capture Methods	F _{dust_control}	kg/kg	0.79	0	1.0	0.79	Triangular	See Appendix D.4.15
Fraction of BBP Lost During Sampling – 1 (Q _{BBP_day} < 50 kg/site-day)	F _{sampling_1}	kg/kg	2.0E–02	2.0E–03	2.0E–02	2.0E–02	Triangular	See Appendix D.4.17
Fraction of BBP Lost During Sampling – 2 (Q _{BBP_day} 50–200 kg/site-day)	F _{sampling_2}	kg/kg	5.0E–03	6.0E–04	5.0E–03	5.0E–03	Triangular	See Appendix D.4.17
Fraction of BBP Lost During Sampling – 3 (Q _{BBP_day} 200–5,000 kg/site-day)	F _{sampling_3}	kg/kg	4.0E–03	5.0E–04	4.0E–03	4.0E–03	Triangular	See Appendix D.4.17
Fraction of BBP Lost During Sampling – 4 (Q _{BBP_day} > 5,000 kg/site-day)	F _{sampling_4}	kg/kg	4.0E–04	8.0E–5	4.0E–04	4.0E–04	Triangular	See Appendix D.4.17

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Drum Residual Loss Fraction	LF _{drum}	kg/kg	2.5E-02	1.7E-02	3.0E-02	2.5E-02	Triangular	See Appendix D.4.12
Air Speed	RATE _{air_speed}	cm/s	10	1.3	202	–	Lognormal	See Appendix D.4.10
Diameter of Opening, Blending	D _{blend}	cm	10	10	169	–	Uniform	See Appendix D.4.13
Diameter of Opening, Sampling	D _{sampling}	cm	2.5	2.5	10	–	Uniform	See Appendix D.4.13
Hours per Batch for Equipment Cleaning	OH _{batch_equip_clean}	hours/batch	4	1	4	4	Triangular	See Appendix D.4.14
Molecular Weight	MW	g/mol	312	–	–	–	–	Physical property
Vapor Pressure at 25 °C	VP	mmHg	8.3E-06	–	–	–	–	Physical property
Density of BBP	RHO	kg/L	1.1	–	–	–	–	Physical property
Operating Days	OD	days/year	250	–	–	–	–	See Appendix D.4.18
Batch Size	Q _{batch}	kg/batch	4,000	–	–	–	–	See Appendix D.4.19
Drum and Tote Fill Rate	RATE _{fill_drum_tote}	containers/h	20	–	–	–	–	See Appendix D.4.20
Small Container Fill Rate	RATE _{fill_cont}	containers/h	60	–	–	–	–	See Appendix D.4.20
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	2.0E-2	–	–	–	–	See Appendix D.4.21
Diameter of Opening, Equipment Cleaning	D _{equip_clean}	cm	92	–	–	–	–	See Appendix D.4.13
Diameter of Opening, Container Cleaning	D _{cont_clean}	cm	5.1	–	–	–	–	See Appendix D.4.13
Off-Spec and Waste Loss Fraction	LF _{offspec}	kg/kg	1.0E-02	–	–	–	–	See Appendix D.4.22

D.4.3 Number of Sites

EPA used 2020 CDR data ([U.S. EPA, 2020a](#)) to identify the number of sites that may incorporate BBP into adhesive and sealant products. In CDR under industrial use, there were three reporters that identified BBP use in adhesives manufacturing: M. Argueso & Co., Inc., Polymer Additives, Inc., and Tremco Incorporated. The data specified 10-24 industrial use sites for adhesive manufacturing.

D.4.4 Throughput Parameters

EPA estimated the total production volume for all sites using 2020 CDR data ([U.S. EPA, 2020a](#)). One reporting manufacturing site, M. Argueso Co., Inc. reported an overall PV of 5,903 lb/year (2,678 kg/year) for 2019. This value is associated with BBP in pellets/large crystals.

Polymer Additives, Inc. reported their PV as CBI but is estimated to have a PV between 388,885 and 19,388,885 lb/year. This was calculated as the remainder of the aggregate PV after the known CDR PV was subtracted. The site indicates that 80 percent of the manufactured PV is used for adhesives/sealants, with BBP as a liquid in this process.

One site, Tremco Incorporated in Beachwood, OH, indicated an import of 605,212 lb of BBP in 2019 ([U.S. EPA, 2020a](#)). This site matched the name of a site in the Use Report for BBP that produced several products containing BBP, including both paints/coatings and adhesives. Therefore, EPA assumed a 50/50 split of the PV between this OES and the Application of adhesives and sealants OES, which is 302,606 lb (137,260 kg) for each OES.

Table_Apx D-10. Site CDR Volumes Used for the Production Volume Estimate in the Formulation into Adhesives and Sealants OES

Site Name	Overall PV Estimate (lb)	Percent Industrial Use	Estimated PV Contribution to this OES (lb)
Polymer Additives, Inc.	388,855–19,388,885	80	311,084–15,511,108
M. Argueso & Co., Inc.	5,903	100	5,903
Tremco Incorporated	605,212	50	302,606

EPA calculated that the overall PV for use of liquid formulations is $0.8 \times (388,885 - 19,388,885 \text{ lb/year}) + 0.5 \times 605,212 \text{ lb/year} = 613,714 - 15,813,714 \text{ lb/year}$ (278,376–7,172,980 kg/year).

The annual throughput of BBP is calculated using Equation_Apx D-22 by multiplying batch size by the concentration of BBP in the final adhesive product and by operating days. Batch size is determined according to Appendix D.4.19 and operating days is determined according to Appendix D.4.18. EPA assumes the number of batches is equal to the number of operating days.

Equation_Apx D-22.

$$Q_{BBP\_year} = Q_{batch} * OD * F_{BBP\_final} * N_{batch\_day}$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
Q_{batch}	=	Adhesive/sealant batch size (see Appendix D.4.19) (kg/batch)
OD	=	Operating days (see Appendix D.4.18) (days/year)
F_{BBP_final}	=	Concentration of BBP in final adhesive/sealant (see Appendix D.4.8)

$$N_{batch\_day} = \frac{(kg/kg)}{\text{Number of batches per day of adhesive/sealant (default of 1) (batch/day)}}$$

The daily throughput of BBP is calculated using Equation_Apx D-23 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Appendix D.4.18.

Equation_Apx D-23.

$$Q_{BBP\_day} = \frac{Q_{BBP\_year}}{OD}$$

Where:

$$\begin{aligned} Q_{BBP\_day} &= \text{Facility throughput of BBP (kg/site-day)} \\ Q_{BBP\_year} &= \text{Facility annual throughput of BBP (kg/site-year)} \\ OD &= \text{Operating days (see Appendix D.4.18) (days/year)} \end{aligned}$$

D.4.5 Number of Containers per Year

The number of imported BBP containers for solids unloaded by a site per year is calculated using the following equation:

Equation_Apx D-24.

$$N_{cont\_unload\_yr} = \frac{Q_{BBP\_year}}{V_{cont} * F_{BBP\_initial\_1}}$$

Where:

$$\begin{aligned} V_{cont} &= \text{Solid container size (see Appendix D.4.9) (gal)} \\ Q_{BBP\_year} &= \text{Facility annual throughput (kg/site-year)} \\ F_{BBP\_initial\_1} &= \text{Initial BBP concentration (Run 1 – Solid) (kg/kg)} \\ N_{cont\_unload\_year} &= \text{Annual number of containers unloaded (containers/site-year)} \end{aligned}$$

The number of imported BBP containers for liquids unloaded by a site per year is calculated using the following equation:

Equation_Apx D-25.

$$N_{cont\_unload\_year} = \frac{Q_{BBP\_year}}{V_{drum} * 3.79 \frac{L}{gal} * RHO * F_{BBP\_initial\_2}}$$

Where:

$$\begin{aligned} V_{drum} &= \text{Initial container size (see Appendix D.4.9) (gal)} \\ Q_{BBP\_year} &= \text{Facility annual throughput (kg/site-year)} \\ F_{BBP\_initial\_2} &= \text{Initial BBP concentration (Run 2 – Liquid) (kg/kg)} \\ RHO &= \text{BBP density (g/L)} \\ N_{cont\_unload\_year} &= \text{Annual number of containers unloaded (containers/site-year)} \end{aligned}$$

The number of BBP containers for liquids loaded by a site per year is calculated using the following equation:

Equation_Apx D-26.

$$N_{cont\_load\_year} = \frac{Q_{BBP\_year}}{F_{BBP\_final\_adjusted} * V_{cont\_packaged} * 3.79 \frac{L}{gal} * RHO}$$

Where:

Q_{BBP_year}	=	Facility throughput (kg/site-year)
$V_{cont\_packaged}$	=	Packaged container size (see Appendix D.4.9) (gal)
$F_{BBP\_final\_adjusted}$	=	Final BBP adjusted concentration (see Appendix D.4.8) (kg/kg)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (containers/site-year)
RHO	=	Density of BBP (g/L)

The number of BBP containers for solids loaded by a site per year is calculated using the following equation:

Equation_Apx D-27.

$$N_{cont\_load\_year} = \frac{Q_{BBP\_year}}{V_{cont}}$$

Where:

Q_{BBP_year}	=	Facility throughput (kg/site-year)
V_{cont}	=	Solid container size (see Appendix D.4.9) (kg)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (containers/site-year)

D.4.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the ESD for Adhesive Formulation ([OECD, 2009a](#)), ChemSTEER User Guide ([U.S. EPA, 2015](#)), and/or through calculation from other parameters. Release points with operating hours provided from these sources include unloading, container cleaning, blending/process operations, product sampling, equipment cleaning, and loading into transport containers.

For unloading (release point 1), the operating hours are calculated based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-28.

$$OH_{unload\_cont} = \frac{N_{cont\_unload\_year}}{RATE_{fill\_cont} * OD}$$

Where:

OH_{unload_cont}	=	Daily operating hours for unloading containers (h/site-day)
$RATE_{fill\_cont}$	=	Fill rate of containers (see Appendix D.4.20) (containers/h)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (see Appendix D.4.5) (container/site-year)
OD	=	Operating days (see Appendix D.4.18) (days/site-year)

For loading into transport containers (release point 9), the operating hours are calculated based on number of product containers filled per year unless the operating hours per day exceeds 24 hours. If the total operating hours exceeds 24 hours, the duration for loading containers is estimated as the remaining

time after accounting for container unloading. The operating hours are calculated using the following equation:

Equation_Apx D-29.

$$OH_{load\_cont} = \begin{cases} \frac{N_{cont\_load\_year}}{RATE_{fill\_cont} * OD}, & \frac{N_{cont\_load\_year}}{RATE_{fill\_cont} * OD} \leq [24 - OH_{unload\_cont}] \\ 24 - OH_{unload\_cont}, & \frac{N_{cont\_load\_year}}{RATE_{fill\_cont} * OD} > [24 - OH_{unload\_cont}] \end{cases}$$

Where:

OH_{load_cont}	=	Operating time for release point 9 (h/site-day)
$RATE_{fill\_cont}$	=	Fill rate of containers (see Appendix D.4.20) (containers/h)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (see Appendix D.4.5) (container/site-year)
OD	=	Operating days (see Appendix D.4.18) (days/site-year)
OH_{unload_cont}	=	Daily operating hours for unloading containers (h/site-day)

D.4.7 Initial BBP Concentration

EPA modeled the initial solid BBP concentration using a uniform distribution with a lower bound of 1 percent and upper bound of 30 percent and modeled the initial liquid BBP concentration using a uniform distribution with a lower bound of 1 percent and upper bound of 100 percent based on information reported in the 2020 CDR by sites indicating BBP use in adhesives and sealants ([U.S. EPA, 2020a](#)).

D.4.8 Final BBP Concentration

EPA modeled final BBP concentration in adhesives and sealants using a triangular distribution with a lower bound of 0.1 percent and an upper bound of 70 percent with a mode of 10 percent. This value was bound in the model so that it was never higher than the initial concentration of BBP for the model iteration and was identified as $F_{BBP\_final\_adjusted}$.

D.4.9 Container Size

For BBP in solid form, EPA modeled solid containers using a triangular distribution with a lower bound and mode of 25 kg and upper bound of 500 kg. This is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), which states that compounded plastics in pellet form are routinely shipped in containers ranging from 25 kg bags to 500 kg gaylords. EPA assumes that manufacturers ship BBP in powder/pellet in similarly sized containers. EPA converted the mass of the container to volume assuming a density of 1 kg/L. EPA used a volumetric distribution with a lower bound and mode of 7 gallons and an upper bound of 132 gallons.

EPA considered container sizes for solid BBP-containing additive products, including those for adhesives/sealants as well as paints and coatings. Container sizes for the solids containing BBP had capacities ranging from less than 0.1 gallons up to approximately 10 gallons based on available technical data sheets reviewed by EPA (see Appendix E for EPA identified BBP-containing products for this OES).

For BBP in liquid form, EPA modeled drum sizes using a triangular distribution with a lower bound of 20 gallons, an upper bound of 100 gallons, and a mode of 55 gallons. This is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)). For the packaged container size for liquid materials, EPA assumed BBP may be packaged into bottles or other small containers and modeled the size range based on values from the ChemSTEER User Guide ([U.S. EPA, 2015](#)).

According to the ChemSTEER User Guide, bottles are defined as containing between one and five gallons of material with a default bottle size of one gallon, and small containers are defined as containing between five and twenty gallons of material with a default size of five gallons ([U.S. EPA, 2015](#)). EPA modeled container size using a triangular distribution accounting for the identified product container sizes and the ChemSTEER User Guide size ranges. EPA used a lower bound of 0.1 gallons based on an order-of-magnitude estimate for identified product container sizes, an upper bound of twenty gallons based on the upper bound for small containers defined by the ChemSTEER User Guide, and a mode of one gallon based on typical identified container sizes and the default bottle size defined by the ChemSTEER User Guide.

D.4.10 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.4.11 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The Manual also indicates that saturation concentration for bottom filling was expected to be about 0.5. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.4.12 Drum Residual Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pumping in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 1.7 to 4.7 percent and an average of 2.6 percent. The EPA/OPPT Drum Residual Model from the ChemSTEER User Guide recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent ([U.S. EPA, 2015](#)).

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study ([PEI Associates, 1988](#)) for emptying drums by pumping.

D.4.13 Diameters of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities ([U.S. EPA, 2015](#)). For equipment cleaning operations, the ChemSTEER User Guide indicates a single default value of 92 cm ([U.S. EPA, 2015](#)).

For container cleaning activities, the ChemSTEER User Guide indicates a single default value of 5.08 cm for containers less than 5,000 gallons ([U.S. EPA, 2015](#)).

For sampling liquid product, sampling liquid raw material, or general liquid sampling, the ChemSTEER User Guide indicates that the typical diameter of opening for vaporization of the liquid is 2.5 cm ([U.S. EPA, 2015](#)). Additionally, the ChemSTEER User Guide provides 10 cm as a high-end value for the diameter of opening during sampling. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the estimated lower bound, upper bound, and mode of the parameter. EPA assigned the value of 2.5 cm as a lower bound for the parameter and 10 cm as the upper bound based on the values provided in the ChemSTEER User Guide. EPA also assigned 2.5 cm as the mode diameter value for sampling liquids based on the typical value described in that User Guide ([U.S. EPA, 2015](#)).

For blending operations, the ESD for Adhesive Formulation ([OECD, 2009a](#)) and GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) assumes a closed vessel with a 4-inch diameter process vent, corresponding to 10 cm in diameter. In addition, EPA considered the potential for open process vessels used for blending as mentioned in both the ESD for Adhesive Formulation ([OECD, 2009a](#)) and GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)), with diameters of the open vessel calculated based on the batch volume for the simulation iteration and the assumption in the ESD and GS of a one-to-one height to diameter ratio for the process vessel. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution defined by an estimated lower bound, upper bound, and mode of the parameter. EPA assigned the value of 10 cm for both the lower bound and mode of the triangular distribution as the recommended value by the ESD for Adhesive Formulation ([OECD, 2009a](#)) and GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)). For the upper-bound value of the triangular distribution, EPA assigned an equation calculating the diameter of an open process

vessel with a one-to-one height to diameter ratio and fixed batch volume of approximately 1,000 gallons based on the batch size discussed in Appendix D.4.19 and the equation below:

Equation_Apx D-30.

$$D_{blending\_max} = \left[\frac{4 * V_{batch} * 3785.41 \frac{cm^3}{gal}}{\pi} \right]^{1/3}$$

D.4.14 Hours per Batch for Equipment Cleaning

The ESD for Adhesive Formulation ([OECD, 2009a](#)) cites a cleaning time per batch of one to four hours and suggests that a value of four hours per cleaning be used for model defaults. Therefore, EPA modeled this parameter via a triangular distribution with a lower bound of 1 hour/batch, upper bound of 4 hours/batch, and mode of 4 hours/batch.

D.4.15 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Dust Release Model) compiled data for loss fractions of solids from various sources in addition to the capture and removal efficiencies for control technologies in order to estimate releases of dust to the environment. Dust releases estimated from the model are based on three different parameters: the initial loss fraction, the fraction captured by the capture technology, and the fraction removed/controlled by the control technology. The underlying distributions for each of these parameters is not known; therefore, EPA assigned triangular distributions, since triangular distributions require the fewest assumptions and are completely defined by the range and mode of a parameter.

EPA assigned the range and mode for each of the three parameters using the data presented in the Dust Release Model. For the initial loss fraction, EPA assigned a range of 6.0×10^{-6} to 0.045 with a mode of 0.005 by mass. EPA assigned the mode based on the recommended default value for the parameter in the Dust Release Model. The range of initial loss fraction values comes from the range of values compiled from various sources and considered in the development of the Dust Release Model ([U.S. EPA, 2021b](#)).

For the fraction captured, EPA assigned a range of 0 to 1.0 with a mode of 0.963 by mass. EPA assigned the range for the fraction captured based on the minimum and maximum estimated capture efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction captured based on the average of all lower bound estimated capture efficiency values for all capture technologies presented in the model.

For the fraction removed/controlled, EPA assigned a range of 0 to 1.0 with a mode of 0.79 by mass. EPA assigned the range for the fraction controlled based on the minimum and maximum estimated control efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction controlled based on the average of all lower bound estimated control efficiency values for all control technologies presented in the model.

D.4.16 Container Residue Loss Fraction

For solid containers, EPA used the EPA/OPPT Solid Residuals in Transport Containers Model to estimate residual releases from solid container cleaning. The EPA/OPPT Solid Residuals in Transport

Containers Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of one percent from container cleaning.

D.4.17 Sampling Loss Fraction

Sampling loss fractions were estimated using the *March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes* ([U.S. EPA, 2023b](#)). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and Low Volume Exemptions (LVEs). Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites ($\approx 75\%$ of IRERs), were obtained. The data points were analyzed as a function of the chemical daily throughput and industry type. This analysis showed that the sampling loss fraction generally decreased as the chemical daily throughput increased. Therefore, the methodology provides guidance for selecting a loss fraction based on chemical daily throughput. Table_Apx D-11 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-11. Sampling Loss Fraction Data from the March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

Chemical Daily Throughput (kg/site-day) ($Q_{\text{chem\_site\_day}}$)	Number of Data Points	Sampled Quantity (kg chemical/day)		Sampling Loss Fraction (LF_{sampling})	
		50th Percentile	95th Percentile	50th Percentile	95th Percentile
<50	13	0.03	0.20	0.002	0.02
50 to <200	10	0.10	0.64	0.0006	0.005
200 to <5,000	25	0.37	3.80	0.0005	0.004
$\geq 5,000$	10	1.36	6.00	0.00008	0.0004
All	58	0.20	5.15	0.0005	0.008

For each range of daily throughputs, EPA estimated sampling loss fractions using a triangular distribution of the 50th percentile value as the lower bound, and the 95th percentile value as the upper bound and mode. The sampling loss fraction distribution was chosen based on the calculation of daily throughput, as shown in Appendix D.4.4.

D.4.18 Operating Days

EPA was unable to identify BBP-specific information for operating days in the production of adhesives and sealants. Therefore, EPA assumes a constant value of 250 days/year, which assumes the production sites operate 5 days per week and 50 weeks per year, with 2 weeks down for turnaround.

D.4.19 Batch Size

The ESD for Adhesive Formulation ([OECD, 2009a](#)) cites a default batch size of 4,000 kg adhesive per batch with an approximate batch volume of 1,000 gallons.

D.4.20 Container Fill Rates

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical fill rate of 20 containers per hour for containers with 20 to 1,000 gallons of material, a rate of two containers per hour for containers with 1,000 to 10,000 gallons of material, and a typical fill rate of one container per hour for containers with over 10,000 gallons of liquid.

To account for situations where operating times for container unloading and loading exceeded a 24-hour period in the simulation, EPA applied an equation to determine a corrected fill rate that would replace the deterministic values provided in the ChemSTEER User Guide. The equation for the corrected fill rate in cases where operating time for unloading and loading is greater than 24 hours is included below. EPA only used the corrected fill rate for loading product containers (release point 5).

Equation_Apx D-31.

$$\text{if } 24 < (OH_{\text{unload\_cont}} + OH_{\text{load\_cont}}), RATE_{\text{fill\_adjusted}} = \frac{N_{\text{cont\_load\_year}}}{(24 - OH_{\text{unload\_cont}}) * OD}$$

Where:

$RATE_{\text{fill\_adjusted}}$	=	Corrected fill rate for product containers (containers/h)
$N_{\text{cont\_load\_year}}$	=	Annual number of product containers (containers/site-year)
$OH_{\text{unload\_cont}}$	=	Operating time for release point 1 (h/site-day)
$OH_{\text{load\_cont}}$	=	Operating time for release point 9 (h/site-day)
OD	=	Operating days see Appendix D.4.18 (days/site-year)

D.4.21 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. That model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides an overall loss fraction of two percent from equipment cleaning.

D.4.22 Off-Spec Loss Fraction

The ESD for Adhesive Formulation ([OECD, 2009a](#)) and GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) provides a loss fraction of one percent of throughput disposed from off-specification material during manufacturing. The one percent default loss fraction was provided as an estimate from a Source Reduction Research Partnership (SRRP) study referenced in the ESD for Adhesive Formulation ([OECD, 2009a](#)).

D.5 Formulation into Paints and Coatings Model Approaches and Parameters

This appendix presents the modeling approaches and equations used to estimate environmental releases for BBP during the Formulation into paints and coatings OES. This approach utilizes the Generic Scenario for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) and CDR data ([U.S. EPA, 2020d](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD, EPA identified the following release sources from formulation into paints and coatings:

- Release source 1: Transfer Operations Losses to Air from Unloading Imported Product
- Release source 2: Paint Component Container Residue
- Release source 3: Open Surface Losses to Air During Container Cleaning
- Release source 4: Product Sampling Wastes
- Release source 5: Equipment Cleaning
- Release source 6: Filter Waste Losses
- Release source 7: Vented Losses to Air During Dispersion and Blending/Process Operations
- Release source 8: Open Surface Losses to Air During Equipment Cleaning
- Release source 9: Open Surface Losses to Air During Filter Media Replacement
- Release source 10: Transfer Operations Losses to Air from Loading Paint/Coating Component

- Release source 11: Off-Specification and Other Waste Paint

Environmental releases for BBP during Formulation into paints and coatings are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production volume and rate, BBP concentrations, air speed, container size, loss fractions, and operating durations. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.5.1 Model Equations

Table_Apx D-12 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Formulation into paints and coatings OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.5.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-12. Models and Variables Applied for Release Sources in the Formulation into Paints and Coatings OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses to Air from Unloading the Paint Component	EPA/OAQPS AP-42 Loading Model (Appendix D.1)	Vapor Generation Rate: F_{BBP_import} ; V_{cont} ; VP ; f_{sat} ; MW ; R ; T ; $RATE_{fill\_drum\_tote}$ Operating Time: OH_{unload_cont}
Release source 2: Paint Component Container Residue	EPA/OPPT Drum Residual Model (Appendix D.1)	Q_{BBP_year} ; LF_{drum} ; V_{cont} ; RHO ; OD ; $N_{cont\_unload\_day}$
Release source 3: Open Surface Losses to Air During Container Cleaning	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix D.1)	OH_{unload_cont} ; MW ; F_{BBP_import} ; VP ; $RATE_{air\_speed}$; D_{cont_clean}
Release source 4: Product Sampling Wastes	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix D.1)	$LF_{sampling}$; Q_{BBP_day}
Release source 5: Equipment Cleaning	EPA/OPPT Multiple Process Vessel Residual Model (Appendix D.1)	LF_{equip_clean} ; Q_{BBP_day}
Release source 6: Filter Waste Losses	No applicable models for estimation.	N/A
Release source 7: Vented Losses to Air During Dispersion and Blending/Process Operations	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP_final} ; MW ; VP ; $RATE_{air\_speed}$; D_{blend} ; T ; p Operating Time: OH_{blend}

Release Source	Model(s) Applied	Variables Used
Release source 8: Open Surface Losses to Air During Equipment Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP_final} ; MW ; VP ; $RATE_{air\_speed}$; D_{equip_clean} ; T ; P Operating Time: OH_{equip_clean}
Release source 9: Open Surface Losses to Air During Filter Media Replacement	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP_final} ; MW ; VP ; $RATE_{air\_speed}$; D_{filter} ; T ; P Operating Time: OH_{filter}
Release source 10: Transfer Operations Losses to Air from Loading Paint/Coating Component	EPA/OAQPS AP-42 Loading Model (Appendix D.1)	Vapor Generation Rate: F_{BBP_final} ; VP ; f_{sat} ; MW ; R ; T ; $V_{cont\_packaged}$; $RATE_{fill\_adjusted}$ Operating Time: $OH_{load\_cont\_adjusted}$
Release source 11: Off-Specification and Other Waste Paint	See Equation_Apx D-32	Q_{BBP_day} ; $LF_{offspec}$

Release source 11 daily release (off-spec and other waste coating) is calculated using the following equation:

Equation_Apx D-32.

$$Release\_perDay_{RP11} = Q_{DCHP\_day} * LF_{offspec}$$

Where:

$Release\_perDay_{RP11}$	=	BBP released for release source 11 (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (see Appendix D.5.4) (kg/site-day)
$LF_{offspec}$	=	Loss fraction for off-spec and waste adhesive (see Appendix D.5.19) (unitless)

D.5.2 Model Input Parameters

Table_Apx D-13 summarizes the model parameters and their values for the Formulation into Paints and Coatings Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-13. Summary of Parameter Values and Distributions Used in the Formulation into Paints and Coatings Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Number of Sites	N _{sites}	Dimensionless	9	1	9	—	Discrete	See Appendix D.5.3
Total PV of BBP at All Sites	PV _{total}	kg/year	1.4E05	—	—	—	—	See Appendix D.5.4
Filter Media Replacement Duration	OH _{filter}	h/day	1	—	—	—	—	See Appendix D.5.6
Initial BBP Concentration	F _{BBP_import}	kg/kg	0.6	1.0E-2	0.6	—	Uniform	See Appendix D.5.8
Adhesive/ Sealant BBP Concentration	F _{BBP_final}	kg/kg	1.8E-2	1.0E-3	0.6	1.8E-2	Triangular	See Appendix D.5.8
Initial Container Size	V _{drum}	gal	100	20	1000	100	Triangular	See Appendix D.5.9
Packaged Container Size	V _{cont_packaged}	gal	1.0	0.10	100	1.0	Triangular	See Appendix D.5.9
Container Residue Loss Fraction	LF _{cont}	kg/kg	0.01	—	—	—	—	See Appendix D.5.10
Fraction of BBP Lost During Sampling – 1 (Q _{BBP_day} < 50 kg/site-day)	F _{sampling_1}	kg/kg	2.0E-02	2.0E-03	2.0E-02	2.0E-02	Triangular	See Appendix D.5.11
Fraction of BBP Lost During Sampling – 2 (Q _{BBP_day} 50–200 kg/site-day)	F _{sampling_2}	kg/kg	5.0E-03	6.0E-04	5.0E-03	5.0E-03	Triangular	See Appendix D.5.11
Fraction of BBP Lost During Sampling – 3 (Q _{BBP_day} 200–5,000 kg/site-day)	F _{sampling_3}	kg/kg	4.0E-03	5.0E-04	4.0E-03	4.0E-03	Triangular	See Appendix D.5.11
Fraction of BBP Lost During Sampling – 4 (Q _{BBP_day} > 5,000 kg/site-day)	F _{sampling_4}	kg/kg	4.0E-04	8.0E-05	4.0E-04	4.0E-04	Triangular	See Appendix D.5.11
Vapor Pressure at 25 °C	VP	mmHg	8.3E-06	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	312	—	—	—	—	Physical property
Density of BBP	RHO	kg/L	1.1	—	—	—	—	Physical property

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Diameter of Opening – Container Cleaning	D _{cont_clean}	cm	5.1	–	–	–	–	See Appendix D.5.12
Diameter of Opening – Equipment Cleaning	D _{equip_clean}	cm	92	–	–	–	–	See Appendix D.5.12
Diameter of Opening – Filter Media Replacement	D _{filter}	cm	182	–	–	–	–	See Appendix D.5.12
Air Speed	RATE _{air_speed}	ft/min	20	2.6	398	–	Lognormal	See Appendix D.5.13
Saturation Factor	f _{sat}	dimensionless	0.5	0.5	1.5	0.5	Triangular	See Appendix D.5.14
Operating Days	OD	days/year	250	–	–	–	–	See Appendix D.5.15
Batch Size	Q _{batch}	kg/batch	5,030	–	–	–	–	See Appendix D.5.16
Drum and Tote Fill Rate	RATE _{fill_drum_tote}	containers/h	20	–	–	–	–	See Appendix D.5.17
Small Container Fill Rate	RATE _{fill_cont}	containers/h	60	–	–	–	–	See Appendix D.5.17
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	0.02	–	–	–	–	See Appendix D.5.18
Off-Spec and Waste Loss Fraction	LF _{offspec}	kg/kg	1.2E–02	–	–	–	–	See Appendix D.5.19

D.5.3 Number of Sites

EPA used 2020 CDR data ([U.S. EPA, 2020d](#)) to identify the number of sites that may incorporate BBP into paint and coating products. In CDR under industrial use, there was one entry tagged as “Incorporation into formulation, mixture, or reaction product” under use for paints and coatings. The report does not specify number of sites, however; the submission specifies less than 10 workers. Based on this, EPA assumes this operation occurs at 1 to 9 sites (the minimum reportable range for number of sites).

D.5.4 Throughput Parameters

EPA assessed this OES using a single value for potential BBP production volume based on CDR data for paint and coating products ([U.S. EPA, 2020a](#)). One site, Tremco Incorporated in Beachwood, OH, indicated their use of BBP in paint and coating products and reported an import of 605,212 lb of BBP in 2019 ([U.S. EPA, 2020a](#)). This site matched the name of a site in the Use Report for BBP that produced several products containing BBP, including both paints/coatings and adhesives. Therefore, EPA assumed a 50/50 split of the PV between this OES and the Application of adhesives and sealants OES, which is 302,606 lb (137,260 kg) for each OES.

The annual throughput of BBP per facility is calculated using Equation_Apx D-33 by dividing the overall PV for all sites by the number of use sites. The number of sites is determined according to Appendix D.5.3.

Equation_Apx D-33.

$$Q_{BBP\_year} = \frac{PV}{N_{sites}}$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (see Appendix D.5.4) (kg/site-year)
PV	=	Overall annual production volume for BBP in paints/coating products for all sites (kg/year)
N_{sites}	=	Number of paint/coating production sites (see Appendix D.5.3)

The daily throughput of BBP is calculated using Equation_Apx D-34 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Appendix D.5.15.

Equation_Apx D-34.

$$Q_{BBP\_day} = \frac{Q_{BBP\_year}}{OD}$$

Where:

Q_{BBP_day}	=	Facility throughput of BBP (kg/site-day)
Q_{BBP_year}	=	Facility annual throughput of BBP (see Appendix D.5.4) (kg/site-year)
OD	=	Operating days (see Appendix D.5.15) (days/year)

D.5.5 Number of Containers per Year

The number of BBP raw material containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-35.

$$N_{cont\_unload\_year} = \frac{Q_{BBP\_year}}{RHO * F_{BBP\_import} * \left(3.79 \frac{L}{gal}\right) * V_{drum}}$$

Where:

V_{drum}	=	Import container volume (see Appendix D.5.9) (kg/container)
Q_{BBP_year}	=	Facility annual throughput of BBP (see Appendix D.5.4) (kg/site-year)
F_{BBP_import}	=	Initial concentration of BBP (kg/kg) (see Appendix D.5.7)
RHO	=	BBP density (kg/L)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (container/site-year)

The number of product containers loaded by a site per year is calculated using the following equation:

Equation_Apx D-36.

$$N_{cont\_load\_year} = \frac{Q_{BBP\_year}}{RHO * F_{BBP\_final} * \left(3.79 \frac{L}{gal}\right) * V_{cont\_packaged}}$$

Where:

$V_{cont\_packaged}$	=	Product container volume (see Appendix D.5.9) (gal/container)
Q_{BBP_year}	=	Facility annual throughput of BBP (see Appendix D.5.4) (kg/site-year)
F_{BBP_final}	=	Initial concentration of BBP (kg/kg) (see Appendix D.5.8)
RHO	=	BBP density (kg/L)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (container/site-year)

D.5.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)), ESD for Adhesive Formulation ([OECD, 2009a](#)), ChemSTEER User Guide ([U.S. EPA, 2015](#)), and/or through calculation from other parameters. Release points with operating hours provided from these sources include unloading, container cleaning, blending/process operations, product sampling, equipment cleaning, filter media replacement, and loading into transport containers.

For unloading (release point 1), the operating hours are calculated based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-37.

$$OH_{unload\_cont} = \frac{N_{cont\_unload\_year}}{RATE_{fill\_drum\_tote} * OD}$$

Where:

OH_{unload_cont}	=	Daily operating time for unloading containers (release point 1) (h/day)
$RATE_{fill\_drum\_tote}$	=	Fill rate of drums and totes (see Appendix D.5.17) (containers/h)

$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (see Appendix D.5.5) (container/site-year)
OD	=	Operating days (see Appendix D.5.15) (days/site-year)

For blending (release point 7), the operating hours are calculated based on number batches blended per day unless the operating hours per day exceeds 24 hours. The operating hours are calculated using the following equation:

Equation_Apx D-38.

$$OH_{blend} = \left(8 \frac{hours}{batch}\right) * N_{batch\_day}$$

Where:

OH_{blend}	=	Daily operating hours for blending (h/day)
N_{batch_day}	=	Batches per day (see Appendix D.5.5) (container/site-year)

The annual operating hours for blending are calculated using the following equation:

Equation_Apx D-39.

$$OH_{blend\_year} = OH_{blend} * OD$$

Where:

OH_{blend_year}	=	Annual operating hours for blending (h/year)
OD	=	Operating days (see Appendix D.5.15) (days/year)
OH_{blend}	=	Daily operating hours for blending (h/day)

For equipment cleaning (release point 8), the operating hours are calculated based on the number of batches per day unless the operating hours per day exceeds 24 hours. The operating hours are calculated using the following equation:

Equation_Apx D-40.

$$OH_{equip\_clean} = N_{batch\_day} * OH_{batch\_equip\_clean}$$

Where:

OH_{equip_clean}	=	Daily operating hours for equipment cleaning (h/day)
$OH_{batch\_equip\_clean}$	=	Hours per batch for equipment cleaning (h/batch)
N_{batch_day}	=	Batches per day (see Appendix D.5.5) (container/site-year)

The annual operating hours for equipment cleaning are calculated using the following equation:

Equation_Apx D-41.

$$OH_{equip\_clean\_year} = OH_{equip\_clean} * OD$$

Where:

$OH_{equip\_clean\_year}$	=	Annual operating hours for equipment cleaning (h/year)
OH_{equip_clean}	=	Daily operating hours for equipment cleaning (h/day)
OD	=	Operating days (see Appendix D.5.15) (days/year)

For loading into transport containers (release point 10), the operating hours are calculated using the following equation:

Equation_Apx D-42.

$$OH_{load\_cont} = \frac{N_{cont\_load}}{OD * RATE_{fill\_cont}}$$

Where:

OH_{load_cont}	=	Operating hours for loading of containers (h/day)
$RATE_{fill\_cont}$	=	Fill rate of containers, dependent on volume (see Appendix D.5.17) (containers/h)
N_{cont_load}	=	Number of containers loaded per day (see Appendix D.5.5) (container/site-year)
OD	=	Operating days (see Appendix D.5.15) (days/site-year)

D.5.7 Initial BBP Concentration

Based on information reported in the 2020 CDR by sites indicating BBP use in paints and coatings, BBP is contained in coating products in concentrations of 1 to 30 percent (see Appendix E for EPA identified BBP-containing products for this OES) ([U.S. EPA, 2020a](#)). However, several product SDSs listed BBP concentrations that exceeded the 30 percent maximum that was reported in CDR, with some products reporting a maximum BBP concentration of 60 percent. Because of this, EPA increased the maximum concentration for paint/coating products to 60 percent, for a final BBP initial concentration range of 1 to 60 percent modeled using a uniform distribution.

D.5.8 Final BBP Concentration

EPA modeled the final BBP concentration in paints and coatings using a triangular distribution with a lower bound of 0.01 percent, upper bound of 60 percent, and mode of 1.75 percent. This is based on compiled SDS information for paint and coating products containing BBP. The lower and upper bounds represent the minimum and maximum reported concentrations in the SDSs. The mode represents the mode of all range endpoints reported in the SDSs (see Appendix E for EPA identified BBP-containing products for this OES).

To avoid cases where the BBP concentration in the initial material exceeded the concentration in the finished product while modeling, EPA adjusted the concentration of the finished product to bind it to a maximum concentration equal to the concentration of the initial material.

D.5.9 Container Size

EPA assumed that paint and coating manufacturing sites would receive BBP in drums. According to the ChemSTEER User Guide, drums are defined as containing between 20 and 100 gallons of liquid, and the default drum size is 55 gallons ([U.S. EPA, 2015](#)). Therefore, EPA modeled import container size using a triangular distribution with a lower bound of 20 gallons, an upper bound of 100 gallons, and a mode of 55 gallons.

Container sizes for additive products containing BBP had capacities ranging from less than 0.1 gallons up to approximately 100 gallons based on available technical data sheets reviewed by EPA (see Appendix E for EPA identified BBP-containing products for this OES). Additionally, EPA considered default container size ranges for bottles, small containers, and drums identified in the ChemSTEER User Guide. According to the ChemSTEER User Guide, bottles are defined as containing between one and five gallons of material with a default bottle size of one gallon. Small containers are defined as containing between 5 and 20 gallons of material with a default size of 5 gallons. Drums are defined as

containing between 20 and 100 gallons of material with a default drum size of 55 gallons ([U.S. EPA, 2015](#)). EPA modeled container size using a triangular distribution accounting for the identified product container sizes and the ChemSTEER User Guide size ranges. Specifically, EPA used a lower bound of 0.1 gallons based on for the minimum identified product container size, an upper bound of 100 gallons based on the upper bound for drums defined by the ChemSTEER User Guide, and a mode of 1 gallon based on typical identified container sizes and the default bottle size defined by the ChemSTEER User Guide.

D.5.10 Drum Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pumping in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 1.7 percent to 4.7 percent and an average of 2.6 percent. The EPA/OPPT Drum Residual Model from the ChemSTEER User Guide recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent ([U.S. EPA, 2015](#)).

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study ([PEI Associates, 1988](#)) for emptying drums by pumping.

D.5.11 Sampling Loss Fraction

Sampling loss fractions were estimated using the March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes ([U.S. EPA, 2023b](#)). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and LVEs. Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites ($\approx 75\%$ of IRERs), were obtained. The data points were analyzed as a function of the chemical daily throughput and industry type. This analysis showed that the sampling loss fraction generally decreased as the chemical daily throughput increased. Therefore, the methodology provides guidance for selecting a loss fraction based on chemical daily throughput. Table_Apx D-14 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-14. Sampling Loss Fraction Data from the March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

Chemical Daily Throughput (kg/site-day) ($Q_{chem\_site\_day}$)	Number of Data Points	Sampled Quantity (kg chemical/day)		Sampling Loss Fraction ($LF_{sampling}$)	
		50th Percentile	95th Percentile	50th Percentile	95th Percentile
<50	13	0.03	0.20	0.002	0.02
50 to <200	10	0.10	0.64	0.0006	0.005
200 to <5,000	25	0.37	3.80	0.0005	0.004
≥5,000	10	1.36	6.00	0.00008	0.0004
All	58	0.20	5.15	0.0005	0.008

For each range of daily throughputs, EPA estimated sampling loss fractions using a triangular distribution of the 50th percentile value as the lower bound, and the 95th percentile value as the upper bound and mode. The sampling loss fraction distribution was chosen based on the calculation of daily throughput, as shown in Appendix D.5.4.

D.5.12 Diameters of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities ([U.S. EPA, 2015](#)). For equipment cleaning operations, the ChemSTEER User Guide indicates a single default value of 92 cm ([U.S. EPA, 2015](#)). For container cleaning activities, the ChemSTEER User Guide indicates a single default value of 5.08 cm for containers less than 5,000 gallons ([U.S. EPA, 2015](#)). For filter media replacement, the ChemSTEER User Guide indicates a single default value of 182.4 cm.

For sampling liquid product, sampling liquid raw material, or general liquid sampling, the ChemSTEER User Guide indicates that the typical diameter of opening for vaporization of the liquid is 2.5 cm ([U.S. EPA, 2015](#)). Additionally, the ChemSTEER User Guide provides 10 cm as a high-end value for the diameter of opening during sampling ([U.S. EPA, 2015](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the estimated lower bound, upper bound, and mode of the parameter. EPA assigned the value of 2.5 cm as a lower bound for the parameter and 10 cm as the upper bound based on the values provided in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA also assigned 2.5 cm as the mode diameter value for sampling liquids based on the typical value described in ChemSTEER User Guide ([U.S. EPA, 2015](#)).

For blending operations, the ESD for Adhesive Formulation ([OECD, 2009a](#)) and GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) assumes a closed vessel with a 4-inch diameter process vent, corresponding to 10 cm in diameter. In addition, EPA considered the potential for open process vessels used for blending as mentioned in both the ESD for Adhesive Formulation ([OECD, 2009a](#)) and GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)), with diameters of the open vessel calculated based on the batch volume for the simulation iteration and the assumption in the ESD and GS of a one-to-one height to diameter ratio for the process vessel. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution defined by an estimated lower bound, upper bound, and mode of the parameter. EPA assigned the value of 10 cm for both the lower bound and mode of the triangular distribution as the recommended value by the ESD for Adhesive Formulation ([OECD, 2009a](#)) and GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)). For the upper bound value of the triangular distribution, EPA assigned an equation calculating the diameter of an open process

vessel with a one-to-one height to diameter ratio and fixed batch volume of approximately 1,000 gallons based on the batch size discussed in Appendix D.5.16:

Equation_Apx D-43.

$$D_{blending\_max} = \left[\frac{4 * V_{batch} * 3785.41 \frac{cm^3}{gal}}{\pi} \right]^{1/3}$$

D.5.13 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.5.14 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([CEB, 1991](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.5.15 Operating Days

EPA was unable to identify BBP-specific information for operating days in the production of paints and coatings. The GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) assumes a constant value

of 250 days/year, which assumes the production sites operate 5 days per week and 50 weeks per year, with two weeks down for turnaround.

D.5.16 Batch Size

The GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) cites a default batch size of 5,030 kg coatings per batch with an approximate batch volume of 1,000 gallons.

D.5.17 Container Fill Rates

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical fill rate of 20 containers per hour for containers with 20 to 100 gallons of liquid and a typical fill rate of 60 containers per hour for containers with less than 20 gallons of liquid.

To account for situations where operating times for container unloading and loading exceeded a 24-hour period in the simulation, EPA applied an equation to determine a corrected fill rate that would replace the deterministic values provided in the ChemSTEER User Guide. The equation for the corrected fill rate in cases where operating time for unloading and loading is greater than 24 hours is included below. EPA only used the corrected fill rate for loading product containers (release point 10).

Equation_Apx D-44.

$$\text{if } 24 < (OH_{RP1}), RATE_{fill\_adjusted} = \frac{N_{cont\_load\_year}}{(24 - OH_{RP1}) * OD}$$

Where:

$RATE_{fill\_adjusted}$	=	Corrected fill rate for product containers (containers/h)
$N_{cont\_load\_year}$	=	Annual number of product containers (containers/site-year)
OH_n	=	Operating time for release point “n” (h/site-day)
OD	=	Operating days (days/site-year)

D.5.18 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. That model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides an overall loss fraction of 2 percent from equipment cleaning.

D.5.19 Off-Spec Loss Fraction

The GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) provides a loss fraction of 1.2 percent of throughput disposed from off-specification material during manufacturing. This 1.2 percent default loss fraction was provided as an estimate from a Source Reduction Research Partnership (SRRP) study referenced in the GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)).

D.6 Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Incorporation into other formulations, mixtures, and reaction products not covered elsewhere OES. This approach utilizes the same equations and assumptions presented for Formulation into paints and coatings in Appendix D.5. Therefore, only the parameters that differ between approaches, which includes the throughput parameters, number of formulation sites, and the final product BBP concentrations, will be presented in this section for brevity.

D.6.1 Throughput Parameters

EPA estimated the total BBP production volume for these other formulated materials using a discrete value of 22,813 kg/year. This value is based on BBP CDR data and reporting thresholds for CDR reporters. CDR reports require a site to report processing and use for a chemical if the usage exceeds 5 percent of its reported PV or if the use exceeds 25,000 lb per year (whichever is smaller). EPA assumed that all unique sites reporting to CDR manufactured or imported BBP for other formulation end-uses up to the reporting threshold limit. Using these volume estimates, EPA calculated the total BBP production volume for these products at 50,295.15 lb/year (22,813 kg/year).

Table_Apx D-15. Site CDR Volumes Used for the Production Volume Estimate in the Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere OES

Reporting Year	Site Name	Estimated PV Contribution to this OES (lb)
2020	M. Argueso & Co., Inc.	295.15
2020	Polymer Additives, Inc.	25,000
2020	Tremco Incorporated	25,000

D.6.2 Number of Sites

The number of sites is calculated using the following equation.:

Equation_Apx D-45.

$$N_s = \frac{PV}{Q_{\text{formulation site\_year\_GS}} \times F_{BBP}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume (see Appendix 4.2D.6.1) (kg/year)
$Q_{\text{formulation site-year,GS}}$	=	Facility annual throughput of formulated product estimate per the GS (1.6–16 million kg/site-year)
F_{BBP}	=	Weight fraction of BBP in the formulation (see Appendix D.6.3)

The GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) provides two estimates for overall paint/coating production rates. For architectural coatings, the GS estimates 16 million kg of coatings/site-year. For special purpose coatings, the GS estimates 1.6 million kg of coatings/site-year. EPA estimated the number of sites using this PV range, multiplying the production rates by the concentration range of BBP in the final products (see Appendix D.6.3) and capping the production rate at the total annual PV across all sites (see Appendix D.6.1). To calculate the overall range, EPA multiplied the minimum formulation throughput by the minimum BBP concentration and the maximum formulation throughput by the maximum BBP concentration. Because the maximum calculation resulted in a BBP throughput greater than the PV assessed for this OES, EPA assessed at a max of 22,813 kg/site-year.

Using this range of BBP site throughputs and Equation_Apx D-50, the number of sites was estimated to be one site.

D.6.3 Final BBP Concentration

EPA modeled final BBP concentration in other articles using a triangular distribution with a lower bound of 0.1 percent, upper bound of 100 percent, and mode of 0.65 percent. The lower and upper bounds and the mode are based on compiled SDS information for formulation products containing BBP (see Appendix E for EPA identified BBP-containing products for this OES). From the compiled data, the minimum concentration was 0.1 percent, the max was 100 percent, and the mode was 0.65 percent based on the median of all the endpoint ranges.

D.7 Non-PVC Material Compounding and Converting Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Non-PVC materials compounding and Non-PVC materials converting OESs. This approach utilizes the Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)), the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), Emission Scenario Document on Additives in Rubber Industry ([OECD, 2004a](#)), and CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the GS, EPA identified the following release sources from Non-PVC materials compounding, with differences between assessments for solid BBP-containing additives and liquid BBP-containing additives:

- Release source 1: Transfer Operations Losses from Unloading Plastics Additives (liquids only)
- Release source 2: Dust Generation from Transfer Operations (solids only)
- Release source 3: Container Residue Losses
- Release source 4: Open Surface Losses to Air During Container Cleaning (liquids only)
- Release source 5: Vapor Emissions from Blending/Compounding
- Release source 6: Equipment Cleaning Losses
- Release source 7: Direct Contact Cooling Water Losses
- Release source 8: Release of Additives during Loading

Based on the GS, EPA identified the following release sources from non-PVC materials converting:

- Release source 1: Transfer Operations Losses from Unloading Plastics Additives
- Release source 2: Container Residue Losses
- Release source 3: Vapor Emissions During Converting
- Release source 4: Particulate Emissions During Converting
- Release source 5: Equipment Cleaning Losses
- Release source 6: Direct Contact Cooling Water Losses
- Release source 7: Solid Wastes from Trimming Operations

Environmental releases for BBP during non-PVC materials production are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: BBP concentrations, operating days, number of sites, container size, air speeds, saturation factor, loss fractions, and dust control/capture efficiencies. Additionally, EPA conducted an assessment for two compounding scenarios: one in which the BBP-containing additive is a solid, and another in which the BBP-containing additive is a liquid. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.7.1 Model Equations

Table_Apx D-16 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the non-PVC materials OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.7.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-16. Models and Variables Applied for Release Sources in the Non-PVC Materials OES

Release Source	Model(s) Applied	Variables Used
Compounding		
Release source 1: Transfer Operations Losses from Unloading Plastics Additives (liquids only)	EPA/OAQPS AP-42 Loading Model (Appendix D.1)	Vapor Generation Rate: $F_{BBP\_MFG\_L}$; VP ; f_{sat} ; MW ; R ; T ; V_{drum} ; $RATE_{fill}$ Operating Time: Q_{BBP_day} ; $F_{BBP\_MFG\_L}$; V_{drum} ; RHO ; $RATE_{fill}$
Release source 2: Dust Generation from Transfer Operations (solids only)	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix D.1)	Q_{BBP_day} ; $F_{dust\_generation}$; $F_{dust\_capture}$; $F_{dust\_control\_filter}$; $F_{dust\_control\_scrubber}$; OD_{comp}
Release source 3: Container Residue Losses	EPA/OPPT Drum Residual Model or EPA/OPPT Bulk Transport Residual Model, based on container size (Appendix D.1)	Q_{BBP_day} ; LF_{drum} ; LF_{solid} ; V_{cont} ; V_{drum} ; $F_{BBP\_MFG\_L}$; $F_{BBP\_MFG\_S}$; OD_{comp} ; RHO
Release source 4: Open Surface Losses to Air During Container Cleaning (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: $F_{BBP\_MFG\_L}$; MW ; VP ; $RATE_{air\_speed}$; D_{cont} ; T ; P Operating Time: $OH_{unload\_day\_comp}$
Release source 5: Vapor Emissions from Blending/Compounding	See Equation_Apx D-46	Q_{BBP_day} ; $F_{vapor\_emissions}$
Release source 6: Equipment Cleaning Losses	EPA/OPPT Multiple Process Vessel Residual Model (Appendix D.1)	Q_{BBP_day} ; LF_{equip_clean}
Release source 7: Direct Contact Cooling Water Losses	See Equation_Apx D-48	Q_{BBP_day} ; $F_{cooling\_water}$
Release source 8: Release of Additives During Loading	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading	Q_{BBP_day} ; $F_{dust\_generation}$; $F_{dust\_capture}$; $F_{dust\_control\_filter}$; $F_{dust\_control\_scrubber}$; OD_{comp}

Release Source	Model(s) Applied	Variables Used
	Operations of Solid Powders (Appendix D.1)	
Converting		
Release source 1: Transfer Operations Losses from Unloading Plastics Additives	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix D.1)	$Q_{BBP\_day}; F_{dust\_generation}; F_{dust\_capture}; F_{dust\_control\_filter}; F_{dust\_control\_scrubber}; OD_{conv}$
Release source 2: Container Residue Losses	EPA/OPPT Solid Residuals in Transport Containers Model (Appendix D.1)	$Q_{BBP\_year}; LF_{solid}; V_{cont}; F_{BBP\_prod}; N_{cont\_unload\_year}; OD_{conv}$
Release source 3: Vapor Emissions During Converting	See Equation_Apx D-46	$Q_{BBP\_day}; F_{vapor\_emissions}; OD_{conv}$
Release source 4: Particulate Emissions During Converting	See Equation_Apx D-47	$Q_{BBP\_day}; F_{particulate\_emissions}; OD_{conv}$
Release source 5: Equipment Cleaning Losses	EPA/OPPT Multiple Process Vessel Residual Model (Appendix D.1)	$Q_{BBP\_day}; LF_{equip\_clean}; OD_{conv}$
Release source 6: Direct Contact Cooling Water Losses	See Equation_Apx D-48	$Q_{BBP\_day}; F_{cooling\_water}; OD_{conv}$
Release source 7: Solid Wastes from Trimming Operations	See Equation_Apx D-49	$Q_{BBP\_day}; F_{trimming}; OD_{conv}$

Compounding and converting release source 3 daily release (vapor emissions during compounding/converting) is calculated using the following equation:

Equation_Apx D-46.

$$Release\_perDay_{RP5/3} = Q_{BBP\_day} * F_{vapor\_emissions}$$

Where:

$$\begin{aligned}
 Release\_perDay_{RP5/3} &= \text{BBP released for release source 5 (compounding) and 3 (converting) (kg/site-day)} \\
 Q_{BBP\_day} &= \text{Facility throughput of BBP (see Appendix D.7.4) (kg/site-day)} \\
 F_{vapor\_emissions} &= \text{Fraction of BBP lost from volatilization during compounding/converting operations (see Appendix D.7.20) (kg/kg)}
 \end{aligned}$$

Converting release source 4 daily release (Particulate Emissions from Converting) is calculated using the following equation:

Equation_Apx D-47.

$$Release\_perDay_{RP4} = Q_{BBP\_day} * F_{particulate\_emissions}$$

Where:

$$\begin{aligned}
 Release\_perDay_{RP4} &= \text{BBP released for converting release source 4 (kg/site-day)} \\
 Q_{BBP\_day} &= \text{Facility throughput of BBP (see Appendix D.7.4) (kg/site-day)} \\
 F_{particulate\_emissions} &= \text{Fraction of BBP lost as particulates during converting operations}
 \end{aligned}$$

(see Appendix D.7.15) (kg/kg)

Compounding release source 6 and converting release source 7 daily releases (Direct Contact Cooling Water Losses) are calculated using the following equation:

Equation_Apx D-48.

$$Release\_perDay_{RP7/6} = Q_{BBP\_day} * F_{cooling\_water}$$

Where:

$Release\_perDay_{RP7/6}$	=	BBP released for release source 7 (compounding) and 6 (converting) (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (see Appendix D.7.4) (kg/site-day)
$F_{cooling\_water}$	=	Cooling water loss fraction (see Appendix D.7.19) (kg/kg)

Converting release source 7 daily release (Solid Wastes from Trimming Operations) is calculated using the following equation:

Equation_Apx D-49.

$$Release\_perDay_{RP7} = Q_{BBP\_day} * F_{trimming}$$

Where:

$Release\_perDay_{RP7}$	=	BBP released for release source 7 (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (see Appendix D.7.3) (kg/site-day)
$F_{trimming}$	=	Trimming loss fraction (see Appendix D.7.21) (kg/kg)

D.7.2 Model Input Parameters

Table_Apx D-17 and summarizes the model parameters and their values for the Non-PVC Materials Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-17. Summary of Parameter Values and Distributions Used in the Non-PVC Materials Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Number of Sites	N _{sites}	sites	24	10	24	–	Uniform	See Appendix D.7.3
Manufactured BBP Concentration – Liquids	F _{BBP_MFG_L}	kg/kg	1.0	1.0E–02	1.0	–	Uniform	See Appendix D.7.7
Manufactured BBP Concentration – Solids	F _{BBP_MFG_S}	kg/kg	0.30	1.0E–02	0.30	–	Uniform	See Appendix D.7.7
Non-PVC Materials BBP Concentration	F _{BBP_prod}	kg/kg	0.20	0.10	0.20	–	Uniform	See Appendix D.7.8
Operating Days – Compounding	OD _{comp}	days/year	246	147	301	246	Triangular	See Appendix D.7.9
Operating Days – Converting	OD _{conv}	days/year	253	136	255	253	Triangular	See Appendix D.7.9
Air Speed	RATE _{air_speed}	ft/min	20	2.6	398	–	Lognormal	See Appendix D.7.10
Saturation Factor	f _{sat}	dimensionless	0.50	0.50	1.45	0.50	Triangular	See Appendix D.7.11
Liquid Container Size	V _{drum}	gal	55	20	100	55	Triangular	See Appendix D.7.12
Solid Container Size	V _{cont}	kg	25	25	499	25	Triangular	See Appendix D.7.12
Drum Residue Loss Fraction	LF _{drum}	kg/kg	2.5E–02	3.0E–03	3.0E–02	2.5E–02	Triangular	See Appendix D.7.13
Fraction of Chemical Lost During Transfer of Solid Powders	F _{dust_generation}	kg/kg	5.0E–03	1.0E–03	3.0E–02	5.0E–03	Triangular	See Appendix D.7.14
Capture Efficiency for Dust Capture Methods	F _{dust_capture}	kg/kg	0.96	0	1.0	0.9633	Triangular	See Appendix D.7.14
Control Efficiency for Dust Filters	F _{dust_control_filter}	kg/kg	0.99	0.97	0.99999	0.99	Triangular	See Appendix D.7.14
Control Efficiency for Wet Scrubbers	F _{dust_control_scrubber}	kg/kg	0.55	0.20	0.995	0.55	Triangular	See Appendix D.7.14

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Fraction of BBP Lost as Particulates During Converting Processes	F _{particulate_emissions}	kg/kg	6.0E-05	2.0E-05	1.0E-04	6.0E-05	Triangular	See Appendix D.7.15
Vapor Pressure at 25 °C	VP	mmHg	8.25E-06	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	312.37	–	–	–	–	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	–	–	–	–	Universal constant
Density of BBP	RHO	kg/L	1.119	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1.0	–	–	–	–	Process parameter
Total PV of BBP at All Sites	PV	kg/year	22,813	–	–	–	–	See Appendix D.7.3
Solid Container Loss Fraction	LF _{cont}	kg/kg	1.0E-02	–	–	–	–	See Appendix D.7.13
Drum and Tote Fill Rate	RATE _{fill_drum}	containers/h	20	–	–	–	–	See Appendix D.7.16
Small Container Fill Rate	RATE _{fill_cont}	containers/h	60	–	–	–	–	See Appendix D.7.16
Container Diameter of Opening	D _{cont}	cm	5.08	–	–	–	–	See Appendix D.7.17
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	2.0E-02	–	–	–	–	See Appendix D.7.18
Cooling Water Loss Fraction	F _{cooling_water}	kg/kg	1.0E-02	–	–	–	–	See Appendix D.7.19
Fraction of the Chemical of Interest Lost from Volatilization	F _{vapor_emissions_open}	kg/kg	1.0E-04	–	–	–	–	See Appendix D.7.20

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
During Forming and Molding Processes (Open Process)								
Fraction of the Chemical of Interest Lost from Volatilization During Forming and Molding Processes (Closed Process)	F _{vapor_emissions_closed}	kg/kg	2.0E-05	–	–	–	–	See Appendix D.7.20
Trimming Loss Fraction	F _{trimming}	kg/kg	2.5E-02	–	–	–	–	See Appendix D.7.21

D.7.3 Production Volume and Number of Sites

EPA estimated the total BBP production volume for non-PVC materials using a discrete value of 22,813 kg/year. This value is based on BBP CDR data and reporting thresholds for CDR reporters. CDR reports require a site to report processing and use for a chemical if the usage exceeds 5 percent of its reported PV or if the use exceeds 25,000 lb per year (whichever is smaller). No sites reporting to CDR listed the manufacture of rubber as a downstream use for BBP; therefore, EPA assumed that all unique sites reporting to CDR manufactured or imported BBP for rubber end-uses up to the reporting threshold limit. Using these volume estimates, EPA calculated the total BBP production volume for non-PVC materials at 50,295.15 lb/year (22,813 kg/year).

Table_Apx D-18. Site CDR Volumes Used for the Production Volume Estimate in the Non-PVC Materials Compounding and Converting OES

Reporting Year	Site Name	Estimated PV Contribution to this OES (lb)
2020	M. Argueso & Co., Inc.	295.15
2020	Polymer Additives, Inc.	25,000
2020	Tremco Incorporated	25,000

EPA estimated the number of sites for non-PVC material compounding and converting as a uniform distribution of 10 to 24 sites based on the number of downstream industrial sites reported under the “Plastics Product Manufacturing” industrial sector in CDR for BBP ([U.S. EPA, 2020a](#)). While this number of sites is attributed to PVC plastics compounding and converting, EPA used the same range of sites based on similarities between PVC plastics and non-PVC materials industries. EPA calculated the per-site throughput based on this assumption for BBP production volume and number of sites as shown in Appendix D.7.4.

D.7.4 Throughput Parameters

For compounding and converting, the annual throughput of BBP per site is calculated by dividing the production volume of BBP for these OESs by the number of sites as shown in Equation_Apx D-50. The production volume and number of sites are determined according to Appendix D.7.3.

Equation_Apx D-50.

$$Q_{BBP\_year} = \frac{PV}{N_{sites}}$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
N_{sites}	=	Number of sites (see Appendix D.7.3) (sites)
PV	=	Production volume (see Appendix D.7.3) (kg/year)

For both OESs, the daily throughput of BBP is calculated using Equation_Apx D-51 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Appendix D.7.9.

Equation_Apx D-51.

$$Q_{BBP\_day} = \frac{Q_{BBP\_year}}{OD_{comp/conv}}$$

Where:

Q_{BBP_day}	=	Facility throughput of BBP (kg/site-day)
Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
$OD_{comp/conv}$	=	Operating days for either compounding or converting (based on the specific OES assessed) (see Appendix D.7.9) (days/year)

D.7.5 Number of Containers per Year

The number of BBP raw material containers received and unloaded by a site per year is calculated using one of two equations, based on the physical form of the raw material:

Equation_Apx D-52.

$$\left\{ \begin{array}{ll} \text{if liquid,} & N_{cont\_unload\_year} = \frac{Q_{BBP\_year}}{V_{drum} * F_{BBP\_MFG} * \frac{3.79L}{gal} * RHO} \\ \text{if solid,} & N_{cont\_unload\_year} = \frac{Q_{BBP\_year}}{V_{cont} * F_{BBP\_MFG}} \end{array} \right.$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (see Appendix D.7.4) (kg/site-year)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (container/site-year)
V_{cont}	=	Container mass for solid BBP raw material (see Appendix D.7.12) (kg/container)
V_{drum}	=	Container volume for liquid BBP raw material (see Appendix D.7.12) (gal/container)
F_{BBP_MFG}	=	BBP mass fraction in raw material (see Appendix D.7.7) (kg/kg)
RHO	=	BBP density (g/L)

The number of compounded plastic product containers loaded (for compounding) or unloaded (for converting) by a site per year is calculated using the following equation:

Equation_Apx D-53.

$$N_{cont\_load\_year} = \frac{Q_{BBP\_year}}{V_{cont} * F_{BBP\_prod}}$$

Where:

V_{cont}	=	Product container mass (see Appendix D.7.12) (kg/container)
Q_{BBP_year}	=	Facility annual throughput of BBP (see Appendix D.7.4) (kg/site-year)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (container/site-year)
F_{BBP_prod}	=	Mass fraction of BBP in final product (see Appendix D.7.8) (kg/kg)

D.7.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the 2021 Use of Additives in Plastic Compounding Draft Generic Scenario ([U.S. EPA, 2021c](#)), 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), ChemSTEER User Guide ([U.S. EPA, 2015](#)),

and/or through calculation from other parameters. Release points with operating hours provided from these sources include unloading, compounding, converting, and loading into transport containers.

For unloading during compounding and raw material container cleaning (compounding release points 1 and 4), the operating hours are calculated only for liquid raw materials and are based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-54.

$$OH_{RP1\&4} = \frac{N_{cont\_unload\_year}}{RATE_{fill\_drum} * OD_{comp}}$$

Where:

$OH_{RP1\&4}$	=	Operating time for compounding release points 1 and 4 (h/site-day)
$RATE_{fill\_drum}$	=	Fill rate of drums (see Appendix D.7.16) (containers/h)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (see Appendix D.7.5) (container/site-year)
OD_{comp}	=	Operating days for compounding (see Appendix D.7.9) (days/year)

For loading during compounding (release point 8) and unloading during converting (release point 1), the operating hours are calculated based on the number of containers loaded/unloaded at the site, the loading rate for the given container size (see volume ranges below), and the number of operating days using the following equation:

Equation_Apx D-55.

$$\begin{cases} \text{if } < 20 \text{ gallons,} & OH_{RP8/1} = \frac{N_{cont\_load\_year}}{RATE_{fill\_cont} * OD_{comp/conv}} \\ \text{if } \geq 20 \text{ gallons,} & OH_{RP8/1} = \frac{N_{cont\_load\_year}}{RATE_{fill\_drum} * OD_{comp/conv}} \end{cases}$$

Where:

$OH_{RP8/1}$	=	Operating time for compounding release point 8 and converting release point 1 (h/site-day)
$RATE_{fill\_cont}$	=	Fill rate of containers (see Appendix D.7.16) (containers/h)
$RATE_{fill\_drum}$	=	Fill rate of drums (see Appendix D.7.16) (containers/h)
$N_{cont\_load\_year}$	=	Annual number of containers loaded (see Appendix D.7.5) (container/site-year)
$OD_{comp/conv}$	=	Operating days for compounding or converting (see Appendix D.7.9) (days/year)

For compounding and converting operations (release point 5 for compounding, 3 and 4 for converting), EPA assumes compounding and converting occurs for the entirety of a work-shift and assigns a duration of 8 hours/day. EPA did not have data on operating times for other release points.

D.7.7 Initial BBP Concentration

EPA modeled the initial BBP concentration using a uniform distribution, with a different range for solid raw materials and liquid raw materials. For the solid raw materials, EPA used a lower bound of 1 percent and an upper bound of 30 percent based on information reported in the 2020 CDR with the physical form “Pellets or Large Crystals” ([U.S. EPA, 2020a](#)). For liquid raw materials, EPA used a lower bound of 1 percent and an upper bound of 100 percent since information reported in the 2020 CDR with the physical form “Liquid” showed either a concentration of 1 to <30 percent or 90+ percent ([U.S. EPA, 2020a](#)).

D.7.8 Fraction of BBP in Compounded Non-PVC Materials

EPA modeled final BBP concentration in non-PVC materials using a uniform distribution with a lower bound of 10 percent and upper bound of 20 percent. This is based on the Emission Scenario Document on Additives in Rubber Industry ([OECD, 2004a](#)). The ESD states that plasticizers for rubber additives are expected to be present at 10-20 percent for rubber products.

D.7.9 Operating Days

For compounding, EPA modeled the operating days per year using a triangular distribution with a lower bound of 148 days/year, an upper bound of 300 days/year, and a mode of 246 days/year. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 148-300 days/year. The lower bound is based on the 2014 Plastics Compounding Draft Generic Scenario ([U.S. EPA, 2014b](#)). The generic scenario states that a typical range of 148-264 days/year are assumed. The upper bound is based on ESIG’s Specific Environmental Release Category for Rubber Production and Processing ([ESIG, 2020](#)). The SpERC indicates a default of 300 days/year for rubber manufacturing. The mode is based on the 2021 Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)), which states that 246 days/year should be used as a default.

For converting, EPA modeled the operating days per year using a triangular distribution with a lower bound of 137 days/year, an upper bound of 254 days/year, and a mode of 253 days/year. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 137 to 254 days/year. The lower and upper bounds are based on the 2014 Use of Additives in the Thermoplastic Converting Industry Draft GS ([U.S. EPA, 2014c](#)), which states 137 to 254 days/year should be assumed. The mode is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), which states that an average value of 253 days/year should be used as a default.

D.7.10 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors’ observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.7.11 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([CEB, 1991](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.7.12 Container Size

EPA assumed that non-PVC material manufacturing sites would receive liquid BBP raw material in drums. The ChemSTEER User Guide provides 55 gallons as the default drum size and a range of volumes from 20 to 100 gallons ([U.S. EPA, 2015](#)). EPA developed a triangular distribution for liquid BBP raw material containers using these values, with a mode of 55 gallons and a range of 20 to 100 gallons.

EPA assumed that non-PVC material manufacturing sites would receive solid BBP raw material and package compounded plastics in containers with capacities ranging in size from 24.95 kg to 498.95 kg. These container sizes are based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), which states that compounded plastics in pellet form are routinely shipped in containers ranging from 55-lb bags to 1,100-lb gaylord boxes. EPA developed a triangular distribution for BBP raw material and compounded plastic container sizes using these values, with the lower bound and mode set equal to 24.95 kg and an upper bound of 498.95 kg.

D.7.13 Container Residue Loss Fractions

The EPA/OPPT Drum Residual Model from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent.

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum

value for the triangular distribution using the central tendency residual fraction value prescribed by the ChemSTEER User Guide for pouring from containers ([U.S. EPA, 2015](#)).

D.7.14 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Dust Release Model) compiled data for loss fractions of solids from various sources in addition to the capture and removal efficiencies for control technologies in order to estimate releases of dust to the environment. Dust releases estimated from the model are based on three different parameters: the initial loss fraction, the fraction captured by the capture technology, and the fraction removed/controlled by the control technology. The underlying distributions for each of these parameters is not known; therefore, EPA assigned triangular distributions, since triangular distribution requires least assumptions and is completely defined by range and mode of a parameter.

EPA assigned the range and mode for each of the three parameters using the data presented in the Dust Release Model. For the initial loss fraction, EPA assigned a range of 0.001 to 0.03 with a mode of 0.005 by mass. EPA assigned the mode based on the recommended default value for the parameter in the Dust Release Model. The range of initial loss fraction values comes from the range of values compiled from various sources and considered in the development of the Dust Release Model ([U.S. EPA, 2021b](#)).

For the fraction captured, EPA assigned a range of 0 to 1.0 with a mode of 0.9633 by mass. EPA assigned the upper bound for the fraction captured based on the maximum estimated capture efficiency listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction captured based on the average of all lower bound estimated capture efficiency values for all capture technologies presented in the model, since potential capture technologies are unknown. EPA assigned 0 for the lower bound because there is potential for some sites to have no capture technology in operation ([U.S. EPA, 2021b](#)).

For the fraction removed/controlled, the 2021 Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)) and 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)) state that many facilities collect fugitive dust emissions in filters or utilize wet scrubbers. Therefore, EPA used two triangular distributions: a distribution for filter efficiency, and a distribution for wet scrubber efficiency. Each control technology distribution has an equal probability of being selected during each iteration of the simulation. The triangular distribution for filter efficiency has a lower bound of 0.97, upper bound of 0.99999, and mode of 0.99. The triangular distribution for wet scrubber efficiency has a lower bound of 0.20, upper bound of 0.995, and mode of 0.55. These distributions are based on the minimum, maximum, and default values presented for each control technology in the Dust Release Model ([U.S. EPA, 2021b](#)).

D.7.15 Fraction of BBP Lost as Particulates During Converting Processes

EPA modeled the loss fraction of particulate BBP during converting using a triangular distribution with a lower bound of 2.0×10^{-5} kg/kg, upper bound of 1.0×10^{-4} kg/kg, and mode of 6.0×10^{-5} kg/kg. This is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)). The GS presents loss fractions for “Other or unknown unreacted additive types” for three types of converting: open process (1.0×10^{-4} kg/kg), partially open process (6.0×10^{-5} kg/kg), or closed process (2.0×10^{-5} kg/kg). EPA used these loss fractions to build the triangular distribution based on magnitude of the values, with the loss fraction for a partially open process set as the mode of the triangular distribution. The distribution does not reflect prevalence of each type of process in the industry.

D.7.16 Container Fill Rates

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides typical fill rates of 20 containers per hour for containers with 20 to 100 gallons of liquid, and 60 containers per hour for containers with less than 20 gallons of liquid. EPA assumed the density of BBP, or 1.119 kg/L, for applying the container fill rates to containers holding solids.

D.7.17 Diameter of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities ([U.S. EPA, 2015](#)). For container cleaning operations, the ChemSTEER User Guide indicates a single default value of 5.08 cm ([U.S. EPA, 2015](#)).

D.7.18 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA/OPPT Multiple Process Residual Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of two percent from equipment cleaning.

D.7.19 Cooling Water Loss Fraction

The 2021 Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)) and 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)) state that if direct contact cooling water is used for compounding/converting, that the EPA/OPPT Single Vessel Residual Model should be used to estimate releases. The EPA/OPPT Single Vessel Residual Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of one percent residual in equipment. This model is intended for equipment; however, in the context of losses to contact cooling water, using this model assumes one percent of the batch size remains available on plastic resin (*e.g.*, extruded pellets, granules) being cooled and is transferred to the cooling water, which is discharged from the site ([U.S. EPA, 2014c](#)).

D.7.20 Vapor Emissions Loss Fraction

For compounding, EPA used the applicable vapor emission loss fraction presented in the 2021 Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)), with BBP assessed as a plasticizer additive with a low volatility (<0.2 torr at 200°C). The GS assigned a loss fraction of 0.002 percent to plasticizers with low volatility during blending/compounding activities.

For converting, EPA used the applicable vapor emission loss fractions presented in the 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)), with BBP assessed as a plasticizer additive with a low volatility (<0.2 torr at 200°C). The GS assigned loss fractions of 0.002 percent for closed converting processes and 0.01 percent for open converting processes with low volatility plasticizers. Each converting process type (open or closed) has an equal probability of being selected during each iteration of the simulation. EPA assessed both vapor emissions and particulate emissions during converting due to the melting point of BBP being above room temperature and below 200°C.

D.7.21 Trimming Loss Fraction

The 2021 Use of Additives in Plastics Converting Draft Generic Scenario ([U.S. EPA, 2021d](#)) recommends a default trimming loss fraction of 0.025 kg/kg.

D.8 PVC Plastics Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the PVC plastics compounding and PVC plastics converting OESs. This approach utilizes a majority of the same equations and assumptions presented for non-PVC materials in Appendix D.7. Therefore, only the equations and parameters that differ between approaches, including production volume, number of sites, total additive use rates and fractions, and BBP concentrations, will be presented in this section for brevity.

Based on identified products in CDR, BBP is assumed to be primarily imported as a liquid. Therefore, solid releases are not assessed, unlike non-PVC materials compounding. EPA identified the following release sources from PVC plastics compounding.

- Release source 1: Transfer Operations Losses to Air from Unloading Plastics Additives (liquids only)
- Release source 2: Container Residue Losses to Water, Incineration, or Landfill
- Release source 3: Open Surface Losses to Air During Container Cleaning (liquids only)
- Release source 4: Vapor Emissions from Blending/Compounding to Fugitive or Stack Air
- Release source 5: Equipment Cleaning Losses to Water, Landfill, or Incineration
- Release source 6: Direct Contact Cooling Water Losses to Water
- Release source 7: Release of Additives during Loading Released to Air, or Collected and Released to Water, Incineration, or Landfill

The release sources from PVC plastics converting are identical to those presented in Appendix D.7.

D.8.1 Production Volume

EPA estimated the total BBP production volume for plastics using a uniform distribution with a lower bound of 35,279 kg/year and an upper bound of 1,758,930 kg/year. This range is based on BBP CDR data of site production volumes, national aggregate production volumes, and percentages of the production volumes going to various industrial sectors.

CDR data for BBP provides a national aggregate production volume of 1,000,000 to 20,000,000 lb/year. One site, Polymer Additives, Inc. in Bridgeport, NJ, reported an industrial sector of “Plastics Product Manufacturing”. This site reported a CBI production value in 2019 ([U.S. EPA, 2020a](#)). The potential PV for this site was calculated by taking the national aggregate production volume and subtracting the reported non-CBI PVs from all other sites. Polymer Additives, Inc. reported to CDR that 20 percent of their PV will be used in plastic product manufacturing, so the resulting number was multiplied by this 20 percent ([U.S. EPA, 2020a](#)). The total PV of BBP across all sites was therefore estimated to be 77,777 to 3,877,777 lb (35,279–1,758,930 kg).

EPA’s estimated use volumes for the site were the following:

Table_Apx D-19. Site CDR Volumes Used for the Production Volume Estimate in the Plastics Compounding and Converting OES

Site Name	Overall PV Estimate (lb)	Percent Industrial Use	Estimated PV Contribution to this OES (lb)
Polymer Additives, Inc.	388,855 – 19,388,885	20%	77,777 – 3,877,777

D.8.2 Throughput Parameters and Number of Sites

For PVC plastics compounding, the annual throughput of BBP is calculated using Equation_Apx D-56 by multiplying the annual use rate of all plastics additives by the concentration of BBP in the final article and dividing by the mass fraction of all additives in the compounded plastic resin. Annual use rate of all plastics additives is determined according to Appendix D.8.5, concentration of BBP in the final article is determined according to Appendix D.8.4, and mass fraction of all additives in compounded resin is determined according to Appendix D.8.6.

Equation_Apx D-56.

$$Q_{BBP\_year} = \frac{Q_{additives\_year} * F_{BBP\_resin}}{F_{additives\_resin}}$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
$Q_{additives\_year}$	=	Annual use rate of all plastic additives (see Appendix D.8.5) (kg/site-year)
F_{BBP_resin}	=	Concentration of BBP in final plastic (see Appendix D.8.4) (kg/kg)
$F_{additives\_resin}$	=	Mass fraction of all additives in the compounded plastic resin (see Appendix D.8.6) (kg/kg)

For compounding, the number of sites is calculated by dividing the production volume of BBP for these OESs by the facility annual throughput of BBP as shown in the equation below. The production volume is determined according to Appendix D.8.1.

Equation_Apx D-57.

$$N_{sites} = \frac{PV}{Q_{BBP\_year}}$$

Where:

N_{sites}	=	Number of sites (sites)
Q_{BBP_year}	=	Facility annual throughput of BBP (see Equation_Apx D-56) (kg/site-year)
PV	=	Production volume (see Appendix D.8.1) (kg/year)

D.8.3 Initial BBP Concentration

EPA modeled the initial BBP concentration using a uniform distribution with a lower bound of 90 percent and an upper bound of 100 percent based on information reported in the 2020 CDR, with a concentration range of 90+ percent listed by reporters ([U.S. EPA, 2020a](#)). The single CDR entry with industrial sector “Plastics Product Manufacturing” showed a concentration range of 90+ percent, so EPA used a single uniform distribution covering the full range of possible concentrations.

D.8.4 Fraction of BBP in Compounded Plastic Resin

EPA modeled the mass fraction of BBP in compounded plastic resin using a uniform distribution with a lower bound of 0.3 and an upper bound of 0.45. This is based on the Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)). The GS provides a range of 0.3 to 0.45 for the typical weight fraction of plasticizers in rigid PVC.

D.8.5 Annual Use Rate of All Plastic Additives During Compounding

The Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)) estimates that the annual facility use rate of all plastic additives at compounding sites is 4,319,048 kg additives/site-year. This was calculated by dividing the annual U.S. demand for plastics additives by the number of sites estimated in the GS.

D.8.6 Mass Fraction of All Additives in Compounded Plastic Resin

EPA modeled the mass fraction of additives in compounded plastic resin using a uniform distribution with a lower bound of 0.49 and an upper bound of 0.87. This is based on the 2021 Generic Scenario for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021c](#)). The GS provides a range of 0.49 to 0.87 for the fraction of additives in flexible PVC.

D.8.7 Container Size

EPA assumed that PVC plastic manufacturing sites would receive liquid BBP raw material in drums or totes. The ChemSTEER User Guide provides 55 gallons as the default drum size and a range of volumes from 20 to 100 gallons ([U.S. EPA, 2015](#)). For totes, the ChemSTEER User Guide provides a range of volumes from 100 to 1,000 gallons. EPA developed a triangular distribution for liquid BBP raw material containers using these values, with a mode of 55 gallons and a range of 20 to 1,000 gallons.

D.8.8 Bulk Container Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying tanks by gravity-draining was aligned with the default central tendency and high-end values from the EPA/OPPT Bulk Transport Residual Model. For unloading tanks by gravity-draining in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.02 percent to 0.19 percent and an average of 0.06 percent ([PEI Associates, 1988](#)). The EPA/OPPT Bulk Transport Residual Model from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) recommends a default central tendency loss fraction of 0.07 percent and a high-end loss fraction of 0.2 percent.

The underlying distribution of the loss fraction parameter for bulk containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Bulk Transport Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study for emptying tanks by gravity-draining ([PEI Associates, 1988](#)).

D.9 Application of Adhesives and Sealants Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Application of adhesives and sealants OES. This approach utilizes the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)) combined with Monte Carlo simulation (a type of stochastic simulation). EPA assessed this OES with BBP arriving on site as an additive in liquid adhesive or sealant formulations. In addition, all identified products are in liquid form, so solid releases are not assessed.

Based on the ESD, EPA identified the following release sources from the application of adhesives and sealants:

- Release source 1: Transfer Operation Losses from Unloading
- Release source 2: Container Cleaning Residue
- Release source 3: Open Surface Losses to Air During Container Cleaning
- Release source 4: Equipment Cleaning Releases
- Release source 5: Open Surface Losses to Air During Equipment Cleaning
- Release source 6: Process Releases During Adhesive Applications
- Release source 7: Open Surface Losses to Air During Curing/Drying
- Release source 8: Trimming Wastes

Environmental releases for BBP during use of adhesives and sealants are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: product throughput, BBP concentrations, air speed, container size, loss fractions, control technology efficiencies, and operating days. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.9.1 Model Equations

Table_Apx D-20 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the use of adhesives and sealants OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.9.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-20. Models and Variables Applied for Release Sources in the Application of Adhesives and Sealants OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses from Unloading	EPA/OAQPS AP-42 Loading Model (Appendix D.1)	Vapor Generation Rate: f_{sat} ; MW ; VP ; $RATE_{fill\_cont}$; F_{BBP} ; T ; R ; V_{cont} Operating Time: $N_{cont\_unload\_day}$; $RATE_{fill\_cont}$
Release source 2: Container Cleaning Residues	EPA/OPPT Drum Residual Model or EPA/OPPT Bulk Transport Residual Model, based on container size (Appendix D.1)	Q_{BBP_day} ; $F_{drum\_residue}$; $F_{cont\_residue}$; V_{cont} ; F_{BBP} ; RHO
Release source 3: Open Surface Losses to Air During Container Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP} ; MW ; VP ; $RATE_{air\_speed}$; $D_{opening\_cont}$; T ; P Operating Time: $N_{cont\_unload\_day}$; $RATE_{fill\_cont}$

Release Source	Model(s) Applied	Variables Used
Release source 4: Equipment Cleaning Releases	EPA/OPPT Multiple Process Vessel Residual Model (Appendix D.1)	$Q_{BBP\_day}; F_{equipment\_cleaning}$
Release source 5: Open Surface Losses to Air During Equipment Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: $F_{BBP}; MW; VP;$ $RATE_{air\_speed}; D_{opening\_equip}; T; P$ Operating Time: OH_{equip_clean}
Release source 6: Open Surface Losses to Air During Adhesive Application	Unable to estimate due to lack of substrate surface area data.	N/A
Release source 7: Open Surface Losses to Air During Curing/Drying	Unable to estimate due to a lack of the required data for BBP pertaining to curing times and conditions.	N/A
Release source 8: Trimming Wastes	See Equation_Apx D-58	$Q_{BBP\_day}; F_{trimming}$

Release source 8 daily release (Trimming Wastes) is calculated using the following equation:

Equation_Apx D-58.

$$Release\_perDay_{RP8} = Q_{BBP\_day} * F_{trimming}$$

Where:

$$\begin{aligned}
 Release\_perDay_{RP8} &= \text{BBP released for release source 8 (kg/site-day)} \\
 Q_{BBP\_day} &= \text{Facility throughput of BBP (see Appendix D.9.4) (kg/site-day)} \\
 F_{trimming} &= \text{Fraction of BBP released as trimming waste} \\
 &\quad \text{(see Appendix D.9.14) (kg/kg)}
 \end{aligned}$$

D.9.2 Model Input Parameters

Table_Apx D-21 summarizes the model parameters and their values for the Application of Adhesives and Sealants Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-21. Summary of Parameter Values and Distributions Used in the Application of Adhesives and Sealants Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
BBP Production Volume for Adhesives/ Sealants	PV	kg/year	3,728,356	281,054	7,175,658	—	Uniform	See Appendix D.9.3
Annual Facility Throughput of Adhesive/Sealant	Q _{product_year}	kg/site-year	13,500	1,500	141,498	13,500	Triangular	See Appendix D.9.4
Operating Hours for Equipment Cleaning	OH _{equip_clean}	hr/day	4	—	—	—	—	See Appendix D.9.7
Adhesive/ Sealant BBP Concentration	F _{BBP}	kg/kg	0.1	1.0E-03	0.7	0.1	Triangular	See Appendix D.9.8
Operating Days	OD	days/year	260	50	365	260	Triangular	See Appendix D.9.9
Air Speed	RATE _{air_speed}	ft/min	20	2.6	398	—	Lognormal	See Appendix D.9.10
Container Volume	V _{cont}	gal	55	0.10	100	55	Triangular	See Appendix D.9.11
Container Residual Loss Fraction	F _{cont_residue}	kg/kg	3.0E-03	3.0E-04	6.0E-03	3.0E-03	Triangular	See Appendix D.9.12
Drum Residual Loss Fraction	F _{drum_residue}	kg/kg	2.5E-02	1.7E-02	3.0E-02	2.5E-02	Triangular	See Appendix D.9.13
Fraction of BBP Released as Trimming Waste	F _{trimming}	kg/kg	4.0E-02	0	4.0E-02	4.0E-02	Triangular	See Appendix D.9.14
Vapor Pressure at 25 °C	VP	mmHg	8.25E-06	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	312	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82	—	—	—	—	Universal constant
Density of BBP	RHO	kg/L	1.1	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Small Container Fill Rate	RATE _{fill_cont}	containers/h	60	—	—	—	—	See Appendix D.9.15

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Drum Fill Rate	RATE _{fill_drum}	containers/h	20	—	—	—	—	See Appendix D.9.15
Saturation Factor	f _{sat}	dimensionless	0.50	0.50	1.5	0.50	Triangular	See Appendix D.9.16
Diameter of Opening – Equipment Cleaning	D _{opening_equip}	cm	92	—	—	—	—	See Appendix D.9.17
Diameter of Opening – Container Cleaning	D _{opening_cont}	cm	5.1	—	—	—	—	See Appendix D.9.17
Equipment Cleaning Loss Fraction	F _{equipment_cleaning}	kg/kg	2.0E-02	—	—	—	—	See Appendix D.9.18

D.9.3 Production Volume and Number of Sites

EPA estimated the total BBP production volume for adhesive and sealant products using a uniform distribution with a lower bound of 281,054 kg/year and an upper bound of 7,175,658 kg/year. This range is based on BBP CDR data of site production volumes, national aggregate production volumes, and percentages of the production volumes going to various industrial sectors.

Three CDR reporters were used to calculate the total production volume. One site, M. Argueso & Co. in Muskegon, MI, reported a commercial use in machinery/appliances/electrical articles, indicating either an adhesive or a polymer used in these articles. This site reported an import PV of 5,903 lb ([U.S. EPA, 2020a](#)). The second site, Polymer Additives, Inc. in Bridgeport, NJ, is a manufacturer that reported their PV as CBI, but is estimated to have a PV between 388,885 to 19,388,885 lb. The site indicates that 80 percent of the manufactured PV is used for adhesives/sealants. The third site, Tremco Incorporated in Beachwood, OH, indicated their use of BBP in paint and coating products and reported an import of 605,212 lb of BBP in 2019 ([U.S. EPA, 2020a](#)). This site matched the name of a site in the Use Report for BBP that produced several products, including both paints/coatings and adhesives. Therefore, since this last site uses BBP in the formulation of both products, a 50/50 split of the PV between these uses is assumed. EPA's estimated use volumes for the sites were the following:

Table_Apx D-22. Site CDR Volumes Used for the Production Volume Estimate in the Application of Adhesives and Sealants OES

Site Name	Overall PV Estimate (lb)	Percent Industrial Use	Estimated PV Contribution to this OES (lb)
Polymer Additives, Inc.	388,855–19,388,885	80	311,084–15,511,108
M. Argueso & Co., Inc.	5,903	100	5,903
Tremco Incorporated	605,212	50	302,606

The total PV of BBP across all sites was therefore estimated to be 613,714 to 15,813,714 lb (281,054–7,175,658 kg).

D.9.4 Throughput Parameters

The annual throughput of adhesive and sealant product is modeled using a triangular distribution with a lower bound of 1,500 kg/year, an upper bound of 141,498 kg/year, and mode of 13,500 kg/year. This is based on the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)). The ESD provides default adhesive use rates based on end-use category. EPA compiled the end-use categories that were relevant to downstream uses for adhesives and sealants containing BBP, which included computer and electronic product manufacturing, motor and non-motor vehicles, vehicle parts and tire manufacturing, and general assembly. The lower and upper bound adhesive use rates for these categories were 1,500 to 141,498 kg/year. The mode is based on the ESD default for unknown end-use markets. The annual throughput of BBP in adhesives/sealants is calculated using Equation_Apx D-59 by multiplying the annual throughput of all adhesives and sealants by the concentration of BBP in the adhesives/sealants.

Equation_Apx D-59.

$$Q_{BBP\_year} = Q_{product\_year} * F_{BBP}$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
$Q_{product\_year}$	=	Facility annual throughput of all adhesives/sealants (kg/site-year)

$$F_{BBP} = \text{Concentration of BBP in adhesives/sealants (see Appendix D.9.8) (kg/kg)}$$

The daily throughput of BBP is calculated using Equation_Apx D-60 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Appendix D.9.9.

Equation_Apx D-60.

$$Q_{BBP\_day} = \frac{Q_{BBP\_year}}{OD}$$

Where:

$$\begin{aligned} Q_{BBP\_day} &= \text{Facility daily throughput of BBP (kg/site-day)} \\ Q_{BBP\_year} &= \text{Facility annual throughput of BBP (kg/site-year)} \\ OD &= \text{Operating days (see Appendix D.9.9) (days/year)} \end{aligned}$$

D.9.5 Number of Sites

Per 2020 U.S. Census Bureau data for the NAICS codes identified in the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)), there are 10,144 adhesive and sealant use sites ([U.S. BLS, 2016](#)). Therefore, this value is used as a bounding limit, not to be exceeded by the calculation. Number of sites is calculated using a per-site throughput and total production volume with the following equation:

Equation_Apx D-61.

$$N_s = \frac{PV_{total}}{Q_{BBP\_year}}$$

Where:

$$\begin{aligned} N_s &= \text{Number of sites (sites)} \\ PV_{total} &= \text{BBP production volume for adhesives/sealants (kg/year)} \\ Q_{BBP\_year} &= \text{Facility annual throughput of BBP (kg/site-year)} \end{aligned}$$

D.9.6 Number of Containers per Year

The number of BBP raw material containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-62.

$$N_{cont\_unload\_year} = \frac{Q_{product\_year}}{RHO * \left(3.79 \frac{L}{gal}\right) * V_{cont}}$$

Where:

$$\begin{aligned} N_{cont\_unload\_year} &= \text{Annual number of containers unloaded (container/site-year)} \\ Q_{product\_year} &= \text{Facility annual throughput of all adhesives/sealants (see Appendix D.9.4) (kg/site-year)} \\ RHO &= \text{BBP density (g/L)} \\ V_{cont} &= \text{Container volume (see Appendix D.9.11) (gal/container)} \end{aligned}$$

D.9.7 Operating Hours

EPA estimated operating hours or hours of release duration using data provided from the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)), ChemSTEER User Guide ([U.S. EPA, 2015](#)), and/or through calculation from other parameters.

For container unloading and container cleaning (release points 1 and 3), the operating hours are calculated based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-63.

$$OH_{RP1\&3} = \frac{N_{cont\_unload\_year}}{RATE_{fill\_cont} * OD}$$

Where:

$OH_{RP1\&3}$	=	Operating time for release points 1 and 3 (h/site-day)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (see Appendix D.9.6) (container/site-year)
$RATE_{fill\_cont}$	=	Container fill rate (see Appendix D.9.15) (containers/h)
OD	=	Operating days (see Appendix D.9.9) (days/site-year)

For equipment cleaning (release point 5), the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)) states that the default operating hours for equipment cleaning is four hours/batch multiplied by the number of batches per day. Per the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)), the default number of batches per day is one. Therefore, EPA assumes that equipment cleaning occurs for four hours/day.

D.9.8 Adhesive/ Sealant BBP Concentration

EPA determined BBP concentrations in final adhesive/sealant products using compiled SDS information (see Appendix E for EPA identified BBP-containing products for this OES). For final adhesive/sealant products, EPA developed the triangular distribution of BBP concentration using a lower bound of 0.1 percent, an upper bound of 70 percent, and a mode of 10 percent. The lower and upper bounds are based on the minimum and maximum concentrations compiled from SDS for multiple adhesives and sealant products containing BBP, excluding products with 0 percent or 100 percent BBP. The mode is based on the overall median of all low-end and high-end values of the provided product ranges.

D.9.9 Operating Days

EPA modeled the operating days per year using a triangular distribution with a lower bound of 50 days/year, an upper bound of 365 days/year, and a mode of 260 days/year. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 50 and 365 days/year. This is based on the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)). The ESD provides operating days for several end-use categories, as listed in Appendix D.9.3. The range of operating days for the end-use categories is 50 to 365 days/year. The mode of the distribution is based on the ESD's default of 260 days/year for unknown or general use cases.

D.9.10 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities.

EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.9.11 Container Size

Container sizes for additive products containing BBP had capacities ranging from less than 0.1 gallons up to approximately 100 gallons based on available technical data sheets reviewed by EPA (see Appendix E for EPA identified BBP-containing products for this OES). Additionally, EPA considered default container size ranges for bottles, small containers, and drums identified in the ChemSTEER User Guide. According to the ChemSTEER User Guide, bottles are defined as containing between one and five gallons of material with a default bottle size of one gallon. Small containers are defined as containing between five and twenty gallons of material with a default size of five gallons. Drums are defined as containing between twenty and 100 gallons of material with a default drum size of 55 gallons ([U.S. EPA, 2015](#)). EPA modeled container size using a triangular distribution accounting for the identified product container sizes and the ChemSTEER User Guide size ranges. Specifically, EPA used a lower bound of 0.1 gallons based on for the minimum identified product container size, an upper bound of 100 gallons based on the upper bound for drums defined by the ChemSTEER User Guide, and a mode of 55 gallon based on typical identified container sizes and the default drum size defined by the ChemSTEER User Guide.

D.9.12 Small Container Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying drums by pouring was aligned with the default central tendency and high-end values from the EPA/OPPT Small Container Residual Model. For unloading drums by pouring in the PEI Associates Inc. study ([PEI Associates, 1988](#)), EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.03 percent to 0.79 percent and an average of 0.32 percent. The EPA/OPPT Small Container Residual Model from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent.

The underlying distribution of the loss fraction parameter for small containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Small Container Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study ([PEI Associates, 1988](#)) for emptying drums by pouring.

D.9.13 Drum Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pumping in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 1.7 percent to 4.7 percent and an average of 2.6 percent. The EPA/OPPT Drum Residual Model from the ChemSTEER User Guide recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent ([U.S. EPA, 2015](#)).

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study ([PEI Associates, 1988](#)) for emptying drums by pumping.

D.9.14 Fraction of BBP Released as Trimming Waste

EPA modeled the fraction of BBP released as trimming waste using a triangular distribution with a lower bound of 0, an upper bound of 0.04, and a mode of 0.04. This is based on the Emission Scenario Document on Use of Adhesives ([OECD, 2015](#)). The ESD states that trimming losses should only be assessed if trimming losses are expected for the end-use. Since not all adhesive and sealant end uses will result in trimming losses, EPA assigned a lower bound of 0. The upper bound and mode are based on the ESD's default waste fraction of 0.04 kg chemical in trimmings/kg chemical applied.

D.9.15 Container Fill Rate

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical fill rate of 20 containers per hour for containers with 20 to 100 gallons of liquid and a typical fill rate of 60 containers per hour for containers with less than 20 gallons of liquid.

D.9.16 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([CEB, 1991](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.9.17 Diameter of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities ([U.S. EPA, 2015](#)). For equipment cleaning operations, the ChemSTEER User Guide indicates a single default value of 92 cm ([U.S. EPA, 2015](#)). For container cleaning activities, the ChemSTEER User Guide indicates a single default value of 5.08 cm for containers less than 5,000 gallons ([U.S. EPA, 2015](#)).

D.9.18 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. That model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of 2 percent from equipment cleaning.

D.10 Application of Paints and Coatings Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Application of paints and coatings OES. This approach utilizes the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry ([OECD, 2011a](#)), ESD on the Coating Industry (Paints, Lacquers, and Varnishes) ([OECD, 2009c](#)), and ESD on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating ([OECD, 2011b](#)) combined with Monte Carlo simulation (a type of stochastic simulation). BBP is used to formulate standard liquid paints and coatings, as well as components of two-part coating systems. All product SDSs identified indicate that BBP is present in liquid form (see Appendix E for EPA identified BBP-containing products for this OES). EPA modeled spray application as opposed to other application methods because it provides a more protective estimate of releases and exposures, with the prevalence of each application method unknown for BBP-containing coatings. Based on the ESDs, EPA identified the following release sources from the application of paints and coatings:

- Release source 1: Transfer Operation Losses from Unloading
- Release source 2: Open Surface Losses to Air During Raw Material Sampling
- Release source 3: Container Cleaning Wastes
- Release source 4: Open Surface Losses to Air During Container Cleaning
- Release source 5: Process Releases During Application Operations
- Release source 6: Equipment Cleaning Wastes
- Release source 7: Open Surface Losses to Air During Equipment Cleaning
- Release source 8: Raw Material Sampling Wastes

Environmental releases for BBP during the application of paints and coatings are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production volume, paint and coating throughput, BBP concentrations, air speed, container size, loss fractions, control technology efficiencies, transfer efficiency, and operating days. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.10.1 Model Equations

Table_Apx D-23 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Application of paints and

coatings OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.10.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-23. Models and Variables Applied for Release Sources in the Application of Paints and Coatings OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses from Unloading	EPA/OAQPS AP-42 Loading Model (Appendix D.1)	Vapor Generation Rate: F_{BBP} ; VP ; f_{sat} ; MW ; R ; T ; V_{cont} ; $RATE_{fill\_cont}$ Operating Time: Q_{BBP_year} ; $RATE_{fill\_cont}$; $RATE_{fill\_drum}$; V_{cont} ; RHO ; F_{BBP} ; OD
Release source 2: Open Surface Losses to Air During Raw Material Sampling	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP} ; MW ; VP ; $RATE_{air\_speed}$; $D_{opening\_sample}$; T ; P Operating Time: $OH_{sampling}$
Release source 3: Container Cleaning Wastes	EPA/OAQPS AP-42 Small Container Residual Model (Appendix D.1)	Q_{BBP_day} ; $F_{cont\_residue}$; $F_{drum\_residue}$; RHO ; F_{BBP} ; V_{cont}
Release source 4: Open Surface Losses to Air During Container Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP} ; MW ; VP ; $RATE_{air\_speed}$; $D_{opening\_cont}$; T ; P Operating Time: Q_{BBP_year} ; $RATE_{fill\_cont}$; $RATE_{fill\_drum}$; V_{cont} ; RHO ; F_{BBP} ; OD
Release source 5: Process Releases During Operations	See Equation_Apx D-64. through Equation_Apx D-68	Q_{BBP_day} ; $F_{transfer\_eff}$; $F_{capture\_eff}$; $F_{solidrem\_eff}$
Release source 6: Equipment Cleaning Wastes	EPA/OPPT Multiple Process Vessel Residual Model (Appendix D.1)	Q_{BBP_day} ; LF_{equip_clean}
Release source 7: Open Surface Losses to Air During Equipment Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP} ; MW ; VP ; $RATE_{air\_speed}$; $D_{opening\_equip}$; T ; P Operating Time: OH_{equip_clean}
Release source 8: Raw Material Sampling Wastes	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix D.1)	Q_{BBP_day} ; $LF_{sampling}$

Release source 5 (Process Releases During Operations) is partitioned out by release media depending upon the paint and coating overspray control technology employed. EPA modeled two scenarios: one scenario in the absence of control technology with a total release from release source 5 to unknown

media (i.e., a release to fugitive air, water, incineration, or landfill), and one scenario with control technology and releases partitioned to land, stack air, or water for release source 5 based on capture and removal efficiencies. In order to calculate the total release from release source 5, the following equation was used:

Equation_Apx D-64.

$$Release\_perDay_{RP5\_total} = Q_{BBP\_day} * (1 - F_{transfer\_eff})$$

Where:

$Release\_perDay_{RP5\_total}$	=	BBP released for release source 5 to all release media (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (see Appendix D.10.4) (kg/site-day)
$F_{transfer\_eff}$	=	Paint/coating transfer efficiency fraction (see Appendix D.10.14) (unitless)

Transfer efficiency is determined according to Appendix D.10.14. For the scenario in which control technologies are accounted for, the percent of the total release that is released to water is calculated using the following equation:

Equation_Apx D-65.

$$\%_{water} = F_{capture\_eff} * (1 - F_{solidrem\_eff})$$

Where:

$\%_{water}$	=	Percent of release 5 that is released to water (unitless)
$F_{capture\_eff}$	=	Booth capture efficiency for spray-applied paints/coatings (see Appendix D.10.19) (kg/kg)
$F_{solidrem\_eff}$	=	Fraction of solid removed in the spray mist of sprayed paints/coatings (see Appendix D.10.20) (kg/kg)

Booth capture efficiency is determined according to Appendix D.10.19, and solid removal efficiency is determined according to Appendix D.10.20. The percent of the total release that is released to stack air is calculated using the following equation:

Equation_Apx D-66.

$$\%_{air} = (1 - F_{capture\_eff})$$

Where:

$\%_{air}$	=	Percent of release 5 that is released to stack air (unitless)
$F_{capture\_eff}$	=	Booth capture efficiency for spray-applied paints/ coatings (see Appendix D.10.19) (kg/kg)

The percent of the total release that is released to land is calculated using the following equation:

Equation_Apx D-67.

$$\%_{land} = F_{capture\_eff} * F_{solidrem\_eff}$$

Where:

$\%_{land}$	=	Percent of release 5 that is released to land (unitless)
$F_{capture\_eff}$	=	Booth capture efficiency for spray-applied paints/ coatings (see Appendix D.10.19) (kg/kg)

$$F_{solidrem\_eff} = \text{Fraction of solid removed in the spray mist of sprayed Paints/ Coatings (see Appendix D.10.20) (kg/kg)}$$

If control technologies are used, the release amounts to each media are calculated using the following equation:

Equation_Apx D-68.

$$Release\_perDay_{RP5\_media} = Release\_perDay_{RP5\_total} * \%_{media}$$

Where:

$Release\_perDay_{RP5\_media}$	=	Amount of release 5 that is released to water, air, or land (kg/site-day)
$Release\_perDay_{RP5\_total}$	=	BBP released for release source 5 to all release media (kg/site-day)
$\%_{media}$	=	Percent of release 5 that is released to water, air, or land (unitless)

D.10.2 Model Input Parameters

Table_Apx D-24 summarizes the model parameters and their values for the Application of Paints and Coatings Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-24. Summary of Parameter Values and Distributions Used in the Application of Paints and Coatings Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Production Volume of BBP	PV	kg/year	137,260	–	–	–	–	See Appendix D.10.3
Annual Facility Throughput of Paint/Coating	Q _{coat_year}	kg/site-year	225,000	12,684	446,600	225,000	Triangular	See Appendix D.10.4
Paint/Coating BBP Concentration	F _{BBP}	kg/kg	0.0175	0.001	0.6	0.0175	Triangular	See Appendix D.10.7
Operating Days	OD	days/year	250	225	300	250	Triangular	See Appendix D.10.8
Air Speed	RATE _{air_speed}	ft/min	19.686	2.56	398.05	–	Lognormal	See Appendix D.10.9
Container Size	V _{cont}	gal	1.0	0.10	100	1.0	Triangular	See Appendix D.10.10
Container Residual Loss Fraction	F _{cont_residue}	kg/kg	0.003	0.0003	0.006	0.003	Triangular	See Appendix D.10.11
Drum Residual Loss Fraction	F _{drum_residue}	kg/kg	0.025	0.017	0.03	0.025	Triangular	See Appendix D.10.12
Fraction of BBP Lost During Sampling – 1 (Q _{BBP_day} < 50 kg/site-day)	F _{sampling_1}	kg/kg	2.0E–03	2.0E–03	2.0E–02	2.0E–02	Triangular	See Appendix D.10.13
Fraction of BBP Lost During Sampling – 2 (Q _{BBP_day} 50–200 kg/site-day)	F _{sampling_2}	kg/kg	6.0E–04	6.0E–04	5.0E–03	5.0E–03	Triangular	See Appendix D.10.13
Fraction of BBP Lost During Sampling – 3 (Q _{BBP_day} 200–5,000 kg/site-day)	F _{sampling_3}	kg/kg	5.0E–04	5.0E–04	4.0E–03	4.0E–03	Triangular	See Appendix D.10.13
Fraction of BBP Lost During Sampling – 4 (Q _{BBP_day} > 5,000 kg/site-day)	F _{sampling_4}	kg/kg	8.0E–05	8.0E–05	4.0E–04	4.0E–04	Triangular	See Appendix D.10.13
Transfer Efficiency Fraction	F _{transfer_eff}	unitless	0.65	0.20	0.80	0.65	Triangular	See Appendix D.10.14
Diameter of Opening – Sampling	D _{sampling}	cm	2.5	2.5	10	–	Uniform	See Appendix D.10.15
Saturation Factor	f _{sat}	dimensionless	0.50	0.50	1.45	0.50	Triangular	See Appendix D.10.17
Vapor Pressure at 25 °C	VP	mmHg	8.25E–06	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	312.37	–	–	–	–	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	–	–	–	–	Universal constant

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Density of BBP	RHO	kg/L	1.1190	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1.0	–	–	–	–	Process parameter
Equipment Cleaning Duration	OH _{equip_clean}	hr/day	4.0	–	–	–	–	See Appendix D.9.7
Diameter of Opening – Equipment Cleaning	D _{opening equip}	cm	92	–	–	–	–	See Appendix D.10.15
Diameter of Opening – Container Cleaning	D _{opening_cont}	cm	5.08	–	–	–	–	See Appendix D.10.15
Small Container Fill Rate	RATE _{fill_cont}	containers/h	60	–	–	–	–	See Appendix D.10.16
Drum Fill Rate	RATE _{fill_drum}	containers/h	20	–	–	–	–	See Appendix D.10.16
Equipment Cleaning Loss Fraction	F _{equipment_cleaning}	kg/kg	0.02	–	–	–	–	See Appendix D.10.18
Capture Efficiency for Spray Booth	F _{capture_eff}	kg/kg	0.90	–	–	–	–	See Appendix D.10.19
Fraction of Solid Removed in Spray Mist	F _{solidrem_eff}	kg/kg	1.0	–	–	–	–	See Appendix D.10.20

D.10.3 Production Volume and Number of Sites

EPA assessed this OES using a single value for potential BBP production volume based on CDR data for paint and coating products ([U.S. EPA, 2020a](#)). One site, Tremco Incorporated in Beachwood, OH, indicated their use of BBP in paint and coating products and reported an import of 605,212 lb of BBP in 2019 ([U.S. EPA, 2020a](#)). This site matched the name of a site in the Use Report for BBP that produced several products containing BBP, including both paints/coatings and adhesives. Therefore, EPA assumed a 50/50 split of the PV between this OES and the Application of adhesives and sealants OES, which is 302,606 lb (137,260 kg) for each OES.

Per 2020 U.S. Census Bureau data for the NAICS codes identified in the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry ([OECD, 2011a](#)), ESD on the Coating Industry (Paints, Lacquers, and Varnishes) ([OECD, 2009c](#)), and ESD on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating ([OECD, 2011b](#)), there are 83,456 paints and coatings use sites ([U.S. BLS, 2016](#)). Therefore, this value is used as a bounding limit, not to be exceeded by the calculation. Number of sites is calculated using a per-site throughput and BBP production volume with the following equation:

Equation_Apx D-69.

$$N_s = \frac{PV}{Q_{BBP\_year}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume of BBP (kg/year)
Q_{BBP_year}	=	Facility annual throughput of BBP (see Appendix D.10.4) (kg/site-year)

D.10.4 Throughput Parameters

The annual site throughput of paint and coating product (Q_{coat}) is modeled using a triangular distribution with a lower bound of 12,684 kg/site-year, an upper bound of 446,600 kg/site-year, and mode of 225,000 kg/site-year. The upper bound is based on the GS for Spray Coatings in the Furniture Industry ([U.S. EPA, 2004d](#)), which provides a range of 5,000 to 446,600 liters of furniture coatings used per year based on plant size, with an assumption of 1 kg/L as the density of the coating. The mode is based on CEPE's SpERC Industrial application of coatings by spraying ([CEPE, 2020](#)). The factsheet provides a production rate of 1,000 kg/day for 225 days/year, for a total of 225,000 kg/year. The lower bound is based on the ESD on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating ([OECD, 2011b](#)), which provides an annual product use rate of 12,684 kg/site-year for furniture coating application sites.

The annual throughput of BBP in the Application of paints and coatings OES is calculated using Equation_Apx D-70 by multiplying the annual throughput of all paints and coatings by the concentration of BBP found in the paints and coatings.

Equation_Apx D-70.

$$Q_{BBP\_year} = Q_{coat\_year} * F_{BBP}$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
Q_{coat_year}	=	Facility annual throughput of all paints/ coatings (kg/site-year)

$$F_{BBP} = \text{Concentration of BBP in paints/ coatings (see Appendix D.10.7) (kg/kg)}$$

The daily throughput of BBP is calculated using Equation_Apx D-71 by dividing the annual throughput by the number of operating days. The number of operating days is determined according to Appendix D.10.8.

Equation_Apx D-71.

$$Q_{BBP\_day} = \frac{Q_{BBP\_year}}{OD}$$

Where:

$$\begin{aligned} Q_{BBP\_day} &= \text{Facility daily throughput of BBP (kg/site-day)} \\ Q_{BBP\_year} &= \text{Facility annual throughput of BBP (kg/site-year)} \\ OD &= \text{Operating days (see Appendix D.10.8) (days/year)} \end{aligned}$$

D.10.5 Number of Containers per Year

The number of solid BBP-containing coating additive containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-72.

$$N_{cont\_unload\_year} = \frac{Q_{coat\_year}}{RHO * \left(3.79 \frac{L}{gal}\right) * V_{cont}}$$

Where:

$$\begin{aligned} N_{cont\_unload\_yr} &= \text{Annual number of containers unloaded (container/site-year)} \\ Q_{coat\_yr} &= \text{Facility annual throughput of all paints/ coatings (kg/site-year)} \\ RHO &= \text{BBP density (assumed to be similar to product density) (g/L)} \end{aligned}$$

D.10.6 Operating Hours

EPA estimated operating hours or hours of release duration using data provided from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) and/or through calculation from other parameters.

For unloading (release point 1) and container cleaning (release point 4), the operating hours are calculated based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-73.

$$OH_{RP1\&4} = \frac{N_{cont\_unload\_year}}{RATE_{fill} * OD}$$

Where:

$$\begin{aligned} OH_{RP1\&4} &= \text{Operating time for release points 1 and 4 (h/site-day)} \\ N_{cont\_unload\_year} &= \text{Annual number of containers unloaded (see Appendix D.10.5) (container/site-year)} \\ RATE_{fill} &= \text{Container or drum fill rate, depending on container volume (see Appendix D.10.16) (containers/h)} \\ OD &= \text{Operating days (see Appendix D.10.8) (days/site-year)} \end{aligned}$$

For product sampling (release point 2), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) indicates a single value of 1 hour/day.

For equipment cleaning (release point 7), the ChemSTEER User Guide provides an estimate of 4 hours per day for cleaning multiple vessels ([U.S. EPA, 2015](#)).

D.10.7 Paint/Coating BBP Concentration

EPA modeled BBP concentrations in the final paint and coating products using compiled SDS information (see Appendix E for EPA identified BBP-containing products for this OES). EPA assumed a triangular distribution with a lower bound of 0.1 percent, upper bound of 60 percent, and mode of 1.75 percent. The lower and upper bounds represent the minimum and maximum reported concentrations in the SDSs. The mode represents the median of all range endpoints reported in the SDS.

D.10.8 Operating Days

EPA modeled the operating days per year using a triangular distribution with a lower bound of 225 days/year, an upper bound of 300 days/year, and a mode of 250 days/year. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 225 to 300 days/year. The lower bound is based on ESIG's Specific Environmental Release Category Factsheet for Industrial Application of Coatings by Spraying ([CEPE, 2020](#)), which estimates 225 days/year as the number of emission days. The upper bound is based on the European Risk Report for BBP ([ECJRC, 2008](#)), which provided a default of 300 days/year. The mode is based on the GS for Automobile Spray Coating ([SAIC, 1996](#)), which estimates 250 days/year, based on 5 days/week operation that takes place 50 weeks/year.

D.10.9 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting.

However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.10.10 Container Size

Container sizes for additive products containing BBP had capacities ranging from less than 0.1 gallons up to approximately 100 gallons based on available technical data sheets reviewed by EPA (see Appendix E for EPA identified BBP-containing products for this OES). Additionally, EPA considered default container size ranges for bottles, small containers, and drums identified in the ChemSTEER User Guide. According to the ChemSTEER User Guide, bottles are defined as containing between one and five gallons of material with a default bottle size of one gallon. Small containers are defined as containing between five and twenty gallons of material with a default size of five gallons. Drums are defined as containing between twenty and 100 gallons of material with a default drum size of 55 gallons ([U.S. EPA, 2015](#)). EPA modeled container size using a triangular distribution accounting for the identified product container sizes and the ChemSTEER User Guide size ranges. Specifically, EPA used a lower bound of 0.1 gallons based on for the minimum identified product container size, an upper bound of 100 gallons based on the upper bound for drums defined by the ChemSTEER User Guide, and a mode of 1 gallon based on typical identified container sizes and the default bottle size defined by the ChemSTEER User Guide.

D.10.11 Small Container Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying drums by pouring was aligned with the default central tendency and high-end values from the EPA/OPPT Small Container Residual Model. For unloading drums by pouring in the PEI Associates Inc. study ([PEI Associates, 1988](#)), EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.03 percent to 0.79 percent and an average of 0.32 percent. The EPA/OPPT Small Container Residual Model from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent.

The underlying distribution of the loss fraction parameter for small containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Small Container Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study ([PEI Associates, 1988](#)) for emptying drums by pouring.

D.10.12 Drum Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) such that the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pumping in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 1.7 percent to 4.7 percent and an average of 2.6 percent. The EPA/OPPT Drum Residual Model from the ChemSTEER User Guide recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent ([U.S. EPA, 2015](#)).

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for

the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study ([PEI Associates, 1988](#)) for emptying drums by pumping.

D.10.13 Sampling Loss Fraction

Sampling loss fractions were estimated using the March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes ([U.S. EPA, 2023b](#)). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and Low Volume Exemptions (LVEs). Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites ($\approx 75\%$ of IRERs), were obtained. The data points were analyzed as a function of the chemical daily throughput and industry type. This analysis showed that the sampling loss fraction generally decreased as the chemical daily throughput increased. Therefore, the methodology provides guidance for selecting a loss fraction based on chemical daily throughput. Table_Apx D-25 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-25. Sampling Loss Fraction Data from the March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

Chemical Daily Throughput (kg/site-day) ($Q_{\text{chem\_site\_day}}$)	Number of Data Points	Sampled Quantity (kg chemical/day)		Sampling Loss Fraction (LF_{sampling})	
		50th Percentile	95th Percentile	50th Percentile	95th Percentile
<50	13	0.03	0.20	0.002	0.02
50 to <200	10	0.10	0.64	0.0006	0.005
200 to <5,000	25	0.37	3.80	0.0005	0.004
$\geq 5,000$	10	1.36	6.00	0.00008	0.0004
All	58	0.20	5.15	0.0005	0.008

For each range of daily throughputs, EPA estimated sampling loss fractions using a triangular distribution of the 50th percentile value as the lower bound, and the 95th percentile value as the upper bound and mode. The sampling loss fraction distribution was chosen based on the calculation of daily throughput, as shown in Appendix D.10.3.

D.10.14 Transfer Efficiency Fraction

EPA modeled paint and coating spray application transfer efficiency fraction using a triangular distribution with a lower bound of 0.2, an upper bound of 0.8, and a mode of 0.65. The lower bound and mode are based on the EPA/OPPT Automobile OEM Overspray Loss Model. Per the model, the transfer efficiency varies based on the type of spray gun used. For high volume, low pressure (HVLP) spray guns, the default transfer efficiency is 0.65. For conventional spray guns, the default transfer efficiency is 0.2 by mass. Across all spray technologies, the ESD on Coating Industry ([OECD, 2009c](#)) estimates a transfer efficiency between 30 and 80 percent. Therefore, EPA used 0.8 as the upper bound.

D.10.15 Diameters of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities ([U.S. EPA, 2015](#)). For

equipment cleaning operations, the ChemSTEER User Guide indicates a single default value of 92 cm ([U.S. EPA, 2015](#)). For container cleaning activities, the ChemSTEER User Guide indicates a single default value of 5.08 cm for containers less than 5,000 gallons ([U.S. EPA, 2015](#)).

For sampling liquid product, sampling liquid raw material, or general liquid sampling, the ChemSTEER User Guide indicates that the typical diameter of opening for vaporization of the liquid is 2.5 cm ([U.S. EPA, 2015](#)). Additionally, the ChemSTEER User Guide provides 10 cm as a high-end value for the diameter of opening during sampling ([U.S. EPA, 2015](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a uniform distribution based on the estimated lower bound and upper bounds of the parameter. EPA assigned the value of 2.5 cm as a lower bound for the parameter and 10 cm as the upper bound based on the values provided in the ChemSTEER User Guide ([U.S. EPA, 2015](#)).

D.10.16 Container Unloading Rate

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical fill rate of 20 containers per hour for containers with 20 to 100 gallons of liquid and a typical fill rate of 60 containers per hour for containers with less than 20 gallons of liquid.

D.10.17 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([CEB, 1991](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.10.18 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA/OPPT Multiple Process Residual Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of two percent from equipment cleaning.

D.10.19 Capture Efficiency for Spray Booth

The ESD on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating ([OECD, 2011b](#)) uses the EPA/OPPT Automobile Refinish Coating Overspray Loss Model to estimate releases from spray coating. This model assumes a spray booth capture efficiency of 90 percent.

D.10.20 Fraction of Solid Removed in Spray Mist

The Emission Scenario Document on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating ([OECD, 2011b](#)) uses the EPA/OPPT Automobile Refinish Coating Overspray Loss Model to estimate releases from spray coating. The model assumes both a capture efficiency and a solid removal efficiency for spray booths. The solid removal efficiency refers to the fraction of overspray material that is disposed to incineration or landfill after being captured. This model assumes a solid removal efficiency of 100 percent.

D.11 Use of Laboratory Chemicals Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Use of laboratory chemicals OES. This approach utilizes the GS on Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)) and CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the GS, EPA identified the following release sources from use of laboratory chemicals:

- Release source 1: Release from Transferring BBP from Transport Containers (liquids only)
- Release source 2: Dust Emissions from Transferring Powders Containing BBP (solids only)
- Release source 3: Releases from Transport Container Cleaning
- Release source 4: Release from Cleaning Containers Used for Volatile Chemicals (liquids only)
- Release source 5: Labware Equipment Cleaning
- Release source 6: Releases During Labware Cleaning (liquids only)
- Release source 7: Releases During Laboratory Analysis (liquids only)
- Release source 8: Releases from Laboratory Waste Disposal

Environmental releases for BBP during the use of laboratory chemicals are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: facility throughput, operating days, BBP concentrations, air speed, saturation factor, container size, control technology efficiencies, loss fractions, and diameters of equipment openings. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.11.1 Model Equations

Table_Apx D-26 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Use of laboratory chemicals OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The simulation was run two times, once for liquid chemicals and once for solids. The values for the variables used for each simulation are provided in Appendix D.11.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the two simulation runs. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-26. Models and Variables Applied for Release Sources in the Use of Laboratory Chemicals OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Release from Transferring BBP from Transport Containers (liquids only)	EPA/OAQPS AP-42 Loading Model (Appendix D.1)	Vapor Generation Rate: F_{BBP-L} ; VP ; f_{sat} ; MW ; R ; T ; V_{cont} ; $RATE_{fill}$ Operating Time: $RATE_{fill}$; $Q_{chem\_site\_day\_L}$; F_{BBP-L} ; V_{cont} ; RHO

Release Source	Model(s) Applied	Variables Used
Release source 2: Dust Emissions from Transferring Powders Containing BBP (solids only)	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix D.1)	$Q_{chem\_site\_day\_S}$; $F_{dust\_generation}$; $F_{dust\_capture}$; $F_{dust\_control}$
Release source 3: Releases from Transport Container Cleaning	EPA/OAQPS AP-42 Small Container Residual Model or EPA/OPPT Solid Residuals in Transport Containers Model, based on physical form (Appendix D.1)	$Q_{chem\_site\_day\_L}$; $Q_{chem\_site\_day\_S}$; $F_{container\_residue-L}$; $F_{container\_residue-S}$; V_{cont} ; RHO ; F_{BBP-S} ; F_{BBP-L} ; Q_{cont_solid} ; Q_{cont_liquid}
Release source 4: Release from Cleaning Containers Used for Volatile Chemicals (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP-L} ; MW ; VP ; $RATE_{air\_speed}$; $D_{cleaning}$; T ; P Operating Time: $RATE_{fill}$; $Q_{chem\_site\_day\_L}$; F_{BBP-L} ; V_{cont} ; RHO
Release source 5: Labware Equipment Cleaning	EPA/OPPT Multiple Process Vessel Residual Model or EPA/OPPT Solid Residuals in Transport Container Model, based on physical form (Appendix D.1)	$Q_{chem\_site\_day\_L}$; $Q_{chem\_site\_day\_S}$; $F_{lab\_residue\_L}$; $F_{lab\_residue\_S}$
Release source 6: Releases during Labware Cleaning (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP-L} ; MW ; VP ; $RATE_{air\_speed}$; $D_{cleaning}$; T ; P Operating Time: $OH_{cleaning}$
Release source 7: Releases During Laboratory Analysis (liquids only)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix D.1)	Vapor Generation Rate: F_{BBP-L} ; MW ; VP ; $RATE_{air\_speed}$; $D_{testing}$; T ; P Operating Time: $OH_{testing}$
Release source 8: Releases from Laboratory Waste Disposal	See Equation_Apx D-74 and Equation_Apx D-75	$Q_{chem\_site\_day\_L}$; $Q_{chem\_site\_day\_S}$; $F_{container\_residue-S}$; $F_{container\_residue-L}$; $F_{lab\_residue-S}$; $F_{lab\_residue-L}$; $F_{dust\_generation}$; Release Points 1, 3, 6, and 7

For liquid BBP, release source 8 (Laboratory Waste Disposal) is calculated via a mass-balance, using the following equation:

Equation_Apx D-74.

$$\begin{aligned}
 Release\_perDay_{RP8-L} &= (Q_{chem\_site\_day\_L} - Release\_perDay_{RP1} - Release\_perDay_{RP3} - Release\_perDay_{RP6} \\
 &\quad - Release\_perDay_{RP7}) * (1 - F_{container\_residue-L} - F_{lab\_residue-L})
 \end{aligned}$$

Where:

$$Release\_perDay_{RP8-L} = \text{Liquid BBP released for release source 8 (kg/site-day)}$$

$Q_{chem\_site\_day\_L}$	=	Facility throughput of liquid BBP (see Appendix D.11.3) (kg/site-day)
$Release\_perDay_{RP1}$	=	Liquid BBP released for release source 1 (kg/site-day)
$Release\_perDay_{RP3}$	=	Liquid BBP released for release source 3 (kg/site-day)
$Release\_perDay_{RP6}$	=	Liquid BBP released for release source 6 (kg/site-day)
$Release\_perDay_{RP7}$	=	Liquid BBP released for release source 7 (kg/site-day)
$F_{container\_residue-L}$	=	Fraction of BBP remaining in container as residue (see Appendix D.11.12) (kg/kg)
$F_{lab\_residue\_L}$	=	Fraction of BBP remaining in lab equipment (see Appendix D.11.16) (kg/kg)

For solids containing BBP, release source 8 (Laboratory Waste Disposal) is calculated via a mass-balance, via the following equation:

Equation_Apx D-75.

$$Release\_perDay_{RP8-S} = Q_{chem\_site\_day\_S} * (1 - F_{dust\_generation} - F_{container\_residue-S} - F_{lab\_residue\_S})$$

Where:

$Release\_perDay_{RP8-S}$	=	Solid BBP released for release source 8 (kg/site-day)
$Q_{chem\_site\_day\_S}$	=	Facility throughput of solid BBP (see Appendix D.11.3) (kg/site-day)
$F_{dust\_generation}$	=	Fraction of BBP lost during unloading of solid powder (see Appendix D.11.13) (kg/kg)
$F_{container\_residue-S}$	=	Fraction of BBP remaining in transport containers (see Appendix D.11.12) (kg/kg)
$F_{lab\_residue\_S}$	=	Fraction of solid BBP remaining in lab equipment (see Appendix D.11.16) (kg/kg)

D.11.2 Model Input Parameters

Table_Apx D-27 summarizes the model parameters and their values for the Use of Laboratory Chemicals Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-27. Summary of Parameter Values and Distributions Used in the Use of Laboratory Chemicals Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Production Volume	PV	kg/year	22,813	–	–	–	–	See Appendix D.11.3
Facility Throughput of Solid BBP	Q _{stock_site_day_S}	g/site-day	255	3.0E–03	510	–	Uniform	See Appendix D.11.3
Facility Throughput of Liquid BBP	Q _{stock_site_day_L}	mL/site-day	2,000	0.50	4,000	–	Uniform	See Appendix D.11.3
BBP Solid Lab Chemical Concentration	F _{BBP_solid}	kg/kg	3.0E–03	1.0E–03	3.0E–03	–	Uniform	See Appendix D.11.7
BBP Liquid Lab Chemical Concentration	F _{BBP_liquid}	kg/kg	1.0E–03	1.0E–03	1.0E–02	1.0E–03	Triangular	See Appendix D.11.7
Operating Days	OD	days/year	260	174	260	–	Discrete	See Appendix D.11.8
Air Speed	RATE _{air_speed}	ft/min	20	2.56	398.03	–	Lognormal	See Appendix D.11.9
Saturation Factor	f _{sat}	dimensionless	0.50	0.50	1.45	0.50	Triangular	See Appendix D.11.10
Liquid Container Size	V _{cont}	gal	1.0	0.50	1.0	1.0	Triangular	See Appendix D.11.11
Solid Container Mass	Q _{cont_solid}	kg	1.0	0.50	1.0	1.0	Triangular	See Appendix D.11.11
Fraction of BBP Remaining in Container as Residue – Liquid	F _{container_residue-L}	kg/kg	3.0E–03	3.0E–04	6.0E–03	3.0E–03	Triangular	See Appendix D.11.12
Fraction of chemical lost during transfer of solid powders	F _{dust_generation}	kg/kg	5.0E–03	1.0E–03	3.0E–02	5.0E–03	Triangular	See Appendix D.11.13
Dust Capture Technology Efficiency	F _{dust_capture}	kg/kg	0.95	0	1.0	0.95	Triangular	See Appendix D.11.13
Dust Control Technology Removal Efficiency	F _{dust_control}	kg/kg	0.99	0	1.0	0.99	Triangular	See Appendix D.11.13
Diameter of Opening, Lab Analyses	D _{testing}	cm	2.5	2.5	10	2.5	Triangular	See Appendix D.11.15

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Vapor Pressure at 25C	VP	mmHg	8.25E-06	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	312.37	–	–	–	–	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	–	–	–	–	Universal constant
Density of BBP	RHO	kg/L	1.1190	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Lab Testing Duration	OH _{testing}	hr/day	1.0	–	–	–	–	See Appendix D.11.6
Equipment Cleaning Duration	OH _{cleaning}	hr/day	4.0	–	–	–	–	See Appendix D.11.6
Fraction of BBP Remaining in Container as Residue – Solid	F _{container_residue-S}	kg/kg	1.0E-02	–	–	–	–	See Appendix D.11.12
Unloading Rate	RATE _{fill}	containers/h	60	–	–	–	–	See Appendix D.11.14
Diameter of Opening – Container Cleaning	D _{cleaning}	cm	5.08	–	–	–	–	See Appendix D.11.15
Fraction of BBP Remaining in Container as Residue Lab Equipment – Liquid	F _{lab_residue_L}	kg/kg	2.0E-02	–	–	–	–	See Appendix D.11.16
Fraction of BBP Remaining in Container as Residue Lab Equipment – Solid	F _{lab_residue_S}	kg/kg	1.0E-02	–	–	–	–	See Appendix D.11.16

D.11.3 Production Volume and Throughput Parameters

No sites reported to CDR for use of BBP in laboratory chemicals. EPA estimated the total production volume (PV) for all sites assuming a static value of 50,295 lb/year (22,813 kg/year) that was estimated based on the reporting requirements for CDR. The threshold for CDR reporters requires a site to report processing and use for a chemical if the usage exceeds 5 percent of its reported PV or if the use exceeds 25,000 lb per year. For the four sites that reported to CDR for the manufacture or import of BBP, EPA assumed that each site used BBP for laboratory chemicals in volumes up to the reporting threshold limit of 5 percent of their reported PV. If 5 percent of each site's reported PV exceeds the 25,000 lb reporting limit, EPA assumed the site used only 25,000 lb annually. If the site reported a PV that was CBI, EPA assumed the maximum PV contribution of 25,000 lb. The CDR sites and their PV contributions to this OES are shown in Table_Apx D-17. The final PV assessed for this use was 50,295.15 lb/year (22,813 kg/year).

The GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)) provides daily throughput of BBP required for laboratory stock solutions. According to the GS, laboratory liquid use rates range from 0.5 mL up to four liters per day, and laboratory solid use rates range from 0.003 grams to 510 grams per day. Laboratory stock solutions are used for multiple analyses and eventually need to be replaced. The expiration or replacement times range from daily to six months ([U.S. EPA, 2023c](#)). For this scenario, EPA assumes stock solutions are prepared daily per the GS. EPA assigned a uniform distribution for the daily throughput of laboratory stock solutions with upper and lower bounds corresponding to the high and low use rates, respectively.

The daily throughput of BBP in liquid laboratory chemicals is calculated using Equation_Apx D-76 by multiplying the daily throughput of all laboratory solutions by the concentration of BBP in the solutions and converting volume to mass.

Equation_Apx D-76.

$$Q_{chem\_site\_day\_L} = Q_{stock\_site\_day\_L} * F_{BBP-L} * RHO * \frac{0.001L}{mL}$$

Where:

$Q_{chem\_site\_day\_L}$	=	Facility daily throughput of liquid BBP (kg/site-day)
$Q_{stock\_site\_day\_L}$	=	Facility annual throughput of liquid laboratory chemicals (mL/site-day)
F_{BBP-L}	=	Concentration of BBP in liquid laboratory chemicals (see Appendix D.11.7) (kg/kg)
RHO	=	Density of BBP (g/L)

The daily throughput of BBP in solid laboratory chemicals is calculated using Equation_Apx D-77 by multiplying the daily throughput of all laboratory solids by the concentration of BBP in the solids.

Equation_Apx D-77.

$$Q_{chem\_site\_day\_S} = Q_{stock\_site\_day\_S} * F_{BBP-S} * \frac{0.001kg}{g}$$

Where:

$Q_{chem\_site\_day\_S}$	=	Facility daily throughput of solid BBP (kg/site-day)
$Q_{stock\_site\_day\_S}$	=	Facility annual throughput of solid laboratory chemicals (g/site-day)
F_{BBP-S}	=	Concentration of BBP in solid laboratory chemicals (see Appendix D.11.7) (kg/kg)

To avoid cases where the number of sites is greater than the bounding estimate of 36,873 sites (see Appendix D.11.4), EPA calculated an adjusted value for the daily throughput of BBP. If the number of sites is less than the bounding estimate, then the adjusted facility throughput of BBP will be the same as the facility throughput calculated in Equation_Apx D-77. Otherwise, the adjusted facility throughput is calculated using Equation_Apx D-78 by dividing the facility production rate by the maximum number of sites and operating days. The number of operating days is determined according to Appendix D.11.8.

Equation_Apx D-78.

$$Q_{chem\_site\_day\_adj} = \frac{PV}{N_{sites,max} * OD}$$

$Q_{chem\_site\_day\_adj}$	=	Adjusted daily facility throughput of BBP (kg/site-day)
$N_{sites,max}$	=	Maximum number of sites (see Appendix D.11.4) (sites)
PV	=	Production volume of BBP in laboratory chemicals (kg/year)
OD	=	Operating days (see Appendix D.11.8) (days/year)

D.11.4 Number of Sites

Per 2020 U.S. Census Bureau data for the NAICS codes identified in the GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)), there are 36,873 laboratory chemical use sites ([U.S. BLS, 2016](#)). Therefore, this value is used as a bounding limit, not to be exceeded by the calculation. Number of sites is calculated using a per-site throughput and BBP production volume with the following equation:

Equation_Apx D-79.

$$N_{sites} = \frac{PV}{Q_{chem\_site\_day} * OD}$$

Where:

N_{sites}	=	Number of sites (sites)
PV	=	Production volume of BBP in laboratory chemicals (kg/year)
$Q_{chem\_site\_day}$	=	Facility daily throughput of BBP (kg/site-day)
OD	=	Operating days (see Appendix D.11.8) (days/year)

D.11.5 Number of Containers per Year

The number of liquid BBP laboratory containers unloaded by a site per year is calculated using the following equation:

Equation_Apx D-80.

$$N_{cont\_unload\_year} = \frac{Q_{chem\_site\_day\_L} * OD}{F_{BBP-L} * RHO * \left(3.79 \frac{L}{gal}\right) * V_{cont}}$$

Where:

$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (container/site-year)

$Q_{chem\_site\_day\_L}$	=	Facility daily throughput of BBP (kg/site-day)
OD	=	Operating days (see Appendix D.11.8) (days/site-year)
V_{cont}	=	Container volume (see Appendix D.11.11) (gal/container)
RHO	=	BBP density (g/L)
F_{BBP-L}	=	Mass fraction of BBP in liquid (see Appendix D.11.7) (kg/kg)

The number of laboratory containers containing solids with BBP unloaded by a site per year is calculated using the following equation:

Equation_Apx D-81.

$$N_{cont\_unload\_year} = \frac{Q_{chem\_site\_day\_S} * OD}{F_{BBP-S} * Q_{cont\_solid}}$$

Where:

$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (container/site-year)
$Q_{chem\_site\_day\_S}$	=	Facility daily throughput of BBP (kg/site-day)
OD	=	Operating days (see Appendix D.11.8) (days/site-year)
F_{BBP-S}	=	Mass fraction of BBP in solid (see Appendix D.11.7) (kg/kg)
Q_{cont_solid}	=	Mass in container of solids (see Appendix D.11.11) (kg/container)

D.11.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)), ChemSTEER User Guide ([U.S. EPA, 2015](#)), and/or through calculation from other parameters.

For unloading and container cleaning (release points 1 and 4), the operating hours are calculated based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-82.

$$OH_{RP1/RP4} = \frac{N_{cont\_unload\_year}}{RATE_{fill} * OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 (h/site-day)
$N_{cont\_unload\_year}$	=	Annual number of containers unloaded (see Appendix D.11.5) (container/site-year)
$RATE_{fill}$	=	Container fill rate (see Appendix D.11.14) (containers/h)
OD	=	Operating days (see Appendix D.11.8) (days/site-year)

For equipment cleaning (release point 6), the ChemSTEER User Guide provides an estimate of four hours per day for cleaning multiple vessels ([U.S. EPA, 2015](#)).

For product sampling (release point 7), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) indicates a single value of 1 hour/day.

D.11.7 BBP Concentration in Laboratory Chemicals

EPA modeled BBP concentration in liquid laboratory chemicals using a triangular distribution with a lower bound of 0.1 percent, an upper bound of 1 percent, and a mode of 0.1 percent based on concentrations reported in five SDSs found for liquid laboratory chemicals. For solid laboratory

chemicals, EPA modeled concentrations using a uniform distribution with a lower bound of 0.1 percent and upper bound of 0.3 percent, based on the concentrations reported in two SDSs found for solid laboratory chemicals. The lower and upper bounds represent the minimum and maximum reported concentrations in the SDSs, with EPA assuming a concentration of 0.1 percent for SDSs that list a minimum concentration of 0 percent. The mode for the liquid laboratory chemical products represents the median of all high-end range endpoints reported in the SDSs (see Appendix E for EPA identified BBP-containing products for this OES).

D.11.8 Operating Days

EPA modeled the operating days per year using a discrete distribution with a low end of 174 days/year, and a high-end and mode of 260 days/year. These values are from the GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)), and are based on U.S. BLS Occupational Employment Statistics ([U.S. BLS, 2016](#)). Per the U.S. BLS website, operating duration for each NAICS code is assumed as a 'year-round, full-time' hours figure of 2,080 hours ([U.S. BLS, 2016](#)). Therefore, dividing this time by an assumed working duration of 8 or 12 hours/day yields 174 or 260 days/year. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 174 and 260 days/year.

D.11.9 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom ([Baldwin and Maynard, 1998](#)). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed ([Baldwin and Maynard, 1998](#)). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large ([Baldwin and Maynard, 1998](#)).

Baldwin and Maynard only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

D.11.10 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 ([CEB, 1991](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([CEB, 1991](#)). The

underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization ([CEB, 1991](#)). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model ([U.S. EPA, 2015](#)).

D.11.11 Container Size

The GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)) states that, in the absence of site-specific information, a default liquid volume of one gallon and a default solid quantity of one kilogram may be used. Laboratory products containing BBP showed container sizes less than one gallon or one kilogram. Based on model assumptions of site daily throughput, EPA decided to allow for a lower bound of 0.5 gallons or 0.5 kg to account for smaller container sizes while maintaining the daily number of containers unloaded per site at a reasonable value. Therefore, EPA built a triangular distribution for liquid volumes with a lower bound of 0.5 gallons, and an upper bound and mode of one gallon. EPA similarly built a triangular distribution for solid quantities with a lower bound of 0.5 kg, and an upper bound and mode of one kilogram.

D.11.12 Container Loss Fractions

The EPA/OPPT Small Container Residual Model from the ChemSTEER User Guide ([U.S. EPA, 2015](#)) recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent.

The underlying distribution of the loss fraction parameter for small containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Small Container Residual Model in the ChemSTEER User Guide ([U.S. EPA, 2015](#)). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study ([PEI Associates, 1988](#)).

For solid containers, EPA used the EPA/OPPT Solid Residuals in Transport Containers Model to estimate residual releases from solid container cleaning. The EPA/OPPT Solid Residuals in Transport Containers Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides an overall loss fraction of one percent from container cleaning.

D.11.13 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Dust Release Model) compiled data for loss fractions of solids from various sources in addition to the capture and removal efficiencies for control technologies in order to estimate releases of dust to the environment during transfer operations. Dust releases estimated from the model are based on three different parameters: the initial loss fraction, the fraction captured by the capture technology, and the fraction removed/controlled by the control technology. The underlying distributions for each of these parameters is not known; therefore, EPA assigned triangular distributions, since triangular distribution requires least assumptions and is completely defined by range and mode of a parameter.

EPA assigned the range and mode for each of the three parameters using the data presented in the Dust Release Model. For the initial loss fraction, EPA assigned a range of 6.0×10^{-6} to 0.045 with a mode of 0.005 by mass. EPA assigned the mode based on the recommended default value for the parameter in

the Dust Release Model. The range of initial loss fraction values comes from the range of values compiled from various sources and considered in the development of the Dust Release Model ([U.S. EPA, 2021b](#)).

For the fraction of dust captured, EPA assigned a range of 0 to 1.0 with a mode of 0.95 by mass. EPA assigned the range for the fraction captured based on the minimum and maximum estimated capture efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction captured based on the capture efficiency for laboratory fume hoods, since EPA expects that capture technology will likely be used.

For the fraction of captured dust that is removed/controlled, EPA assigned a range of 0 to 1.0 with a mode of 0.99 by mass. EPA assigned the range for the fraction controlled based on the minimum and maximum estimated control efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction controlled based on control efficiency for filtering systems.

D.11.14 Small Container Fill Rate

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical fill rate of 60 containers per hour for containers with less than 20 gallons of liquid.

D.11.15 Diameters of Opening

For container cleaning activities, the ChemSTEER User Guide indicates a single default value of 5.08 cm for containers less than 5,000 gallons ([U.S. EPA, 2015](#)). For sampling and equipment cleaning releases, the GS on the Use of Laboratory Chemicals ([U.S. EPA, 2023c](#)) estimates using a triangular distribution between a 1-inch (2.5 cm) diameter bottle opening for typical releases, and a 4-inch (10 cm) diameter beaker opening for worst-case estimates.

D.11.16 Equipment Cleaning Loss Fraction

For liquids, EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA/OPPT Multiple Process Residual Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides an overall loss fraction of 2 percent from equipment cleaning.

For solids, used the EPA/OPPT Solid Residuals in Transport Containers Model to estimate the releases from equipment cleaning. The EPA/OPPT Solid Residuals in Transport Containers Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides an overall loss fraction of 1 percent from equipment cleaning.

D.12 Use of Lubricants and Functional Fluids Model Approach and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for BBP during the Use of lubricants and functional fluids OES. This approach utilizes the ESD on Lubricants and Lubricant Additives ([OECD, 2004b](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD, EPA identified the following release sources from the use of lubricants and functional/hydraulic fluids:

- Release source 1: Release During the Use of Equipment
- Release source 2: Release During Changeout of Lubricants and Hydraulic Fluids

Environmental releases for BBP during the use of lubricants and functional fluids are a function of BBP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production volume, BBP concentrations, product density, container size, loss fractions, and operating days. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

D.12.1 Model Equations

Table_Apx D-28 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Use of lubricants and fluids OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.12.2. The Monte Carlo simulation calculated the total BBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-28. Models and Variables Applied for Release Sources in the Use of Lubricants and Hydraulic Fluids OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Release During the Use of Equipment	See Equation_Apx D-85 through Equation_Apx D-87	$Q_{BBP\_day}; LF_{land\_use}; LF_{water\_use}$
Release source 2: Release During Changeout of Lubricants and Hydraulic Fluids		$Q_{BBP\_day}; LF_{land\_disposal}; LF_{water\_disposal}; LF_{waste\_recycle}; LF_{waste\_incineration}$

Release source 1 (Release During the Use of Equipment) and 2 (Release During Changeout) are partitioned out by release media. Loss fractions are described in the model parameter sections below. For both water and land media, release 1 is then calculated using the following equation:

Equation_Apx D-83.

$$Release\_perDay_{RP1\_land/water} = Q_{BBP\_day} * (LF_{land\_use} + LF_{water\_use})$$

Where:

$Release\_perDay_{RP1\_land/water}$	=	BBP loss to land/water for release source 1 (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (see Appendix D.12.3) (kg/site-day)
LF_{land_use}	=	Loss fraction to land during the use of equipment (see Appendix D.12.7) (unitless)
LF_{water_use}	=	Loss fraction to water during the use of equipment (see Appendix D.12.7) (unitless)

A similar equation is used to calculate release 2 to water and land:

Equation_Apx D-84.

$$Release\_perDay_{RP2\_land/water} = Q_{BBP\_day} * (LF_{land\_disposal} + LF_{water\_disposal})$$

Where:

$Release\_perDay_{RP2\_land/water}$	=	BBP loss to land/water for release source 2 (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (see Appendix D.12.3) (kg/site-day)
$LF_{land\_disposal}$	=	Loss fraction to land during lubricant disposal (see Appendix D.12.7) (unitless)
$LF_{water\_disposal}$	=	Loss fraction to water during lubricant disposal (see Appendix D.12.7) (unitless)

If the sum of LF_{land_use} , LF_{water_use} , $LF_{land\_disposal}$, and $LF_{water\_disposal}$ is over 100 percent, EPA creates adjusted loss fractions based on weighted contributions to equal exactly 100 percent release. The releases per day are then re-calculated using the adjusted loss fractions. For example, the adjusted land use loss fraction would be calculated using the following equation:

Equation_Apx D-85.

$$LF_{land\_use\_adjusted} = \frac{LF_{land\_use}}{(LF_{land\_use} + LF_{water\_use} + LF_{land\_disposal} + LF_{water\_disposal})}$$

Where:

$LF_{land\_use\_adjusted}$	=	Adjusted loss fraction to land during the use of equipment (unitless)
LF_{land_use}	=	Loss fraction to land during the use of equipment (see Appendix D.12.7) (unitless)
LF_{water_use}	=	Loss fraction to water during the use of equipment (see Appendix D.12.7) (unitless)
$LF_{land\_disposal}$	=	Loss fraction to land during lubricant disposal (see Appendix D.12.7) (unitless)
$LF_{water\_disposal}$	=	Loss fraction to water during lubricant disposal (see Appendix D.12.7) (unitless)

Finally, EPA will assess any BBP not released to the environment after accounting for release sources 1 and 2 as going to recycling and fuel blending (incineration). If all BBP is released during release sources 1 and 2, then the release to recycling and fuel blending will not be calculated. The following equations are used to calculate the amount of remaining BBP sent for recycling and fuel blending:

Equation_Apx D-86.

$$Release\_perDay_{RP2\_recycle} = (Q_{DIDP\_day} - Release\_perDay_{RP1\_land} - Release\_perDay_{RP1\_water} - Release\_perDay_{RP2\_land} - Release\_perDay_{RP2\_water}) * F_{waste\_recycle}$$

Equation_Apx D-87.

$$\begin{aligned}
 & \text{Release\_perDay}_{RP2\_fuel\_blend} \\
 &= \left(Q_{BBP\_day} - \text{Release\_perDay}_{RP1\_land} - \text{Release\_perDay}_{RP1\_water} - \text{Release\_perDay}_{RP2\_land} \right. \\
 & \quad \left. - \text{Release\_perDay}_{RP2\_water} \right) * F_{waste\_incineration}
 \end{aligned}$$

Where:

$\text{Release\_perDay}_{RP2\_recycle}$	=	BBP recycled (kg/site-day)
$\text{Release\_perDay}_{RP2\_fuel\_blend}$	=	BBP sent for fuel blending (kg/site-day)
Q_{BBP_day}	=	Facility throughput of BBP (see Appendix D.12.3) (kg/site-Day)
$\text{Release\_perDay}_{RP1\_land}$	=	BBP released for release source 1 to land (kg/site-day)
$\text{Release\_perDay}_{RP1\_water}$	=	BBP released for release source 1 to water (kg/site-day)
$\text{Release\_perDay}_{RP2\_land}$	=	BBP released for release source 2 to land (kg/site-day)
$\text{Release\_perDay}_{RP2\_water}$	=	BBP released for release source 2 to water (kg/site-day)
$F_{waste\_recycle}$	=	Fraction of BBP that goes to recycling (see Appendix D.12.8) (kg/kg)
$F_{waste\_incineration}$	=	Fraction of BBP that goes to fuel blending (see Appendix D.12.9) (kg/kg)

D.12.2 Model Input Parameters

Table_Apx D-29 summarizes the model parameters and their values for the Use of Lubricants and Hydraulic Fluids Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-29. Summary of Parameter Values and Distributions Used in the Use of Lubricants and Hydraulic Fluids Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Total Production Volume of BBP at All Sites	PV _{total}	kg/year	2.3E04	–	–	–	–	See Appendix D.12.3
Mass Fraction of BBP in Product	F _{BBP}	kg/kg	0.50	1.0E–05	0.50	–	Uniform	See Appendix D.12.4
Density of BBP-based Products	RHO _{product}	kg/m3	900	840	1,000	900	Triangular	See Appendix D.12.4
Operating Days	OD	days/year	4	1	4	–	Uniform	See Appendix D.12.5
Container Size	V _{cont}	gal	55	20	330	55	Triangular	See Appendix D.12.6
Loss Fraction to Land During Use	LF _{land_use}	kg/kg	0.16	1.4E–02	0.16	–	Uniform	See Appendix D.12.7
Loss Fraction to Water During Use	LF _{water_use}	kg/kg	0.45	3.0E–03	0.45	–	Uniform	See Appendix D.12.7
Loss Fraction to Land During Disposal	LF _{land_disposal}	kg/kg	0.30	1.0E–02	0.30	–	Uniform	See Appendix D.12.7
Loss Fraction to Water During Disposal	LF _{water_disposal}	kg/kg	0.37	0.230	0.37	–	Uniform	See Appendix D.12.7
Percentage of Waste to Recycling	F _{waste_recycle}	kg/kg	4.3E–02	–	–	–	–	See Appendix D.12.8
Percentage of Waste to Fuel Blending	F _{waste_incineration}	kg/kg	0.957	–	–	–	–	See Appendix D.12.9

D.12.3 Production Volume and Throughput Parameters

No sites reported to CDR for use of BBP in lubricants or hydraulic fluids. EPA estimated the total PV for all sites assuming a static value of 50,295 lb/year (22,813 kg/year) that was estimated based on the reporting requirements for CDR. The threshold for CDR reporters requires a site to report processing and use for a chemical if the usage exceeds 5 percent of its reported PV or if the use exceeds 25,000 lb per year. For the four sites that reported to CDR for the manufacture or import of BBP, EPA assumed that each site used BBP for lubricants/hydraulic fluids in volumes up to the reporting threshold limit of 5 percent of their reported PV. If 5 percent of each site's reported PV exceeds the 25,000 lb reporting limit, EPA assumed the site used only 25,000 lb annually. If the site reported a PV that was CBI, EPA assumed the maximum PV contribution of 25,000 lb. The CDR sites and their PV contributions to unknown uses are show in Table_Apx D-17. The final PV assessed for this use was 50,295.15 lb/year (22,813 kg/year).

Product throughput is calculated by converting container volume to mass using the product density and multiplying by operating days, under EPA's assumption that each site uses one container of product each day. Container size is determined according to Appendix D.12.6. Product density is determined according to Appendix D.12.4. Operating days are determined according to Appendix D.12.5.

Equation_Apx D-88.

$$Q_{product\_year} = V_{cont} * 0.00379 \frac{m^3}{gal} * RHO_{product} * OD$$

Where:

$Q_{product\_year}$	=	Facility annual throughput of lubricant/fluid (kg/site-year)
V_{cont}	=	Container size (see Appendix D.12.6) (gal)
$RHO_{product}$	=	Product density (see Appendix D.12.4) (kg/m ³)
OD	=	Operating days (see Appendix D.12.5) (days/year)

The annual throughput of BBP is calculated using Equation_Apx D-89 by multiplying product annual throughput by the concentration of BBP in the product. Concentration of BBP in the product is determined according to Appendix D.12.4.

Equation_Apx D-89.

$$Q_{BBP\_year} = Q_{product\_year} * F_{BBP}$$

Where:

Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
$Q_{product\_year}$	=	Facility annual throughput of lubricant/fluid (kg/site-year)
F_{BBP}	=	Concentration of BBP in lubricant/fluid (see Appendix D.12.4) (kg/kg)

The daily throughput of BBP is calculated using Equation_Apx D-90 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Appendix D.12.5.

Equation_Apx D-90.

$$Q_{BBP\_day} = \frac{Q_{BBP\_year}}{OD}$$

Where:

Q_{BBP_day}	=	Facility throughput of BBP (kg/site-day)
Q_{BBP_year}	=	Facility annual throughput of BBP (kg/site-year)
OD	=	Operating days (see Appendix D.12.5) (days/year)

D.12.4 Mass Fraction of BBP in Lubricant/Fluid and Product Density

EPA modeled BBP mass fraction in lubricants and fluids using a uniform distribution with a lower bound of 0.001 percent and an upper bound of 50 percent. EPA modeled product density using a triangular distribution with a lower bound of 840 kg/m³, an upper bound of 1,000 kg/m³, and a mode of 900 kg/m³. EPA was not able to identify products for this uses that contained BBP. For that reason, EPA based the concentration and density estimates on compiled SDS information for lubricants and fluids containing DINP and assumed that BBP-containing lubricants and fluids would have similar concentrations and density ranges. The DINP-containing product are identified in Appendix F of the Technical Support Document for the Risk Evaluation for DINP ([U.S. EPA, 2025b](#)).

D.12.5 Operating Days

EPA modeled operating days per year using a uniform distribution with a lower bound of 1 day/year and an upper bound of 4 days/year. To ensure that only integer values of this parameter were selected, EPA nested the uniform distribution probability formula within a discrete distribution that listed each integer between (and including) one to four days/year. Both bounds are based on the ESD on Lubricants and Lubricant Additives ([OECD, 2004b](#)). The ESD states that changeout rates for hydraulic fluids range from three to 60 months. This corresponds to one to four changeouts per year, which EPA assumes is equal to operating days. Where changeout frequency occurs over 12 months, EPA used a value one container per 12 months as a representative value.

D.12.6 Container Size

EPA modeled container size using a triangular distribution with a lower bound of 20 gallons, an upper bound of 330 gallons, and a mode of 55 gallons. This was based on SDS and technical data sheets for DINP-containing lubricants, as lubricant products containing BBP were not identified. In this data, EPA identified lubricants in containers from less than one gallon to 330 gallons. The mode of the reported container sizes was 55 gallons. However, when running the model, smaller use rates produced an unreasonable number of use sites. Therefore, EPA assumed this to be an indication that it is unlikely that sites only have one small piece of equipment. Based on this and the remaining technical data, EPA selected 20 gallons as the lower bound ([U.S. EPA, 2025b](#)).

D.12.7 Loss Fractions

The loss fractions to each release media for the use and disposal of lubricants are based on the ESD on Lubricants and Lubricant Additives ([OECD, 2004b](#)). The ESD provides multiple values for loss fractions to land and water. EPA used these values to build the uniform distributions for each loss fraction. For the use of lubricants, the ESD provided a range of 0.014 to 0.16 for loss fractions to land, and 0.003 to 0.45 for loss fractions to water. For the disposal of lubricants, the ESD provided a range of 0.01 to 0.3 for loss fractions to land, and 0.23 to 0.37 for loss fractions to water.

D.12.8 Percentage of Waste to Recycling

The ESD on Lubricants and Lubricant Additives ([OECD, 2004b](#)) estimates that 4.3 percent of all hydraulic fluids are recycled.

D.12.9 Percentage of Waste to Fuel Blending

The ESD on Lubricants and Lubricant Additives ([OECD, 2004b](#)) estimates that 95.7 percent of all hydraulic/hydraulic fluids are reused for fuel oil or other general incineration releases.

D.13 Inhalation Exposure to Respirable Particulates Model Approach and Parameters

The Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021b](#)) estimates worker inhalation exposure to respirable solid particulates using personal breathing zone Particulate, Not Otherwise Regulated (PNOR) monitoring data from OSHA's Chemical Exposure Health Data (CEHD) data set. The CEHD data provides PNOR exposures as 8-hour TWAs by assuming exposures outside the sampling time are zero, and the data also include facility NAICS code information for each data point. To estimate particulate exposures for relevant OESs, EPA used the 50th and 95th percentiles of respirable PNOR values for applicable NAICS codes as the central tendency and high-end exposure estimates, respectively.

Due to lack of data on the concentration of BBP in the particulates, EPA assumed BBP is present in particulates at the same mass fraction as in the bulk solid material, whether that is a plastic product or another solid article. Therefore, EPA calculates the 8-hour TWA exposure to BBP present in dust and particulates using the following equation:

Equation_Apx D-91.

$$C_{BBP,8hr-TWA} = C_{PNOR,8hr-TWA} \times F_{BBP}$$

Where:

$C_{BBP,8hr-TWA}$	=	8-hour TWA exposure to BBP (mg/m ³)
$C_{PNOR,8hr-TWA}$	=	8-hour TWA exposure to PNOR (mg/m ³)
F_{BBP}	=	Mass fraction of BBP in PNOR (mg/mg)

Table_Apx D-30 provides a summary of the OESs assessed using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021b](#)) along with the associated NAICS code, PNOR 8-hour TWA exposures, BBP mass fraction, and BBP 8-hour TWA exposures assessed for each OES.

Table_Apx D-30. Summary of BBP Exposure Estimates for OESs Using the Generic Model for Exposure to PNOR

Occupational Exposure Scenario	NAICS Code Assessed	Respirable PNOR 8-Hour TWA from Model (mg/m ³)		BBP Mass Fraction Assessed	BBP 8-hour TWA (mg/m ³)	
		Central Tendency	High-End		Central Tendency	High-End
Import – Repackaging	42 – Wholesale and Retail Trade	0.22	5.0	0.30	6.6E-02	1.5
Incorporation into Formulation, Mixture, or Reaction Product – Adhesives and Sealants	325 – Chemical Manufacturing	0.48	5.0	0.7	0.34	3.5

Occupational Exposure Scenario	NAICS Code Assessed	Respirable PNOR 8-Hour TWA from Model (mg/m ³)		BBP Mass Fraction Assessed	BBP 8-hour TWA (mg/m ³)	
		Central Tendency	High-End		Central Tendency	High-End
Incorporation into Formulation, Mixture, or Reaction Product – Paints and Coatings	325 – Chemical Manufacturing	0.48	5.0	0.6	0.29	3
Incorporation into Formulation, Mixture, or Reaction Product – Other Formulations	325 – Chemical Manufacturing	0.48	5.0	1.0	0.48	5.0
Use of Laboratory Chemicals (Solid)	54 – Professional, Scientific, and Technical Services	0.19	2.7	1.0	0.19	2.7
Recycling	56 – Administrative and Support and Waste Management and Remediation Services	0.24	3.5	0.45	0.11	1.6
Fabrication or Use of Final Product / Articles Containing BBP	337 – Furniture and Related Product Manufacturing	0.20	1.8	0.45	9.0E-02	0.81
Waste Handling, Treatment, and Disposal	56 – Administrative and Support and Waste Management and Remediation Services	0.24	3.5	0.45	0.11	1.6

D.14 Spray Exposure Model Approach and Parameters

This section presents the modeling approach and equations used to estimate occupational exposures for BBP during the Application of paints and coatings OES. This approach utilizes the Automotive Refinishing Spray Coating Mist Inhalation Model from the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry ([OECD, 2011a](#)). The model estimates worker inhalation exposure based on the concentration of the chemical of interest in the nonvolatile portion of the sprayed product and the concentration of over sprayed mist/particles. The model is based on PBZ monitoring data for mists during automotive refinishing. EPA used the 50th and 95th percentile mist concentration along with the concentration of BBP in the paint to estimate the central tendency and high-end inhalation exposures, respectively.

D.14.1 Model Design Equations

The Automotive Refinishing Spray Coating Mist Inhalation Model calculates the 8-hour TWA exposure to BBP present in mist and particulates using the following equation:

Equation_Apx D-92.

$$C_{BBP,8hr-TWA} = \frac{C_{mist} \times F_{BBP\_solids} \times ED}{8 \text{ hrs}}$$

Where:

$C_{BBP,8hr-TWA}$	=	8-hour TWA inhalation exposure to BBP (mg/m ³)
C_{mist}	=	Over sprayed product mist concentration in the air within worker's breathing zone (mg/m ³)
F_{BBP_solids}	=	Mass fraction of BBP in the non-volatile portion of the spray (mg _{BBP} /mg _{nonvolatile components})
ED	=	Exposure Duration (hour)

D.14.2 Model Parameters

Table_Apx D-31 summarizes the input model parameters and their values for the Automotive Refinishing Spray Coating Mist Inhalation Model. Additional explanations of EPA's selection of the values for each parameter are provided after this table.

Table_Apx D-31. Summary of Parameter Values Used in the Spray Inhalation Model

Input Parameter	Symbol	Unit	OES	Parameter Value		Rationale/ Basis
				Central Tendency	High-End	
Concentration of Mist	C_{mist}	mg/m ³	Use of Paints and Coatings	3.38	22.1	See Appendix D.14.2.1
BBP Concentration in Product	F_{BBP_prod}	kg/kg	Use of Paints and Coatings	0.25	0.5	See Appendix D.14.2.2
Concentration of Nonvolatile Solids in the Spray Product	F_{solids_prod}	mg/mg	Use of Paints and Coatings	0.5	0.25	See Appendix D.14.2.3
BBP Concentration of Nonvolatile Components	F_{BBP_solids}	mg/mg	Use of Paints and Coatings	0.5	1.0	See Appendix D.14.2.4
Exposure Duration	ED	hr	Use of Paints and Coatings	8		See Appendix D.14.2.5

D.14.2.1 Concentration of Mist

EPA utilized coating mist concentrations within spray booths obtained through a search of available OSHA In-Depth Surveys of the Automotive Refinishing Shop Industry and other relevant studies, as published in the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry ([OECD, 2011a](#)). The data is divided into various combinations of spray booth types (*e.g.*, downdraft and crossdraft) and spray gun types (*e.g.*, conventional, high-volume low-pressure). EPA expects there to be a variety of facility types and substrates being coated such that a variety of spray booth and spray gun combinations may be used to apply the products. Due to this, EPA used mist concentrations from all scenarios for this parameter. Central tendency and high-end scenario parameters represent the 50th and 95th percentile mist concentrations, respectively. The central tendency mist concentration was 3.38 mg/m³ and the high-end concentration was 22.1 mg/m³.

D.14.2.2 BBP Product Concentration

EPA developed the concentration inputs based on the single finished liquid coating product SDS available, which listed BBP concentration with a range of 0.1 to 50 percent by weight (see Appendix E

for EPA identified BBP-containing products for this OES). EPA notes that Appendix E contains a product with a concentration range of 30 to 60 percent BBP by weight, but this was for a pigment product and the concentration of BBP in the formulated coating product would be less than the next highest value on the list of less than 50 percent. From this range, EPA used the average of the minimum and maximum concentrations as the central tendency and the maximum concentration as the high-end BBP concentration. The central tendency value was 0.25, and the high-end value was 0.50.

D.14.2.3 Concentration of Nonvolatile Solids in the Spray Product

The ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry cites data from Volume 6 of the Kirk-Othmer Encyclopedia of Chemical Technology stating that nonvolatile solids in a spray paint or coating product can range from 0.15 to 0.50 mg/mg ([OECD, 2011a](#); [Bryant, 1993](#)). EPA used the ESD recommended value of 0.50 mg/mg and the upper bound of the underlying distribution of 0.25 mg/mg for the central tendency and high-end parameters, respectively ([OECD, 2011a](#)).

D.14.2.4 BBP Concentration in Nonvolatile Components

The mass fraction of BBP in the nonvolatile portion of the sprayed product is calculated using the following equation:

Equation_Apx D-93.

$$F_{BBP\_solids} = \frac{F_{BBP\_prod}}{F_{solids\_prod}}$$

Where:

F_{BBP_solids}	=	Mass fraction of BBP in the nonvolatile portion of the sprayed product (mgBBP/mgnonvolatile components)
F_{BBP_prod}	=	Mass fraction of BBP in the paint or coating product, spray-applied (mgBBP/mgsprayed product)
F_{solids_prod}	=	Mass fraction of nonvolatile components within the sprayed product (mgnonvolatile components/mgsprayed product)

If this equation results in F_{BBP_solids} exceeds 1, then the value of F_{BBP_solids} is assessed at a value of 1. EPA divided the high-end F_{BBP_prod} by the central tendency F_{solids_prod} in order to calculate the highest concentration of F_{BBP_solids} given the available central tendency and high-end parameters. EPA also divided the central tendency F_{BBP_prod} by the high-end F_{solids_prod} in order to calculate the lowest F_{BBP_solids} given the available central tendency and high-end parameters. EPA used these calculated F_{BBP_solids} values as the central tendency and high-end parameters for the variable, 0.5 and 1.0, respectively.

D.14.2.5 Exposure Duration

EPA did not identify BBP-specific data on spray application duration. Due to this, and the expected variety in substrates and facility types for these scenarios, the exposure duration was assessed at a full 8-hour shift. The full-shift assumption may overestimate the application duration as workers likely have other activities (*e.g.*, container unloading and cleaning) during their shift; however, those activities may also result in exposures to vapors that volatilize during those activities. Since EPA is not factoring in those vapor exposures, an 8-hour duration for spraying is used and assumed to be protective of any contribution to exposures from vapors.

Appendix E PRODUCTS CONTAINING BBP

This appendix includes a sample of products containing BBP. This is not a comprehensive list of products containing BBP. In addition, some manufacturers may appear over-represented in this table. This may mean that they are more likely to disclose product ingredients online than other manufacturers but does not imply anything about use of the chemical compared to other manufacturers in this sector.

Table_Apx E-1. Products Containing BBP

OES	Product	Manufacturer	BBP Concentration	Source
Adhesives and sealants	126VR Disc Brake Quiet 0.25 Fl. Oz Pouch	ITW Permatex	5–10%, by weight	(Permatex, 2020)
Adhesives and sealants	Air Bloc 33	Henry Company	1–5%, by weight	(Henry Company, 2015)
Adhesives and sealants	Spectrem 3 Aluminum Stone -30 CTG	Tremco Canadian Sealants [Canada]	7–13%, by weight	(Tremco Canadian Sealants, 2015b)
Adhesives and sealants	Permatite Acrylic Sealant	Permatite / Division of DSI	7–13%, unspecified	(Permatite, 2015)
Adhesives and sealants	Protecto Sealant 25XL	Protecto Wrap Company	10–30%, by weight	(Protecto Wrap, 2020)
Adhesives and sealants	Spectrem 4	Tremco U.S Sealants	5 to <10%, by weight	(Tremco Sealants, 2018a)
Adhesives and sealants	Wilsonart Color Matched Caulk	Wilsonart LLC	7–13%, by weight	(Wilsonart LLC, 2013)
Adhesives and sealants	Double Bubble Urethane High Peel Strength D50 Part A (04022)	Royal Adhesives & Sealants	5–20%, unspecified	(Royal Adhesives & Sealants, 2017)
Adhesives and sealants	Dymonic FC Anodized Aluminum	Tremco Canadian Sealants [Canada]	15–40%, by weight	(Tremco Canadian Sealants, 2015a)
Adhesives and sealants	Hercules Plumber's Caulk -White/Linen	HCC Holdings Inc.	5–10%, by weight	(HCC Holdings Inc., 2015)
Adhesives and sealants	FLEXER Epoxy Flexibilizer	Smooth-On, Inc.	0–20%, by weight	(Smooth-On Inc., 2018)
Adhesives and sealants	GE7000	Momentive Performance Materials	5 to <10%, by weight	(Momentive, 2017)
Adhesives and sealants	Part A: PMC-724	Smooth-On, Inc.	40–70%, by weight	(Smooth-On, 2023a)
Adhesives and sealants	Part A: Smooth-Cast 325	Smooth-On, Inc.	5–15%, unspecified	(Smooth-On, 2022)
Adhesives and sealants	Task 9 and Task 10 Part A	Smooth-On, Inc.	10–20%, by weight	(Smooth-On Inc., 2010)
Adhesives and sealants	Part A: Task 9	Smooth-On, Inc.	5–15%, by weight	(Smooth-On, 2023b)

OES	Product	Manufacturer	BBP Concentration	Source
Paints and coatings	IC 1-gl 2pk Gray Shop Coat Primer	Rust-Oleum Corporation	1.5%, by weight	(Rust-Oleum Corporation, 2018)
Paints and coatings	Klean-Strip Mask & Peel Paint Booth Coating	W. M. Barr	<2.0%, unspecified	(W.M. Barr, 2015)
Paints and coatings	Lacquer Touch-up Paint -Clear Topcoat	Ford Motor Company	5%, unspecified	(Ford Motor Company, 2019)
Paints and coatings	A/D Firefilm III	A/D Fire Protection Systems [Canada]	0.1–1.0%, unspecified	(Carboline, 2022a)
Paints and coatings	A/D Firefilm III	Carboline Company	0.1 to <1.0%, unspecified	(Carboline, 2023)
Paints and coatings	A/D Firefilm III C	Carboline Company	0.1 to <1.0%, unspecified	(Carboline, 2018)
Paints and coatings	Carbocrylic 3359 DTM	Carboline Company	1.0–2.5%, unspecified	(Carboline, 2022b)
Paints and coatings	Black Tire Paint Concentrate	Akron Paint and Varnish (dba APV Engineered Coatings)	0.70%, by weight	(APV, 2018)
Paints and coatings	Repair and Refinishing Spray	Multi-Tech Products Corp.	0.1 to <1%, unspecified	(Multi-Tech Products Corp, 2015)
Paints and coatings	SK Clear-Seal Satin Sealer 5 Gal	Rust-Oleum Corporation	0.1–1.0%, by weight	(Rust-Oleum, 2017)
Paints and coatings	Steri-Crete SL Component A	Dudick, Inc.	20–25%, by weight	(Dudick Inc., 2015)
Paints and coatings	Stonclad UT Resin Polyol	Stonhard, Division of StonCor Group, Inc.	25 to <50%, unspecified	(Stonhard, 2024)
Paints and coatings	Vulkem 360 NF	Tremco Canadian Sealants [Canada]	10 to <20%, by weight	(Tremco Sealants, 2018b)
Paints and coatings	Carbothane 133 HB Part A	Carboline Company	1.0 to <2.5%, unspecified	(Carboline, 2022c)
Paints and coatings (inks)	6840 Ultra Black	BJB Enterprises, Inc.	30–60%, by weight	(BJB Enterprises, 2019)
Paints and coatings (inks)	Handstamp – Blue	Identity Group	15–25%, unspecified	(Identity Group, 2017)
Plastic compounding/ converting	ENSURE Sterilization Emulator	SciCan Ltd. [Canada]	<0.1%, by weight	(SciCan Ltd, 2015)
Plastic compounding/ converting	So-Flex	Smooth-On, Inc.	≥99%, unspecified	(Smooth-On, 2007)
Non-PVC materials	TC-680 Part B	BJB Enterprises, Inc.	60–100%, by weight	(BJB Enterprises, 2021a)
Non-PVC materials	TC-690 Part B	BJB Enterprises, Inc.	40–70%, by weight	(BJB Enterprises, 2022)

OES	Product	Manufacturer	BBP Concentration	Source
Non-PVC materials	TC-9445 Part B	BJB Enterprises, Inc.	40–70%, by weight	(BJB Enterprises, 2021c)
Non-PVC materials	TC-995 Part B	BJB Enterprises, Inc.	40–70%, by weight	(BJB Enterprises, 2021b)
Laboratory chemicals	PermaMounter	Bio SB, Inc.	<1%, by weight	(Bio SB Inc., 2019)
Laboratory chemicals	Base/Neutrals Mix 1	SPEX CertiPrep, LLC	0.2%, unspecified	(SPEX CertiPrep, 2019)
Laboratory chemicals	Butyl Benzyl Phthalate Standard	Phenova	0.1%, unspecified	(Phenova, 2018)
Laboratory chemicals	Custom 8061 Phthalates Mix	Phenova	0.1%, unspecified	(Phenova, 2017a)
Laboratory chemicals	Custom Low ICAL Mix	Phenova	0.1%, unspecified	(Phenova, 2017b)
Laboratory chemicals	Butylbenzyl phthalate in PE	SPEX CertiPrep, LLC	0.1%, unspecified	(SPEX CertiPrep, 2016)
Laboratory chemicals	Phthalates in Poly(vinyl chloride)	SPEX CertiPrep, LLC	0.3%, unspecified	(SPEX CertiPrep, 2021)