



United States
Environmental Protection Agency

EPA Document# EPA-740-R-25-026

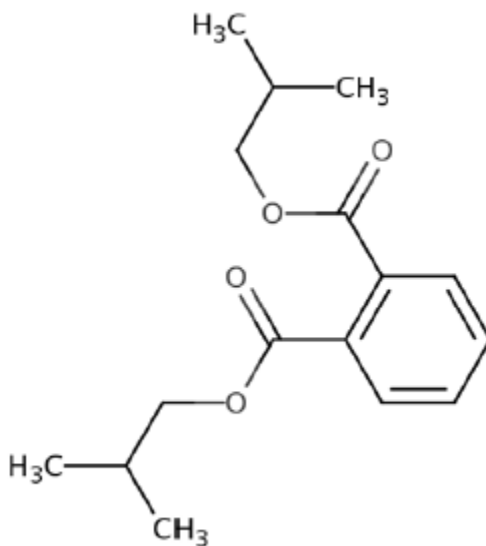
December 2025

Office of Chemical Safety and
Pollution Prevention

Environmental Release and Occupational Exposure Assessment for Diisobutyl Phthalate (DIBP)

Technical Support Document for the Risk Evaluation

CASRN 84-69-5



December 2025

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KEY ABBREVIATIONS AND ACRONYMS

AC	Acute exposure concentration
ACGIH	American Conference of Governmental Industrial Hygienists
AD	Acute retained dose
ADD	Average daily dose
ADC _{intermediate}	Intermediate average daily concentration
AIHA	American Industrial Hygiene Association
APDR	Acute potential dermal dose rate
APF	Assigned protection factor
AT _{acute}	Acute averaging time
AT _C	Averaging time for cancer risk
AT _I	Averaging time for intermediate exposure
AWD	Annual working days
BLS	Bureau of Labor Statistics (U.S.)
BR	Breathing rate
BW	Body weight
CDR	Chemical Data Reporting
CEB	Chemical Engineering Branch
CEC	Commission for Environmental Cooperation
CEHD	Chemical Exposure Health Database
CFR	Code of Federal Regulations
COU	Condition of use
CPS	Current Population Survey
CPSC	Consumer Product Safety Commission (U.S.)
CT	Central tendency
DBP	Dibutyl phthalate
DD	Dermal daily dose
DIBP	Diisobutyl phthalate
DMR	Discharge Monitoring Report
ECETOC TRA	European Centre for Ecotoxicology and Toxicology of Chemicals Targeted Risk Assessment
ED	Exposure duration
EF	Exposure frequency
EF _{int}	Intermediate exposure frequency
ELG	Effluent Limitation Guidelines
EPA	Environmental Protection Agency (U.S.)
ESD	Emission Scenario Document
ETIMEOFF	Months When Not Working (CPS data)
GS	Generic Scenario
h	Exposure durations
HAP	Hazardous Air Pollutant
HE	High-end
HVLP	High volume low pressure
IADC	Intermediate average daily concentration
ID	Days for intermediate duration
LADC	Lifetime average daily concentrations
LADD	Lifetime average daily dose
LOD	Limit of detection
LT	Lifetime years for cancer risk

MW	Molecular weight of DIBP
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
OARS	Occupational Alliance for Risk Science
OECD	Organisation for Economic Co-Operation and Development
OEL	Occupational exposure limit
OES	Occupational exposure scenario
OIS	Occupational Safety and Health Information System
ONU	Occupational non-users
OPPT	Office of Pollution Prevention and Toxics (EPA)
OSHA	Occupational Safety and Health Administration
OVS	OSHA versatile sampler
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
RD	Release days
REL	Recommended exposure limits
ρ_{product}	Product density
ρ_{DIBP}	DIBP density
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
T_{AGE}	Worker Age in SIPP
TDS	Technical data sheets
TJBIND1	Employed Individual Works (SIPP data)
TLV	Threshold limit value
TMAKMNYR	First Year Worked (SIPP data)
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TSD	Technical support document
TWA	Time-weighted average
V_{mDIBP}	Molar volume of DIBP
VP	DIBP vapor pressure
WEEL	Workplace environmental exposure level
WWT	Wastewater treatment
WY	Working Years per Lifetime

SUMMARY

This technical support document (TSD) accompanies the Toxic Substances Control Act (TSCA) *Risk Evaluation for Diisobutyl Phthalate (DIBP)* ([U.S. EPA, 2025c](#)). DIBP is on the TSCA Inventory, making it reportable under the Chemical Data Reporting (CDR) rule. This TSD describes the use of reasonably available information to estimate environmental releases of DIBP and to evaluate occupational exposure to workers. See the risk evaluation for DIBP for a complete list of all the TSDs for DIBP.

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 DIBP. The 2016 CDR report indicated that less than one million pounds (lb) of CASRN 84-69-5 were manufactured or imported in the United States in 2015 ([U.S. EPA, 2019a](#)). The 2020 CDR report indicates that 184,750 kg of DIBP were manufactured in 2019, and there were no reports of DIBP importing. Review of preliminary 2024 CDR data shows that that total production volume for the years 2020 – 2023 are similar to the previously reported range from 2020 CDR. The largest number of reported uses of DIBP is as a plasticizer in plastics, adhesives, sealants, paints, coatings, catalysts, and other applications.

Exposures to workers, consumers, general populations, and ecological species may occur from releases of DIBP to air, land, and water from industrial, commercial, and from consumer uses of DIBP and DIBP-containing articles. Workers and occupational non-users (ONUs) may be exposed to DIBP while handling solid and liquid formulations that contain DIBP or during dust and mist generating activities that may be present during most 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 document provides the details of the assessment of the environmental releases and occupational exposures from each COU of DIBP.

Approach for Assessing Environmental Releases and Occupational Exposures

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 DIBP to air, water, and land from the OESs associated with the COUs assessed in the risk evaluation. Due to the lack of release data for DIBP, the Agency used modeling approaches to assess release estimates.

EPA evaluated acute, intermediate, and chronic exposures to workers and ONUs for each OES. The Agency did not find DIBP-specific inhalation monitoring data from literature and assessed inhalation exposures using exposure models and surrogate monitoring data for all OESs. EPA also used empirical dermal absorption data from a surrogate chemical (*i.e.*, dibutyl phthalate [DBP]) as well as modeling approaches to estimate dermal exposures to workers and ONUs.

Results for Environmental Releases and Occupational Exposures

EPA evaluated environmental releases of DIBP to air, water, and/or land for all but two OESs assessed in the risk evaluation. EPA did not quantitatively assess environmental releases for the Fabrication of

final product from articles OES and Waste handling, treatment, and disposal OES due to the lack of readily available process-specific and DIBP-specific data. The OES with the highest expected daily release was the Plastics compounding OES. Detailed release results for each OES to each media can be found in Section 3.

EPA also evaluated inhalation and dermal exposures to worker populations, including ONUs and females of reproductive age, for each OES. DIBP inhalation exposures may be to vapors when DIBP is in liquid form and to particulates when DIBP is in a solid form. Also, liquid paint, coating, adhesive, and sealant products containing DIBP may be sprayed, generating a mist that may lead to inhalation and dermal exposures. Worker exposures to vapors and particulates are relatively low compared to mist exposures. Dermal exposures of DIBP in neat and liquid formulations, as well as solid materials, are not expected to be significant based on modeled estimates. Detailed exposure results for each OES and exposure route can be found in Section 3.

Uncertainties of the Results for Environmental Releases and Occupational Exposures

Uncertainties exist with the modeling approaches used to assess DIBP environmental releases and occupational exposures. For example, the lack of DIBP facility production volume data resulted in the use of throughput estimates based on CDR reporting thresholds for some OESs, which may not be representative of the actual production volume of DIBP for that OES. EPA also used generic EPA models and default input parameter values as 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. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and the chemical is contacted at least once per day. Because DIBP 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. In absence of exposure duration data, EPA has assumed that absorption of DIBP from occupational dermal contact with materials containing DIBP may extend up to 8 hours per day ([U.S. EPA, 1991b](#)). However, if a worker uses proper personal protective equipment (PPE) or washes their hands after contact with DIBP or DIBP-containing materials, dermal exposure may be largely reduced.

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

EPA assessed environmental releases to air, water, and land to estimate exposures to the general population and ecological species for DIBP COUs. The environmental release estimates developed by the Agency are used to estimate the presence of DIBP 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 and ONUs for each OESs. The Agency assumed that workers and ONUs would be individuals of both sexes (ages 16+ years, including pregnant workers) based upon occupational work permits. 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 technical support document (TSD) provides details on the occupational exposure and environmental release assessment and supplements the risk evaluation for diisobutyl phthalate (DIBP) under the Frank R. Lautenberg Chemical Safety for the 21st Century Act, the legislation that amended the Toxic Substances Control Act (TSCA) on June 22, 2016. The new law includes statutory requirements and deadlines for actions related to conducting risk evaluations of existing chemicals.

Under TSCA section 6(b), the Environmental Protection Agency (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 non-risk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator under the conditions of use.”

TSCA section 6(b)(4)(D) and implementing regulations require that EPA publish the scope of the risk evaluation to be conducted, including the hazards, exposures, COUs and potentially exposed or susceptible subpopulations (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. DIBP is one of the chemicals designated as a high priority substance for risk evaluation.

DIBP is a colorless liquid that is used primarily as a plasticizer in a variety of products, including adhesives, sealants, and plastic and rubber products. It is a phthalate ester that is typically manufactured through catalytic esterification of phthalic anhydride with isobutanol. DIBP is not reported to the Toxics Release Inventory (TRI). DIBP is on the TSCA Inventory and reported under the Chemical Data Reporting (CDR) rule.

1.2 Scope

EPA assessed environmental releases and occupational exposures for COUs as described in Table 2-2 of the *Final Scope of the Risk Evaluation for Di-isobutyl Phthalate (DIBP) CASRN 84-69-5* ([U.S. EPA, 2020c](#)). To estimate environmental releases and occupational exposures, EPA first developed OES related to the TSCA COUs of DIBP. An OES is based on a set of facts, assumptions, and inferences that describe how releases and exposures take place within an occupational COU. The occurrence of releases/exposures may be similar across multiple COUs, or there may be several ways in which releases/exposures take place for a given COU. Table 1-1 shows mapping between the COUs from the risk evaluation and the OES assessed in this TSD.

In general, EPA mapped OESs to COUs using professional judgment based on available data and information. Several of the COU 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, COU subcategories were further delineated into multiple OES based on expected differences in process equipment and associated releases/exposure potentials between facilities. EPA assessed environmental releases and occupational exposures as described in Table 1-1.

Table 1-1. Crosswalk of COUs Listed in the Risk Evaluation to Assessed OES

COU			OES
Life Cycle Stage	Category	Subcategory of Use	
Manufacturing	Domestic manufacturing	Domestic manufacturing	Manufacturing
	Import	Import	Repackaging into large and small containers
Processing	Repackaging (<i>e.g.</i> , laboratory chemicals)	Repackaging (<i>e.g.</i> , laboratory chemicals)	Repackaging into large and small containers
	Incorporation into article	Plasticizer in plastic product manufacturing	Plastics converting
		Plasticizer in transportation equipment manufacturing	Plastics converting
	Incorporation in formulation, mixture, or reaction product	Plasticizer in adhesive manufacturing	Incorporation into adhesives and sealants
		Plasticizer in plastic product manufacturing	Plastic compounding
		Solvents (which become part of product formulations or mixture) in plastic material and resin manufacturing	Plastic compounding
		Paint and coating manufacturing	Incorporation into paints and coatings
		Processing aids, not otherwise listed	Plastic compounding
		Plastic and rubber products not covered elsewhere	Rubber manufacturing
		Pre-catalyst manufacturing (<i>e.g.</i> , catalyst component for polyolefins production)	Use as a catalyst – formulation into pre-catalyst
		Foam pipeline pig manufacturing	Rubber manufacturing
	Processing – as a reactant	Intermediate in plastic manufacturing	Use as a catalyst

COU			OES
Life Cycle Stage	Category	Subcategory of Use	
	Recycling	Recycling	Recycling
Distribution in Commerce	Distribution in commerce	Distribution in commerce	Distribution in commerce
Industrial Use	Paints and coatings	Paints and coatings	Application of paints and coatings
	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Fabrication of final product from articles
	Adhesives and sealants	Two component glues and adhesives	Application of adhesives and sealants
		Transportation equipment manufacturing	Application of adhesives and sealants
Commercial Uses	Adhesives and sealants	Two component glues and adhesives	Application of adhesives and sealants
	Paints and coatings	Paints and coatings	Application of paints and coatings
	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Fabrication of final product from articles
	Laboratory chemicals	Laboratory chemicals	Use of laboratory chemicals
	Toys, playground, and sporting equipment	Toys, playground, and sporting equipment	Fabrication of final product from articles
Disposal	Disposal	Disposal	Waste handling, treatment, and disposal

EPA's assessment of releases includes quantifying annual and daily releases of DIBP 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 report, 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). For purposes of this risk evaluation, EPA did not evaluate discharges to POTW and non-POTW WWT using the same methodology as discharges to surface water. 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 DIBP 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 DIBP* ([U.S. EPA, 2025c](#)) describes how these factors were considered for the purpose of risk characterization.

For workplace exposures, EPA considered exposures to both workers who directly handle DIBP and ONUs who do not directly handle DIBP, but may be exposed to dust, vapors or mists that enter their breathing zone while working in locations near where DIBP handling occurs. 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 *Risk Evaluation for DIBP* ([U.S. EPA, 2025c](#)) and the calculations can be found in the *Risk Calculator for Occupational Exposures for DIBP* ([U.S. EPA, 2025a](#)).

2 TYPICAL COMPONENTS OF EPA's RELEASE AND OCCUPATIONAL EXPOSURE ASSESSMENT

EPA describes the assessed COUs for DIBP in Section 1.1.2 of the *Risk Evaluation for DIBP* ([U.S. EPA, 2025c](#)); however, some COUs differ in terms of specific DIBP processes and associated exposure/release scenarios. Therefore, Table 1-1 provides a crosswalk that maps the DIBP 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 DIBP 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 DIBP 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.
 - **Number of Workers and ONUs:** An estimate of the number of workers and ONUs potentially exposed to the chemical for the given OES. This is contextual information and is not necessary for the assessment of occupational exposure. This document does not include estimates of the number of workers and ONUs but the final version of this document will contain this information.
 - **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.

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 DIBP-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 3.14 to 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 DIBP in the 2016 and 2020 CDR to an OES ([U.S. EPA, 2019a](#)); ([U.S. EPA, 2020b](#)). 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 dataset, evaluate whether the data in the reporting programs is expected to cover most or all of the facilities within the OES. If so, EPA assessed the total number of facilities in the OES as equal to the count of facilities mapped to the OES from each dataset. 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 DIBP instead of other chemicals. Market penetration refers to the extent to which one chemical is utilized within an industry relative to the total estimated potential market.
 - d. Combine the data generated in Steps 3.a. through 3.c. to produce an estimate of the number of facilities using DIBP 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, EPA assumed this estimate encompassed the facilities identified in Step 1; therefore, EPA assessed the total number of facilities for the OES as the total generated from this analysis.
4. If market penetration data required for Step 3.c. are not available, use generic industry data from GSs, ESDs, and other literature sources on typical throughputs/use rates, operating schedules, and the DIBP 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, EPA used stochastic modeling to provide a range of estimates for the number of facilities within the OES. EPA describes the approaches, equations, and input parameters used in stochastic modeling in the relevant OES sections throughout this report.

2.3 Environmental Releases Approach and Methodology

EPA assessed releases to the environment 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), apart from the OES for Fabrication of final product from articles and Waste handling, treatment, and disposal, which were assessed qualitatively for releases as discussed in Section 3.9.3 and Section 3.13.3.

EPA used the following hierarchy 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).

Where available, EPA may also use data from literature sources to estimate environmental releases. However, there were no studies identified in the systematic review process for use in environmental release estimation. 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:** EPA used a combination of point estimates of each input parameter (*e.g.*, high-end and low-end values) 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 3.14.

2.3.1 Identifying Release Sources

EPA performed a literature search to identify process operations that could potentially result in releases of DIBP to air, water, or land from each OES. EPA identified the release sources and the associated media of release. Where DIBP-specific release sources were unclear or unavailable, EPA referenced relevant ESDs or GSs. Sections 3.1 through 3.14 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 2 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 2 weeks down for turnaround).
5. **Other Chemical Plant OESs (e.g., Processing into formulation and repackaging):** For these OES, EPA assumed that the facility does not always use the chemical of interest, even if the facility operates 24/7. 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 OES) 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, EPA used a value of 365 days per year.
7. **All Other OESs:** Regardless of the facility operating schedule, other OES are unlikely to use the chemical of interest every day. Therefore, EPA used a value of 250 days per year for these OES.

2.3.3 Estimating Releases from Models

EPA utilized models to estimate environmental releases for OES without TRI, DMR, or NEI data. These models apply deterministic calculations, stochastic calculations, or a combination of both 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](#)). Section 3 and Appendix D provide 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 modelled releases, the media of release is dependent on site- and process-specific practices that are unknown. 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. This may reduce the confidence of these assessments.

2.4 Occupational Exposure Approach and Methodology

EPA evaluated inhalation and dermal exposures and developed occupational exposure results representative of central tendency and high-end exposure conditions for the purpose of this risk evaluation. The central tendency is expected to represent occupational exposures in the center of the distribution for a given COU. 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](#)). EPA's approach to the assessment of central tendency and high-end values is discussed below.

With regard to a central tendency value, 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.

With regard to a high-end value, 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 99th 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 estimated air concentrations to calculate exposure concentration metrics required for risk assessment, such as average daily concentration (ADC). 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 attempted to provide 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
 - 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 average daily dose (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

For the DIBP exposure assessment, inhalation monitoring data were not available. Therefore, EPA used a modeling approach as described in Section 2.4.2.2.

2.4.2.2 Inhalation Exposure Modeling

Where inhalation exposures are expected for an OES, EPA utilized models to estimate inhalation exposures because inhalation monitoring data were unavailable for DIBP. 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 by assuming that all of the identified activities are done by the same worker during a single shift. Accordingly, 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 version 8.0 software with 100,000 iterations and the Latin Hypercube sampling method ([Palisade, 2022](#)). Appendix D through D.15 provides detailed descriptions of the model approaches used for each OES, model equations, and input parameter values and associated distributions.

EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES based on the summation of results of environmental fugitive releases to air and their associated exposure durations for each OES (to see environmental releases by OES, refer to Section 3). Therefore, EPA only estimated worker vapor inhalation exposures for the DIBP manufacturing OES to represent the most protective exposure outcome of all possible vapor exposure OESs. The method of this determination is described in Section D.14.

2.4.3 Estimating Dermal Exposures

This section summarizes the available dermal absorption data related to DIBP (Section 2.4.3.1), the interpretation of the dermal absorption data for estimating dermal absorption from liquid materials (Section 2.4.3.2), dermal absorption modeling efforts for estimating dermal absorption from solid materials (Section 2.4.3.3), and consideration of vapor to skin exposures (Section 2.4.3.4). Dermal absorption data were sufficient to characterize occupational dermal exposures to liquids or formulations containing DIBP (Section 2.4.3.1); however, dermal data were not sufficient to estimate dermal exposures to solids or articles containing DIBP. Therefore, modeling efforts described in Section 2.4.3.3 were utilized to estimate dermal exposures to solids or articles containing DIBP. See Appendix C for more details on occupational dermal exposure estimation.

2.4.3.1 Dermal Absorption Data

Dermal absorption data related to DIBP are limited. Specifically, EPA identified only one study directly related to the dermal absorption of DIBP ([Elsisi et al., 1989](#)), which is an *in vivo* absorption study using male F344 rats. For each *in vivo* dermal absorption experiment, neat DIBP was applied to a freshly shaven area of 1.3 cm² in doses ranging from 5 to 8 mg/cm² and the site of application was covered with a perforated cap. Urine and feces were collected and analyzed every 24 hours for a duration of 7 days, and at the end of the seventh day, each rat was killed and all remaining contents (tissues, organs, *etc.*) were analyzed. Results of the study show 52 percent absorption of DIBP over the 7-day period, and EPA calculated the maximum flux of neat DIBP in rats equal to 2.48×10^{-2} mg/cm²/hr. [Elsisi et al. \(1989\)](#) also measured dermal absorption for dibutyl phthalate (DBP), and results show 64.8 percent absorption of DIBP over the 7-day period. EPA calculated the maximum flux of neat DBP in rats equal to 3.08×10^{-2} mg/cm²/hr. Though EPA did not identify any studies measuring absorption of DIBP through human skin, there were three studies identified that measured the dermal absorption of DBP using human skin ([Hopf et al., 2024](#); [Beydon et al., 2010](#); [Scott et al., 1987](#)). Because DIBP and DBP are isomers with similar physical and chemical properties and similar absorption profiles in rats ([Elsisi et al., 1989](#)), human absorption data measured for DBP is used as surrogate to estimate the absorption potential of DIBP in humans.

As mentioned above, EPA did not identify any studies measuring absorption of DIBP through human skin, though there were three studies identified that measured the dermal absorption of DBP using human skin ([Hopf et al., 2024](#); [Beydon et al., 2010](#); [Scott et al., 1987](#)). The *in vitro* experiments of the [Scott et al. \(1987\)](#) study utilized non-viable human skin samples and a 50 percent aqueous ethanol solution for the receptor fluid which may lead to increased levels of absorption. However, [Scott et al. \(1987\)](#) showed that rat skin was about 40 times more permeable than human skin. The *in vitro* experiments of the [Hopf et al. \(2024\)](#) study only measured for metabolites of DBP but did not verify that the previously frozen skin samples were metabolically active. Therefore, it is likely that results of the *in vitro* experiments of the [Hopf et al. \(2024\)](#) study slightly underestimate DBP absorption. The *ex vivo* experiments of the [Beydon et al. \(2010\)](#) study were selected as the most representative study for estimating dermal absorption of DBP from liquids, and the study reported a rate of dermal absorption of 5.9×10^{-4} mg/cm²/h in human skin. [Beydon et al. \(Beydon et al., 2010\)](#) conducted *ex vivo* experiments in human, rat, rabbit, guinea pig, and mouse skin, and results showed that rat skin was about 40 – 80 times more permeable than human skin. The skin samples were exposed to neat radiolabeled DBP (50 mg/cm²) without occlusion, and skin samples were determined to be viable and metabolically active at the time of testing.

2.4.3.2 Dermal Absorption for Liquids

The dermal absorption study by Elsisi *et al.* (1989) reports the dermal absorption of both DBP and DIBP in live rats, with the maximum rates of dermal absorption equal to 3.08×10^{-2} mg/cm²/h and 2.48×10^{-2} mg/cm²/h, respectively. The study by Elsisi *et al.* (1989) shows that the rates of dermal absorption measured in live rats are quite similar between the two chemicals. However, dermal absorption rates measured from rat skin may overestimate dermal absorption rates applicable to human skin (Beydon *et al.*, 2010; Scott *et al.*, 1987).

Since DIBP and DBP are isomers, and the two isomers share very similar physical-chemical properties (*i.e.*, identical molecular weights and very similar octanol-water partition coefficients), it is expected that the difference in permeability between rat skin and human skin exhibited by DBP is also relevant for DIBP. Because absorption data from live rats likely overestimate dermal absorption of DIBP in humans, and due to the similar physical-chemical properties between DBP and DIBP, EPA prefers the use of surrogate dermal absorption data for DBP in human skin samples over dermal absorption data for DIBP in live rats to estimate the potential rate of dermal absorption of DIBP in humans. Therefore, the rate of absorption of DIBP from liquid materials is estimated using surrogate data reported by Beydon *et al.* (2010) for dermal absorption of DBP in human skin samples (*i.e.*, 5.9×10^{-4} mg/cm²/h).

2.4.3.3 Dermal Absorption for Solids

Because DIBP has low volatility and relatively low absorption, the dermal absorption of DIBP was estimated based on the flux of material rather than percent absorption. For cases of dermal absorption of DIBP from a solid matrix, EPA assumes that DIBP first migrates from the solid matrix to a thin layer of moisture on the skin surface. It is important to note that there are mass transfer limitations from powders and solid matrices to the aqueous phase. However, it is conservatively assumed that the migration rate from the solid material will be sufficient to saturate the aqueous layer on the skin surface. Therefore, absorption of DIBP from solid matrices is considered limited by aqueous solubility and is estimated using an aqueous absorption model as described below.

The first step in determining the dermal absorption through aqueous media is to estimate the steady-state permeability coefficient, K_p (cm/hr). EPA utilized the Consumer Exposure Model (CEM) (U.S. EPA, 2023b) to estimate the steady-state aqueous permeability coefficient of DIBP. Next, EPA relied on Equation 3.2 from the *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual, (Part E: Supplemental Guidance for Dermal Risk Assessment)* (U.S. EPA, 2004b) which characterizes dermal uptake for aqueous organic compounds. Specifically, Equation 3.2 from U.S. EPA (2004b), also shown in Equation 2-1 below, was used to estimate the dermally absorbed dose (DA_{event} , mg/cm²) for an absorption event occurring for some duration (t_{abs}).

Equation 2-1. Dermal Absorption Dose During Absorption Event

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

Where:

DA_{event}	=	Dermally absorbed dose during absorption event t_{abs} (mg/cm ²)
FA	=	Effect of stratum corneum desquamation on quantity absorbed = 0.9 (see Exhibit A-5 of U.S. EPA (2004b))
K_p	=	Permeability coefficient = 0.0157 cm/h (calculated using CEM (U.S. EPA, 2023b))

S_w	=	Water solubility of DIBP = 6.2 mg/L (see U.S. EPA (2025c))
t_{lag}	=	$0.105 \times 10^{0.0056MW} = 0.105 \times 10^{0.0056 \times 278.35} = 3.8$ hours [calculated from A.4 of U.S. EPA (2004b)]
t_{abs}	=	Duration of absorption event (hours)

The term “FA” is used to estimate the effect of desquamation of the stratum corneum during the absorption period. For DBP, FA = 0.9 which means that 10 percent of the chemical in the skin may be lost to desquamation during absorption. By dividing the dermally absorbed dose (DA_{event}) by the duration of absorption (t_{abs}), the resulting expression yields the average absorptive flux. Figure 2-1 illustrates the relationship between the average absorptive flux and the absorption time.

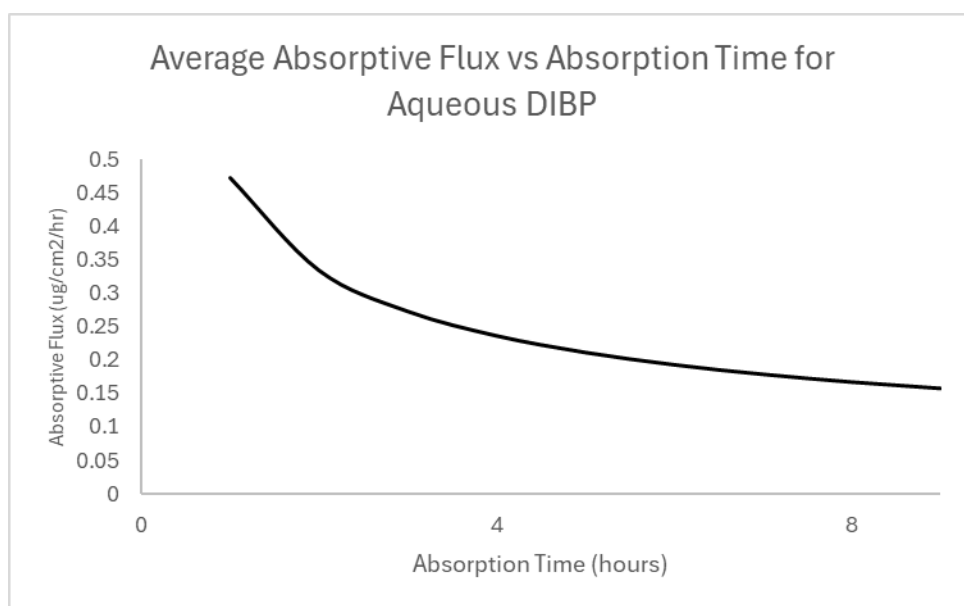


Figure 2-1. Average Absorptive Flux (DA_{event}/t_{abs}) as Function of Absorption Time (t_{abs})

Using Equation 3.2 from the *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual, (Part E: Supplemental Guidance for Dermal Risk Assessment)* ([U.S. EPA, 2004b](#)), which characterizes dermal uptake for aqueous organic compounds, EPA estimates the flux of DIBP to be 0.47 and 0.17 $\mu\text{g}/\text{cm}^2/\text{h}$ at 1 and 8 hours, respectively. EPA assumed that the flux was constant over the absorption time and estimated the average absorptive flux of 0.17 $\mu\text{g}/\text{cm}^2/\text{h}$.

2.4.3.4 Vapor to Skin Exposures

Though the primary route of occupational exposure to DIBP vapor is through inhalation, there is also potential for dermal exposure from DIBP vapor. Though dermal exposure to DIBP vapor has not been empirically studied, there are studies available that quantify dermal uptake from DBP vapor ([Morrison et al., 2016](#); [Weschler et al., 2015](#)) that can be considered as surrogate data for DIBP.

The work of Weschler *et al.* ([2015](#)) measured dermal uptake of DBP vapors over 6-hour durations for air concentrations ranging from 0.108 – 0.163 mg/m^3 . The participants wore only shorts during the 6-hour exposure periods. Some participants also wore breathing hoods to restrict inhalation exposure of DBP, and these experiments were used in comparison to participants that did not wear hoods to determine

contributions from both dermal and inhalation exposure separately. The Weschler *et al.* (2015) study concluded that the median exposures from DBP vapor were $3.1 \mu\text{g}/(\mu\text{g}/\text{m}^3 \text{ in air})$ from dermal exposure and $3.9 \mu\text{g}/(\mu\text{g}/\text{m}^3 \text{ in air})$ from inhalation exposure. However, it is important to note that participants wore only shorts during the exposure period which is not expected in occupational settings. Therefore, these data overestimate dermal uptake of phthalate vapor in occupational settings.

To measure the effect of clothing on dermal uptake of DBP vapor, Morrison *et al.* (2016) investigated dermal uptake of DBP vapors over 6-hour durations for a participant wearing clean clothing and participants wearing contaminated clothing. In preparing the contaminated clothing, items were hung inside-out in a chamber with DBP vapor concentrations ranging from $0.114 - 0.123 \text{ mg}/\text{m}^3$ for nine days and forced air convection was used to enhance the transfer of phthalates from air to clothing. Morrison *et al.* (2016) concluded that clean clothes are rather protective of dermal exposure from DBP vapor, whereas the contaminated clothing enhanced dermal exposure. More specifically, it was determined that dermal uptake from DBP vapor while wearing clean clothing was $0.007 \mu\text{g}/\text{kg}/(\mu\text{g}/\text{m}^3 \text{ in air})$ and dermal uptake of DBP while wearing contaminated clothing was $0.261 \mu\text{g}/\text{kg}/(\mu\text{g}/\text{m}^3 \text{ in air})$.

The studies of dermal exposure to DBP vapor (Morrison *et al.*, 2016; Weschler *et al.*, 2015) show that dermal exposure from DBP vapor may be significant for particular scenarios, such as exposure with minimal clothing or exposure from highly contaminated clothing. However, the study of Morrison *et al.* (2016) illustrates the protective effect of standard clean clothing to the dermal uptake of DBP vapor. Because it is expected that workers will wear standard clean clothing (*i.e.*, clothes that have been washed since last use) to the workplace, EPA considers the dermal exposure estimate from DBP vapor while wearing clean clothing to be representative surrogate data for occupational dermal exposure to DIBP vapor.

For standard occupational scenarios such as manufacturing and processing, workers may be exposed to DIBP vapor levels up to $1.8 \times 10^{-2} \text{ mg}/\text{m}^3$ (see Section 3 for exposure estimates). Therefore, based on the work of Morrison *et al.* (2016), the contribution from vapor to skin exposure would be approximately $1.26 \times 10^{-4} \text{ mg}/\text{kg}\text{-day}$ for exposure to vapor levels of $1.8 \times 10^{-2} \text{ mg}/\text{m}^3$ in occupational settings. Consequently, the contribution of vapor to skin exposure for DIBP is not expected to result in a significant increase in overall exposure in occupational settings where workers are wearing clean clothing. However, EPA acknowledges the possibility of vapor to skin exposure for DIBP, though limited in overall impact.

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

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

The remainder of this section discusses respiratory protection and glove protection, including protection factors for various respirators and dermal protection strategies. EPA's estimates of occupational exposure presented in this document do not assume the use of engineering controls or PPE; however, the effect of respiratory and dermal protection factors on EPA's occupational exposure estimates can be explored in the *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](https://www.epa.gov/dibp/occupational-risk-calculator-for-dibp)).

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 and 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 respiratory protection program according to the requirements of OSHA's Respiratory Protection Standard.

Workers are required to use respirators that 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 July 29, 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. 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 only 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, the highest preference was given to data that is 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, the Agency 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 surrogate monitoring data and worker activity information from standard engineering sources and systematic review. The Agency 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 DIBP and the number of potentially exposed workers and ONUs.

2.7.1 Number of Workers and ONUs 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 (Table 2-2 below).
2. Estimate total employment by industry/occupation combination using the BLS' Occupational Employment Statistics data (BLS Data).
3. 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.
4. Use market penetration data to estimate the percentage of employees likely to be using DIBP instead of other chemicals.
5. 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.
6. Combine the data generated in Steps 1 through 5 to produce an estimate of the number of employees using DIBP 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

OES	Relevant NAICS Codes	Exposed Workers per Site ^a	Exposed ONUs per Site ^a
Manufacturing	325100 – Basic Chemical Manufacturing 325900 – Other Chemical Product and Preparation Manufacturing	22	9
Repackaging	424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers 424690 – Other Chemical and Allied Products Merchant Wholesalers	1	0.4
Incorporation into adhesives and sealants	325520 – Adhesive Manufacturing	18	7
Incorporation into paints and coatings	325510 – Paint and Coating Manufacturing	14	5
Use as a catalyst	325100 – Basic Chemical Manufacturing 325200 – Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing 325500 – Paint, Coating, and Adhesive Manufacturing 325900 – Other Chemical Product and Preparation Manufacturing 326100 – Plastics Product Manufacturing	22	9
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	54	17
Application of paints and coatings	337110 – Wood Kitchen Cabinet and Countertop Manufacturing 337122 – Nonupholstered Wood Household Furniture Manufacturing 337124 – Metal Household Furniture Manufacturing	12	6

OES	Relevant NAICS Codes	Exposed Workers per Site ^a	Exposed ONUs per Site ^a
	337127 – Institutional Furniture Manufacturing 337211 – Wood Office Furniture Manufacturing 337212 – Custom Architectural Woodwork and Millwork 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 541712 – Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)	1	4
Use of laboratory chemicals – solid	541380 – Testing Laboratories 541712 – Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)	1	4
Plastics compounding	313310 – Textile and Fabric Finishing Mills 325211 – Plastics Material and Resin Manufacturing	27	12
Plastics converting	313310 – Textile and Fabric Finishing Mills 326100 – Plastics Product Manufacturing	18	5
Fabrication of final product 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
Recycling and disposal	562212 – Solid Waste Landfill 562213 – Solid Waste Combustors and Incinerators 562219 – Other Nonhazardous Waste Treatment and Disposal	6	4
Rubber manufacturing	325212 – Synthetic Rubber Manufacturing 326200 – Rubber Product Manufacturing 326150 – Urethane and Other Foam Product (Except Polystyrene) Manufacturing	27	7
^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, 2020b](#)), NEI ([U.S. EPA, 2023a](#)), DMR ([U.S. EPA, 2024a](#)), and TRI databases ([U.S. EPA, 2024c](#)).

Table 2-3. Summary of Total Number of Workers and ONUs Potentially Exposed to DIBP for Each OES

OES	Total Exposed Workers	Total Exposed ONUs	Number of Facilities	Notes
Manufacturing	22	9	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.
Repackaging	1–4	1–2	1 (CT); 4 (HE)	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	14–28	5–10	1 (CT); 2 (HE)	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 adhesives and sealants	18	7	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 results from Monte Carlo modeling.
Use as a Catalyst	66–110	27–45	3 (CT); 5 (HE)	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 Adhesives and Sealants	270–864	85–272	5 (CT); 16 (HE)	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	72–336	36 (central tendency); 168 (high-end)	6 (CT); 28 (HE)	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.

OES	Total Exposed Workers	Total Exposed ONUs	Number of Facilities	Notes
Use of Laboratory Chemicals – Liquid	20–202	80–808	20 (CT); 202 (HE)	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.
Plastics Compounding	135–243	60–108	5 (CT); 9 (HE)	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.
Plastics Converting	684–1,206	335–190	38 (CT); 67 (HE)	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 and Disposal	354	236	59	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 Plastic, 2024).
Rubber Manufacturing	27	7	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.

^a The central tendency estimate for total exposed ONUs in the Repackaging OES was <0.5, which was rounded up to a minimum of 1.

^b When the number of facilities was estimated from monte carlo simulation, the 50th percentile was the CT and 95th percentile was the HE. The number of workers and ONUs were obtained by multiplying the workers and ONUs for relevant NAICS codes with the number of facilities estimates (CT and HE for ranges).

2.8 Concentration of DIBP for Each OES

EPA has determined the concentration of DIBP for each OES based on reasonably available information. These concentrations of DIBP (Table 2-4) were used in the modeling to estimate releases for different OES.

Table 2-4. Concentration of DIBP for Each OES

OES	Parameter	Lower-Bound (kg/kg)	Upper-Bound (kg/kg)
Manufacturing	Manufactured DIBP Concentration	0.9	1
Repackaging into large and small containers	Repackaging DIBP Concentration	1	
Incorporation into adhesives and sealants	Feed DIBP Concentration	0.9	1
	Final DIBP Concentration	1.0E-03	0.75
Incorporation into paints and coatings	Feed DIBP Concentration	0.9	1
	Post-Formulation DIBP Concentration	1.0E-03	0.6
Use as a catalyst	Feed DIBP Concentration	0.99	
	Pre-Catalyst DIBP Concentration	6.24E-02	0.12
	Residual DIBP in PP Polymer	1.60E-07	1.33E-06
Application of paints and coatings	Paint/Coating DIBP Concentration	1.0E-02	0.6
Use of laboratory chemicals	Liquid DIBP Concentration	0.9	1
	Solid DIBP Concentration	1.0E-03	
Fabrication of final product from articles	Solid DIBP Concentration	5.0E-07	0.2
Plastics compounding and plastics converting	Initial DIBP Concentration	0.9	1
	Plastic DIBP Concentration	6.5E-03	7.4E-02
Recycling	Solid DIBP Concentration	5.0E-07	0.2
Waste handling, treatment, and disposal	Solid DIBP Concentration	0.2	
Rubber manufacturing	Initial DIBP Concentration	0.9	1
	Rubber DIBP Concentration	0.01	0.2
Distribution in commerce	N/A	N/A	N/A
Application of adhesives and sealants	Adhesive/ Sealant DIBP Concentration	1.0E-03	0.6

3 ENVIRONMENTAL RELEASE AND OCCUPATIONAL EXPOSURE ASSESSMENTS BY OES

3.1 Manufacturing

3.1.1 Process Description

At a typical manufacturing site, DIBP is formed through the catalytic esterification of phthalic anhydride with isobutanol in a closed system ([U.S. CPSC, 2011](#)). Typical manufacturing operations consist of esterification, followed by a purification process using vacuum distillation or activated charcoal. Assumption has been made that manufacturing operations may also include quality control sampling of the DIBP product. Additionally, manufacturing operations may include equipment cleaning/reconditioning and product loading for transport to other areas of the manufacturing facility or offsite shipment for downstream processing or use. Figure 3-1 provides an illustration of the manufacturing process and was created based on the above process information ([U.S. CPSC, 2011](#)).

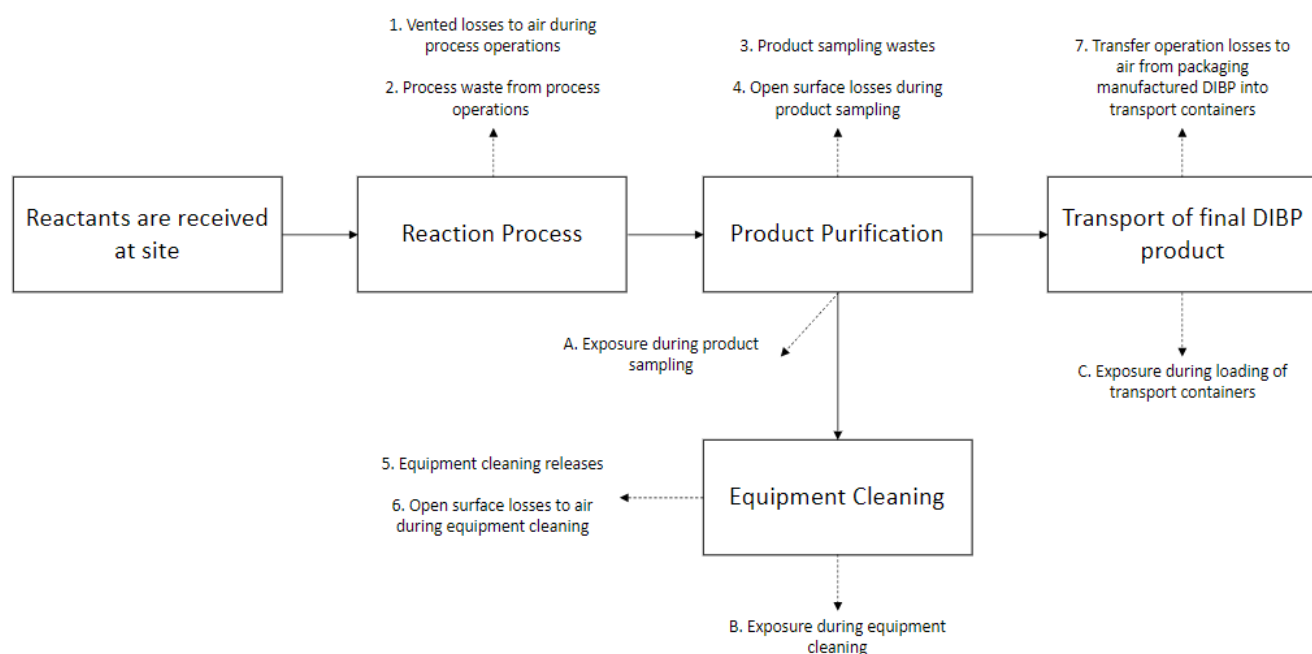


Figure 3-1. Manufacturing Flow Diagram

3.1.2 Facility Estimates

In the 2020 CDR, one site reported domestic manufacturing of DIBP. The site, Lanxess Corporation in Greensboro, NC, reported a production volume of 184,750 kg for the 2019 reporting year. Review of preliminary 2024 CDR data shows that that total production volume for the years 2020 through 2023 are similar to the previously reported range from 2020 CDR. EPA did not identify other data on current manufacturing sites or volumes from systematic review. EPA evaluated potential releases using the total production volume from the one reported site, thereby assuming the Greensboro site was the sole domestic manufacturing site of DIBP.

Based on CDR reports, DIBP is manufactured in liquid form in concentrations ranging from 90 to 100 percent ([U.S. EPA, 2020a](#)) as shown in Table 2-4. EPA assessed the number of facility operating days as 250 days/year accounting for yearly operations with 2 weeks of downtime. EPA did not identify any other site- or chemical-specific facility operating data for manufacturing.

3.1.3 Release Assessment

3.1.3.1 Environmental Release Points

According to the U.S. Consumer Product Safety Commission (CPSC), DIBP is formed through the catalytic esterification of phthalic anhydride with isobutanol in a closed system ([U.S. CPSC, 2011](#)). EPA identified release points for the release assessment using this process information and the ESD on the Chemical Industry ([OECD, 2011c](#)). EPA assigned each release point and suspected fugitive air release point a default EPA model to quantify potential releases. EPA expects stack air releases from vented losses to air during process operations and fugitive air releases from sampling, equipment cleaning, and container loading. EPA expects releases to wastewater, incineration, or landfill from equipment cleaning and product sampling.

3.1.3.2 Environmental Release Assessment Results

Table 3-1 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for DIBP Manufacturing. See Appendix D.2.2 for additional details on model equations and parameters. The *Manufacturing OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

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

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
184,750 kg/year production volume	Fugitive Air	2.8E-02	7.7E-02	250		1.1E-04	3.1E-04
	Stack Air	1.9				0.74	
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment) ^a	1.2				4.6E-03	
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), Incineration, or Landfill ^a	564	737			17	18
^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 available to estimate the partitioning between media.							
^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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 DIBP via inhalation of vapors or dermal contact with liquids occur during product sampling, equipment cleaning, packaging and loading of DIBP into transport containers for shipment. EPA did not identify information on engineering controls or worker PPE used at DIBP manufacturing sites.

ONUs include employees (*e.g.*, supervisors, managers) that work at the manufacturing facility, but do not directly handle DIBP. Therefore, EPA expects ONUs to have lower inhalation exposures. EPA does not expect ONUs to have dermal exposures for this OES because ONUs do not directly handle DIBP and there are no mists or dusts generated that may deposit on surfaces.

3.1.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the manufacture of DIBP during systematic review of literature sources. However, EPA estimated the inhalation exposure to workers via vapors using Monte Carlo modeling (a type of stochastic simulation). In this simulation, EPA applied the EPA Mass Balance Inhalation Model ([U.S. EPA, 2015](#)) to all release points with inhalation exposure potential (*i.e.*, those with fugitive air releases) and estimated an 8-hour TWA by assuming no exposure occurred outside of the duration of those manufacturing activities with fugitive air releases. The EPA Mass Balance Inhalation Model estimates worker inhalation exposures to an estimated concentration of chemical vapors within the worker's breathing zone using a one box model. The model estimates the amount of chemical inhaled by a worker during an activity in which the chemical has volatilized, with the airborne concentration of the chemical vapor a function of the source vapor generation rate or the saturation level of the chemical in air. Based on the fugitive air release points, workers are expected to be exposed to DIBP during product sampling, equipment cleaning, and loading of DIBP into transport containers.

EPA used a Monte Carlo simulation to capture variability in the following model input parameters: DIBP concentration, air speed, diameter of openings, saturation factor, container size. See Section D.14 to see the full explanation of the inhalation exposure modeling.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-2 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during the manufacture of DIBP. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end and central tendency exposures use 250 days per year as the exposure frequency, which is the expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-2. Summary of Modeled Worker Inhalation Exposures for Manufacture of DIBP

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.0E-04	2.3E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-04	1.7E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.4E-04	1.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.5E-04	2.5E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-04	1.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.8E-04	1.7E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	
	Acute Dose (AD) (mg/kg/day)	5.0E-04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.4E-04	
^a The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively.			

3.1.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, manufacturing) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-3 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Because there is no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed.

Table 3-3 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

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

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.0E-02
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end and central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days.			

3.1.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-4. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

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

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.1E-02
ONU	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.4E-04	
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.2 Repackaging into Large and Small Containers

3.2.1 Process Description

At a typical repackaging site, DIBP will arrive via water, air, land, or intermodal shipment on oceangoing chemical tankers, rail cars, tank trucks, or intermodal tank containers ([Tomer and Kane, 2015](#)). Sites unload the import containers and transfer DIBP into smaller containers (drums or totes) for

downstream processing, use within the facility, or offsite use. Operations may include quality control sampling of DIBP products and equipment cleaning. No changes to chemical composition occur during transportation or repackaging ([U.S. EPA, 2022](#)). Figure 3-2 provides an illustration of the import and repackaging process based on the above process information ([U.S. EPA, 2022](#)).

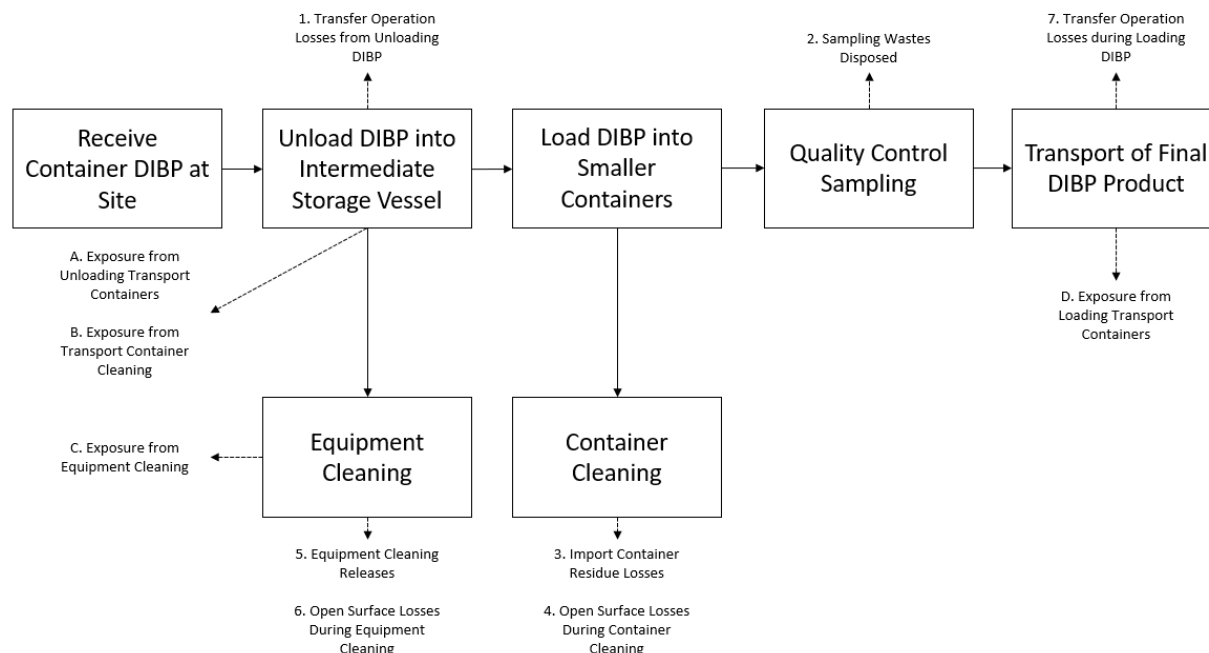


Figure 3-2. Repackaging Flow Diagram

3.2.2 Facility Estimates

In the 2016 CDR, one site, Sika Corp in Lyndhurst, NJ, reported repackaging of DIBP but their production volume was withheld ([U.S. EPA, 2019a](#)). EPA estimated the production volume for this site and any additional smaller repackaging sites that were not required to report to CDR based on the upper threshold for CDR reporting of 100,000 lb (43,359 kg) irrespective of sales. This estimation accounts for the potential operation of smaller DIBP repackaging sites that do not exceed the CDR reporting threshold requirements in addition to the known repackaging site. The estimated production volume for import and repackaging of DIBP was 45,359 kg/year.

The 2022 GS on Chemical Repackaging estimated the total number of operating days for repackaging as 174 to 260 days per year based on the length of worker shifts ([U.S. EPA, 2022](#)). Import and repackaging facilities operate 24 hours/day, 7 days/week (*i.e.*, multiple shifts) up to the total operating days assessed. EPA assumed sites receive DIBP in totes and repackage the product into smaller drums for offsite/downstream shipment. EPA assumed DIBP was repackaged as a neat liquid, or 100 percent DIBP. EPA assessed a facility throughput using a Monte Carlo model (see Section D.3.4 for details) and neat repackaging of DIBP. The 50th and 95th percentile range was 410 to 1,077 kg/site-yr. EPA did not identify any other site- or chemical-specific import and repackaging operating data (*e.g.*, facility throughput, operating days).

3.2.3 Release Assessment

3.2.3.1 Environmental Release Points

EPA assigned release points based on the 2022 GS on Chemical Repackaging ([U.S. EPA, 2022](#)) and used default models to quantify releases from each identified release point. Release points include fugitive air releases from loading and unloading, product sampling, and equipment cleaning as well as releases to wastewater, discharges to POTW, and waste disposal from sampling, container residue, and equipment cleaning.

3.2.3.2 Environmental Release Assessment Results

Table 3-5 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for Repackaging of DIBP. See Section D.3 for additional details on model equations and parameters used. The *Container Repackaging OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-5. Summary of Modeled Environmental Releases for Repackaging of DIBP

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
45,359 kg/year production volume	Fugitive Air	1.4E-04	3.3E-04	208	260	8.8E-06	1.4E-05
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), or landfill ^a	313	991			11	29

^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 available to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end releases, respectively.

3.2.4 Occupational Exposure Assessment

3.2.4.1 Workers Activities

During repackaging, worker exposures to DIBP via inhalation of vapors or dermal contact with liquids occur when transferring DIBP from the received totes into smaller drums, cleaning totes, loading and unloading DIBP, 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 repackaging DIBP.

ONUs include employees (*e.g.*, supervisors, managers) that work at the repackaging site but do not directly handle DIBP. Therefore, EPA expects the ONUs to have lower inhalation exposures. EPA does not expect ONUs to have dermal exposures for this OES because ONUs do not directly handle DIBP formulations and there are no mists or dusts generated that may deposit on surfaces.

3.2.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the DIBP repackaging during systematic review of literature sources. Therefore, EPA used modeled inhalation estimates from DIBP manufacturing as surrogate for estimating potential occupational exposures of DIBP during repackaging. More specifically, EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES based on the summation of results of environmental fugitive releases to air and their associated exposure durations for each OES. Consequently, EPA only estimated worker vapor inhalation exposures for the DIBP manufacturing OES to represent the most protective exposure outcome of all possible vapor exposure OESs. The method of this determination is described in Section D.14.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-6 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during the repackaging of DIBP. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentiles of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of working days. The central tendency exposures use 208 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 *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-6. Summary of Modeled Worker Inhalation Exposures for Repackaging of DIBP

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.0E-04	2.3E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-04	1.7E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	2.8E-04	1.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.5E-04	2.5E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-04	1.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.1E-04	1.7E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	
	Acute Dose (AD) (mg/kg/day)	5.0E-04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	2.8E-04	3.4E-04
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated			

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively.			

3.2.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, repackaging) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-7 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Because there is no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed.

Table 3-7 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-7. Summary of Estimated Worker Dermal Exposures for Repackaging of DIBP

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.8E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.7E-02	4.0E-02
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 208 days out of 365 days.			

3.2.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-8. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-8. Summary of Estimated Worker Aggregate Exposures for Repackaging of DIBP

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.8E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.7E-02	4.1E-02
ONU	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.8E-04	3.4E-04
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.3 Incorporation into Adhesives and Sealants

3.3.1 Process Description

DIBP is a plasticizer in adhesive and sealant products for industrial and commercial use, including grouts and industrial adhesives (see Appendix E for EPA identified DIBP-containing products for this OES). Based on the 2009 ESD on the Manufacture of Adhesives, a typical adhesive incorporation site receives and unloads DIBP into adhesive and sealant formulations in industrial mixing vessels as a batch blending or mixing process, with no reactions or chemical changes occurring to the plasticizer (*i.e.*, DIBP) during the mixing process. Blending or mixing operations can take up to 8 hours per day. Assumption has been made that process operations may also include quality control sampling which will generate fugitive emissions. EPA expects that sites will load DIBP-containing products into bottles, small containers, or drums depending on the product type. Incorporation sites may dispose of off-specification products that do not meet quality or desired standards ([OECD, 2009a](#)). Figure 3-3 provides an illustration of the adhesive and sealant manufacturing process based on the above information ([OECD, 2009a](#)).

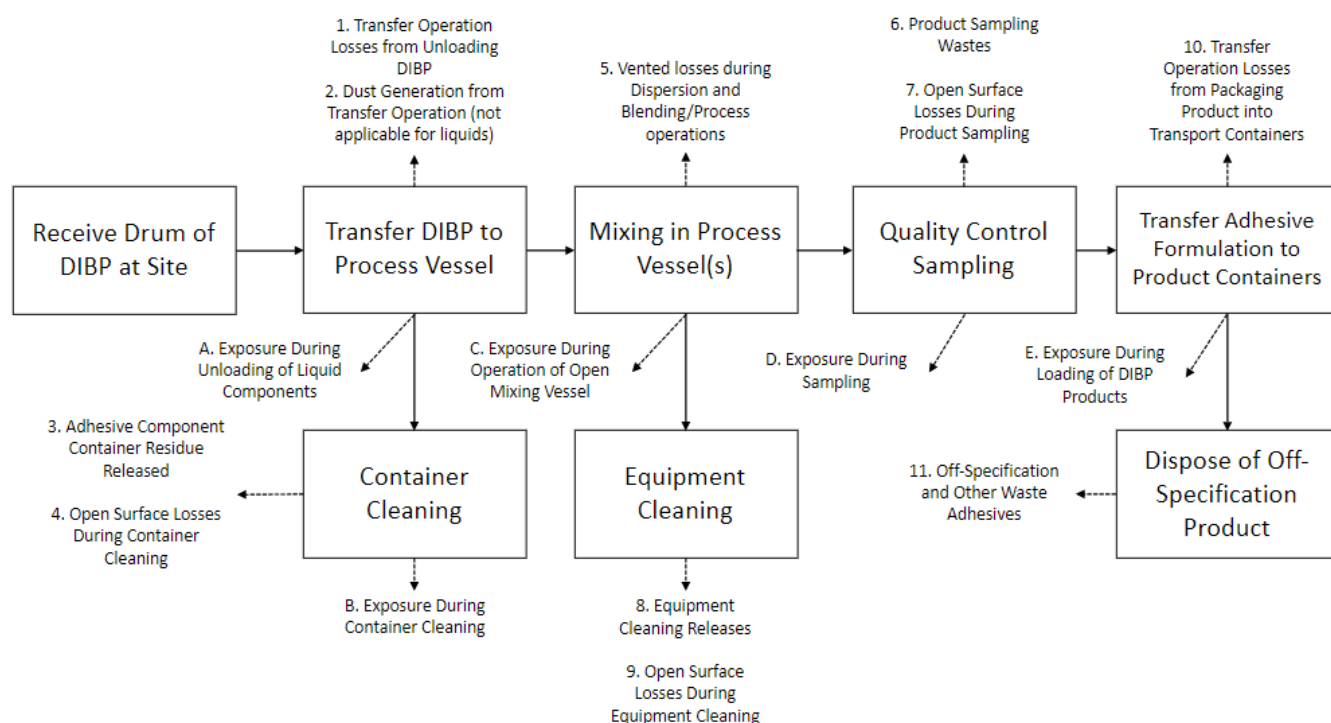


Figure 3-3. Incorporation into Adhesives and Sealants Flow Diagram

3.3.2 Facility Estimates

In the 2016 CDR, only one site, Sika Corp in Lyndhurst, NJ, reported using DIBP for adhesives manufacturing, but listed its production volume as CBI ([U.S. EPA, 2021a](#)). In the 2020 CDR, Sika Corp did not report adhesives manufacturing ([U.S. EPA, 2020a](#)). Though Sika Corp did not report adhesives manufacturing using DIBP in the 2020 CDR, EPA still assessed one site for incorporation into adhesives and sealants manufacturing to account for the 2016 CDR.

EPA estimated the production volume for the one assessed site as 3,694 kg/year, based on CDR data ([U.S. EPA, 2020a](#)) and the 2003 Danish EPA Restriction Report on DIBP ([ECHA, 2011](#)). The Danish EPA estimated that six percent of DIBP goes to non-polymer end use categories. EPA split this production volume percentage evenly between three DIBP uses, adhesive and sealant manufacturing, paints and coatings manufacturing, and incorporation into other formulations mixtures or reaction products. CDR states that the total U.S. national production volume of DIBP is 407,303 lbs/year. Multiplying this value by two percent results in 8,146 lbs/year (3,694 kg/year). EPA assumed the annual throughput of DIBP was equal to the total production volume for the one assessed site.

EPA was unable to identify DIBP-specific information for operating days in the production of adhesives and sealants. Therefore, EPA assumed 250 days/year of operation based on 50 weeks per year of operation for 5 days per week. Based on CDR reports, DIBP is received in liquid form in concentrations ranging from 90 to 100 percent ([U.S. EPA, 2020a](#)). According to the ESD on Adhesive Formulation ([OECD, 2009a](#)), liquid DIBP is expected to be received onsite in drums. The ESD for Adhesive Formulation ([OECD, 2009a](#)) cites a default batch size of 4,000 kg adhesive with an approximate batch volume of 1,000 gallons. The concentration of DIBP used as feed in the adhesive and sealant manufacturing process is expected to be between 90 to 100 percent ([U.S. EPA, 2020a](#)). EPA did not identify any other site- or chemical-specific manufacturing facility operating data.

3.3.3 Release Assessment

3.3.3.1 Environmental Release Points

EPA assigned release points based on the 2009 ESD on the Manufacture of Adhesives ([OECD, 2009a](#)). EPA assigned default models to quantify release from each release point and suspected fugitive air release point. EPA expects fugitive air releases from unloading of DIBP containers, container cleaning, sampling, and equipment cleaning. EPA expects stack air releases from vented losses during process operations and packaging into transport containers. EPA expects releases to wastewater, incineration, or landfill from container residue, sampling waste, equipment cleaning waste, and off-specification trimmings.

3.3.3.2 Environmental Release Assessment Results

Table 3-9 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for incorporation into adhesives and sealants. See Section D.4 for additional details on model equations and parameters. The *Incorporation into Adhesives and Sealants OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-9. Summary of Modeled Environmental Releases for Incorporation into Adhesives and Sealants

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,694 kg/year production volume	Fugitive Air	6.43E-06	1.39E-05	250		2.57E-08	5.57E-08
	Stack Air	6.15E-06	2.00E-05			2.46E-08	8.01E-08
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment) ^a	75	76			0.34	0.37
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), Incineration, or Landfill ^a	111	111			0.44	0.44

^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 available to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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 DIBP, worker exposures via inhalation of vapor or dermal contact may occur when transferring DIBP from transport containers into process vessels, taking quality control samples, packaging formulated products into containers, and cleaning residuals from transport containers or process vessels ([OECD, 2009a](#)). EPA did not identify information on engineering controls or worker PPE used at DIBP-containing adhesive and sealant formulation facilities.

For this OES, ONUs may include supervisors, managers, and other employees that work in the formulation area but do not directly contact DIBP that is received or processed onsite or handle the formulated product. Therefore, EPA expects ONUs to have lower inhalation exposures. EPA does not expect ONUs to have dermal exposures for this OES because ONUs do not directly handle adhesive or sealant formulations and there are no mists or dusts generated that may deposit on surfaces.

3.3.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the incorporation of DIBP into adhesives and sealants during systematic review of literature sources. EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in Section D.14. Therefore, EPA chose the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for a conservative assessment of vapor inhalation exposures of all relevant OESs.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-10 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during the incorporation into adhesives and sealants. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end and central tendency exposures use 250 days per year as the exposure frequency, which is the expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-10. Summary of Estimated Worker Inhalation Exposures for Incorporation into Adhesives and Sealants

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.0E-04	2.3E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-04	1.7E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.4E-04	1.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.5E-04	2.5E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-04	1.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.8E-04	1.7E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	
	Acute Dose (AD) (mg/kg/day)	5.0E-04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.4E-04	
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively.			

3.3.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, incorporation into adhesives and sealants) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-11 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Because there is no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed.

Table 3-11 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-11. Summary of Estimated Worker Dermal Exposures for Incorporation into Adhesives and Sealants

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.0E-02
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end and central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days.			

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 3-12. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-12. Summary of Estimated Worker Aggregate Exposures for Incorporation into Adhesives and Sealants

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.1E-02
ONU	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.4E-04	
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.4 Incorporation into Paints and Coatings

3.4.1 Process Description

DIBP is an additive in paint and coating products for industrial and commercial use, including paints and colorants (see Appendix E for EPA identified DIBP-containing products for this OES). Table_Apx E-1 for EPA identified DIBP-containing products for this OES). The concentration of DIBP used as feed in the paints and coatings manufacturing process is expected to be between 90 to 100 percent ([U.S. EPA, 2020a](#)). A typical incorporation site receives and unloads DIBP into industrial mixing vessels as a batch blending or mixing process, with no reactions or chemical changes occurring to the plasticizer (*i.e.*, DIBP) during the mixing process. Blending or mixing operations can take up to eight hours per day. Process operations may include quality control sampling. In the case of waterborne coatings, the formulator will transfer the blended formulation through an in-line filter. Following formulation, incorporation sites will load DIBP-containing products into bottles, small containers, or drums depending on the product type. Sites may dispose of off-specification product when the product does not meet quality or desired standards ([U.S. EPA, 2014a](#)). Figure 3-5 provides an illustration of the paint and coating manufacturing process based on the above information ([U.S. EPA, 2014a](#)).

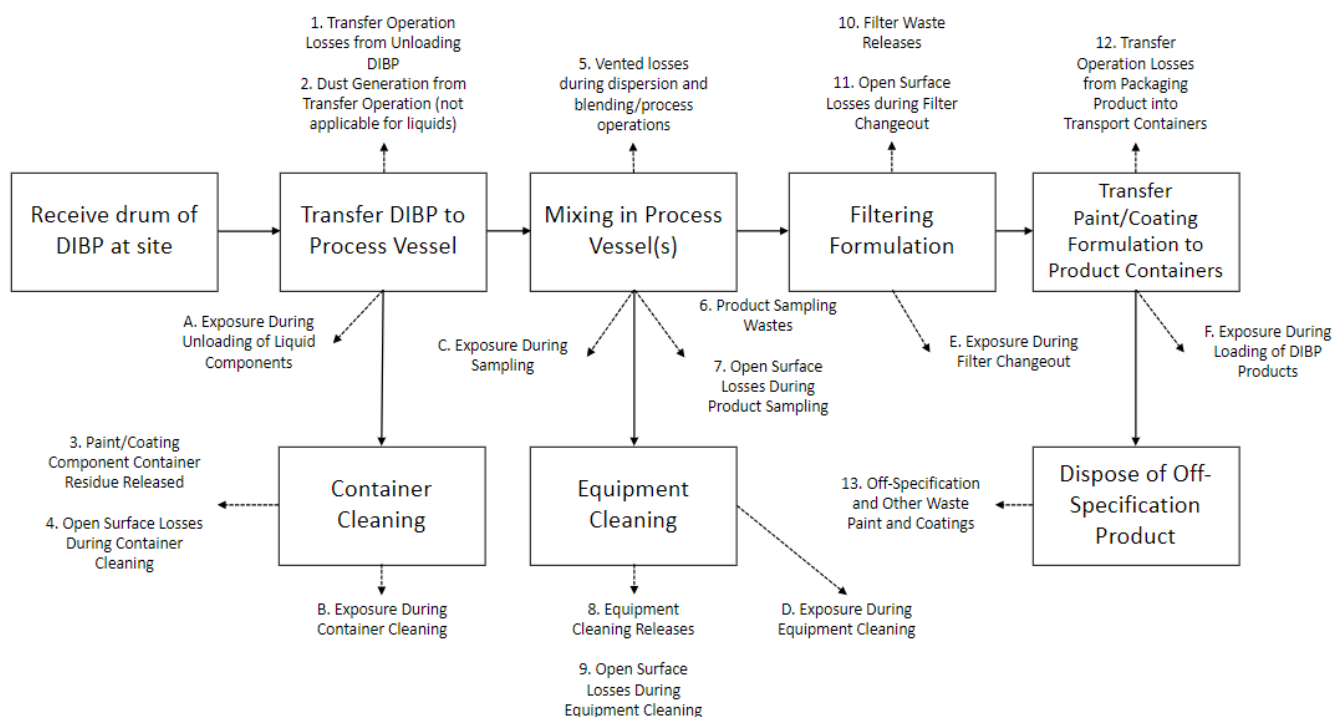


Figure 3-4. Incorporation into Paints and Coatings Flow Diagram

3.4.2 Facility Estimates

No facilities reported manufacturing paints and coatings to the 2020 CDR ([U.S. EPA, 2020a](#)). EPA identified a total of five DIBP-containing paint and coatings products, formulated by five different manufacturers (see Appendix E for EPA identified DIBP-containing products). Two of the five manufacturers (IKO PLC and ITW Plexus) maintain at least one plant in the United States. Therefore, EPA assessed the number of sites using a discrete distribution of one to two sites, with equal probability of each.

EPA estimated the total production volume for incorporation into paints and coating formulations as 3,694 kg/year, based on CDR data ([U.S. EPA, 2020a](#)) and the 2003 Danish EPA Restriction Report on DIBP ([ECHA, 2011](#)). The Danish EPA estimated that six percent of DIBP goes to non-polymer end use categories. EPA split this production volume percentage evenly between three DIBP uses, adhesive and sealant manufacturing, paints and coatings manufacturing, and incorporation into other formulations mixtures or reaction products. CDR states that the total U.S. national production volume of DIBP is 407,303 lb/year. Multiplying this value by two percent results in 8,146 lb/year (3,694 kg/year). The annual throughput of DIBP is calculated from dividing the production volume by the number of sites. For scenarios with two sites, this results in an annual facility throughput of 4,073 lb/year (1,847 kg/year), and for scenarios with one site, the annual facility throughput is equal to the total production volume.

EPA was unable to identify DIBP-specific information for operating days in the production of adhesives and sealants. Therefore, EPA assumed 250 days/year of operation, based on 50 weeks per year of operation for 5 days per week based on the GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)). Based on CDR reports, DIBP is received in liquid form in concentrations ranging from 90 to 100 percent ([U.S. EPA, 2020a](#)). According to the GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)), liquid DIBP is expected to be received onsite in drums. The batch size of the model is calculated based on annual facility throughput of DIBP and the number of operating days, with the results ranging from 7.39 to 14.78 kg/batch. EPA did not identify any other site- or chemical-specific manufacturing facility operating data.

3.4.3 Release Assessment

3.4.3.1 Environmental Release Points

EPA assigned release points based on the 2014 GS on the Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)). EPA assigned a default model to quantify releases from each identified release point and fugitive air release point. EPA expects fugitive air releases from unloading DIBP containers, container cleaning, sampling, equipment cleaning, and filter replacements. EPA expects stack air releases from vented losses during process operations and from packaging paints and coatings into transport containers. EPA expects releases to wastewater, incineration, or landfill from container residue, sampling wastes, equipment cleaning wastes, filter wastes, and off-specification product wastes.

3.4.3.2 Environmental Release Assessment Results

Table 3-13 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for incorporation into paints and coatings. See Section D.5 for additional details on model equations and parameters. The *Incorporation into Paints and Coatings OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-13 Summary of Modeled Environmental Releases for Incorporation into Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,694 kg/year production volume	Fugitive Air	5.22E-04	1.65E-03	250		2.09E-06	6.61E-06
	Stack Air	5.82E-04	3.37E-03			2.33E-06	1.35E-05
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment) ^a	38	75			0.19	0.36
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), Incineration, or Landfill ^a	59	118			0.24	0.47

^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 available to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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

During the formulation of paints and coatings that contain DIBP, worker exposures to DIBP may occur via inhalation of vapors or dermal contact with liquids when unloading DIBP containers, cleaning transport containers, product sampling, equipment cleaning, changing filter media, and during packaging paint and coating products ([U.S. EPA, 2014a](#)). EPA did not identify information on engineering controls or worker PPE used at DIBP-containing paint and coating formulation sites.

ONUs include supervisors, managers, and other employees that work in the formulation area but do not directly contact DIBP received or processed onsite or handle the formulated product. Therefore, EPA expects ONUs to have lower inhalation exposures. EPA does not expect ONUs to have dermal exposures for this OES because ONUs do not directly handle paint and coating formulations and there are no mists or dusts generated that may deposit on surfaces.

3.4.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the incorporation of DIBP into paints and coatings during systematic review of literature sources. EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in see Section D.14. Therefore, EPA chose

the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for conservative assessment of vapor inhalation exposures of all relevant OESs.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-13 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during incorporation into paints and coatings. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end and central tendency exposures use 250 days per year as the exposure frequency, which is the expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-14. Summary of Estimated Worker Inhalation Exposures for Incorporation into Paints and Coatings

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.0E-04	2.3E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-04	1.7E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.4E-04	1.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.5E-04	2.5E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-04	1.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.8E-04	1.7E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	
	Acute Dose (AD) (mg/kg/day)	5.0E-04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.4E-04	

^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively.

3.4.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, incorporation into paints and coatings) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-15 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Because there is no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed.

Table 3-15 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-15. Summary of Estimated Worker Dermal Exposures for Incorporation into Paints and Coatings

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.0E-02
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end and central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days.			

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 in Table 3-16. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-16. Summary of Estimated Worker Aggregate Exposures for Incorporation into Paints and Coatings

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.1E-02
ONU	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.4E-04	
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.5 Use as a Catalyst

3.5.1 Process Description

DIBP is used as an electron donor in pre-catalyst formulations that are ultimately used as a catalyst intermediate in polypropylene (PP) manufacturing ([W.R. Grace & Co, 2022](#); [Company Withheld](#)). The pre-catalyst mixture consists of a titanium metal salt and an electron donor on the surface of magnesium chloride crystallites and is used for polypropylene production in fourth generation Ziegler-Natta catalyst systems ([Company Withheld](#)). A typical manufacturing site receives and unloads DIBP into process vessels, formulates the pre-catalyst mixture, and pumps it, along with an aluminum alkyl substance, into a reactor to form an active catalyst. Process operations may include quality control sampling. Following formulation, the manufacturing sites load DIBP-containing pre-catalyst into drums under a nitrogen blanket, due to its sensitivity to atmospheric conditions ([W.R. Grace & Co, 2022](#)).

A typical PP manufacturing site receives and unloads the pre-catalyst into industrial reaction vessels with propylene and optional co-monomers to form a final polymer powder. The polymer powder is purged of residual hydrocarbons, extruded into pellets, and packaged for shipment offsite. During the polymerization process, most of the DIBP reacts to form non-phthalate derivatives. As a result, the final polypropylene products are only expected to contain DIBP as a residual. PP manufacturing operations may also include quality control sampling ([W.R. Grace & Co, 2022](#); [Company Withheld](#)).

Figure 3-5 and Figure 3-6 provide an illustration of the pre-catalyst formulation and PP manufacturing process based on the above information.

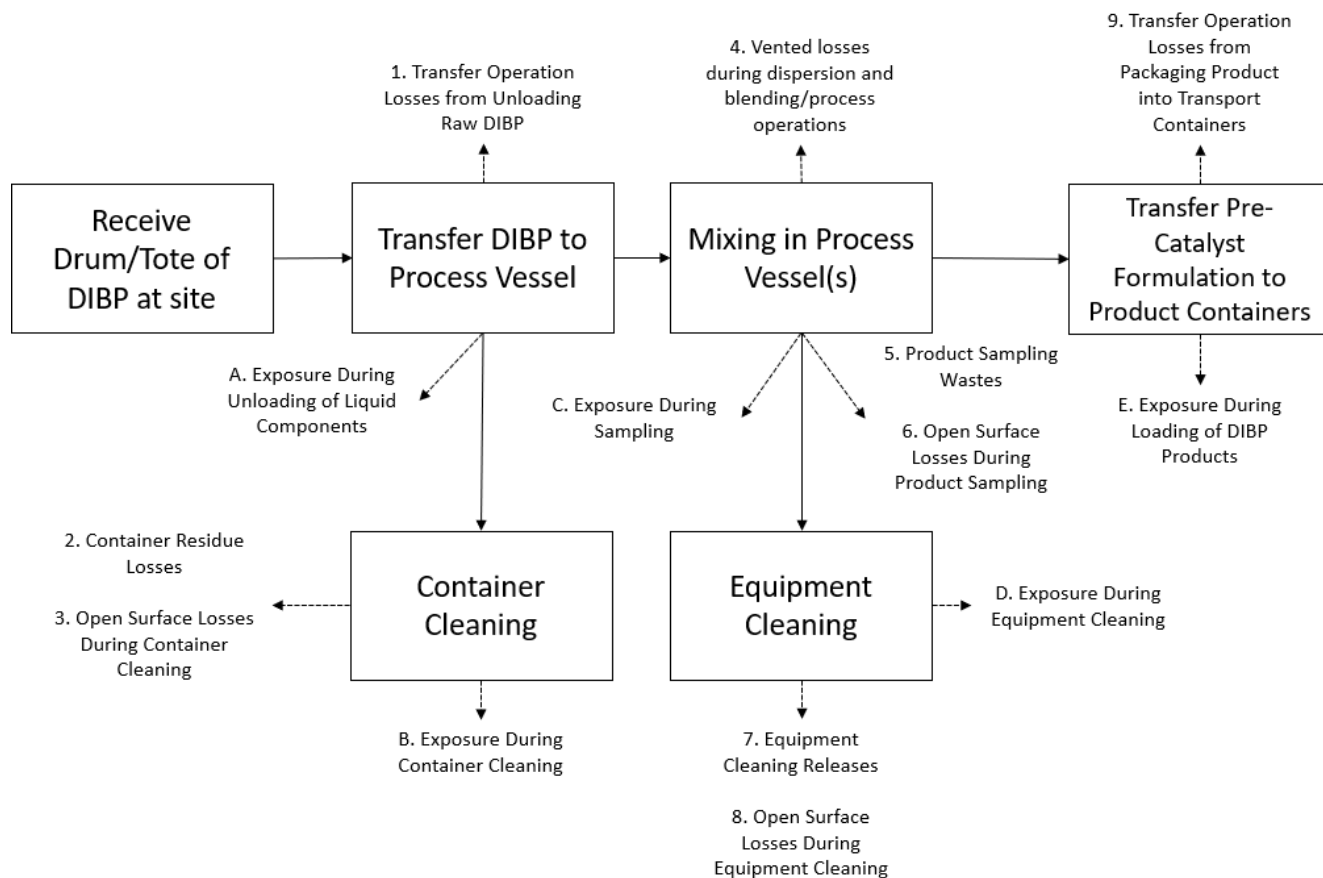


Figure 3-5. Formulation into Pre-Catalyst Flow Diagram

Intermediate in Polypropylene Manufacturing

EPA assumed that the total production volume of DIBP as an intermediate in PP manufacturing was the same as the total production volume for the formulation of pre-catalyst. EPA calculated the number of sites for PP manufacturing using the production volume of PP and the annual facility throughput of PP, which resulted in a range of 19 to 38 sites.

EPA was unable to identify DIBP-specific information on operating days for the use of DIBP as an intermediate in PP manufacturing. Therefore, EPA assumed 250 days/year of operation based on 50 weeks per year and 5 days per week of operation. EPA calculated the annual facility throughput of DIBP using the total production volume divided by the number of sites, which resulted in a range of 503 to 4,026 kg/site-yr. W.R. Grace and Co. provided information that indicates DIBP is received in within the pre-catalyst formulation at concentrations ranging from 6.24 to 11.5 percent DIBP ([W.R. Grace & Co., 2022](#)). EPA expects the DIBP feed to be received onsite in drums. EPA did not identify any other site- or chemical-specific manufacturing facility operating data.

3.5.3 Release Assessment

3.5.3.1 Environmental Release Points

EPA assigned release points based on the ESD on Adhesive Formulation ([OECD, 2009a](#)) and 2020 CDR data ([U.S. EPA, 2020a](#)). EPA assumed the release points of the adhesive formulation process is similar to the release points for this OES since the processing of adhesive formulations is similar to the processing of pre-catalyst formulations. For formulation of pre-catalyst, EPA assigned a default model to quantify releases from each identified release point and fugitive air release point. EPA expects fugitive air releases from unloading DIBP containers, container cleaning, product sampling, and equipment cleaning. EPA expects stack air releases from vented losses during process operations. EPA expects releases to wastewater, incineration, or landfill from container residue, product sampling, and equipment cleaning.

For use as an intermediate in polypropylene manufacturing, EPA assigned a generic model to quantify releases from each identified release point and fugitive air release point. EPA expects stack air releases from vented process operations and captured uncontrolled dust releases from the loading of product into containers. EPA expects releases to incineration or landfill from captured and controlled dust releases from loading of product into containers. EPA expects releases to wastewater, incineration, or landfill from container cleaning residue, product sampling wastes, and equipment cleaning residue. EPA expects releases to uncertain media (fugitive air, wastewater, incineration, or landfill) from uncaptured dust releases from loading of product.

3.5.3.2 Environmental Release Assessment Results

Table 3-17 and Table 3-18 summarize the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for the formation of pre-catalyst and polypropylene manufacturing. See Section D.6 for additional details on model equations and parameters. The *Use as a Catalyst, Formulation of Pre-Catalyst OES Environmental Release Modeling Results for DIBP* and *Use as a Catalyst, Intermediate in PP Manufacturing OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to these supplemental documents.

Table 3-17 Summary of Modeled Environmental Releases for Formation of Pre-Catalyst

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
19,125 – 76,500 kg production volume	Fugitive air	1.3E-04	2.5E-04	250		5.1E-07	1.0E-06
	Stack air	3.2E-04	1.1E-03			1.3E-06	4.4E-06
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	393	1,045			4.6	8.9

^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 available to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table 3-18 Summary of Modeled Environmental Releases for Use as an Intermediate in Polypropylene Manufacturing

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
19,125 – 76,500 kg production volume	Incineration or landfill ^a	0.64	2.7	250		2.5E-03	1.1E-02
	Stack air	0.40	2.0			1.6E-03	7.8E-03
	Uncertain – Air, Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	0.51	2.6			2.0E-03	1.0E-02
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	43	80			0.49	0.83

^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 available to estimate the partitioning between media.

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end releases, respectively.							

3.5.4 Occupational Exposure Assessment

3.5.4.1 Worker Activities

During the formulation of pre-catalyst using DIBP, worker exposures to DIBP may occur via inhalation of vapors or dermal contact with liquids when unloading raw DIBP, cleaning transport containers, product sampling, and equipment cleaning. W.R. Grace and Co. reported the formulated DIBP-containing pre-catalyst is drummed under a nitrogen blanket due to product sensitivity. Therefore, inhalation or dermal exposure during loading of pre-catalyst is not expected ([W.R. Grace & Co, 2022](#)).

During the use of DIBP as an intermediate in polypropylene manufacturing, workers are potentially exposed to DIBP via dust inhalation or dermal contact during the loading of manufactured polypropylene, product sampling, equipment cleaning, and product container cleaning. W.R. Grace and Co. reported the formulated DIBP-containing pre-catalyst is drummed under a nitrogen blanket due to product sensitivity. Therefore, inhalation or dermal exposure during unloading of pre-catalyst is not expected ([W.R. Grace & Co, 2022](#)). EPA did not identify information on engineering controls or worker PPE used at DIBP-containing pre-catalyst formulation sites or polypropylene manufacturing sites.

ONUs include supervisors, managers, and other employees that work in the formulation area but do not directly contact DIBP received or processed onsite or handle the formulated products. ONU exposures to DIBP may be through the inhalation of dusts or dermal contact with dusts that deposit onto surfaces that ONUs contact.

3.5.4.2 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring during systematic review of literature sources or receive any inhalation monitoring data for DIBP use of a catalyst prior to the release of the draft risk evaluation for DIBP. However, EPA received inhalation monitoring submissions from W.R. Grace ([2025](#)) and LyondellBasell ([2025](#)) for facilities utilizing DIBP in pre-catalyst formulations. The monitoring data consisted of 56 PBZ samples, 54 of which were below the LOD (*i.e.*, 96 percent nondetectable measurements). The two detectable values from the LyondellBasell ([2025](#)) monitoring study were measured as 2.4×10^{-2} and 2.5×10^{-2} mg/m³. The LODs are dependent on the sampling volume of the measurement, and ranged from 1.3×10^{-2} to 2.9×10^{-2} mg/m³. EPA follows the *Guidelines for Statistical Analysis of Occupational Exposure Data* ([U.S. EPA, 1994](#)) to estimate the monitoring values below the LOD, where the nondetectable values are replaced by the LOD divided by square root of 2 (for geometric standard deviation less than 3.0) or the LOD divided by 2 (for geometric standard deviation greater than 3.0). EPA used the LOD divided by the square root of 2 due to the high percentage of nondetectable results. Therefore, correcting the nondetectable values, the range of potential exposures from the 54 nondetectable measurements is estimated as 9.2×10^{-3} to 2.0×10^{-2} mg/m³ for the 1.3×10^{-2} to 2.9×10^{-2} mg/m³ LODs, respectfully, and are comparable to the central tendency calculated from the EPA Mass Balance Inhalation Model (*i.e.*, 4.0×10^{-3} mg/m³). In addition, two detectable values from the LyondellBasell ([2025](#)) monitoring study (*i.e.*, 2.4×10^{-2} and 2.5×10^{-2} mg/m³) are comparable to the high-end vapor concentration obtained from the EPA Mass Balance Inhalation Model (*i.e.*, 1.8×10^{-2} mg/m³).

Due to the high percentage of samples with no quantifiable measurement above the LOD, the air concentrations used to represent long-term exposure may overestimate true workplace exposures. Therefore, the use of the EPA Mass Balance Inhalation Model for development of central tendency and high-end levels of full-shift exposures is justified.

During intermediate use in polypropylene (PP) manufacturing, EPA also expects worker inhalation exposures to DIBP via exposure to particulates. EPA estimated worker inhalation exposures to particulates using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 325 (Chemical Manufacturing) to estimate particulate concentrations in the air. EPA used the residual concentration of DIBP in PP products to estimate the concentration of DIBP in particulates. For this OES, 1.33 ppm is the maximum expected DIBP concentration, based on the reported PP concentrations in the W.R. Grace and Co. Report ([W.R. Grace & Co, 2022](#)). The estimated exposures assume that DIBP is present in particulates of the plastic at this fixed concentration throughout the working shift.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-19 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during formulation into pre-catalyst, which only includes inhalation exposure to vapor. Table 3-20 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during intermediate use in polypropylene manufacturing, which includes inhalation exposures to both vapor and particulates. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end and central tendency exposures use 250 days per year as the exposure frequency, which is the expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* and the *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about models equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-19. Summary of Estimated Worker Inhalation Exposures for Formation into Pre-Catalyst

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.0E-04	2.3E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-04	1.7E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.4E-04	1.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.5E-04	2.5E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-04	1.9E-03

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.8E-04	1.7E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	
	Acute Dose (AD) (mg/kg/day)	5.0E-04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.4E-04	
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively.			

Table 3-20. Summary of Estimated Worker Inhalation Exposures for Intermediate in Polypropylene Manufacturing

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.0E-04	2.3E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-04	1.7E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.4E-04	1.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.5E-04	2.5E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-04	1.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.8E-04	1.7E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	
	Acute Dose (AD) (mg/kg/day)	5.0E-04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.4E-04	
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. EPA estimated worker inhalation exposures to particulates using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP 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.			

3.5.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, formulation into pre-catalyst) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-21 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with

this OES. Because there is no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed.

Table 3-21 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-21. Summary of Estimated Worker Dermal Exposures for Formulation into Pre-Catalyst

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.0E-02
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end and central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days.			

EPA estimated dermal exposures for the use as an intermediate in polypropylene manufacturing using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-22 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for the intermediate use of DIBP in polypropylene manufacturing.

Table 3-22 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-22. Summary of Estimated Worker Dermal Exposures for Intermediate in Polypropylene Manufacturing

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.3E-02
	Dose Rate (APDR, mg/day)	2.1	4.2

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Female of Reproductive Age	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.0E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.1E-03	
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end and central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days.			

3.5.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-23. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-23. Summary of Estimated Worker Aggregate Exposures for Formulation into Pre-Catalyst

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.1E-02
ONU	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.4E-04	
Note: A worker or ONU 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 Intermediate in Polypropylene Manufacturing

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.1E-02
ONU	Acute (AD, mg/kg-day)	5.0E-03	
	Intermediate (IADD, mg/kg-day)	3.7E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.5E-03	
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.6 Application of Paints and Coatings

3.6.1 Process Description

Application sites transfer paint/coating products from shipping containers to application equipment and apply paint/coating products to substrates ([U.S. EPA, 2014b](#); [OECD, 2011b, 2009c](#); [U.S. EPA, 2004c](#)). Application methods for DIBP-containing paints and coatings include spray, brush, roller, and trowel application ([OECD, 2011b](#)). Manual spray equipment includes air (*e.g.*, low volume/high pressure), air-assisted, and airless spray systems ([U.S. EPA, 2014b](#); [OECD, 2009c](#); [U.S. EPA, 2004c](#)). End use sites may utilize spray booth capture technologies when performing spray applications ([OECD, 2011a](#)). A single application may occur over the course of one or two 8-hour workdays for a given site, accounting for drying times and any additional coats. Figure 3-7 provides an illustration of the application of paints and coatings process based on the above information ([OECD, 2011b](#)).

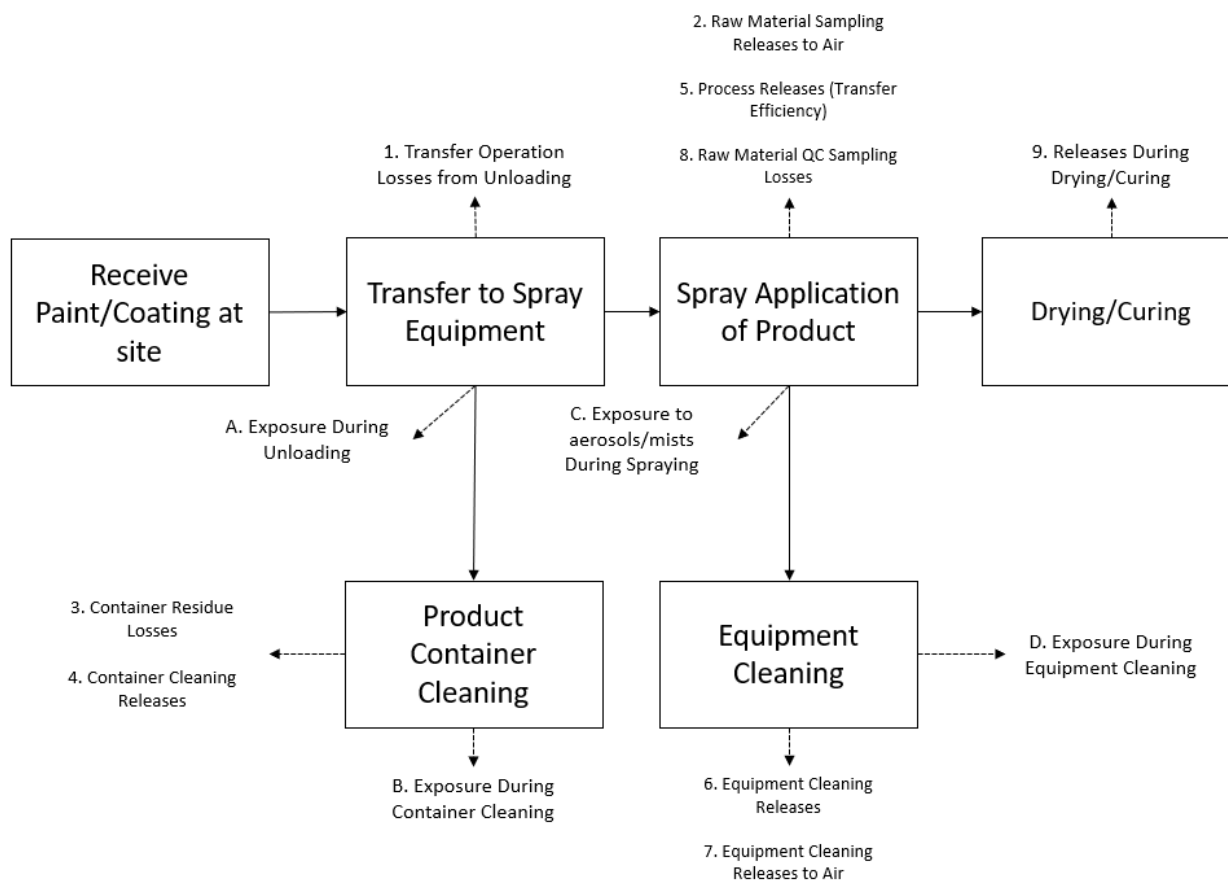


Figure 3-7. Application of Paints and Coatings Flow Diagram

3.6.2 Facility Estimates

Since the application of paints and coatings is expected to occur directly downstream of the incorporation into paints and coatings, EPA expects the production volume to be identical of the incorporation into paints and coatings OES. Based on available product SDSs, EPA used a concentration range of between one to 60 percent for paints and coating products. EPA estimated the total production volume as a deterministic value of 3,694 kg/year (see Section 3.4.2 for details).

EPA modeled the annual throughput of paint and coating products using a uniform distribution with a lower bound of 2,494 kg/year, and an upper bound of 3,694 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). The ESD provides a range of 2,694 to 265,000 kg of radiation curable coatings produced per site, per year. The lower bound was taken from the lower bound of this range. The upper bound is equal to the production volume, such that the facility throughput does not exceed the maximum production volume of DIBP. EPA calculated the annual facility throughput of DIBP as the paint and coating throughput multiplied by the concentration of DIBP in the paint/coating product, which resulted in a range of 25 to 2,216 kg/site-yr. EPA calculated the number of sites by dividing the total production volume by the annual facility throughput of DIBP, which resulted in a range of 9 to 127 sites.

EPA identified DIBP-containing paint and coating products that arrive in containers ranging in size from 0.1 to 5 gallons, with DIBP concentrations of 1 to 60 percent (see Appendix E for EPA identified DIBP-containing products for this OES). Container sizes and product concentrations were based on relevant

identified SDS and the 2011 ESD on Radiation Curable Coatings, Inks and Adhesives, the 2014 ESD on Coating Application via Spray-Painting in the Automotive Finishing Industry, and the 2004 GS on Spray Coatings in the Furniture Industry ([U.S. EPA, 2014b](#); [OECD, 2011b](#), [2009c](#); [U.S. EPA, 2004c](#)).

EPA assessed an operating day range of 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 ([ESIG, 2020a](#)). The upper bound is based on the European Risk Report for DIDP ([ECJRC, 2003](#)), which provided a default of 300 days/year. The mode is based on the GS for Automobile Spray Coating ([U.S. EPA, 1996](#)), which estimates 250 days/year, based on 50 weeks/year of 5 days/week operation. EPA did not identify any other site- or chemical-specific manufacturing facility operating data.

3.6.3 Release Assessment

3.6.3.1 Environmental Release Points

EPA assigned release points based on 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](#)). EPA assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects fugitive air releases from unloading, sampling, container cleaning, and equipment cleaning. EPA expects wastewater, incineration, or landfill releases from container residue losses, equipment cleaning wastes, and sampling wastes. Sites may utilize overspray control technology to prevent additional air releases during spray application. If a site uses overspray control technology, EPA expects stack air releases of approximately 10 percent of process related operational losses. EPA expects the site to release the remaining 90 percent of operational losses to wastewater, landfill, or incineration. If the site does not use control technology, EPA expects the site to release all process related operational losses to fugitive air, wastewater, incineration, or landfill in unknown percentages.

3.6.3.2 Environmental Release Assessment Results

Table 3-25 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for application of paints and coatings. See Section D.7 for additional details on model equations and parameters. The *Application of Paints and Coatings OES Environmental Release Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-25 Summary of Modeled Environmental Releases for Application of Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,694 kg production volume With Engineering Controls	Fugitive air	4.0E-04	1.21E-03	258	257	1.56E-06	4.68E-06
	Stack Air	26	73			9.9E-02	0.29
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	10	29			4.0E-02	0.11
	Incineration or landfill ^a	243	687			0.94	2.7
3,694 kg production volume Without Engineering Controls	Fugitive air	4.0E-04	1.2E-03	258	257	1.6E-06	4.7E-06
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	10	29			4.0E-02	0.11
	Air, Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), Incineration, or Landfill ^a	256	734			0.99	2.9
	Incineration or landfill ^a	12	30			4.7E-02	0.12

^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 available to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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

During the application of DIBP-containing paints and coatings, workers are potentially exposed to DIBP mist when roll or curtain coating and to overspray inhalation during spray coating. Vapor inhalation exposures to DIBP for workers and ONUs may also occur from DIBP that volatilizes during product unloading, raw material sampling, application, and container and equipment cleaning. In the case of the OES of manufacturing and the release source of product loading, the emission rates are 2.28E-07 to

7.30E-07 kg/site-day. The emission rate in the case of unloading of products would be lower because of lower concentration and lower throughput. Workers may be exposed via dermal contact to liquids containing DIBP during product unloading into application equipment, application of the paints and coatings, 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 DIBP-containing paints and coatings.

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 spray application area. ONUs are potentially exposed via inhalation exposure to mists while present in the application area and dermal exposure to mists that settle onto surfaces that ONUs contact.

3.6.4.2 Occupational Inhalation Exposure Results

The worker activities discussed above may result in variable inhalation exposure. To assess this variable exposure, EPA assessed inhalation exposure that is associated with two exposure scenarios, which are spray application and non-spray application of paints/coatings. EPA did not identify any DIBP inhalation monitoring data for the application of paints and coatings during systematic review of literature sources. In the case of the scenario of non-spray application, volatilization of DIBP during worker activities results in inhalation exposure and therefore EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in see Section D.14. Therefore, EPA chose the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for the assessment of vapor inhalation exposures of all relevant OESs. In the case of the scenario of non-spray application, EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14.

In the case of the scenario of spray-application, 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 from the model along with the concentration of DIBP in the paint (a mode of five percent for central tendency and a maximum of 60 percent for high-end, based on the identified products) to estimate the central tendency and high-end inhalation exposures, respectively.

EPA did not identify information on the duration of exposure to DIBP via mists and therefore assessed exposure using spray applications occurring over a full 8-hour period. Exposure via mists from spray applications is assumed to be protective of all worker exposure estimates including inhalation via vapors due to DIBP's low vapor pressure, consistent with EPA's assumption for other phthalates chemicals such as DIDP and DINP ([U.S. EPA, 2025d, 2024b](#)).

Table 3-26 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during the application of paints and coatings. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end and central tendency exposures use 250 days per year as the exposure frequency, which is the

expected maximum number of working days. Appendix A describes the approach for estimating AD, IADD, and ADD.

With regard to the non-spray application scenario, *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* also contains information about the model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document. With regard to the spray application scenario, the *Occupational Spray Application Mist Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-26. Summary of Estimated Worker Inhalation Exposures for Application of Paints and Coatings

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker – Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	0.34	22
	Acute Dose (AD) (mg/kg/day)	4.2E–02	2.8
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.1E–02	2.0
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	2.9E–02	1.9
Female of Reproductive Age – Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	0.34	22
	Acute Dose (AD) (mg/kg/day)	4.7E–02	3.1
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.4E–02	2.2
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.2E–02	2.1
ONU – Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	0.34	
	Acute Dose (AD) (mg/kg/day)	4.3E–02	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.1E–02	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	2.9E–02	
Average Adult Worker – Non-Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	4.0E–03	1.8E–02
	Acute Dose (AD) (mg/kg/day)	5.0E–04	2.3E–03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E–04	1.7E–03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.4E–04	1.6E–03
Female of Reproductive Age – Non-Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	4.0E–03	1.8E–02
	Acute Dose (AD) (mg/kg/day)	5.5E–04	2.5E–03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E–04	1.9E–03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.8E–04	1.7E–03

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
ONU – Non-Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	4.0E–03	
	Acute Dose (AD) (mg/kg/day)	5.0E–04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E–04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.4E–04	
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of the non-spray scenario to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. In the case of the scenario of spray-application, 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 from the model along with the concentration of DIBP in the paint (a mode of five percent for central tendency and a maximum of 60 percent for high-end, based on the identified products) to estimate the central tendency and high-end inhalation exposures, respectively.			

3.6.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, application of paints and coatings) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-27 are explained in Appendix A. Workers may be exposed to liquid formulations containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is mist expected to be deposited on surfaces from the spray application of paints and coatings, dermal exposures to ONUs from contact with mist on surfaces were assessed.

Table 3-27 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-27. Summary of Estimated Worker Dermal Exposures for Application of Paints and Coatings

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker – Spray Application and Non-Spray Application	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E–02	6.3E–02
	Intermediate (IADD, mg/kg-day)	2.3E–02	4.6E–02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E–02	4.3E–02
Female of Reproductive Age – Spray Application and Non-Spray Application	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E–02	5.8E–02
	Intermediate (IADD, mg/kg-day)	2.1E–02	4.3E–02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E–02	4.0E–02
ONU – Spray Application only	Dose Rate (APDR, mg/day)	1.3	
	Acute (AD, mg/kg-day)	1.6E–02	
	Intermediate (IADD, mg/kg-day)	1.2E–02	
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.1E–02	

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end and central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days.			

3.6.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-28. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-28 Summary of Estimated Worker Aggregate Exposures for Application of Paints and Coatings

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Spray Application	Acute (AD, mg/kg-day)	7.4E-02	2.8
	Intermediate (IADD, mg/kg-day)	5.4E-02	2.1
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.1E-02	1.9
Female of Reproductive Age – Spray Application	Acute (AD, mg/kg-day)	7.6E-02	3.1
	Intermediate (IADD, mg/kg-day)	5.5E-02	2.3
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.2E-02	2.1
ONU – Spray Application	Acute (AD, mg/kg-day)	5.8E-02	
	Intermediate (IADD, mg/kg-day)	4.3E-02	
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.0E-02	
Average Adult Worker – Non-Spray Application	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.2E-02	4.5E-02
Female of Reproductive Age – Non-Spray Application	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.1E-02
ONU – Non-Spray Application	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.4E-04	
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.7 Application of Adhesives and Sealants

3.7.1 Process Description

DIBP is an ingredient in various adhesive and sealant products including anchoring adhesive, grouts, and seam adhesives; see Appendix E for information about DIBP-containing products that EPA associated with this OES. According to the SDS and technical data sheets of these products, adhesive and sealant products containing DIBP are available in containers ranging in size from one to five gallons and contain DIBP at concentrations of 0.1 to 60 percent DIBP. These products are shipped in these containers to end use sites where the products are transferred from the shipping containers to the application equipment, such as a caulk gun or syringe, and applied to the substrate ([OECD, 2015a](#)). Application methods may include spray, roll, syringe, bead, and dip application. A single application may occur over the course of one or two 8-hour workdays for a given site, accounting for drying times and any additional coats. The site may trim excess adhesive or sealant from the applied substrate area. Figure 3-8 provides an illustration of the application of adhesives and sealants process based on the above information ([OECD, 2015a](#)).

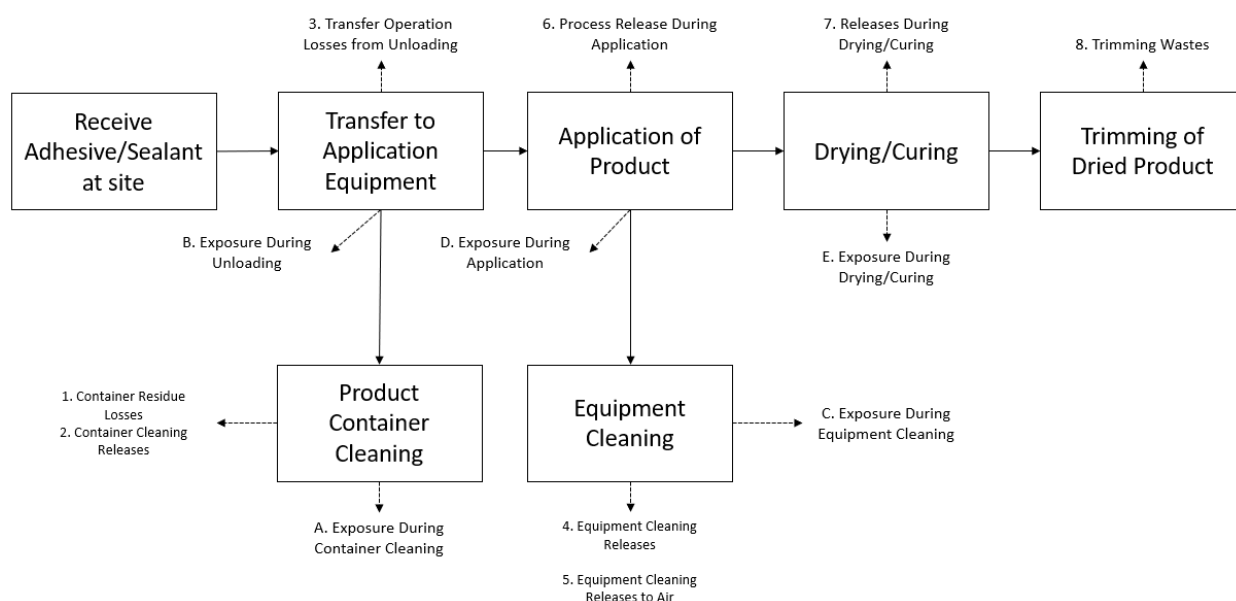


Figure 3-8. Application of Adhesives and Sealants Flow Diagram

3.7.2 Facility Estimates

EPA assessed the production volume of this OES to be equal to the production volume of the OES of incorporation into adhesives and sealants, or 3,694 kg/year, because the products that result from that OES are the same products used in this OES.

EPA estimated the annual facility throughput of DIBP based on the use rates of adhesive products that are reported in The ESD on Use of Adhesives ([OECD, 2015b](#)). This ESD contains a default value of the use rate of an adhesive product in the case of various adhesive end-use categories. Some of these adhesive end-use categories are relevant because these end-use categories are related to the uses of the adhesives and sealants that contain DIBP. These relevant end-use categories include general assembly,

motor and non-motor vehicle, vehicle parts, and tire manufacturing (except retreading). The lower and upper bounds of the default adhesive use rates of these categories are 1,500 kg/year and 141,898 kg/site-year, respectively. The Monte Carlo model includes a constraint that limits the annual facility throughput of DIBP to the DIBP production volume for this OES, or 3,694 kg/site-yr.

EPA assessed the range of operating days from 225 to 300 days/year based on the ESD on Use of Adhesives ([OECD, 2015b](#)). The number of sites is calculated in the Monte Carlo model by dividing total production volume by the annual facility throughput of DIBP (see Section D.8.3). The modeled 50th to 95th percentile range of modeled sites was 5 to 16 sites.

3.7.3 Release Assessment

3.7.3.1 Environmental Release Points

EPA assigned release points based on the ESD on Use of Adhesives ([OECD, 2015b](#)). EPA assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects fugitive air releases from unloading of adhesives, container cleaning, equipment cleaning, and drying or curing processes. EPA expects releases to wastewater, incineration, or landfill from raw material container residue, equipment cleaning waste, and trimming waste.

3.7.3.2 Environmental Release Assessment Results

Table 3-29 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for the application of adhesives and sealants. See Section D.8 for additional details on model equations and parameters used. The *Application of Adhesives and Sealants OES Environmental Release Modeling Results for DIBP* also contains information about model equations and parameters and includes calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-29 Summary of Modeled Environmental Releases for Application of Adhesives and Sealants

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,694 kg production volume	Fugitive or stack air ^a	5.0E-04	1.3E-03	214	247	2.4E-06	5.3E-06
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	178	228	236	134	0.75	1.7
^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 available to estimate the partitioning between media. ^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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 may occur via inhalation of vapors or dermal contact with liquids during product unloading, product container cleaning, application equipment cleaning, adhesive application, and curing or drying ([OECD, 2015a](#)). EPA did not infer spray coating as the application method of any of the adhesive or sealant products that are listed in Appendix E. However, spray application of adhesives in vehicle manufacturing is possible ([OECD, 2015a](#)) and DIBP is used in vehicle manufacturing ([U.S. EPA, 2020c](#)). Therefore, EPA conservatively assumed that workers may spray apply adhesives that contain DIBP, which may lead to elevated levels of exposure compared to non-spray application methods. EPA did not identify information on engineering controls or worker PPE used at DIBP-containing adhesive and sealant 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 inhalation exposure to mists while present in the application area and dermal exposure to mists that settle onto surfaces that ONUs contact.

3.7.4.2 Occupational Inhalation Exposure Results

The worker activities discussed above may result in variable inhalation exposure. To assess this variable exposure, EPA assessed inhalation exposure that is associated with two exposure scenarios, which are spray application and non-spray application of adhesives/sealants. EPA did not identify any DIBP inhalation monitoring data for the application of adhesives and sealants during systematic review of literature sources. In the case of the scenario of non-spray application, volatilization of DIBP during worker activities results in inhalation exposure and therefore EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in Section D.14. Therefore, EPA chose the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for the assessment of vapor inhalation exposures of all relevant OESs. In the case of the scenario of non-spray application, EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14.

In the case of the scenario of spray-application, 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 from the model along with the concentration of DIBP in the adhesive (a mode of 30% for central tendency and a maximum of 60 percent for high-end, based on the identified products) to estimate the central tendency and high-end inhalation exposures, respectively.

EPA did not identify information on the duration of exposure to DIBP via mists and therefore assessed exposure using spray applications occurring over a full 8-hour period. Exposure via mists from spray applications is assumed to be protective of all worker exposure estimates including inhalation via vapors due to DIBP's low vapor pressure, consistent with EPA's assumption for other phthalates chemicals such as DIDP and DINP ([U.S. EPA, 2025d, 2024b](#)).

Table 3-30 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during the use of adhesives and sealants. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentiles of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of working days. The central tendency exposures use 232 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.

With regard to the non-spray application scenario, *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* also contains information about the model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document. With regard to the spray application scenario, the *Occupational Spray Application Mist Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-30. Summary of Estimated Worker Inhalation Exposures for Application of Adhesives and Sealants

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker – Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	2.0	22
	Acute Dose (AD) (mg/kg/day)	0.25	2.8
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	0.19	2.0
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	0.16	1.9
Female of Reproductive Age – Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	2.0	22
	Acute Dose (AD) (mg/kg/day)	0.28	3.1
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	0.21	2.2
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	0.18	2.1
ONU – Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	2.0	
	Acute Dose (AD) (mg/kg/day)	0.25	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	0.19	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	0.16	0.17
Average Adult Worker – Non-Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	4.0E–03	1.8E–02
	Acute Dose (AD) (mg/kg/day)	5.0E–04	2.3E–03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E–04	1.7E–03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.2E–04	1.6E–03

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Female of Reproductive Age – Non-Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	4.0E–03	1.8E–02
	Acute Dose (AD) (mg/kg/day)	5.5E–04	2.5E–03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E–04	1.9E–03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.5E–04	1.7E–03
ONU – Non-Spray Application	8-hour TWA Exposure Concentration (mg/m ³)	4.0E–03	
	Acute Dose (AD) (mg/kg/day)	5.0E–04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E–04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.2E–04	3.4E–04
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of the non-spray scenario to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. In the case of the scenario of spray-application, 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 from the model along with the concentration of DIBP in the adhesive (a mode of 30 percent for central tendency and a maximum of 60 percent for high-end, based on the identified products) to estimate the central tendency and high-end inhalation exposures, respectively.			

3.7.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, application of adhesives and sealants) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-31 are explained in Appendix A. Workers may be exposed to liquid formulations containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is mist expected to be deposited on surfaces from the spray application of adhesives and sealants, dermal exposures to ONUs from contact with mist on surfaces were assessed.

Table 3-31 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-31. Summary of Estimated Worker Dermal Exposures for Application of Adhesives and Sealants

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker – Spray Application and Non-Spray Application	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E–02	6.3E–02
	Intermediate (IADD, mg/kg-day)	2.3E–02	4.6E–02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E–02	4.3E–02
Female of Reproductive Age – Spray Application and Non-Spray Application	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E–02	5.8E–02
	Intermediate (IADD, mg/kg-day)	2.1E–02	4.3E–02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.8E–02	4.0E–02
ONU – Spray Application only	Dose Rate (APDR, mg/day)	1.3	
	Acute (AD, mg/kg-day)	1.6E–02	
	Intermediate (IADD, mg/kg-day)	1.2E–02	
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.0E–02	1.1E–02
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 232 days out of 365 days.			

3.7.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-32. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure.

Table 3-32. Summary of Estimated Worker Aggregate Exposures for Application of Adhesives and Sealants

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Spray Application	Acute (AD, mg/kg-day)	0.29	2.8
	Intermediate (IADD, mg/kg-day)	0.21	2.1
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.18	1.9
Female of Reproductive Age – Spray Application	Acute (AD, mg/kg-day)	0.31	3.1
	Intermediate (IADD, mg/kg-day)	0.23	2.3
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.20	2.1
ONU – Spray Application	Acute (AD, mg/kg-day)	0.27	
	Intermediate (IADD, mg/kg-day)	0.20	

Worker Population	Exposure Concentration Type	Central Tendency	High-End
	Chronic, Non-Cancer (ADD, mg/kg-day)	0.17	0.18
Average Adult Worker – Non-Spray Application	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.5E-02
Female of Reproductive Age – Non-Spray Application	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.9E-02	4.1E-02
ONU – Non-Spray Application	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.2E-04	3.4E-04
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.8 Use of Laboratory Chemicals

3.8.1 Process Description

DIBP is a laboratory chemical used at commercial laboratory sites, and may be used in both liquid or solid form. Raw material container sizes were based on available product sizes for relevant identified SDS and the 2015 GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)). Relevant SDS indicate laboratory chemicals containing DIBP arrive at end use sites in containers ranging in size from 0.25 to 5 gallons or 5 to 5,000 grams, depending on the chemical form (see Appendix E for EPA identified DIBP-containing products for this OES). The end use site transfers the chemical to labware and lab equipment for analyses. After analyses, laboratory sites clean containers, labware, and lab equipment, and dispose of laboratory wastes and unreacted DIBP-containing laboratory chemicals. Figure 3-9 provides an illustration of the use of laboratory chemicals based on the above information ([U.S. EPA, 2023d](#)).

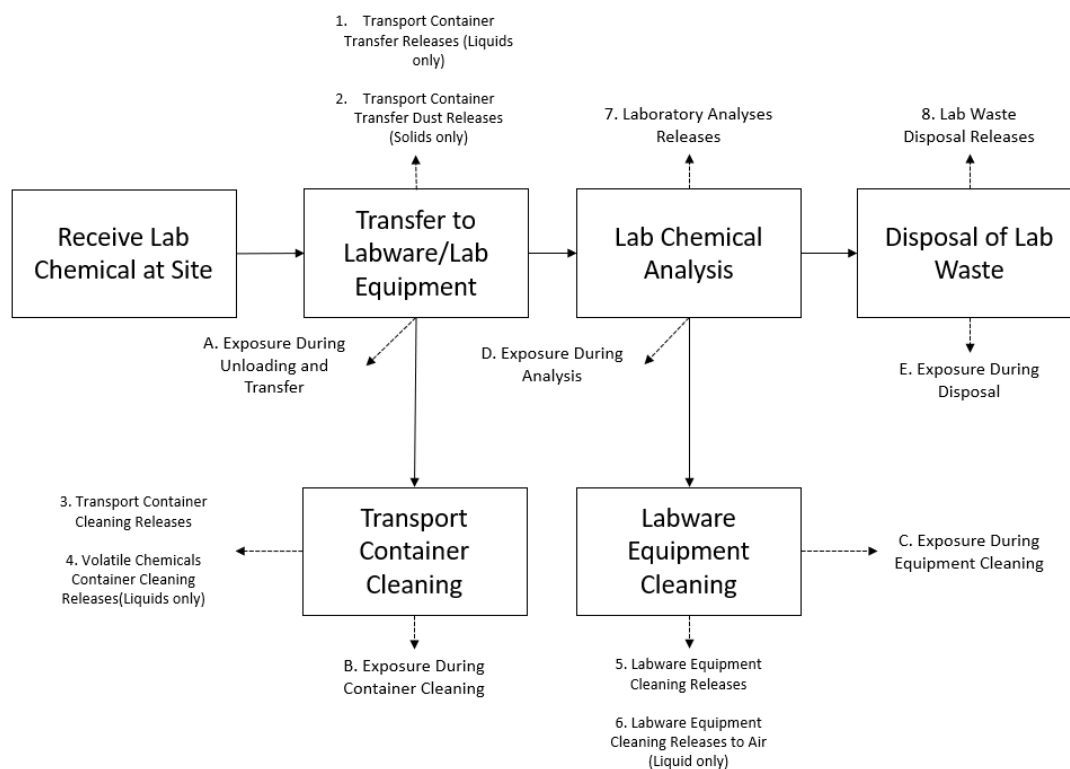


Figure 3-9. Use of Laboratory Chemicals Flow Diagram

3.8.2 Facility Estimates

No sites reported the use of DIBP-containing laboratory chemicals in the 2020 CDR. Instead, EPA estimated the total production volume of DIBP 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. The single site that reported to 2020 CDR for DIBP, Lanxess Corp, reported production volume of 407,303 lbs. Therefore, the total production volume for this OES was 9,327 kg/year.

EPA did not identify site- or chemical-specific operating data for laboratory use of DIBP (*i.e.*, facility throughput, operating days, number of sites). For liquid laboratory chemicals, the 2023 GS on the Use of Laboratory Chemicals provided an estimated throughput of 1.55 to 4,000 mL/site-day. Based on the concentration of DIBP in liquid laboratory chemicals of 90 to 100 percent and the DIBP density of 1.0386 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 1.97 to 3.75 kg/site-day. For solid laboratory chemicals, EPA estimated the daily throughput based on the PV and expected number of operating days and sites (described below). Using a Monte Carlo model (see Section D.9 for details), EPA estimated a daily facility use rate for solid DIBP laboratory chemicals to be 1.07 to 1.29 g/site-day.

The 2023 GS on the Use of Laboratory Chemicals estimated the number of operating days as 174 to 260 days/year, with 8 hour/day operations ([U.S. EPA, 2023d](#)). EPA did not identify estimates of the number of sites that use laboratory chemicals containing DIBP. Therefore, EPA estimated the total number of sites that use DIBP-containing laboratory chemicals using a Monte Carlo model. The 50th to 95th percentile range of the number of sites was 20 to 202 sites for liquid laboratory chemicals. For solid laboratory chemicals, EPA assessed the maximum number of sites of 36,873 due to the low mass

fraction of DIBP in lab chemicals, which results in a number of sites exceeding the maximum for every model iteration ([U.S. EPA, 2023d](#)).

3.8.3 Release Assessment

3.8.3.1 Environmental Release Points

EPA assigned release points based on the GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)). EPA assigned default models to quantify releases from each release point and suspected fugitive air release point. Laboratory sites may use a combination of solid and liquid laboratory chemicals, but for release estimate EPA assumed each site used either the liquid or solid form of the DIBP-containing laboratory chemical. In the liquid laboratory chemical use case, EPA expects fugitive or stack air releases from unloading containers, container cleaning, labware cleaning, and during laboratory analysis. In the solid laboratory chemical use case, EPA expects dust emissions from unloading to fugitive air, wastewater, incineration, or landfill. If a site uses air capture technology, EPA expects dust releases from product loading to be controlled and released to disposal facilities for incineration or landfill. EPA expects that the remaining uncontrolled dust is released to stack air. If the site does not use air control technology, EPA expects releases to fugitive air, wastewater, incineration, or landfill.

For both liquid and solid laboratory chemicals, EPA expects wastewater, incineration, or landfill releases from container cleaning wastes, labware equipment cleaning wastes, and laboratory wastes.

3.8.3.2 Environmental Release Assessment Results

Table 3-33 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for the use of laboratory chemicals. See Section D.9 for additional details on model equations and parameters used. The *Use of Laboratory Chemicals OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and includes calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-33. Summary of Modeled Environmental Releases for Use of Laboratory Chemicals

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
9,237 kg production volume Liquid laboratory chemicals	Fugitive or Stack Air ^a	2.7E-05	4.8E-05	230	236	1.2E-07	2.0E-07
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	450	885	228	237	2.0	3.7
9,237 kg production volume	Stack air	2.8E-04	7.0E-04	231	227	1.2E-06	3.1E-06
	Unknown media (fugitive air, Wastewater to onsite treatment or discharge to	7.3E-04	1.1E-03	232	223	3.1E-06	4.9E-06

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Solid laboratory chemicals	POTW (with or without pretreatment), incineration, or landfill) ^a						
	Wastewater to onsite treatment or discharge to POTW (with or without pretreatment), incineration, or landfill ^a	0.25	0.25	234	193	1.1E-03	1.3E-03
	Incineration or landfill ^a	1.9E-04	5.7E-04	230	227	8.3E-07	2.5E-06
^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 available to estimate the partitioning between media. ^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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

When handling solid laboratory chemicals, worker exposures to DIBP may occur from inhalation of dusts generated during unloading and transferring laboratory chemicals. Exposures via dermal contact with solid laboratory chemicals may occur during container cleaning, equipment cleaning, and disposal of laboratory waste.

When handling liquid laboratory chemicals, inhalation exposures to DIBP vapor and dermal exposure to liquids may occur during laboratory chemical unloading, container cleaning, labware and labware equipment cleaning, chemical use during laboratory analysis, and disposal of laboratory wastes ([U.S. EPA, 2023d](#)). EPA did not find information on the extent to which laboratories that use DIBP-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. ONU inhalation exposures may occur while the ONU is present in the analysis area, but EPA does not expect ONU dermal exposures to liquid laboratory chemical as ONUs do not have direct contact with these products. However, ONU exposures via dermal contact with solid laboratory chemicals can occur while present in the application area from dusts that may settle on surfaces.

3.8.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the DIBP use as a laboratory chemical during systematic review of literature sources. EPA expects workers may be exposed via the inhalation of

vapors when handling liquid laboratory chemicals and by the inhalation of particulates when handling solid laboratory chemicals. EPA separately assessed these two forms of exposure as described below.

For exposure to vapors from handling liquid laboratory chemicals, EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that the potential for vapor inhalation exposure is greatest in the case of the OES of DIBP manufacturing. EPA accomplished this determination by considering the following determinants of inhalation exposure: fugitive emission rates and their respective duration, and worker exposure frequency. Specifically, EPA calculated an index of exposure potential by multiplying the emission rate of each source fugitive air emissions and the duration of emission from this source and then summing these products. This index was calculated for each OES that includes fugitive air emissions, and the value of this index is greatest in the case of the OES of DIBP manufacturing. EPA then considered the exposure frequency that EPA assessed in the case of each OES; these exposure frequencies are all of similar value and therefore the OES of manufacture is confirmed as the worst-case of vapor inhalation exposure. EPA notes that other exposure determinants (*i.e.*, mixing factor, ventilation rate, and working years) do not vary by OES and are therefore not relevant to the determination of the worst-case. Based on this, EPA only modeled vapor exposures for the DIBP manufacturing OES and used these modeled estimates as surrogate for all OES with vapor exposure potential.

For exposure to particulates from handling solid laboratory chemicals, EPA estimated worker inhalation exposures using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 54 (Professional, Scientific, and Technical Services) to estimate particulate concentrations in the air. EPA used the highest expected concentration of DIBP in solid laboratory chemicals to estimate the concentration of DIBP in particulates. For this OES, EPA used 0.1 percent by mass based on identified DIBP-containing products applicable to this OES (see Appendix E). EPA assumed that DIBP is present in particulates of solid laboratory chemicals at this fixed concentration throughout the working shift.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-34 and Table 3-35 summarize the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during the use of liquid and solid laboratory chemicals, respectively. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end exposures use 250 days per year as the exposure frequency since the 95th percentiles of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of 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 *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* and the *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-34. Summary of Estimated Worker Inhalation Exposures for Use of Laboratory Chemicals – Liquids

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.0E-04	2.3E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-04	1.7E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.2E-04	1.6E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	1.8E-02
	Acute Dose (AD) (mg/kg/day)	5.5E-04	2.5E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-04	1.9E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.6E-04	1.7E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-03	
	Acute Dose (AD) (mg/kg/day)	5.0E-04	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.2E-04	3.4E-04
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively.			

Table 3-35. Summary of Estimated Worker Inhalation Exposures for Use of Laboratory Chemicals – Solids

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	1.9E-04	2.7E-03
	Acute Dose (AD) (mg/kg/day)	2.4E-05	3.4E-04
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	1.7E-05	2.5E-04
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	1.5E-05	2.3E-04
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	1.9E-04	2.7E-03
	Acute Dose (AD) (mg/kg/day)	2.6E-05	3.7E-04
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	1.9E-05	2.7E-04
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.7E-05	2.6E-04
ONU	8-hour TWA Exposure Concentration (mg/m ³)	1.9E-04	
	Acute Dose (AD) (mg/kg/day)	2.4E-05	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	1.7E-05	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.5E-05	1.6E-05

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
^a For exposure to particulates from handling solid laboratory chemicals, EPA estimated worker inhalation exposures using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP 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.			

3.8.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, use of liquid laboratory chemicals) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-36 are explained in Appendix A. Workers may be exposed to a liquid formulation containing DIBP during tasks associated with this OES. Because there is no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed.

Table 3-36 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-36. Summary of Estimated Worker Dermal Exposures for Use of Laboratory Chemicals (Liquids)

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.9E-02	4.0E-02
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 235 days out of 365 days.			

EPA estimated dermal exposures for the use of solid laboratory chemicals using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-37 are explained in Appendix A. Workers may be exposed to a solid or powdered material containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for the use of solid laboratory chemicals containing DIBP.

Table 3-37 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-37. Summary of Estimated Worker Dermal Exposures for Use of Laboratory Chemicals (Solids)

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	0.73	1.5
	Acute (AD, mg/kg-day)	9.1E-03	1.8E-02
	Intermediate (IADD, mg/kg-day)	6.7E-03	1.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.9E-03	1.2E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.61	1.2
	Acute (AD, mg/kg-day)	8.4E-03	1.7E-02
	Intermediate (IADD, mg/kg-day)	6.1E-03	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.4E-03	1.1E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.9E-03	3.1E-03
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 235 days out of 365 days.			

3.8.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-38. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-38. Summary of Estimated Worker Aggregate Exposures for Use of Laboratory Chemicals (Liquids)

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.5E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.1E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.9E-02	4.1E-02
ONU	Acute (AD, mg/kg-day)	5.0E-04	
	Intermediate (IADD, mg/kg-day)	3.7E-04	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.2E-04	3.4E-04
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

Table 3-39. Summary of Estimated Worker Aggregate Exposures for Use of Laboratory Chemicals (Solids)

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	9.1E-03	1.9E-02
	Intermediate (IADD, mg/kg-day)	6.7E-03	1.4E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.9E-03	1.3E-01
Female of Reproductive Age	Acute (AD, mg/kg-day)	8.4E-03	1.7E-02
	Intermediate (IADD, mg/kg-day)	6.1E-03	1.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.4E-03	1.2E-02
ONU	Acute (AD, mg/kg-day)	4.6E-03	
	Intermediate (IADD, mg/kg-day)	3.4E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.9E-03	3.1E-03
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.9 Fabrication of Final Product from Articles

3.9.1 Process Description

EPA anticipates that DIBP may be present in a wide array of different final articles that are used both commercially and industrially, including rifle cartridges, glitter boards, and polyurethane foams (see Appendix E for EPA identified DIBP-containing products for this OES) ([U.S. CPSC, 2015](#)). The 2020 *Final Scope of the Risk Evaluation for Di-isobutyl Phthalate* states that DIBP is industrially used in plastic and rubber products in transportation equipment manufacturing and commercially used in “building/construction materials not covered elsewhere” and “plastic and rubber products not covered elsewhere.” Based on uses for similar phthalate chemicals, this may include use of products such as vinyl tiles, resilient flooring, carpeting, scraper mats, and wall coverings ([U.S. EPA, 2020c](#), [2019b](#)). Use cases are expected to include welding or melting articles containing DIBP; drilling, cutting, grinding, or otherwise shaping articles containing DIBP; and the general use of DIBP-containing abrasives.

This OES is associated with multiple COUs including the COU of commercial use, toys, playgrounds, and sporting equipment. This specific COU includes the use of tire crumb rubber in synthetic turf sports

fields. Tire crumb rubber, which contains DIBP, is a component of synthetic turf sports fields ([U.S. EPA, 2019c](#)). EPA notes that tire crumb rubber is not an article per se.

EPA identified multiple products for the fabrication and final use of products or articles OES. The concentration of DIBP in these products varies depending on the type of product and the necessary characteristics of that product. Therefore, EPA used concentration ranges from plastic (6.5×10^{-3} to 7.4×10^{-2} kg/kg) and rubber (1×10^{-2} to 0.2 kg/kg) products to represent this scenario.

3.9.2 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 DIBP-containing article use occurs at many disparate industrial and commercial sites, with different operating conditions. With regard specifically to the use of tire crumb rubber in synthetic turf sports fields, EPA notes that the number of synthetic turf sports fields in the U.S. exceeds 12,000 and tire crumb rubber is an infill material in 95 percent of these fields ([U.S. EPA, 2019d](#)). EPA considered the number of these facilities because occupational exposure to DIBP is possible during the construction of these facilities. However, due to a lack of reasonably available information for the OES of Fabrication of final product from articles as a whole the number of industrial or commercial use sites is unquantifiable and unknown. 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 DIBP. 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.

3.9.3 Release Assessment

3.9.3.1 Environmental Release Points

EPA did not quantitatively assess environmental releases for this OES due to the lack of reasonably available process-specific and DIBP-specific data; however, EPA expects releases from this OES to be small and disperse in comparison to other upstream OES, as EPA expects DIBP to be present in smaller amounts and predominantly remain in the final article, limiting the potential for release. Table 3-40 describes the expected fabrication and use activities that generate releases. All releases are non-quantifiable due to a lack of identified process- and product- specific data.

Table 3-40. Release Activities for Fabrication/Use of Final Articles Containing DIBP

Release Point	Release Behavior	Release Media
Cutting, Grinding, Shaping, Drilling, Abrading, and Similar Activities	Dust Generation	Fugitive or Stack Air, Water, Incineration, or Landfill
Heating/Plastic Welding Activities	Vapor Generation	Fugitive or Stack Air

3.9.4 Occupational Exposure Assessment

3.9.4.1 Worker Activities

During fabrication and final use of products or articles, worker exposures to DIBP may occur via dermal contact while handling and shaping articles containing DIBP 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. Additionally, DIBP vapor inhalation exposure may occur during heating or plastic welding. With regard specifically to the use of tire crumb

rubber in synthetic turf sports fields, worker activities include installation and maintenance of synthetic turf sports fields. Tire crumb rubber is packaged at tire crumb rubber production sites in 1 ton bags ([U.S. EPA, 2019d](#)). During installation of a synthetic turf sports field, it may be mixed with sand prior to application as infill material ([U.S. EPA, 2019d](#)). Maintenance activities include tire crumb rubber replacement or refresh, which occurs every six months or less frequently and brushing and leveling, which occur weekly or less frequently ([U.S. EPA, 2019d](#)). EPA did not identify chemical-specific information on engineering controls and worker PPE used at final product or article formulation or use sites. Based on the presence of DIBP as an additive within solid articles or products, EPA expects particulate inhalation exposures to be higher than vapor exposures for this OES.

ONUs include supervisors, managers, and other employees that may be in manufacturing or use areas but do not directly handle DIBP-containing materials or articles. ONU exposures to DIBP may be through the inhalation of dusts or dermal contact with dusts that settle on workplace surfaces.

3.9.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the fabrication of final products from articles containing DIBP during systematic review of literature sources. Because DIBP is present in solid form for this OES, EPA expects worker inhalation exposures are primarily to particulates. EPA estimated worker inhalation exposures to particulates using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 337 (Furniture and Related Product Manufacturing) to estimate particulate concentrations in the air in the case of all facilities other than synthetic turf sports fields, and used a subset of the data in the model that came from facilities with NAICS codes starting with 23 (Construction) in the case of synthetic turf sports fields. Particulate exposures across end-use industries may include trimming, cutting, and/or abrasive actions on the DIBP-containing product, and EPA expects similar actions during furniture and related products manufacturing. EPA used the highest expected concentration of DIBP in final products to estimate the concentration of DIBP in the particulates in the case of all facilities other than synthetic turf sports fields. For this OES, EPA selected 20 percent by mass as the highest expected DIBP concentration based on the estimated plasticizer concentrations in relevant products given by the Use of Additives in Plastic Compounding GS ([U.S. EPA, 2021d](#)). In the case of synthetic turf sports facilities, EPA used the concentration of DIBP in tire crumb rubber; this concentration equals 0.00005 wt. percent ([U.S. EPA, 2019d](#)). As shown in Table 3-41, the calculated DIBP 8-hour TWA concentrations in the case of synthetic turf sports fields are much lower than the calculated concentrations in the case of the other facilities of the OES, and therefore the exposures calculated for other facilities are considered protective of worker exposure in the case of synthetic turf sports fields. The estimated exposures assume that DIBP is present in particulates at this fixed concentration throughout the working shift.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-41 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposure to DIBP during fabrication and final use of products. The estimated exposures assume that the worker is exposed to DIBP in the form of product particulates and does not account for other potential inhalation exposure routes, such as from vapors, which EPA expects

to not impact risk based on the relatively low vapor exposure estimates from other OES. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The high-end and central tendency exposures both use 250 days per year as the exposure frequency based on the 95th and 50th percentiles of operating days in the release assessment. Appendix A describes the approach for estimating AD, IADD, and ADD. The *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-41. Summary of Estimated Worker Inhalation Exposures for Fabrication and Final Use of Products or Articles

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-02	0.36
	Acute Dose (AD) (mg/kg/day)	1.0E-02	5.0E-02
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.7E-03	3.3E-02
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.0E-03	3.0E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-02	0.36
	Acute Dose (AD) (mg/kg/day)	1.0E-02	5.0E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.1E-03	3.6E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	4.0E-03	3.0E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.0E-02	
	Acute Dose (AD) (mg/kg/day)	1.0E-02	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.7E-03	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.0E-03	
^a EPA estimated worker inhalation exposures to particulates using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP 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.			

3.9.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, fabrication and final use of products or articles) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-42 are explained in Appendix A. Workers may be exposed to a solid material containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for the fabrication and final use of products or articles.

Table 3-42 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-42. Summary of Estimated Worker Dermal Exposures for Fabrication and Final Use of Products or Articles

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	0.73	1.5
	Acute (AD, mg/kg-day)	9.1E-03	1.8E-02
	Intermediate (IADD, mg/kg-day)	6.7E-03	1.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.2E-03	1.2E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.61	1.2
	Acute (AD, mg/kg-day)	8.4E-03	1.7E-02
	Intermediate (IADD, mg/kg-day)	6.1E-03	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.7E-03	1.1E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.1E-03	
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For both high-end and central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days.			

3.9.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-43. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-43. Summary of Estimated Worker Aggregate Exposures for Fabrication and Final Use of Products or Articles

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.4E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	1.0E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	9.7E-03	4.3E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.4E-02	6.6E-02
	Intermediate (IADD, mg/kg-day)	1.0E-02	4.9E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	9.5E-03	4.5E-02
ONU	Acute (AD, mg/kg-day)	9.5E-03	
	Intermediate (IADD, mg/kg-day)	7.0E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.5E-03	
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.10 Plastics Compounding

3.10.1 Process Description

DIBP is used as a plasticizer in plastic compounds to increase flexibility and has been found in various flooring products (ECHA, 2011). EPA expects that a typical compounding site receives DIBP at concentrations ranging from 90 to 100 percent in drums ranging from 20 to 100 gallons (U.S. EPA, 2021d, 2020a). The site unloads and transfers DIBP 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 (U.S. EPA, 2021d). Figure 3-10 provides an illustration of the plastic compounding process based on the above information (U.S. EPA, 2021d).

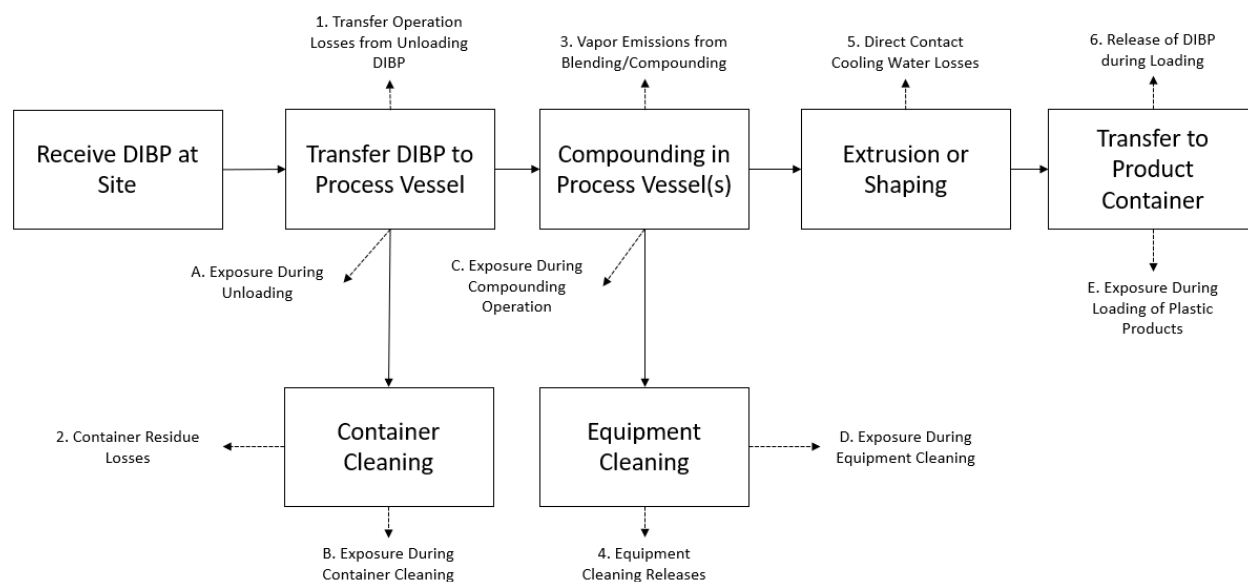


Figure 3-10. Plastics Compounding Flow Diagram

3.10.2 Facility Estimates

In the 2020 CDR, a singular site reported using DIBP. EPA estimated the total production volume for the plastics compounding OES as the total production volume from the singular reported site, or 184,750 kg/year (U.S. EPA, 2020a). This site also reports that DIBP is present at 90 to 100 percent in raw material going into plastics production (U.S. EPA, 2020a). Based on product data from the European Industry Reports, DIBP is expected to be present in plastic at 0.65 to 7.4 percent (ECHA, 2011). While the United Initiators Inc. TMCH-HA-M2 product (see Appendix E) lists a higher concentration of DIBP, this product is expected to be mixed with other material in the process resulting in a lower concentration of DIBP in the process.

EPA did not identify site- or chemical-specific operating data for plastics compounding (*i.e.*, facility production rate, number of batches, or operating days). Using Monte Carlo modeling, EPA estimated the 50th to 95th percentile range of annual facility DIBP throughput to be 36,950 to 184,750 kg/site-year, which is based on the 2021 GS on Plastic Compounding throughput of plastic additives, the mass fraction of DIBP in plastic products, and the mass fraction of all additives in compounded plastic resin (U.S. EPA, 2021d). EPA assessed the total number of operating days of 148 to 264 days/year, with 24 hour/day, 7 day/week operations (*i.e.*, multiple shifts). Additionally, EPA assumed the number of

batches per site year was equivalent to the number of operating days, or one batch per day. EPA estimated the total number of plastic compounding sites using a Monte Carlo model (see Section D.10 for details). The modeled 50th to 95th percentile range of the number of sites was five to nine sites.

3.10.3 Release Assessment

3.10.3.1 Environmental Release Points

EPA assigned release points based on the 2021 GS for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d). EPA assigned a default model to quantify releases for each release point and suspected fugitive air release point. EPA expects fugitive or stack air releases from unloading raw materials and process emissions. EPA expects dust releases to fugitive air, wastewater, incineration, or landfill from loading the solid compounded masterbatch. If a site uses air capture technology, EPA expects dust releases from product loading to be controlled and released to disposal facilities for incineration or landfill. EPA expects that the remaining uncontrolled dust is released to stack air. If the site does not use air control technology, EPA expects releases to fugitive air, wastewater, incineration, or landfill. EPA expects releases to wastewater, incineration, or landfill from container residues and equipment cleaning wastes. EPA expects releases to wastewater from direct contact cooling.

3.10.3.2 Environmental Release Assessment Results

Table 3-44 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for Plastic compounding. See Section D.10 for additional details on model equations and parameters used. The *Plastic Manufacturing OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and includes calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-44. Summary of Modeled Environmental Releases for Plastic Compounding

Modeling Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
184,750 kg production volume	Fugitive or stack air ^a	0.74	3.7	216	219	3.4E-03	1.7E-02
	Stack Air	125	901	218	215	0.57	4.2
	Fugitive air, wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface water, incineration, or landfill ^a	309	1,904	218	216	1.4	8.8
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment),	943	7,594	204	222	4.6	34

Modeling Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	direct to surface water, incineration, or landfill ^a						
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment), or direct to surface water ^a	370	1,848	216	219	1.7	8.4
	Incineration or landfill ^a	85	666	218	216	0.39	3.1
^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 available to estimate the partitioning between media. ^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end releases, respectively.							

3.10.4 Occupational Exposure Assessment

3.10.4.1 Worker Activities

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

ONUs include supervisors, managers, and other employees that work in the compounding area but do not directly contact DIBP received or processed onsite or handle compounded product. ONU exposures to DIBP may be through the inhalation of dusts or dermal contact with dusts that settle onto surfaces in the workplace.

3.10.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the DIBP use in plastic compounding during systematic review of literature sources. As described in the previous section, EPA expects workers may be exposed by the inhalation of both vapors and particulates for this OES. EPA assessed these two forms of exposure as described below.

For exposure to vapors, EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in Section D.14. Therefore, EPA chose the central tendency and high-

end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for the assessment of vapor inhalation exposures of all relevant OESs.

For exposure to particulates, EPA estimated worker inhalation exposures using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 325 (Chemical Manufacturing) to estimate plastic particulate concentrations in the air. EPA used the highest expected concentration of DIBP in plastic products to estimate the concentration of DIBP in particulates. For this OES, EPA selected 7.4 percent by mass as the maximum expected DIBP concentration, based on the reported plastic product concentrations in the Danish EPA Restriction Report ([ECHA, 2011](#)). The estimated exposures assume that DIBP is present in particulates of the plastic at this fixed concentration throughout the working shift.

EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-45 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during plastics compounding. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU 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 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. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* and the *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-45. Summary of Estimated Worker Inhalation Exposures for Plastics Compounding

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	4.2E-03	2.1E-02
	Acute Dose (AD) (mg/kg/day)	5.2E-04	2.6E-03
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	3.8E-04	1.9E-03
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.2E-04	1.80E-03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	4.2E-03	2.1E-02
	Acute Dose (AD) (mg/kg/day)	5.8E-04	2.9E-03
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.2E-04	2.1E-03
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.5E-04	2.0E-03
ONU	8-hour TWA Exposure Concentration (mg/m ³)	4.2E-03	
	Acute Dose (AD) (mg/kg/day)	5.2E-04	

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	3.8E-04	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.2E-04	3.6E-04
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. EPA estimated worker inhalation exposures to particulates using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP 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.			

3.10.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, plastics compounding) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-46 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for plastics compounding.

Table 3-46 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-46. Summary of Estimated Worker Dermal Exposures for Plastics Compounding

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.9E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.8E-02	4.0E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.8E-03	3.1E-03
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. EPA assumes a BW of 80 kg for average adult workers. EPA			

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
assumed a BW of 72.4 kg for females of reproductive age, per Chapter 8 of the Exposure Factors Handbook (U.S. EPA, 2011). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 223 days out of 365 days.			

3.10.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-47. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-47. Summary of Estimated Worker Aggregate Exposures for Plastics Compounding

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	3.2E-02	6.6E-02
	Intermediate (IADD, mg/kg-day)	2.4E-02	4.8E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.5E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	3.0E-02	6.1E-02
	Intermediate (IADD, mg/kg-day)	2.2E-02	4.5E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.8E-02	4.2E-02
ONU	Acute (AD, mg/kg-day)	5.1E-03	
	Intermediate (IADD, mg/kg-day)	3.7E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	3.1E-03	3.5E-03
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.11 Plastics Converting

3.11.1 Process Description

DIBP is used in plastic products to increase flexibility and has been found in various flooring products ([ECHA, 2011](#)). EPA expects that DIBP will arrive at a typical converting site as a solid in containers ranging in size from 20 to 100 gallons ([U.S. EPA, 2021e](#)). A typical converting site will unload DIBP in solid form, as a masterbatch, from plastic compounding sites where it is transferred 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 3-11 provides an illustration of the plastic converting process based on the above information ([U.S. EPA, 2021e](#)).

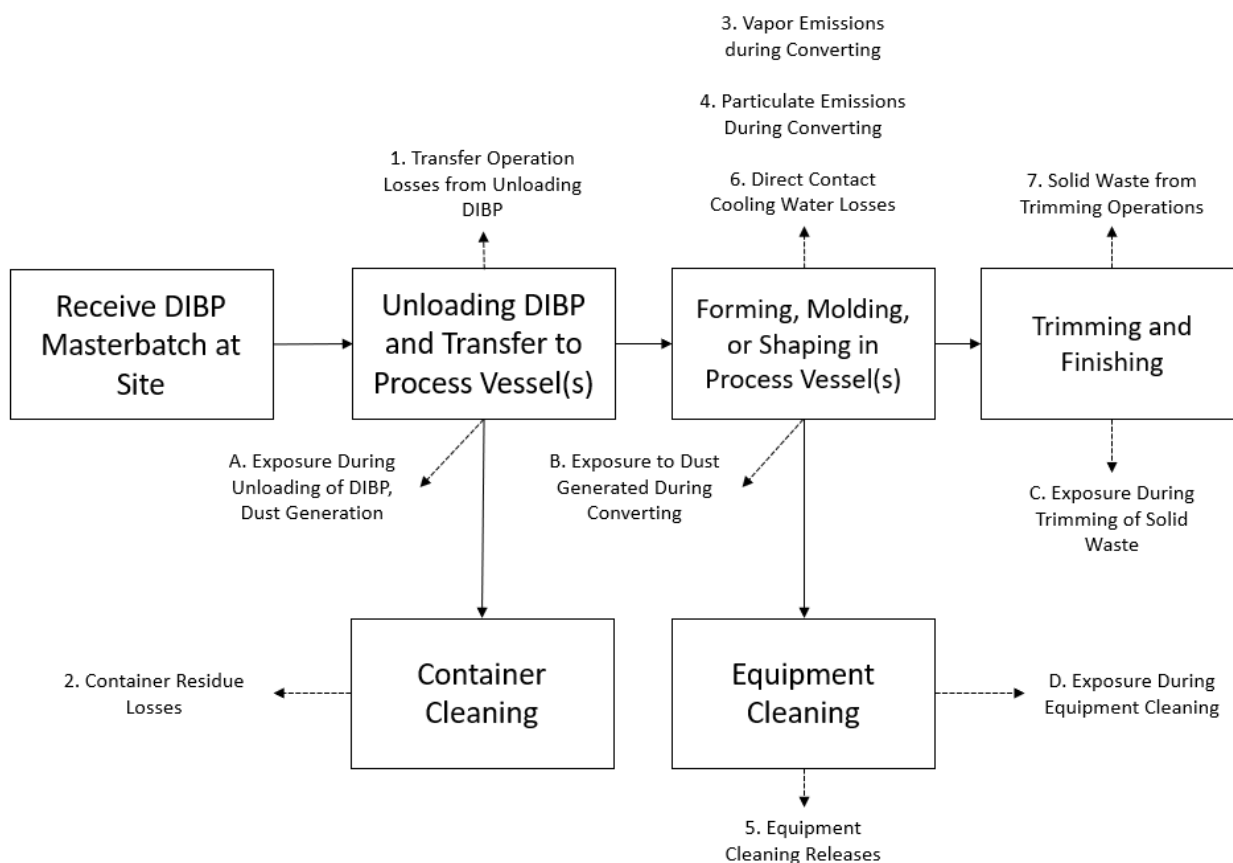


Figure 3-11. Plastics Converting Flow Diagram

3.11.2 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 plastic compounding OES. The production volume of DIBP for use in plastic compounding was 184,750 kg/year (see Section D.10.4 for details). Based on product data from the European Industry Reports, DIBP is expected to be present in plastic at 0.65 to 7.4 percent ([ECHA, 2011](#)).

EPA did not identify plastic converting site operating data (*i.e.*, facility production rate, number of batches, or operating days). Using Monte Carlo modeling, EPA estimated the 50th to 95th percentile range of annual facility DIBP throughput to be 4,862 to 20,528 kg/site-year, which is based on the GS on the Use of Plastic Additives in Plastic Converting throughput of plastic additives, the mass fraction of DIBP in plastic products, and the mass fraction of all additives in plastic resin ([U.S. EPA, 2021e](#)). EPA assessed the total number of operating days as 137 to 254 days/year, of 24 hour/day, 7 day/week operations (*i.e.*, multiple shifts). Additionally, EPA assumed the number of batches completed per site year were equivalent to the number of operating days, or one batch per day based on the GS ([U.S. EPA, 2021e](#)). EPA estimated the total number of plastics converting sites using a Monte Carlo model (see Section D.10.3 for details). The 50th to 95th percentile range of the number of sites calculated from the model is 38 to 67 sites.

3.11.3 Release Assessment

3.11.3.1 Environmental Release Points

EPA assigned release points based on the GS for the Use of Additives in Plastic Converting ([U.S. EPA, 2021e](#)). EPA assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects vapor process emissions to fugitive or stack air. EPA expects particulate emissions to fugitive air, wastewater, incineration, or landfill from unloading and the converting operations. If a site uses air capture technology, EPA expects dust releases from unloading to be controlled and released to disposal facilities for incineration or landfill; The site would release the remaining uncontrolled dust to stack air. If the site does not use air control technology, EPA expects plastic unloading releases to be entirely to fugitive air, wastewater, incineration, or landfill. EPA expects releases to wastewater, incineration, or landfill from container residues, and equipment cleaning. EPA expects releases to wastewater from direct contact cooling and incineration or landfill releases from solid waste trimming.

3.11.3.2 Environmental Release Assessment Results

Table 3-48 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for Plastics converting. See Section D.10 for additional details on model equations and parameters. The *Plastic Manufacturing OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and includes calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-48. Summary of Modeled Environmental Releases for Plastic Converting

Modeling Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
184,750 kg production volume	Fugitive or stack air ^a	0.29	1.5	214	208	1.3E-03	7.4E-03
	Stack air	16	110	213	209	7.6E-02	0.52
	Fugitive air, wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface water, incineration, or landfill ^a	41	226	213	210	0.19	1.1
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface water,	163	693	212	208	0.77	3.3

Modeling Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	incineration, or landfill ^a						
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment), or direct to surface water ^a	49	205	211	205	0.23	1.0
	Incineration or Landfill ^a	137	594	211		0.65	2.8

^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 available to estimate the partitioning between media.

^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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

Workers are potentially exposed to DIBP via dust inhalation during the converting process or via dermal contact with solids during equipment cleaning, container unloading, during the converting process, or trimming of excess plastic. Additionally, workers may be exposed to DIBP via inhalation of vapors during the plastic converting process ([U.S. EPA, 2021e](#)). EPA did not identify information on engineering controls or worker PPE used at plastics converting sites.

ONUs include supervisors, managers, and other employees that work in the converting area but do not directly contact DIBP that is received or processed onsite or handles the finished product. ONUs exposures to DIBP may be through the inhalation of dusts or dermal contact with dusts that settle on surfaces in the converting area.

3.11.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for the DIBP use in plastic compounding during systematic review of literature sources. As described in the previous section, EPA expects workers may be exposed via the inhalation of both vapors and particulates for this OES. EPA assessed these two forms of exposure as described below.

For exposure to vapors, EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in Section D.14. Therefore, EPA chose the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for the assessment of vapor inhalation exposures of all relevant OESs.

For exposure to particulates, EPA estimated worker inhalation exposures using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 326 (Plastics and Rubber manufacturing) to estimate plastic particulate concentrations in the air. EPA used the highest expected concentration of DIBP in plastic products to estimate the concentration of DIBP in particulates. For this OES, EPA selected 7.4 percent by mass as the maximum expected DIBP concentration, based on the reported plastic product concentrations in the Danish EPA Restriction Report ([ECHA, 2011](#)). The estimated exposures assume that DIBP is present in particulates of the plastic at this fixed concentration throughout the working shift.

EPA aggregated estimates from the surrogate modeled vapor exposure data and the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)) to address these two physical forms of DIBP for the full 8-hour work shift. EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-49 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during plastics converting. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU 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. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* and the *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about models, equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-49. Summary of Estimated Worker Inhalation Exposures for Plastics Converting

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	2.1E-02	0.37
	Acute Dose (AD) (mg/kg/day)	2.6E-03	4.6E-02
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	1.9E-03	3.4E-02
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	1.6E-03	3.2E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	2.1E-02	0.37
	Acute Dose (AD) (mg/kg/day)	2.9E-03	5.1E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	2.1E-03	3.7E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.7E-03	3.5E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	2.1E-02	

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
	Acute Dose (AD) (mg/kg/day)	2.6E-03	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	1.9E-03	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	1.6E-03	1.8E-03
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. EPA estimated worker inhalation exposures to particulates using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP 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.			

3.11.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, plastics converting) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-50 are explained in Appendix A. Workers may be exposed to a solid material containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for plastics converting.

Table 3-50 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-50. Summary of Estimated Worker Dermal Exposures for Plastics Converting

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	0.73	1.5
	Acute (AD, mg/kg-day)	9.1E-03	1.8E-02
	Intermediate (IADD, mg/kg-day)	6.7E-03	1.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.5E-03	1.2E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.61	1.2
	Acute (AD, mg/kg-day)	8.4E-03	1.7E-02
	Intermediate (IADD, mg/kg-day)	6.1E-03	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.0E-03	1.1E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.7E-03	3.1E-03
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was			

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 219 days out of 365 days.			

3.11.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-51. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-51. Summary of Estimated Worker Aggregate Exposures for Plastics Converting

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.2E-02	6.4E-02
	Intermediate (IADD, mg/kg-day)	8.6E-03	4.7E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	7.0E-03	4.4E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.1E-02	6.8E-02
	Intermediate (IADD, mg/kg-day)	8.3E-03	5.0E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.8E-03	4.6E-02
ONU	Acute (AD, mg/kg-day)	7.2E-03	
	Intermediate (IADD, mg/kg-day)	5.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.3E-03	4.9E-03
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.12 Recycling

3.12.1 Process Description

EPA identified minimal information regarding the recycling of products containing DIBP with the exception of tire crumb rubber and assumed that DIBP is primarily recycled industrially in the form of plastic waste streams. Mechanical recycling where plastic is grinded or formed into pellets is the predominant method of plastics recycling. While chemical/feedstock recycling is possible, EPA did not identify any market share data indicating chemical/feedstock recycling processes for DIBP-containing waste streams.

The Association of Plastic Recyclers reported that recycled plastic arrives at a typical recycling site tightly baled as crushed finished articles. The bales range in size from 240 to 453 kg ([APR, 2023](#)). The recycling site unloads the bales into process vessels, which grind the DIBP-containing waste and separate the plastic and non-plastic fractions using electrostatic separation, washing/floatation, or air/jet separation. Following cooling of the ground plastic, the site transfers the product to plastic compounding or converting feedstock storage or loads the products into containers for downstream shipment. Figure 3-12 provides an illustration of the plastics recycling process based on the above information ([U.S. EPA, 2021d](#)).

Another product of recycling is tire crumb rubber which is a product that is produced by recycling scrap auto and truck tires ([U.S. EPA, 2019c](#)). It consists of particles and particle size is mostly ≤ 63 to $\geq 4,750$ μm and a small fraction of the particles are smaller: > 63 to 125 μm (0.035 wt. %) and ≤ 63 μm (0.0037 wt. %) ([U.S. EPA, 2019d](#)). Tire crumb rubber is used as infill in synthetic turf sports fields ([U.S. EPA, 2019c](#)). DIBP concentration in tire crumb rubber is 0.00005 wt. percent ([U.S. EPA, 2019d](#)). There are two processes for recycling tires to produce tire crumb rubber: an ambient process and a cryogenic process ([U.S. EPA, 2019c](#)). These processes involve mechanical size reduction of tires and separation of non-rubber components, and therefore are similar to the plastic recycling process described above.

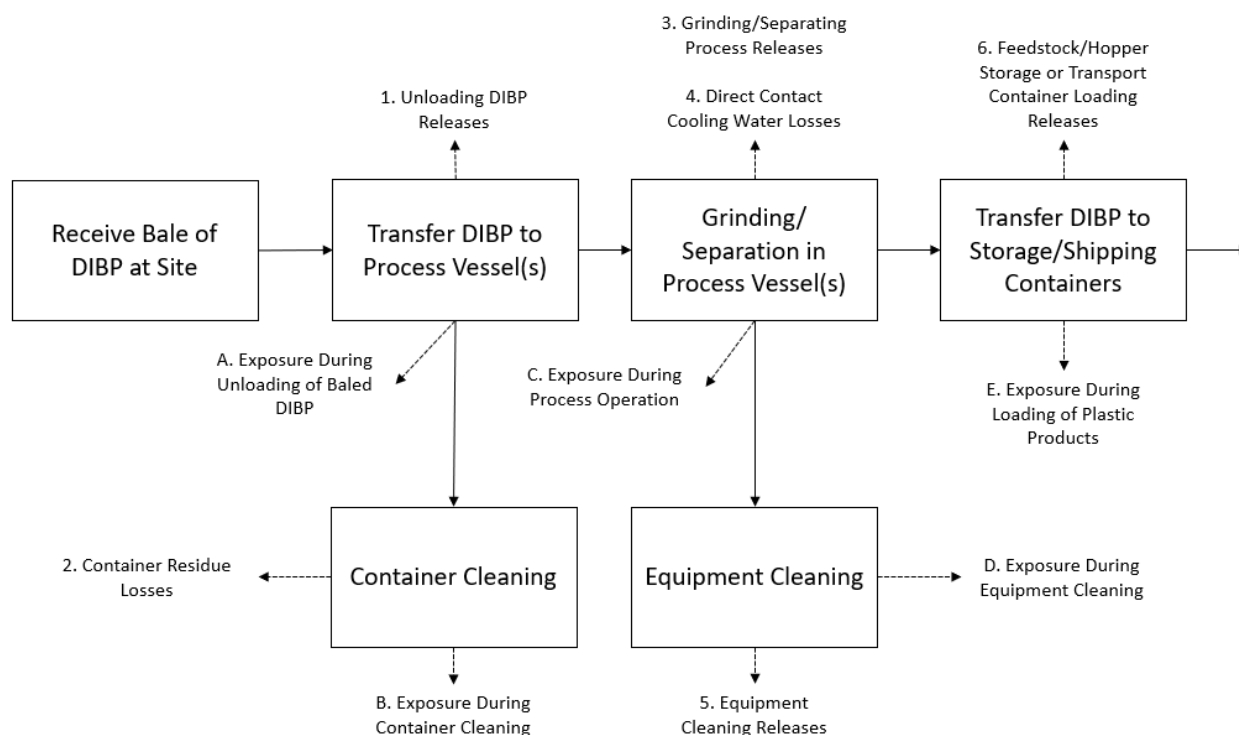


Figure 3-12. DIBP-containing Plastic Recycling Flow Diagram

3.12.2 Facility Estimates

ENF Recycling estimated that there are a total of 228 plastic recyclers operating in the United States, 59 of which accept plastic wastes for recycling, which make up the vast majority of DIBP-containing plastic recycled ([ENF Plastic, 2024](#)). It is unclear if the total number of sites includes some or all circular recycling sites – facilities where new plastics 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 GS on the Use of Additives in Plastics Compounding, which would incorporate all plastic material streams whether from recycled or virgin production ([U.S. EPA, 2021d](#)).

EPA estimated the total production volume for all recycling sites using a constant value of 5,543 kg/year based on 2020 CDR reporting data ([U.S. EPA, 2020a](#)) and industry data from Milbrandt (2022). The Milbrandt article indicates that three percent of plastic products produced during the plastic compounding and converting OESs will be recycled. Based on this, EPA assessed the PV for recycling as three percent of the plastic compounding and converting production volume. The facility annual

throughput of DIBP is 94 kg/site-year based on dividing the total production volume assessed by the number of sites.

With regard to tire crumb rubber, there are nine producers who produce 95 percent of the tire crumb rubber that is used as infill in synthetic turf fields ([U.S. EPA, 2019c](#)). Approximately 975,000 tons of scrap tires were recycled in 2013 and 33 and 17 percent of this volume was recycled for use in playground mulch and sport surfaces, respectively ([U.S. EPA, 2019c](#)). EPA multiplied this volume of recycled tires with the sum of the two fractions that are related to use of scrap tires in playgrounds and sports surfaces (33% and 17%) and the concentration of DIBP in tire crumb rubber and then divided by nine sites to calculate an estimate of DIBP throughput in each of the nine DIBP tire crumb rubber production sites on average that is equal to 27 kg/site-year. Therefore, the estimate of throughput of DIBP in a recycling facility of 94 kg/site-year is inclusive of tire crumb rubber production because this estimate exceeds 27 kg/site-year and is therefore a conservative estimate.

EPA did not identify DIBP-specific recycling operating days information, so the operating days parameter was evaluated in a range from 148 to 264 days/year based on the GS on the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)). EPA expects plastic product waste to be received in bales ranging in size from 240 to 453 kg based on information from the Association of Plastics Recyclers ([APR, 2023](#)). EPA expects the DIBP concentration in this plastic product waste to be the same as the plastic product concentration range from the plastic compounding and converting OES (see Section 3.10 and Section 3.11).

3.12.3 Release Assessment

3.12.3.1 Environmental Release Points

EPA assigned release points based on the GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)). EPA assigned default models to quantify releases from each release point and suspected fugitive air release. EPA expects fugitive air, wastewater, incineration, or landfill releases of dusts from unloading and loading, and general recycling processing. If a site uses air capture technology, EPA expects dust releases from loading to be controlled and released to disposal facilities for incineration or landfill. The site would release the remaining uncontrolled dust to stack air. If the site does not use air control technology, EPA expects plastic unloading releases to be entirely to fugitive air, wastewater, incineration, or landfill. EPA expects wastewater, incineration, or landfill releases from container residue losses and equipment cleaning. EPA expects wastewater releases from direct contact cooling and storage or loading of recycled plastic. EPA expects stack air releases from storage or loading of recycled plastic. Some of the above-mentioned release sources such as wastewater releases from direct cooling may not exist at tire crumb rubber production sites and therefore the release assessment is conservative in the case of this specific operation.

3.12.3.2 Environmental Release Assessment Results

Table 3-52 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for recycling. See Section D.11 for additional details on model equations and parameters. The values of the parameters of concentration of DIBP and number of sites are unrelated to the operation of tire crumb rubber production; these are conservative values with regard to this operation and therefore releases were assessed conservatively with regard to this operation. The *Recycling OES Environmental Release Modeling Results for DIBP* contains additional information about model equations and parameters and includes calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-52. Summary of Modeled Environmental Releases for Recycling

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	Central Tendency
5,543 kg production volume	Stack air	0.28	1.2	218	214	1.3E-03	5.5E-03
	Fugitive air, wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface water, incineration, or landfill ^a	2.2	5.3	218	213	1.0E-02	2.5E-02
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface water, incineration, or landfill ^a	1.9	2.0	138	106	1.4E-02	1.9E-02
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment) ^a	0.94	0.94	223	171	4.2E-03	5.5E-03
^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 available to estimate the partitioning between media. ^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th 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

At plastic recycling sites, worker exposures from dermal contact with solids and inhalation of dusts may occur during the unloading of bailed plastics, loading of processed DIBP-containing plastic onto compounding or converting lines or into transport containers, processing of recycled plastics, and equipment cleaning ([U.S. EPA, 2004a](#)). Additionally, workers may be exposed to DIBP via inhalation of vapors during the plastic converting process ([U.S. EPA, 2021e](#)). EPA did not identify information on worker activities for recycling other plastic types but expects that worker activities would be similar to plastic recycling. With regard to tire crumb rubber production, EPA infers from the process description

that workers are potentially exposed to dust that contains DIBP. Additionally, EPA did not identify information on engineering controls or worker PPE used at recycling sites.

ONUs include supervisors, managers, and other employees that work in the processing area but do not directly handle DIBP-containing plastic or the recycled compounded product. ONUs exposures to DIBP may be through the inhalation of dusts or dermal contact with dusts that settle on surfaces in the recycling area.

3.12.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for exposures to DIBP within recycling processes during systematic review of literature sources. As described in the previous section, EPA expects workers may be exposed via the inhalation of both vapors and particulates for this OES. EPA assessed these two forms of exposure as described below.

For exposure to vapors, EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in Section D.14. Therefore, EPA chose the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for the assessment of vapor inhalation exposures of all relevant OESs.

For exposure to particulates, EPA estimated worker inhalation exposures using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 56 (Administrative and Support and Waste Management and Remediation Services) to estimate plastic particulate concentrations in the air in the case of all facilities other than tire crumb rubber production facilities, and used a subset of the data in the model that came from facilities with NAICS codes starting with 326 (Plastics and Rubber manufacturing) in the case of tire crumb rubber production facilities. EPA used the highest expected concentration of DIBP in recyclable rubber products to estimate the concentration of DIBP present in particulates in the case of all facilities other than tire crumb rubber production facilities. For this OES, 20 percent by mass was the maximum expected DIBP concentration based on the ESD on Additives in Rubber Industry ([OECD, 2004](#)). In the case of tire crumb rubber production facilities, EPA used the concentration of DIBP in tire crumb rubber. As shown in Table 3-53, the calculated DIBP 8-hour TWA concentrations in the case of tire crumb rubber production facilities are much lower than the calculated concentrations in the case of the other facilities of the OES, and therefore the exposures calculated for other facilities are considered protective of worker exposure in the case of tire crumb rubber production sites. The estimated exposures assume that DIBP is present in particulates of the rubber material at this fixed concentration throughout the working shift.

EPA aggregated estimates from the surrogate modeled vapor exposure data and the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)) to address these two physical forms of DIBP for the full 8-hour work shift. EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker

activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-53 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during recycling. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU 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 number of 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. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* and the *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-53. Summary of Estimated Worker Inhalation Exposures for Recycling

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	5.2E-02	0.72
	Acute Dose (AD) (mg/kg/day)	6.5E-03	9.0E-02
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	4.8E-03	6.6E-02
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	4.0E-03	6.1E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	5.2E-02	0.72
	Acute Dose (AD) (mg/kg/day)	7.2E-03	9.9E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	5.3E-03	7.3E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	4.4E-03	6.8E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	5.2E-02	
	Acute Dose (AD) (mg/kg/day)	6.5E-03	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.8E-03	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	4.0E-03	4.5E-03
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. EPA estimated worker inhalation exposures to particulates using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP 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 (*i.e.*, recycling) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-54 are explained in Appendix A. Workers may be exposed to a solid material containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been

contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for recycling.

Table 3-54 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-54. Summary of Estimated Worker Dermal Exposures for Recycling

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	0.73	1.5
	Acute (AD, mg/kg-day)	9.1E-03	1.8E-02
	Intermediate (IADD, mg/kg-day)	6.7E-03	1.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.6E-03	1.2E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.61	1.2
	Acute (AD, mg/kg-day)	8.4E-03	1.7E-02
	Intermediate (IADD, mg/kg-day)	6.1E-03	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.1E-03	1.1E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.8E-03	3.1E-03

^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (*i.e.*, 1070 cm² for male workers and 890 cm² for female workers) ([U.S. EPA, 2011](#)). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (*i.e.*, 268 cm²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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](#)). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 223 days out of 365 days.

3.12.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-55. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-55. Summary of Estimated Worker Aggregate Exposures for Recycling

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.6E-02	0.11
	Intermediate (IADD, mg/kg-day)	1.1E-02	7.9E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	9.5E-03	7.4E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.6E-02	0.12
	Intermediate (IADD, mg/kg-day)	1.1E-02	8.5E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	9.5E-03	7.9E-02
ONU	Acute (AD, mg/kg-day)	1.1E-02	
	Intermediate (IADD, mg/kg-day)	8.1E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.7E-03	7.6E-03
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.13 Waste Handling, Treatment, and Disposal

3.13.1 Process Description

Each of the COUs of DIBP 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:** DIBP may be contained in wastewater discharged to POTW or other, non-public treatment works for treatment. Industrial wastewater containing DIBP 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 DIBP is included in each of the COU assessments in Section 3.1 through Section 3.14.
- **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. DIBP 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 DIBP 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 plastic materials. The assessment of solid waste discharges of DIBP is included in each of the COU assessments in Sections 3.1 through 3.14.

Off-site transfers of DIBP and DIBP-containing substances to land disposal, wastewater treatment, incineration, and recycling facilities are expected based on published EPA and OECD emission documentation such as GSs and ESDs. 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 3-13 ([U.S. EPA, 2017](#)).

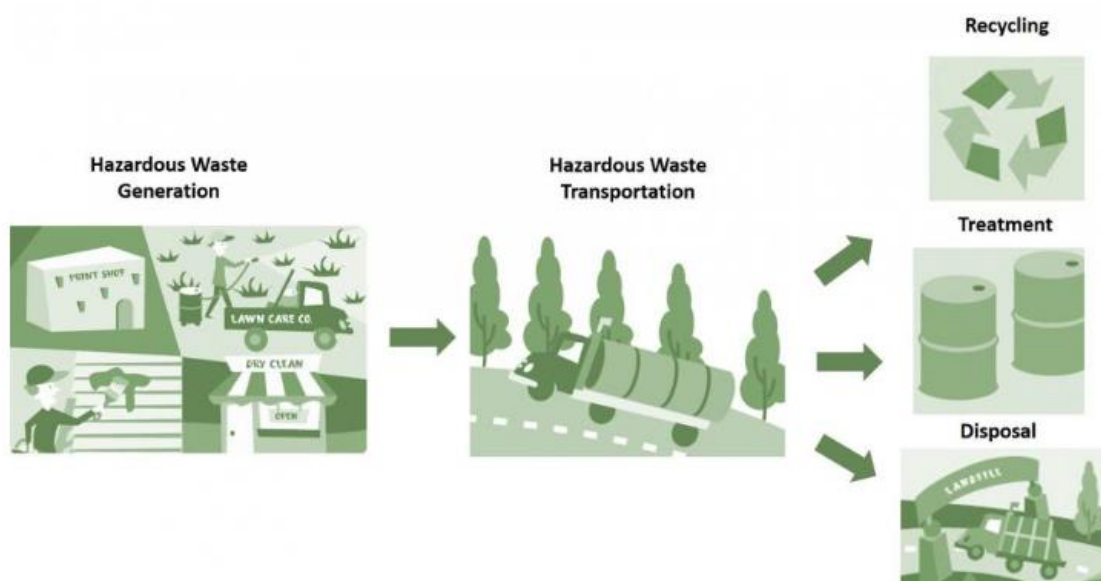


Figure 3-13. Typical Waste Disposal Process

Source: ([U.S. EPA, 2017](#))

Municipal Waste Incineration

Municipal waste combustors (MWCs) that recover energy are generally located at large facilities comprising 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, in order 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](#)).

Hazardous Waste Incineration

Commercial scale hazardous waste incinerators are generally two-chamber units, a rotary kiln followed by an afterburner, that accepts both solid and liquid waste. Liquid wastes are pumped through pipes and

are fed to the unit through nozzles that atomize the liquid for optimal combustion. Solids may be fed to the kiln as loose solids gravity fed to a hopper, or in drums or containers using a conveyor^{2,3}.

Incoming hazardous waste is usually received by truck or rail, and an inspection is required for all waste received. Receiving areas for liquid waste generally consist of a docking area, pumphouse, and some kind of storage facilities. For solids, conveyor devices are typically used to transport incoming waste.

Smaller scale units that burn municipal solid waste or hazardous waste (such as infectious and hazardous waste incinerators at hospitals) may require more direct handling of the materials by facility personnel. Units that are batch-loaded require the waste to be placed on the grate prior to operation and may involve manually dumping waste from a container or shoveling waste from a container onto the grate.

See Table 3-14 for a typical incineration process.

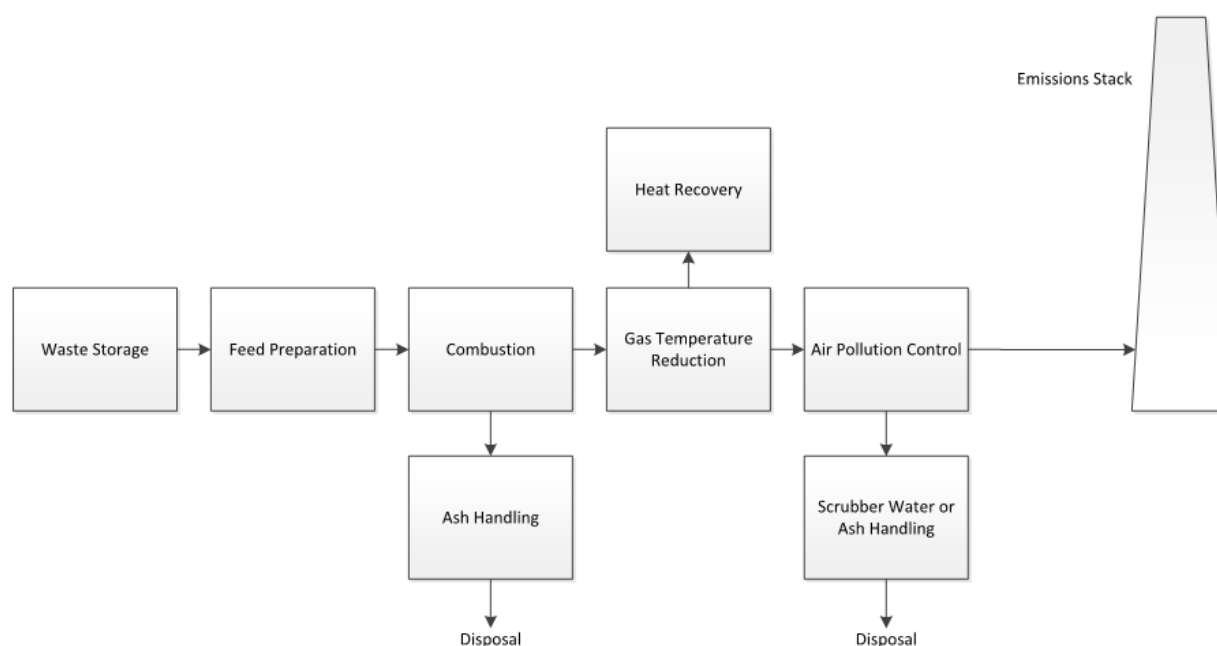


Figure 3-14. Typical Industrial Incineration Process

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 system, operating practices, groundwater monitoring requirements, closure-and post-closure care requirements, corrective action provisions, and financial assurance. Non-hazardous solid wastes are regulated under RCRA Subtitle D, but state may impose more stringent requirements.

² Environmental Technology Council's Hazardous Waste Resource Center; <http://www.etc.org/advanced-technologies/high-temperature-incineration.aspx>

³ Incineration Services; Heritage; <https://www.heritage-enviro.com/services/incineration/>

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 system, run on, runoff and wind dispersal controls, and construction quality assurance program.⁴ 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 Part 264/265, Subpart N.

3.13.2 Facility Estimates

The concentration of DIBP in these products varies depending on the type of product and the necessary 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 DIBP-containing wastes occur at all levels of the DIBP lifecycle. EPA expects disposal routes to include POTW and non-POTWs; 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. 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 DIBP. 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.

3.13.3 Release Assessment

3.13.3.1 Environmental Release Points

EPA did not quantitatively assess environmental releases for this OES due to the lack of readily available process-specific and DIBP-specific data; however, EPA expects releases from this OES to be small and disperse in comparison to other upstream OES, as EPA expects DIBP to be present in smaller amounts and predominantly remain in the disposed article, solution, or material, limiting the potential for release. Releases to all media are possible and all releases are non-quantifiable due to a lack of identified process- and product- specific data.

3.13.4 Occupational Exposure Assessment

3.13.4.1 Worker Activities

At waste disposal sites, workers are potentially exposed via dermal contact with waste containing DIBP or via inhalation of DIBP vapor or dust. Depending on the concentration of DIBP 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

⁴ <https://www.epa.gov/hwpermitting/hazardous-waste-management-facilities-and-units>

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.

3.13.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for exposures to DIBP during waste handling, treatment, and disposal during systematic review of literature sources. As described in the previous section, EPA expects workers may be exposed by the inhalation of both vapors and particulates for this OES. EPA assessed these two forms of exposure as described below.

For exposure to vapors, EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in Section D.14. Therefore, EPA chose the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for the assessment of vapor inhalation exposures of all relevant OESs.

For exposure to particulates, EPA estimated worker inhalation exposures using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 56 (Administrative and Support and Waste Management and Remediation Services) to estimate rubber particulate concentrations in the air. EPA used the highest expected concentration of DIBP in plastic products to estimate the concentration of DIBP present in particulates. For this OES, EPA selected 20 percent by mass as the maximum expected DIBP concentration based on the ESD on Additives in Rubber Industry ([OECD, 2004](#)). The estimated exposures assume that DIBP is present in particulates at this fixed concentration throughout the working shift.

EPA aggregated estimates from the surrogate modeled vapor exposure data and the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)) to address these two physical forms of DIBP for the full 8-hour work shift. EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure

concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-56 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during disposal. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU 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 number of 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. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* and the *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about model equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-56. Summary of Estimated Worker Inhalation Exposures for Disposal

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	5.2E-02	0.72
	Acute Dose (AD) (mg/kg/day)	6.5E-03	9.0E-02
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	4.8E-03	6.6E-02
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	4.0E-03	6.1E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	5.2E-02	0.72
	Acute Dose (AD) (mg/kg/day)	7.2E-03	9.9E-02
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	5.3E-03	7.3E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	4.4E-03	6.8E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	5.2E-02	
	Acute Dose (AD) (mg/kg/day)	6.5E-03	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.8E-03	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	4.0E-03	4.5E-03

^aEPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. EPA estimated worker inhalation exposures to particulates using the *Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)* ([U.S. EPA, 2021c](#)). For the PNOR Model, EPA multiplied the concentration of DIBP 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.

3.13.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, waste handling, treatment, and disposal) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-57 are explained in Appendix A. Workers may be exposed to a solid material containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may

be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for waste handling, treatment, and disposal.

Table 3-57 summarizes the APDR, the AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-57. Summary of Estimated Worker Dermal Exposures for Disposal

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	0.73	1.5
	Acute (AD, mg/kg-day)	9.1E-03	1.8E-02
	Intermediate (IADD, mg/kg-day)	6.7E-03	1.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.6E-03	1.2E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.61	1.2
	Acute (AD, mg/kg-day)	8.4E-03	1.7E-02
	Intermediate (IADD, mg/kg-day)	6.1E-03	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.1E-03	1.1E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.8E-03	3.1E-03

^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (*i.e.*, 1070 cm² for male workers and 890 cm² for female workers) ([U.S. EPA, 2011](#)). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (*i.e.*, 268 cm²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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](#)). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 223 days out of 365 days.

3.13.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in Table 3-58. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-58. Summary of Estimated Worker Aggregate Exposures for Disposal

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.6E-02	0.11
	Intermediate (IADD, mg/kg-day)	1.1E-02	7.9E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	9.5E-03	7.4E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.6E-02	0.12
	Intermediate (IADD, mg/kg-day)	1.1E-02	8.5E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	9.5E-03	7.9E-02
ONU	Acute (AD, mg/kg-day)	1.1E-02	
	Intermediate (IADD, mg/kg-day)	8.1E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.7E-03	7.6E-03
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.14 Rubber Manufacturing

3.14.1 Process Description

The 2020 *Scope of the Risk Evaluation for DIBP* ([U.S. EPA, 2020c](#)) indicates the use of DIBP in rubbers; however, EPA did not identify specific rubber products that contain DIBP from the data sources that underwent systematic review. Also, Lanxess submitted information indicating the manufacture of polyurethane foam pipeline pigs with a final product concentration of 1 – 5 percent ([LANXESS, 2021](#)). The process for manufacturing polyurethane foam pipeline pigs is consistent with the process flow of rubber manufacturing described below.

EPA expects that a typical rubber compounding site receives DIBP at concentrations ranging from 90 to 100 percent in drums ranging from 20 to 100 gallons ([U.S. EPA, 2021d, 2020a](#)). Typical compounding sites receive and unload DIBP and transfer it into mixing vessels to produce a compounded masterbatch. Following completion of the masterbatch, sites transfer the solid resin to a shaping unit operation such as an extruder or injection molding unit to achieve the final product shape. The converting site may trim excess material from the final product after it cools ([U.S. EPA, 2021d](#)). EPA assumed that rubber manufacturing sites consolidate the compounding and converting operation as described in the SpERC Fact Sheet on Rubber Production and Processing ([ESIG, 2020](#)). Figure 3-15 provides an illustration of the rubber production process based on the above information ([ESIG, 2020b](#); [OECD, 2004](#)).

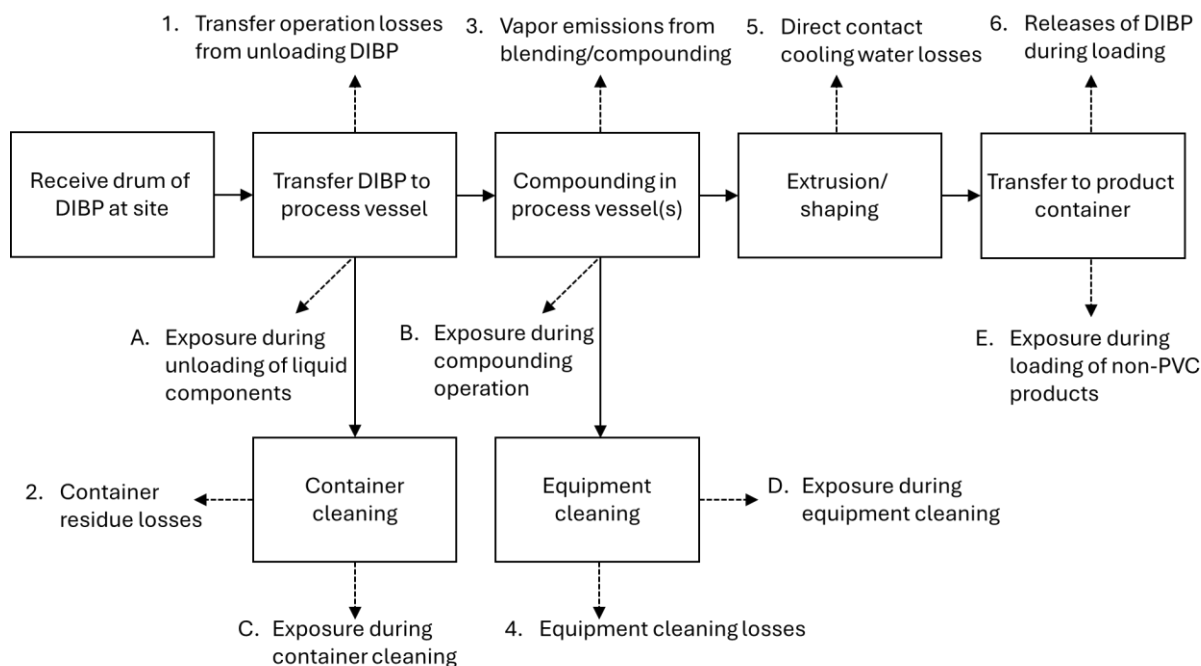


Figure 3-15. Rubber Manufacturing Flow Diagram

3.14.2 Facility Estimates

EPA estimated the total production volume for all sites using a combination of reported national production volume of DIBP from the 2020 CDR ([U.S. EPA, 2020a](#)) and industry data from the Annex XV Restriction Report ([ECHA, 2011](#)). The national PV from CDR is 407,303 lbs/year, and the percentage of PV from the Annex report assigned to each COU under the rubber manufacturing OES is two percent. Based on these values, the EPA assessed the total PV for the rubber manufacturing OES as 7,388 kg/year. Since there are two sites associated with the rubber manufacturing OES (see Section D.12.4), the facility annual throughput of DIBP is 3,694 kg/site-year.

For rubber compounding, EPA assessed operating days as a range from 148 to 264 days/year, based on the GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)). For rubber converting, EPA assessed operating days in a range from 137 to 254 days/year based on the GS on the Use of Additives in Plastics Converting ([U.S. EPA, 2021e](#)). EPA expects that rubber manufacturing sites will receive rubber additives in drums with DIBP mass fractions ranging from 0.90 to 1.0 based on the 2020 CDR reported concentration range ([U.S. EPA, 2020a](#)). EPA did not identify any other site- or chemical-specific facility operating data.

3.14.3 Release Assessment

3.14.3.1 Environmental Release Points

For rubber compounding, EPA assigned release points based on the 2021 GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)). EPA assigned a default model to quantify releases for each release point and suspected fugitive air release point. EPA expects fugitive or stack air releases from unloading rubber additives and process operations. EPA expects releases to wastewater, incineration, or landfill from container residues and equipment cleaning wastes. EPA expects releases to wastewater from direct contact cooling. EPA expects dust release during loading of the compounded material. If a

site uses air capture technology, EPA expects dust releases from product loading to be controlled and released to disposal facilities for incineration or landfill. EPA expects that the remaining uncontrolled dust is released to stack air. If the site does not use air control technology, EPA expects dust releases to fugitive air, wastewater, incineration, or landfill.

For rubber converting, EPA assigned release points based on the GS for the Use of Additives in Plastic Converting ([U.S. EPA, 2021e](#)). EPA assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects vapor emissions to fugitive or stack air from the converting process and particulate emissions to fugitive air, wastewater, incineration, or landfill from unloading the compounded material and converting operations. If a site uses air capture technology, EPA expects dust releases from rubber unloading to be controlled and released to disposal facilities for incineration or landfill. EPA expects that the remaining uncontrolled dust is released to stack air. If the site does not use air control technology, EPA expects dust releases to fugitive air, wastewater, incineration, or landfill. EPA expects releases to wastewater, incineration, or landfill from container residues and equipment cleaning. EPA expects releases to wastewater from direct contact cooling and incineration and landfill releases from solid waste trimming.

3.14.3.2 Environmental Release Assessment Results

Table 3-59 and Table 3-60 summarize the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for rubber compounding and converting. See Section D.12 for additional details on model equations and parameters. The *Rubber Manufacturing OES Environmental Release Modeling Results for DIBP* also contains additional information about model equations and parameters and includes calculation results; refer to Appendix F for a reference to this supplemental document.

Table 3-59. Summary of Modeled Environmental Releases for Rubber Manufacturing – Compounding

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,694 kg production volume	Fugitive or stack air ^a	7.4E-02	7.4E-02	175	234	3.2E-04	4.2E-04
	Fugitive air, wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface water, incineration, or landfill ^a	28	86	223	230	0.12	0.39
	Stack Air	11	46	224	229	4.8E-02	0.21
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment),	80	86	94	123	0.65	0.92

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	direct to surface water, incineration, or landfill ^a						
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment), or direct to surface water ^a	37	37	175	234	0.16	0.21
	Incineration or landfill ^a	7.5	35	224	229	3.3E-02	0.16
^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 available to estimate the partitioning between media. ^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end releases, respectively.							

Table 3-60. Summary of Modeled Environmental Releases for Rubber Manufacturing – Converting

Modeling Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,694 kg production volume	Fugitive or stack air ^a	7.4E-02	0.37	137	172	5.4E-04	2.1E-03
	Fugitive air, wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface water, incineration, or landfill ^a	28	86	209	214	0.13	0.41
	Stack Air	11	46	210	213	5.2E-02	0.22
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment), direct to surface	111	723	202	210	0.53	3.6

Modeling Scenario	Environmental Media	Annual Release (kg/site-yr) ^b		Number of Release Days		Daily Release (kg/site-day) ^b	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	water, incineration, or landfill ^a						
	Wastewater to onsite treatment, discharge to POTW (with or without pretreatment), or direct to surface water ^a	37	37	162	218	0.17	0.23
	Incineration or landfill ^a	100	128	192	212	0.47	0.67
^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 available to estimate the partitioning between media. ^b The Monte Carlo simulation calculated the total DIBP release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end releases, respectively.							

3.14.4 Occupational Exposure Assessment

3.14.4.1 Worker Activities

Worker exposures during the rubber manufacturing process may occur via inhalation of DIBP-containing dusts or dermal contact with solids during product loading, equipment cleaning, rubber converting, or trimming of excess rubbers from the product. Dermal exposures to liquids may occur during equipment cleaning. Worker exposures may also occur via dermal contact with liquids and inhalation of vapors during DIBP unloading and loading, equipment cleaning, and transport container cleaning ([U.S. EPA, 2021d](#)). EPA did not identify information on engineering controls or worker PPE used at rubber compounding and converting sites.

ONUs include supervisors, managers, and other employees that work in the formulation area but do not directly contact DIBP received or processed onsite or handle compounded product. ONU exposures to DIBP may be through the inhalation of dusts or dermal contact with dusts that settle on surfaces while present in the workplace.

3.14.4.2 Occupational Inhalation Exposure Results

EPA did not identify any inhalation monitoring data for exposures to DIBP-containing rubber articles during systematic review of literature sources. EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES to be equal to the corresponding values of the OES of DIBP manufacturing. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES as discussed in Section D.14. Therefore, EPA chose the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES as surrogate data for the assessment of vapor inhalation exposures of all relevant OESs.

For exposure to particulates, EPA estimated worker inhalation exposures using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)). The model uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. Exposures during individual worker activities are not determined using this model. Model approaches and parameters are described in Section D.15. EPA used a subset of the data in the model that came from facilities with NAICS codes starting with 325 (Chemical Manufacturing) and 326 (Plastics and Rubber Manufacturing) to estimate rubber material particulate concentrations in the air. EPA used the highest expected concentration of DIBP in rubber products to estimate the concentration of DIBP present in the particulates of plastic material. For this OES, EPA selected 20 percent by mass as the maximum expected DIBP concentration based on the ESD on Additives in Rubber Industry ([OECD, 2004](#)). The estimated exposures assume that DIBP is present in particulates of the rubber material at this fixed concentration throughout the working shift.

EPA aggregated estimates from the surrogate modeled vapor exposure data and the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) ([U.S. EPA, 2021c](#)) to address these two physical forms of DIBP for the full 8-hour work shift. EPA assumed all worker activities are done by the same worker during a single shift. Therefore, EPA calculated the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES by summing the time-weighted exposure contribution from each worker activity per Section D.14. EPA then aggregated the vapor and particulate 8-hour TWA exposure estimates per the sample calculations in Appendix B. Table 3-61 and Table 3-62 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DIBP during rubber manufacturing. Appendix A describes the approach for estimating AD, IADD, and ADD. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. The *Manufacturing OES Occupational Inhalation Exposure Modeling Results for DIBP* and the *Occupational Particulate Inhalation Exposure Modeling Results for DIBP* also contains information about models equations and parameters and contains calculation results; refer to Appendix F for a reference to this supplemental document.

For rubber compounding, 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.

For rubber converting, 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.

Table 3-61. Summary of Estimated Worker Inhalation Exposures for Rubber Compounding

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	0.10	1.0
	Acute Dose (AD) (mg/kg/day)	1.3E-02	0.13
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	9.2E-03	9.3E-02
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	8.0E-03	8.7E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	0.10	1.0
	Acute Dose (AD) (mg/kg/day)	1.4E-02	0.14

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	1.0E-02	0.10
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	8.9E-03	9.6E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	0.10	
	Acute Dose (AD) (mg/kg/day)	1.3E-02	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	9.2E-03	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	8.0E-03	8.6E-03
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. EPA estimated worker inhalation exposures to particulates using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP 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.			

Table 3-62. Summary of Estimated Worker Inhalation Exposures for Rubber Converting

Modeled Scenario	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.96
	Acute Dose (AD) (mg/kg/day)	6.3E-03	0.12
	Intermediate Non-Cancer Dose (IADD) (mg/m ³)	4.6E-03	8.8E-02
	Chronic Average Daily Dose, Non-Cancer (ADD) (mg/kg/day)	3.8E-03	8.2E-02
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	0.96
	Acute Dose (AD) (mg/kg/day)	6.9E-03	0.13
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	5.1E-03	9.7E-02
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	4.1E-03	9.1E-02
ONU	8-hour TWA Exposure Concentration (mg/m ³)	5.0E-02	
	Acute Dose (AD) (mg/kg/day)	6.3E-03	
	Intermediate Non-Cancer Exposures (IADD) (mg/m ³)	4.6E-03	
	Chronic Average Daily Dose, Non-Cancer Exposures (ADD) (mg/kg/day)	3.8E-03	4.3E-03
^a EPA assessed the central tendency and high-end 8-hour TWA vapor inhalation exposure concentrations of this OES be equal to the corresponding values of the OES of DIBP manufacturing. The Monte Carlo simulation calculated the total DIBP exposure across all exposure points during each iteration of the simulation. EPA then selected 50th and 95th percentile values to estimate the central tendency and high-end exposures, respectively. EPA estimated worker inhalation exposures to particulates using the <i>Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR)</i> (U.S. EPA, 2021c). For the PNOR Model, EPA multiplied the concentration of DIBP with the central tendency and HE estimates of the relevant NAICS code from the PNOR Model to calculate the central tendency and HE estimates for this OES.			

3.14.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES (*i.e.*, rubber compounding) using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-63 are explained in Appendix A. Workers may be exposed to a concentrated liquid material during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for rubber compounding.

Table 3-63 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-63. Summary of Estimated Worker Dermal Exposures for Rubber Compounding

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5	5.1
	Acute (AD, mg/kg-day)	3.2E-02	6.3E-02
	Intermediate (IADD, mg/kg-day)	2.3E-02	4.6E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.0E-02	4.3E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.1	4.2
	Acute (AD, mg/kg-day)	2.9E-02	5.8E-02
	Intermediate (IADD, mg/kg-day)	2.1E-02	4.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.9E-02	4.0E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.9E-03	3.1E-03
^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (<i>i.e.</i> , 1070 cm ² for male workers and 890 cm ² for female workers) (U.S. EPA, 2011). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (<i>i.e.</i> , 268 cm ²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 234 days out of 365 days.			

EPA estimated dermal exposures for rubber converting using the methodology outlined in Appendix C, and the various “Exposure Concentration Types” from Table 3-64 are explained in Appendix A. Workers may be exposed to a solid material containing DIBP during tasks associated with this OES. Also, dermal exposures to ONUs were assessed for scenarios where there may be dust or mist generation since it is possible that an ONU may inadvertently contact a surface that has been contaminated by dust or mist containing DIBP. Because there is dust expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed for rubber converting.

Table 3-64 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age.

Table 3-64. Summary of Estimated Worker Dermal Exposures for Rubber Converting

Worker Population	Exposure Concentration Type	Central Tendency ^a	High-End ^a
Average Adult Worker	Dose Rate (APDR, mg/day)	0.73	1.5
	Acute (AD, mg/kg-day)	9.1E-03	1.8E-02
	Intermediate (IADD, mg/kg-day)	6.7E-03	1.3E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.5E-03	1.2E-02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	0.61	1.2
	Acute (AD, mg/kg-day)	8.4E-03	1.7E-02
	Intermediate (IADD, mg/kg-day)	6.1E-03	1.2E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	5.0E-03	1.1E-02
ONU	Dose Rate (APDR, mg/day)	0.36	
	Acute (AD, mg/kg-day)	4.5E-03	
	Intermediate (IADD, mg/kg-day)	3.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.7E-03	3.1E-03

^a For high-end estimates of workers, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface area (*i.e.*, 1070 cm² for male workers and 890 cm² for female workers) ([U.S. EPA, 2011](#)). For central tendency estimates of workers, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two 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). For dermal exposure estimates of ONUs, EPA assumed the exposure surface area was equivalent to the mean value for one palm of an adult male (*i.e.*, 268 cm²). An absorption duration of 8 hours was used for estimating all occupational dermal exposures. 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](#)). For both high-end and central tendency estimates, averaging time for intermediate dermal exposures was assumed as 22 days out of 30 days. For high-end estimates, averaging time for chronic non-cancer dermal exposures was assumed as 250 days out of 365 days. For central tendency estimates, averaging time for chronic non-cancer dermal exposures was assumed as 219 days out of 365 days.

3.14.4.4 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Section A.3 to arrive at the aggregate worker and ONU exposure estimates in the table below. The *Occupational Risk Calculator for DIBP* ([U.S. EPA, 2025b](#)) contains the calculations of aggregate exposure; refer to Appendix F for a reference to this supplemental document.

Table 3-65. Summary of Estimated Worker Aggregate Exposures for Rubber Compounding

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	4.4E-02	0.19
	Intermediate (IADD, mg/kg-day)	3.2E-02	0.14
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.8E-02	0.13
Female of Reproductive Age	Acute (AD, mg/kg-day)	4.3E-02	0.20
	Intermediate (IADD, mg/kg-day)	3.1E-02	0.15
	Chronic, Non-Cancer (ADD, mg/kg-day)	2.7E-02	0.14
ONU	Acute (AD, mg/kg-day)	1.7E-02	
	Intermediate (IADD, mg/kg-day)	1.3E-02	

Worker Population	Exposure Concentration Type	Central Tendency	High-End
	Chronic, Non-Cancer (ADD, mg/kg-day)	1.1E-02	1.2E-02
Note: A worker or ONU 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 Rubber Converting

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.2E-02	6.4E-02
	Intermediate (IADD, mg/kg-day)	8.6E-03	4.7E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	7.0E-03	4.4E-02
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.1E-02	6.8E-02
	Intermediate (IADD, mg/kg-day)	8.3E-03	5.0E-02
	Chronic, Non-Cancer (ADD, mg/kg-day)	6.8E-03	4.6E-02
ONU	Acute (AD, mg/kg-day)	7.2E-03	
	Intermediate (IADD, mg/kg-day)	5.3E-03	
	Chronic, Non-Cancer (ADD, mg/kg-day)	4.3E-03	4.9E-03
Note: A worker or ONU could be exposed by both the inhalation and dermal routes, and the aggregate exposure is the sum of these exposures.			

3.15 Distribution in Commerce

3.15.1 Process Description

EPA evaluated activities resulting in exposures associated with distribution in commerce throughout the various life cycle stages and COUs (*e.g.*, manufacturing, processing, industrial use, commercial use, disposal) rather than a single distribution scenario. Data were not reasonably available for the Agency to assess risks to the environment from environmental releases and exposures related to distribution of DIBP in commerce as a single OES. However, EPA expects all the DIBP or DIBP-containing products and/or articles to be transported in closed system or otherwise to be transported in a form (*e.g.*, articles containing DIBP) such that there is negligible potential for releases except during an incident (*e.g.*, spill during transportation). Therefore, no separate assessment was performed for estimating releases and exposures from distribution in commerce.

4 Summary of Weight of Scientific Evidence

4.1 Summary of Weight of Scientific Evidence for Environmental Release Estimates

EPA determined the weight of scientific evidence in accordance with the Draft Systematic Review Protocol ([U.S. EPA, 2021b](#)). Judgment on the weight of scientific evidence is based on the strengths, limitations, and uncertainties associated with the estimates of the daily rate of release of DIBP from the generic site and the number of release days. The Agency considers factors that increase or decrease the strength of the evidence supporting these release estimate. Factors that increase or decrease the strength of evidence are given in Table 7-6 of the Draft Systematic Review Protocol ([U.S. EPA, 2021b](#)) and Table 7-7 of this reference provides example judgements based on the information in Table 7-6 of this reference. The best professional judgment about the weight of scientific evidence is summarized using the descriptors of robust, moderate, slight, or indeterminate ([U.S. EPA, 2021b](#)).

Strengths

The strengths of the release estimates in general are as follows: (a) the overall systematic review quality ratings of the references are medium or high, (b) EPA determined sources of releases and the corresponding media of releases or disposal methods at the generic sites of the OESs in accordance with ESDs and GSs that are related to these OESs respectively and that contain well described methodologies, (c) the computational or scientific bases for deriving the estimates of daily rates of release of DIBP from the generic sites of the OESs are robust and all of the data that the Agency used to inform the modeling parameter distributions have overall data quality ratings of either high or medium, (e) daily rates of release of DIBP were calculated via Monte Carlo simulation from model input parameters that in some cases are variable. Parameter variation increases the likelihood that the calculated daily rates of release of DIBP encompass the true daily release rates.

Limitations

The major limitation of the release estimates in general is uncertainty about the estimates of daily DIBP site throughputs, which are the input variables of the models that EPA used to calculate daily release rates. The reasons for this uncertainty are the uncertainties in the values of the parameters from which the daily DIBP site throughputs were calculated. The following is a discussion of these uncertainties:

- CDR information on the downstream processing and use of DIBP at facilities is limited; therefore, the assessed production volume of an OES is uncertain. EPA estimated production volume deterministically (*i.e.*, as a single value) based on reported CDR data, CDR reporting thresholds, the national aggregate production volume of 407,303 lb for DIBP in 2019 and/or literature data. The exception is the OES of use as a catalyst where EPA estimated the production volume as a range of values based on literature data
- EPA estimated the number of release days and the number of sites in the case of most or some OESs, respectively, from the relevant data of GSs, ESDs, or emission release category (SpERC) factsheets but these data may not be pertinent in the case of actual sites at which DIBP is manufactured, processed or used.
- There are uncertainties associated with DIBP-containing product concentrations. In most cases, the number of identified products for a given OES were limited. In such cases, EPA estimated a range of possible concentrations for products in the OES. However, the extent to which these products represent all DIBP-containing products within the OES is uncertain. For OESs with little-to-no reasonably available product data, EPA estimated DIBP concentrations from GSs or

ESDs. Due to these uncertainties, the average product concentrations may be under- or overestimated.

In addition to the major limitation discussed above, other limitations are uncertainties in the values of some of the parameters of the models that EPA used to estimate releases. Table 4-1 contains a summary of the assessment approaches in the case of each OES and the strengths and limitations of the release estimates.

Uncertainties

Given the strengths and limitations discussed above, EPA is uncertain that the assessed daily release rates are representative of actual daily release rates of the corresponding COU. Refer to Table 4-1 for discussions of uncertainties in the case of each OESs. Based on the above information, EPA has slight to moderate confidence in the assessed releases.

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

Table 4-1. Summary of Assumptions and Uncertainty in Release Estimates by OES

OES	Assessment Approach and Uncertainty in Release Estimates
Manufacturing	EPA assessed environmental releases using models and model parameters derived from CDR, the 2023 Methodology for Estimating Environmental Releases from Sampling Wastes, and sources identified through systematic review (including industry-supplied data). EPA used facility-specific reported DIBP manufacturing volumes for all facilities reporting values in CDR.
Repackaging	<p>EPA assessed environmental releases using the assumptions and values from the Chemical Repackaging GS, which the systematic review process rated high for data quality (OECD, 2009b). The Agency also referenced the 2023 Methodology for Estimating Environmental Releases from Sampling Wastes.</p> <p>An uncertainty in the assessment approach is that the default values in the ESD are generic and there is uncertainty in the representativeness of these generic values to actual releases from real-world sites that import and repackage DIBP. In addition, EPA lacks DIBP-specific facility import volume data for the CDR-reporting import and repackaging site; therefore, throughput estimates for these sites are based on the CDR reporting range upper bound of 100,000 lb (45,359 kg). There is uncertainty in the extent to which this estimated volume represents the actual volume of DIBP repackaged, due to CDR reporting thresholds that may result in additional DIBP repackaging sites that are not required to report to CDR. Furthermore, some repackaging sites may not be importers and therefore would not be subject to CDR reporting requirements.</p>
Incorporation into adhesives and sealants	<p>EPA assessed releases to the environment using the ESD on Adhesive Formulation, which also has a high data quality rating from the systematic review process (OECD, 2009a). EPA used DIBP-specific data on concentrations in adhesive and sealant products in the analysis to provide more accurate estimates than the generic values provided by the ESD. The safety and product data sheets from which these values were obtained have high data quality ratings from the systematic review process.</p> <p>Because the default values in the ESD are generic, there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that incorporate DIBP into adhesives and sealants. In addition, EPA lacks DIBP-specific facility production volume data and number of formulation sites; in addition, the Agency lacks DIBP-specific facility use volume data and number of use sites; therefore, EPA based the PV on reported production volume from the 2020 CDR (U.S. EPA, 2020a) and market data from the 2003 Danish EPA Restriction Report on DIBP (ECHA, 2011). The respective share of DIBP use for each OES as presented in the Danish EPA Restriction Report may differ from actual conditions in the United States, adding uncertainty to estimated releases.</p>
Incorporation into paints and coatings	<p>EPA assessed releases to the environment using the GS for Formulation of Waterborne Coatings, which has a medium data quality rating from the systematic review process (U.S. EPA, 2014a). The Agency used DIBP-specific data on concentrations in paint and coating products in the analysis to provide more accurate estimates than the generic values provided by the GS. The safety and product data sheets from which these values were obtained have high data quality ratings from the systematic review process.</p> <p>Because the default values in the GS are generic and specific to waterborne coatings, there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that incorporate DIBP into paints and coatings and how representative the</p>

OES	Assessment Approach and Uncertainty in Release Estimates
	<p>estimates are for sites formulating other coating types (<i>e.g.</i>, solvent-borne coatings). In addition, EPA lacks DIBP-specific facility production volume data and number of formulation sites; therefore, throughput estimates are based on CDR which has a reporting threshold of 25,000 lb (11,340 kg) (<i>i.e.</i>, not all potential sites represented) and market data from the 2003 Danish EPA Restriction Report on DIBP (ECHA, 2011). The respective share of DIBP use for each OES as presented in the Danish EPA Report may differ from actual conditions in the United States, adding uncertainty to estimated releases.</p>
Use as a catalyst	<p>EPA assessed releases to the environment using the ESD on Adhesive Formulation (OECD, 2009a) which has a medium data quality rating from the systematic review process. The Agency used DIBP-specific data on concentrations in different DIBP-containing catalysts in the analysis to provide more accurate estimates than the generic values provided by the ESD. The Zeigler Natta technical report from which these values were obtained have medium data quality ratings from the systematic review process (Company Withheld). EPA based OES PV on reported production volume from the 2020 CDR (U.S. EPA, 2020a) and industry data from the 2019 U.S. polypropylene production volume (Jaganmohan, 2020).</p> <p>Because the default values in the GSs are generic for all types of use sites and the DIBP-specific concentration data was only for Zeigler Natta catalyst, there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that use catalysts containing DIBP. In addition, EPA lacks DIBP-specific facility production volume data and number of polypropylene manufacturing sites; therefore, throughput estimates are based on CDR, which has a reporting threshold of 25,000 lb (11,340 kg) (<i>i.e.</i>, not all potential sites represented) and a magnitude-different low and high range of estimated annual DIBP production.</p>
Application of paints and coatings	<p>EPA assessed releases to the environment using 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), which were all assigned a data quality score of medium in systematic review. Additionally, EPA used DIBP-specific data on concentration and application methods of different DIBP-containing paints and coatings in the analysis to provide more accurate estimates than the generic values provided by the GS and ESDs. The safety and product data sheets from which these values were obtained have high data quality ratings from the systematic review process.</p> <p>Because the default values in the GS and ESDs are generic, there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that use DIBP-containing paints and coatings. EPA assessed releases of spray applications of the coatings, which may not be representative of other coating application methods. In addition, the Agency lacks DIBP-specific facility use volume data and number of use sites; therefore, EPA based OES PV on reported production volume from the 2020 CDR (U.S. EPA, 2020a) and market data from the 2003 Danish EPA Restriction Report on DIBP (ECHA, 2011). The respective share of DIBP used for each OES as presented in the Danish EPA Restriction Report may differ from actual U.S. conditions, adding uncertainty to estimated releases.</p>

OES	Assessment Approach and Uncertainty in Release Estimates
Application of adhesives and sealants	<p>EPA assessed releases to the environment using the ESD on Use of Adhesives, which has a medium data quality rating from the systematic review process (OECD, 2015a). Additionally, the Agency used DIBP-specific data on concentration and application methods of different DIBP-containing adhesives and sealant products in the analysis to provide more accurate estimates than the generic values provided by the ESD. The safety and product data sheets from which these values were obtained have high data quality ratings from the systematic review process.</p> <p>Because the default values in the ESD are generic, there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that use DIBP-containing adhesives and sealants. EPA assessed releases of spray applications of the adhesives and sealants, which may not be representative of other coating application methods such as dip application of casting sealant products or the application of grout products. In addition, the Agency lacks DIBP-specific facility use volume data and number of use sites; therefore, EPA based the PV on reported production volume from the 2020 CDR (U.S. EPA, 2020a) and market data from the 2003 Danish EPA Restriction Report on DIBP (ECHA, 2011). The respective share of DIBP use for each OES as presented in the Danish EPA Restriction Report may differ from actual conditions in the United States, adding uncertainty to estimated releases.</p>
Use of laboratory chemicals	<p>EPA assessed releases to the environment using the GS on Use of Laboratory Chemicals, which has a high data quality rating from the systematic review process (U.S. EPA, 2023d). The Agency assessed media of release using assumptions from the GS and EPA models for solid and liquid DIBP-containing laboratory chemicals. EPA used safety data sheets (SDSs) from identified laboratory DIBP products to inform product concentration and material states. These SDS have high data quality ratings from the systematic review process.</p> <p>The Agency lacks DIBP laboratory chemical throughput data and use information from the GS on the Use of Laboratory Chemicals (U.S. EPA, 2023d). Additionally, because no entries in CDR indicate a laboratory use and there were no other sources to estimate the volume of DIBP used in this OES, EPA developed an estimate based on CDR reporting threshold; however, there is uncertainty as to whether this estimate accurately reflects the true volume of DIBP used in laboratory chemicals.</p>
Plastics compounding	<p>EPA modeled releases to the environment using the 2021 GS for the Use of Additives in Plastic Compounding, which has a medium data quality rating from the systematic review process (U.S. EPA, 2021d). The Agency used DIBP-specific data on concentrations in different DIBP-containing plastic products and additive throughputs in the analysis to provide more accurate estimates than the generic values provided by the GS. The safety and product data sheets from which these values were obtained have high data quality ratings from the systematic review process.</p> <p>Because the default values in the GS are generic for all types of plastic compounding sites, there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that compound DIBP into plastic resin. In addition, EPA lacks DIBP-specific facility production volume data and number of compounding sites; therefore, the Agency based the PV on reported production volume from the 2020 CDR (U.S. EPA, 2020a) and market data from the 2003 Danish EPA Restriction Report on DIBP (ECHA, 2011). The respective share of DIBP use for each OES as presented in the Danish EPA Restriction Report may differ from actual conditions in the United States, adding uncertainty to estimated releases.</p>

OES	Assessment Approach and Uncertainty in Release Estimates
Plastics converting	<p>EPA assessed releases to the environment using the GS for the Use of Additives in Plastic Converting, which has a medium data quality rating from the systematic review process (U.S. EPA, 2021e).</p> <p>Because the default values in the GS are generic for all types of thermoplastics converting sites and processes, there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that convert DIBP-containing plastic masterbatch into plastic articles via a variety of methods such as extrusion or calendaring. In addition, EPA lacks DIBP-specific facility production volume data and number of converting sites; therefore, the Agency based PV on reported production volume from the 2020 CDR (U.S. EPA, 2020a) and market data from the 2003 Danish EPA Restriction Report on DIBP (ECHA, 2011). The respective share of DIBP use for each OES as presented in the Danish EPA Restriction Report may differ from actual conditions in the United States, adding uncertainty to estimated releases.</p>
Recycling	<p>EPA assessed releases to the environment from recycling activities using the 2021 GS for the Use of Additives in Plastic Compounding as surrogate to the recycling process. The GS has a medium data quality rating from the systematic review process (U.S. EPA, 2021d). Additionally, the Agency used DIBP-specific data on concentrations in different DIBP-containing plastic products in the analysis to provide more accurate estimates than the generic values provided by the GS. The safety and product data sheets from which these values were obtained have high data quality ratings from the systematic review process. EPA referenced information from ENF Recycling, which has a medium quality rating from the systematic review process (ENF Plastic, 2024) to estimate the rate of plastic recycling in the United States and applied it to DIBP plastic market share to define an approximate recycling volume of plastic containing DIBP.</p> <p>Because the default values in the GS are generic, there is uncertainty in the representativeness of real-world sites that recycle plastic products containing DIBP. In addition, EPA lacks DIBP-specific plastic recycling rates and facility production volume data; therefore, throughput estimates are based on plastics compounding data and U.S. plastic recycling rates, which are not specific to DIBP.</p>
Waste handling, treatment, and disposal	<p>Releases from this OES are generally considered to be from waste transferred from upstream life cycle stages. The amounts transferred are generally not known; however, estimates from upstream activities identified as to incineration, landfill, or indirect discharges may include either on-site or off-site treatment activities. Therefore, they may include amounts received at dedicated waste treatment/disposal sites.</p>
Rubber manufacturing	<p>EPA assessed releases to the environment using the 2021 GS for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d) and GS for the Use of Additives in Plastic Converting (U.S. EPA, 2021e), both of which have a medium data quality rating from the systematic review process. The Agency used DIBP-specific data on concentrations in different DIBP-containing rubber products in the analysis to provide more accurate estimates than the generic values provided by the GSs. The safety and product data sheets from which these values were obtained have high data quality ratings from the systematic review process. EPA based OES PV on reported production volume from the 2020 CDR (U.S. EPA, 2020a) and market data from the 2003 Danish EPA Restriction Report on DIBP (ECHA, 2011).</p>

OES	Assessment Approach and Uncertainty in Release Estimates
	<p>Because the default values in the GSs are generic for all types of plastic compounding and rubber manufacturing sites and the DIBP-specific concentration data was only for rubber products there is uncertainty in the representativeness of generic site estimates of actual releases from real-world sites that compound DIBP into rubber material. In addition, EPA lacks DIBP-specific facility production volume data and number of compounding sites; therefore, throughput estimates are based on CDR, which has a reporting threshold of 25,000 lb (11,340 kg) (<i>i.e.</i>, not all potential sites represented) and a magnitude-different low and high range of estimated annual DIBP production. The respective share of DIBP use for each OES as presented in the Danish EPA Restriction Report may differ from actual conditions adding some uncertainty to estimated releases.</p>

4.2 Summary of Weight of Scientific Evidence for Occupational Exposures

This section contains summaries of the occupational exposure assessment methodologies of the various OESs in Table 4-2. This section contains discussions of the weight of scientific evidence in the case of the various OESs. EPA determined the weight of scientific evidence in accordance with the Draft Systematic Review Protocol ([U.S. EPA, 2021b](#)). Judgment on the weight of scientific evidence is based on the strengths, limitations, and uncertainties associated with the exposure estimates. The Agency considers factors that increase or decrease the strength of the evidence supporting the exposure estimate. Factors that increase or decrease the strength of evidence are given in Table 7-6 of the Draft Systematic Review Protocol ([U.S. EPA, 2021b](#)) and Table 7-7 of this reference provides example judgements based on the information in Table 7-6 of this reference. The best professional judgment about the weight of scientific evidence is summarized using the descriptors of robust, moderate, slight, or indeterminate ([U.S. EPA, 2021b](#)).

A strength associated with the DIBP occupational exposure estimates in this assessment is that worker body weight, which is an exposure factor of inhalation and dermal exposure, and worker breathing rate, which is an exposure factor of inhalation exposure, were informed by moderate to robust data sources. An uncertainty that is associated with the exposure estimates in general is the assessment of inhalation exposure of ONUs. EPA assumed that worker central tendency exposure values were representative of ONU exposures. In reality, exposures for ONUs can vary substantially and exposure levels will have high variability depending on the specific work activity performed. Another uncertainty that is associated with the DIBP occupational exposure estimates in general is that EPA calculated ADD values assuming that workers and ONUs are regularly exposed during their entire working lifetime, which likely results in an overestimate. For example, individuals may change jobs during the course of their career such that they are no longer exposed to DIBP, and the actual ADD values become lower than the estimates presented.

Table 4-2 provides a summary of EPA's overall confidence in its inhalation and dermal exposure estimates for each OES.

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

OES(s)	Summary of Assessment Methodology and Discussion of Weight of Scientific Evidence Conclusion in Occupational Exposures
Manufacturing	<p><i>Summary of the Assessment Method</i></p> <p>EPA assessed inhalation exposure of workers resulting from DIBP fugitive emissions, which are vapor emissions only, that occur during DIBP manufacturing. EPA determined the sources of these fugitive emissions based on the ESD on the Chemical Industry (OECD, 2011c), and these sources are associated with the following worker activities: product sampling, equipment cleaning and loading of DIBP into transport containers. The Agency calculated the concentration of DIBP vapor that workers are potentially exposed to via inhalation in the case of each of these worker activities in accordance with the EPA Mass Balance Inhalation Model (U.S. EPA, 2015). The DIBP vapor release rate is the input variable of this model, and EPA calculated the rate of release of DIBP vapor from each of the above-mentioned release sources as a probability distribution as part of the assessment of DIBP releases that is discussed Section 3.1.3. EPA also determined the values of two of the model parameters, which are the ventilation rate and the mixing factor, as probability distributions because of uncertainty about the values of these model parameters. The agency incorporated via Monte Carlo simulation all of the above-mentioned probability distributions into the calculation of exposure concentrations and calculated these concentrations as probability distributions. The Agency then assumed all of the three worker activities are done by the same worker during a single 8-hour shift and calculated an 8-hour TWA exposure concentration as a TWA of the three calculated concentrations. This TWA concentration was calculated from the exposure durations of the three worker activities and these exposure durations were equated to the durations of release from each of the release sources which were determined as part of the assessment of DIBP releases that is discussed in Section 3.1.4. This 8-hour TWA concentration was calculated as a probability distribution and EPA assessed the inhalation exposure concentration of the manufacturing OES to be equal to this concentration probability distribution. The Agency assessed both the central tendency and high-end exposure frequencies to be equal to the number of operating days, which EPA estimated as a discrete value of 250 days per year in accordance with EPA’s typical assumption related to the number of operating days of lower-PV specialty chemicals. Section D.2 and Section D.14 of this TSD contains detailed information about the releases and occupational exposure models of the manufacturing OES, respectively.</p> <p><i>Strengths, Limitations, and Uncertainties Associated with the Exposure Estimates</i></p> <p>The strengths of the exposure estimates are as follows: (a) the overall quality rating of the ESD on the Chemical Industry (OECD, 2011c) is medium, (b) with regard to the exposure scenario, the assessed worker activities are frequently occurring activities of chemical industry workers and are pertinent in the case of the OES, (c) the EPA Mass Balance Inhalation Model is well described and the underlying scientific and computational basis of this model is robust, (d) all data that the Agency used to inform the modeling parameter distributions have overall data quality ratings of either high or medium, and (e) exposure concentrations were calculated via Monte Carlo simulation from model input data that are variable. Input data variation increases the likelihood that the calculated exposure concentrations encompass the true occupational inhalation exposure concentrations. The major limitation is uncertainty about the calculated fugitive emission rates because of uncertainty about the number of operating days. Another limitation is uncertainty as to the representativeness of the model parameter distributions because these data are not specific to sites that use DIBP. In general, the effects of these uncertainties on the exposure estimates are unknown, as the uncertainties may result in either overestimation or underestimation of exposures depending on the actual distributions of each of the model input parameters. There is uncertainty in in the representativeness of modeled exposures towards the true distribution of potential exposures. These estimates are likely conservative because of the conservative assumption that a single worker does all worker activities during a single shift.</p>

OES(s)	Summary of Assessment Methodology and Discussion of Weight of Scientific Evidence Conclusion in Occupational Exposures
	<p><i>Weight of Scientific Evidence Conclusion</i></p> <p>EPA has moderate confidence in the assessed exposures for average adult workers and females of reproductive age based on the strengths, limitations, and uncertainties that are discussed above. In summary, the strengths are related to the assessed worker activities, the mathematical model of the assessment calculations, the systematic review overall quality ratings of the values of the parameters of the mathematical model, and the Monte Carlo computations which are related to model input data variation. The limitations are the uncertainties related to the accuracies of the DIBP vapor generation rate and the values of the parameters of the mathematical model. There is uncertainty in the assessed exposures, but these exposures are likely conservative because of the conservative assumption that a single worker does all worker activities during a single shift. EPA has slight to moderate confidence in the assessed inhalation exposures for ONUs since it was assumed that ONU exposures are equal to worker central tendency exposures.</p>
Repackaging Incorporation into adhesives and sealants Incorporation into paints and coatings Use as a catalyst – formulation into pre-catalyst Use of laboratory chemicals – liquids	<p><i>Summary of the Assessment Method</i></p> <p>EPA assessed inhalation exposure to vapor to be equal to surrogate manufacturing exposure concentrations. These surrogate exposure concentrations from the manufacturing OES are upper-bound exposures because these concentrations exceed the concentrations that the Agency would have calculated via mathematical modeling in the case of this OES. Releases associated with each of the five OESs include DIBP fugitive emissions that are vapor emissions only. EPA did not conduct mathematical modeling involving the rates of these emissions to estimate exposure concentrations because the Agency determined that the DIBP fugitive emissions of the Manufacturing OES result in the worst-case worker inhalation exposure as discussed in Section D.14 of this TSD.</p> <p>EPA did receive inhalation monitoring submissions from W.R. Grace (2025) and LyondellBasell (2025) that measured airborne concentrations of DIBP in facilities that use DIBP in pre-catalyst formulation. However, 54 out of the 56 data measurements provided by W.R. Grace and LyondellBasell were below the LOD. The LODs for the full-shift PBZ inhalation monitoring measurements ranged from 1.3×10^{-2} to 2.9×10^{-2} mg/m³ and the two detectable values from the LyondellBasell (2025) monitoring study were measured as 2.4×10^{-2} and 2.5×10^{-2} mg/m³. Because 96% of the submitted monitoring data were below the limit of detection, there is a high degree of uncertainty in quantitative use of the dataset. Instead, EPA considers these data in qualitative comparison to the vapor generation model mentioned above, which resulted in central tendency and high-end exposure concentrations of 4.0×10^{-3} and 1.8×10^{-2} mg/m³, respectively.</p> <p>EPA assumed exposure duration is equal to 8 hours per day in the case of each of these OESs because the surrogate exposure concentrations are 8-hour TWA concentrations. The exposure frequencies that EPA assessed differ moderately depending on the OES. The central tendency exposure frequencies of the five OESs are in the range of 208 to 250 days/year and the high-end exposure frequency is generally 250 days/year. All these values are equal to estimates of the maximum number of workdays per year of a worker or are equal to the number of operating days that EPA assessed in the case of an OES. In some cases, EPA assessed the central tendency and high-end exposure frequency to be equal. Section 3 of this TSD contains a complete discussion of the exposure frequencies of each of the OESs.</p> <p><i>Strengths, Limitations, and Uncertainties Associated with the Exposure Estimates</i></p> <p>The strength of the exposure estimates is EPA's high confidence that the surrogate inhalation exposure concentrations are upper bound exposure estimates for these OESs. This is supported by inhalation monitoring studies submitted by W.R. Grace (2025) and</p>

OES(s)	Summary of Assessment Methodology and Discussion of Weight of Scientific Evidence Conclusion in Occupational Exposures
	<p>LyondellBasell (2025) which measured full-shift PBZ air concentrations of DIBP in processing facilities, and the results of the study were in strong agreement with the modeled estimates of worker inhalation exposure. The major limitation is uncertainty in the assessed exposure frequency. The exposure estimates are likely conservative because of the conservative estimate of exposure concentration.</p> <p>Weight of Scientific Evidence Conclusion</p> <p>EPA's confidence in the assessed exposures for average adult workers and females of reproductive age is moderate based on the strengths, limitations, and uncertainties that are discussed above. EPA has slight to moderate confidence in the assessed inhalation exposures for ONUs since it was assumed that ONU exposures are equal to worker central tendency exposures.</p>
<p>Use as a catalyst – intermediate in polypropylene manufacturing</p> <p>Plastic compounding</p> <p>Plastic converting</p> <p>Rubber manufacturing – rubber compounding</p> <p>Rubber manufacturing – rubber converting</p> <p>Recycling</p> <p>Waste handling, treatment, and disposal</p>	<p>Summary of the Assessment Method</p> <p>Each of these seven OESs involve fugitive emissions of DIBP vapor, fugitive emissions of dust that contains DIBP and various worker activities that are related to these fugitive emissions as discussed in Section 3 of this TSD. In the case of exposure to DIBP vapor EPA estimated the inhalation exposure concentrations of all workers associated with these OESs to be equal to surrogate exposure concentrations. In the case of exposure to dust that contains DIBP, the Agency estimated the inhalation exposure concentrations of all workers associated with these OESs in accordance with the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR Model). EPA assessed inhalation exposure to vapor to be equal to surrogate manufacturing exposure concentrations. These surrogate exposure concentrations from the manufacturing OES are upper-bound exposures because these concentrations exceed the concentrations that the Agency would have calculated via mathematical modeling in the case of these OES. That is, EPA determined that the DIBP fugitive emissions of the Manufacturing OES result in the worst-case worker inhalation exposure concentrations as discussed in Section D.14 of this TSD. With regard to inhalation exposure to dust that contains DIBP, EPA calculated inhalation exposure concentrations as the product of the following two factors: (1) central tendency and high-end worker monitoring data that are inhalation exposure concentrations in the case of worker exposure to respirable dust at sites associated with certain NAICS codes and (2) the concentration of DIBP in products. These respirable dust inhalation exposure concentrations are a part of the PNOR Model and are derived from OSHA CEHD data (OSHA, 2020), which was rated high for data quality via systematic review. These are not DIBP worker monitoring data, and the chemical composition of the dust may not have been reported by OSHA.</p> <p>The worker monitoring data of the PNOR Model that are respirable dust inhalation exposure concentrations are classified by NAICS codes. In the case of each of the seven OESs, EPA selected the monitoring data that are associated with a NAICS code that EPA deemed to be the most appropriate. These NAICS codes are as follows: NAICS code 325 (Chemical Manufacturing) in the cases of use as a catalyst – intermediate in polypropylene manufacturing, plastic compounding, and rubber manufacturing – rubber compounding and converting; NAICS code 326 (Plastics and Rubber Products Manufacturing) in the case of plastic converting; NAICS code 56 (Administrative and Support and Waste Management and Remediation Services) in the case of recycling and waste handling, treatment, and disposal. EPA assessed the mass concentration of DIBP in solid material containing DIBP in the case of each of the seven OESs to be equal to the following concentration data that were generally rated high for data quality via systematic review:</p> <ul style="list-style-type: none"> Use as a catalyst – intermediate in polypropylene manufacturing: the highest expected concentration of DIBP in polypropylene manufacturing based on industry data (W.R. Grace & Co, 2022);

OES(s)	Summary of Assessment Methodology and Discussion of Weight of Scientific Evidence Conclusion in Occupational Exposures
	<ul style="list-style-type: none"> • Plastic compounding and Plastic converting: the highest expected concentration of DIBP in plastics based on data about DIBP content in different types of plastic materials (ECHA, 2011); • Rubber manufacturing – rubber converting compounding and Waste handling, treatment, and disposal: industry data reported in the ESD on Additives in Rubber Industry and GS on Use of Additives in Plastic Compounding, (U.S. EPA, 2021d; OECD, 2004); and • Recycling: industry data reported in the ESD on Additives in Rubber Industry and in the GS on Use of Additives in Plastic Compounding (U.S. EPA, 2021d; OECD, 2004). <p>EPA conservatively assumed all workers of these OESs are exposed to vapor and to dust during a single shift. Therefore, EPA assessed the central tendency and high-end 8-hour TWA inhalation exposure concentrations of each of the seven OESs by aggregating the surrogate DIBP vapor inhalation exposure concentrations and the DIBP dust inhalation exposure concentration that EPA calculated in accordance with the PNOR Model; this aggregation is described in Appendix B of this TSD. The exposure frequencies that EPA assessed differ moderately depending on the OES. The central tendency exposure frequencies of the seven OESs are in the range of 219 to 234 days/year and the high-end exposure frequency is generally 250 days/year. All of these values are equal to estimates of the maximum number of workdays per year of a worker or are equal to the number of operating days that EPA assessed in the case of an OES. In some cases, EPA assessed the central tendency and high-end exposure frequency to be equal.</p> <p><i>Strengths, Limitations, and Uncertainties Associated with the Exposure Estimates</i></p> <p>The strengths of the exposure estimates are the following: (a) the overall quality ratings of the cited references are high, (b) the surrogate dust inhalation exposure concentrations are derived from a large number of monitoring data that are related to the industries that the OESs are associated with, (c) the adjustment of the dust inhalation exposure concentrations based on estimates of the concentration of DIBP in products, (d) the surrogate vapor exposure concentrations are calculated from DIBP fugitive vapor release rates that are conservative relative to the DIBP fugitive vapor release rates expected for these OESs. The limitations of the exposure estimates are exposure concentrations that are surrogate data and uncertainty in the assessed exposure frequency. The uncertainty associated with the exposure estimates is whether the assessed exposures represent the true distribution of potential exposures. The assessed vapor exposure concentrations are likely overestimates as discussed above.</p> <p><i>Weight of Scientific Evidence Conclusion</i></p> <p>EPA’s confidence in the assessed exposures for average adult workers and females of reproductive age is moderate based on the strengths, limitations, and uncertainties that are discussed above. In summary, the strengths are the systematic review overall quality ratings of the data sources that are related to the assessed exposures, and the methods for estimation of the inhalation exposure concentrations, which are surrogate data. The limitations are the surrogate inhalation exposure data and uncertainty in the assessed exposure frequency. The uncertainty associated with the exposure estimates is whether the assessed exposures represent the true distribution of potential exposures. EPA has slight to moderate confidence in the assessed inhalation exposures for ONUs since it was assumed that ONU exposures are equal to worker central tendency exposures.</p>
Application of adhesives and sealants	<p><i>Summary of the Assessment Method</i></p> <p>In the cases of spray application of adhesives and spray application of paints and coatings, EPA estimated DIBP inhalation exposure concentrations in accordance with the Automotive Refinishing Spray Coating Mist Inhalation Model of the ESD on Coating</p>

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Application of paints and coatings	<p>Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a). Specifically, EPA calculated concentrations of DIBP in mist that workers are potentially exposed to via inhalation from the following factors: (1) the worker monitoring data reported in this ESD, (2) concentrations of DIBP in products as reported in SDSs and product data sheets of 28 adhesive and sealant products that contain DIBP in the case of the Application of adhesives and sealants OES and 3 paints and coatings products that contain DIBP in the case of the Application of the paints and coatings OES and, (3) the concentration of nonvolatile material in auto refinishing spray paint or coating products as reported in this ESD. The worker monitoring data that are reported in this ESD are concentrations of mist that workers are potentially exposed to during spray painting at auto refinishing shops and therefore these are surrogate monitoring data.</p> <p>In the case of non-spray application of adhesives and sealants and paints and coatings, EPA expects worker inhalation exposure to result from fugitive emissions of DIBP vapor. Accordingly, EPA assessed DIBP inhalation exposure concentrations by equating these concentrations to the exposure concentrations that EPA assessed in the case of the manufacturing OES. The exposure concentrations that EPA assessed in the case of the manufacturing OES are upper-bound exposures for these OES because the Agency determined that the DIBP fugitive emissions of the Manufacturing OES result in the worst-case of worker inhalation exposure to DIBP vapor as discussed in Section D.14 of this TSD.</p> <p>EPA assessed the same exposure duration and frequency for the spray and non-spray scenarios in the case of both OESs. The Agency assumed the duration of worker exposure is 8 hours per day in the case of both OESs. With regard to exposure frequency and the OES of Application of adhesives and sealants, EPA assessed the central tendency and high-end values of exposure frequency to be equal to 232 days/year and 250 days/year, respectively. This central tendency value is based on the central tendency value of the number of release days and this high-end value is the maximum number of days per year that the Agency expects a worker to work. In the case of the OES of Application of paints and coatings, EPA assessed both the central tendency and high-end values of exposure frequency to be equal to 250 days/year, which the maximum number of days per year that the Agency expects a worker to work.</p> <p><i>Strengths, Limitations, and Uncertainties Associated with the Exposure Estimates of Spray Application</i></p> <p>The strengths of the exposure estimates in the case of the spray application of products, both adhesives and sealants, and paints and coatings, are as follows: (a) the mathematical model of the calculations of inhalation exposure concentrations (<i>i.e.</i>, the Automotive Refinishing Spray Coating Mist Inhalation Model) is a model that is related to the assessed scenarios, (b) the overall quality rating of the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a) is medium, and (c) exposure concentrations were estimated from concentrations of DIBP in pertinent products as reported in the SDSs or product data sheets of these products; there is an exception to this strength because of one of the paints and coatings products as discussed below under limitations. A limitation of the spray application exposure estimates in general is that the mathematical model of the calculations of inhalation exposure concentrations (<i>i.e.</i>, the Automotive Refinishing Spray Coating Mist Inhalation Model) incorporates worker mist inhalation exposure monitoring data that are unrelated to DIBP. These are worker monitoring data that pertain to worker exposure to mist during auto refinishing; whether these data represent the concentrations of mist that workers would potentially be exposed to during spray application of adhesives products and paints and coatings products that contain DIBP is uncertain. Another limitation related to the mathematical model is that EPA is uncertain whether the concentrations of nonvolatile material that the Agency</p>

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	<p>incorporated into the assessment represent the concentrations of nonvolatile material in the adhesive products and the paints and coatings products that contain DIBP that would be spray applied. A discussion of other limitations follows.</p> <p>With regard to the spray application scenario of adhesives and sealants, a limitation of the exposure estimates is uncertainty about whether adhesive products containing DIBP are spray applied. EPA did not infer spray coating as the application method of any of the 28 adhesive or sealant products that are listed in Appendix E of this TSD. However, spray application of adhesives in vehicle manufacturing is possible (OECD, 2015a) and DIBP is used in vehicle manufacturing (U.S. EPA, 2020c). Therefore, EPA assumed that workers may spray apply adhesives that contain DIBP. EPA did not assess spray application of sealant products. With regard to the spray application of paints and coatings, and in contrast to the case of adhesives and sealants, EPA did infer spray coating as the application method of some of the paints or coatings products that are listed in Appendix E of this TSD. However, a limitation of the exposure assessment approach is that EPA classified a certain product that contains DIBP at a concentration of 30–60% by weight as a paint or coating product but EPA is uncertain of this classification because this product may actually be an adhesive product. Excepting this product, the maximum concentration of DIBP in paint or coating products is 5% by weight according to Appendix E of this TSD.</p> <p>With regard to exposure duration, EPA assessed the duration of exposure to mist that results from spray application of adhesive and paint and coating products that contain DIBP to be equal to a full 8-hour work shift, but this duration may be lower if workers are involved in other activities. The duration of spray application of adhesive products may be variable depending on the job site. EPA assessed 232 to 250 days of exposure per year based on workers applying adhesives on every working day, however, application sites may use DIBP-containing adhesives at much lower frequencies. The uncertainties discussed above decrease the weight of evidence.</p> <p><i>Strengths, Limitations, and Uncertainties with the Exposure Estimates of Non-Spray Application</i></p> <p>The strength of the exposure estimates is EPA’s high confidence that the surrogate inhalation exposure concentrations serve as an upper bound of potential worker exposure. The major limitation is uncertainty in the assessed exposure frequency. The exposure estimates are likely conservative because of the conservative estimate of exposure concentration.</p> <p><i>Weight of Scientific Evidence Conclusions in the Case of Spray Application of Products</i></p> <p>EPA’s confidence in the assessed inhalation exposures is moderate based on the strengths, limitations, and uncertainties that are discussed above. In summary, the strengths of the exposure estimates in general are the mathematical model that is related to the assessed scenarios and, with one exception, the input variables of this model (<i>i.e.</i>, the concentrations of DIBP in products), which are DIBP-specific. This exception is the maximum concentration of DIBP in paints and coatings which is uncertain. The limitations of the exposure estimates are that the mist concentration data are not DIBP-specific and that the 8-hour exposure duration may be conservative in some instances. Lastly, EPA has slight to moderate confidence in the assessed central tendency inhalation exposures for ONUs since it was assumed that ONU exposures are equal to worker central tendency exposures.</p> <p><i>Weight of Scientific Evidence Conclusions in the Case of Non-Spray Application of Products</i></p> <p>The strength of the exposure estimates is EPA’s high confidence that the surrogate inhalation exposure concentrations serve as an upper bound for potential worker exposure. The major limitation is uncertainty in the assessed exposure frequency. The exposure</p>

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	<p>estimates are likely conservative because of the conservative estimate of exposure concentration. Therefore, EPA has moderate confidence in the assessed inhalation exposure levels for non-spray applications.</p>
<p>Use of laboratory chemicals – solids</p> <p>Fabrication and final use of products or articles</p>	<p><i>Summary of the Assessment Method</i></p> <p>Each of these two OESs includes fugitive emissions of dust that contains DIBP. Accordingly, EPA assessed inhalation exposure concentrations in accordance with the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR Model). Specifically, EPA calculated inhalation exposure concentration as the product of the following two factors: (1) central tendency and high-end worker monitoring data that are inhalation exposure concentrations in the case of worker exposure to respirable dust at sites associated with certain NAICS codes and (2) the concentration of DIBP in products. These worker monitoring data on respirable dust are a part of the PNOR Model, are derived from OSHA CEHD data (OSHA, 2020) and were rated high for data quality via systematic review.</p> <p>The worker monitoring data of the PNOR Model that are respirable dust inhalation exposure concentrations are classified by NAICS codes. In the case of each of the two OESs, EPA selected the monitoring data that are associated with the NAICS code that EPA deemed to be the most appropriate. These NAICS codes are as follows: NAICS code 54 (Professional, Scientific, and Technical Services) in the case of use of laboratory chemicals – solids and NAICS code 337 (Furniture and Related Product Manufacturing) in the case of fabrication and final use of products or articles. EPA assessed the mass concentration of DIBP in solid material containing DIBP in the case of each of the two OESs to be equal to the following concentration data which were generally rated high for data quality via systematic review:</p> <ul style="list-style-type: none"> • Use of laboratory chemicals – solids: data reported in SDSs; • Fabrication and final use of products or articles: industry data provided by the ESD on Additives in Rubber Industry and GS on Use of Additives in Plastic Compounding, (U.S. EPA, 2021d; OECD, 2004). <p>EPA assessed exposure duration to be 8 hours per day in the case of each of the two OESs because the worker monitoring inhalation exposure concentrations are 8-hour TWA concentrations. The exposure frequencies that EPA assessed differ moderately depending on the OES. The central tendency exposure frequencies of the two OESs are in the range of 219 to 250 days/year and the high-end exposure frequency is generally 250 days/year. All of these values are equal to estimates of the maximum number of workdays per year of a worker or are equal to the number of operating days that EPA assessed in the case of an OES. In the case of the OES of fabrication and final use of products or articles, EPA assessed the central tendency and high-end exposure frequency to be equal.</p> <p><i>Strengths, Limitations, and Uncertainties Associated with the Exposure Estimates</i></p> <p>The strengths of the exposure estimates are the following: (a) the overall quality ratings of the cited references are high, and (b) the dust inhalation exposure concentrations are derived from a large number of monitoring data that are related to the industries that the OESs are associated with, and (c) the adjustment of the dust inhalation exposure concentrations based on estimates of the concentration of DIBP in products. The limitations of the exposure estimates are as follows: (a) the assessment of exposure concentrations that are equal to or are based on surrogate exposure concentrations and (b) uncertainty in the assessed exposure frequency. The uncertainty associated with the exposure estimates is the uncertainty of whether the assessed exposures represent the true distribution of potential exposures.</p>

OES(s)	Summary of Assessment Methodology and Discussion of Weight of Scientific Evidence Conclusion in Occupational Exposures
	<p>Weight of Scientific Evidence Conclusion</p> <p>EPA's confidence in the assessed exposures for average adult workers and females of reproductive age is moderate based on the strengths, limitations, and uncertainties that are discussed above. EPA has slight to moderate confidence in the assessed inhalation exposures for ONUs since it was assumed that ONU exposures are equal to worker central tendency exposures.</p>
Dermal – Liquids	<p>Assessment Summary and Strengths, Limitations, and Uncertainties Associated with the Exposure Estimates</p> <p>Dermal exposure to DIBP was assessed by EPA from dermal absorptive flux, surface area, exposure duration and exposure frequency.</p> <p>There was only one study identified that measured the flux of DIBP, but the study was conducted with <i>in vivo</i> experiments using rat specimens only (Elsisi et al., 1989). It was determined that use of the <i>in vivo</i> rat data would result in an overestimate of dermal absorption in humans. However, DIBP and DBP are isomers with similar physical and chemical properties and similar absorption profiles in rats (Elsisi et al., 1989), and it is expected that dermal absorption data for DBP serve as suitable surrogate data for DIBP. Therefore, for estimating dermal absorptive flux of DIBP from liquid materials, EPA used surrogate absorption data from a study that measured dermal absorption of DBP in metabolically active human skin (Beydon et al., 2010). Specifically, the steady-state absorptive flux of DBP reported in Beydon <i>et al.</i> (2010) was used as surrogate to estimate the dermal uptake of DIBP from occupational exposures to the chemical. The selected study has many strengths, such as the use of metabolically active human skin, compliance with OECD 428 guidelines, similarities to <i>in vivo</i> human data presented in Hopf <i>et al.</i> (2024), similarities to values obtained from aqueous absorption modeling, and moderate rating by the EPA's systematic review process. The Beydon <i>et al.</i> (2010) study is limited in that it only examined absorption of the neat material, and it is known that flux may be dependent on concentration and vehicle of absorption. Dilute materials may absorb at a faster rate but with lower concentration, and neat materials may absorb at a slower rate but with higher concentration. Therefore, there is uncertainty regarding the resulting effects of concentration and vehicle of absorption for DIBP.</p> <p>Regarding surface area of dermal exposure to workers handling DIBP, EPA assumed the high-end exposure surface area was equivalent to mean values for two-hand (both sides of each hand) surface area (<i>i.e.</i>, 1070 cm² for male workers and 890 cm² for female workers) and the central tendency surface area was equivalent to only a single hand (or one side of two hands) (<i>i.e.</i>, 535 cm² for male workers and 445 cm² for female workers). Regarding surface area of dermal exposure to ONUs experiencing incidental contact to mist deposited on surfaces, EPA assumed a representative exposure surface area equivalent to the mean value for one palm (<i>i.e.</i>, 268 cm²) of adult males (U.S. EPA, 2011). Though surface areas related to hands and palms seem representative for handling of chemicals and contact with contaminated surfaces, exposure surface area may vary depending on task and scenario. There is high confidence in the surface area measurements presented in EPA's Exposure Factors Handbook (U.S. EPA, 2011) but moderate confidence in the application of the surface area measurements to the occupational dermal exposure assessment of workers. Since the extent of dermal exposure to ONUs is unknown, there is greater uncertainty regarding the surface area of exposure to ONUs.</p> <p>Regarding duration of dermal absorption of DIBP, it was assumed that a worker may contact DIBP multiple times throughout a workday and that the material can remain on the skin until washed. Therefore, the duration of absorption was assumed as 8 hours (U.S. EPA, 1991a) for estimating both central tendency and high-end exposures for all workers. It is important to note that EPA did</p>

OES(s)	Summary of Assessment Methodology and Discussion of Weight of Scientific Evidence Conclusion in Occupational Exposures
	<p>not assume that the worker handles the chemical for 8 hours, but that a substance with low volatility contacted multiple times per workday may exist on the skin surface for 8 hours. There is moderate confidence that an absorption duration of 8 hours is representative of potential occupational dermal exposures to DIBP. However, the duration may be more or less than 8 hours depending on worker tasks and scenario.</p> <p>Regarding exposure frequency, it is assumed that the number of operating days is equal to the number of exposure days. Though it is possible that a worker may be exposed each working day, there is uncertainty in worker exposure frequency due to variations in worker responsibilities. Therefore, EPA has moderate confidence that the number of operating days for a given OES are representative of potential worker exposure frequencies to DIBP. However, ONUs are not likely to experience dermal contact daily, though incidental contact with a contaminated surface may occur on an acute basis. Therefore, there is greater uncertainty that the number of operating days is representative of potential ONU exposure frequencies to DIBP.</p> <p><i>Weight of Scientific Evidence Conclusion</i></p> <p>The main strength of the assessment approach is the incorporation of the empirical <i>ex vivo</i> human skin absorption data of Beydon <i>et al.</i> (2010) into the assessment. The absorption study used metabolically active skin, received a moderate rating by EPA's systematic review process, and is supported by multiple streams of evidence. However, EPA noted uncertainties in the dermal exposure assessment related to surface area, duration of absorption, and exposure frequency. Further, there is increased uncertainty regarding the extent and frequency of dermal exposures to ONUs. Therefore, EPA has moderate confidence in dermal exposure estimates for workers handling liquid DIBP, and there is slight to moderate confidence in dermal exposure estimates for ONUs contacting mist deposited on surfaces.</p>
Dermal – Solids	<p><i>Assessment Summary and Strengths, Limitations, and Uncertainties Associated with the Exposure Estimates</i></p> <p>Dermal exposure to DIBP was assessed by EPA considering dermal absorptive flux, surface area, exposure duration and exposure frequency.</p> <p>It is expected that dermal exposure to solid matrices would result in far less absorption than contact with liquid materials, but there are no studies that report dermal absorption of DIBP from a solid matrix. For cases of dermal absorption of DIBP from a solid matrix, EPA assumed that DIBP will first migrate from the solid matrix to a thin layer of moisture on the skin surface. Therefore, absorption of DIBP from solid matrices is considered limited by aqueous solubility and is estimated using an aqueous absorption model (U.S. EPA, 2023b, 2004b). Nevertheless, it is assumed that absorption of the aqueous material serves as a reasonable upper bound for contact with solid materials. Also, EPA acknowledges that variations in chemical concentration and co-formulant components affect the rate of dermal absorption.</p> <p>Regarding surface area of dermal exposure to workers handling DIBP, EPA assumed the high-end exposure surface area was equivalent to mean values for two-hand (both sides of each hand) surface area (<i>i.e.</i>, 1070 cm² for male workers and 890 cm² for female workers) and the central tendency surface area was equivalent to only a single hand (or one side of two hands) (<i>i.e.</i>, 535 cm² for male workers and 445 cm² for female workers). Regarding surface area of dermal exposure to ONUs experiencing incidental contact to dust</p>

OES(s)	Summary of Assessment Methodology and Discussion of Weight of Scientific Evidence Conclusion in Occupational Exposures
	<p>deposited on surfaces, EPA assumed a representative exposure surface area equivalent to the mean value for one palm (<i>i.e.</i>, 268 cm²) of adult males (U.S. EPA, 2011). Though surface areas related to hands and palms seem representative for handling of chemicals and contact with contaminated surfaces, exposure surface area may vary depending on task and scenario. There is high confidence in the surface area measurements presented in EPA's Exposure Factors Handbook (U.S. EPA, 2011) but moderate confidence in the application of the surface area measurements to the occupational dermal exposure assessment of workers. Since the extent of dermal exposure to ONUs is unknown, there is greater uncertainty regarding the surface area of exposure to ONUs.</p> <p>Regarding duration of dermal absorption of DIBP, it was assumed that a worker may contact DIBP multiple times throughout a workday and that the material can remain on the skin until washed. Therefore, the duration of absorption was assumed as 8 hours (U.S. EPA, 1991a) for estimating both central tendency and high-end exposures for all workers. It is important to note that EPA did not assume that the worker handles the chemical for 8 hours, but that a substance with low volatility contacted multiple times per workday may exist on the skin surface for 8 hours. There is moderate confidence that an absorption duration of 8 hours is representative of potential occupational dermal exposures to DIBP. However, the duration may be more or less than 8 hours depending on worker tasks and scenario.</p> <p>Regarding exposure frequency, it is assumed that the number of operating days is equal to the number of exposure days. Though it is possible that a worker may be exposed each working day, there is uncertainty in worker exposure frequency due to variations in worker responsibilities. Therefore, EPA has moderate confidence that the number of operating days for a given OES are representative of potential worker exposure frequencies to DIBP. However, ONUs are not likely to experience dermal contact daily, though incidental contact with a contaminated surface may occur on an acute basis. Therefore, there is greater uncertainty that the number of operating days is representative of potential ONU exposure frequencies to DIBP.</p> <p><i>Weight of Scientific Evidence Conclusion</i></p> <p>The main strength of the assessment approach is the assumption that dermal uptake from solid materials is limited by aqueous solubility, and EPA has high confidence that the modeling of aqueous absorption of DIBP serves as an upper bound of dermal uptake from contact with solid materials. However, EPA noted uncertainties in the dermal exposure assessment related to surface area, duration of absorption, and exposure frequency. Further, there is increased uncertainty regarding the extent and frequency of dermal exposures to ONUs. Therefore, EPA has moderate confidence in dermal exposure estimates for workers handling solid materials containing DIBP, and there is slight to moderate confidence in dermal exposure estimates for ONUs contacting dust deposited on surfaces.</p>

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APPENDICES

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

This report assesses DIBP inhalation exposures to workers in occupational settings, presented as 8-hour 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 DIBP dermal exposures to workers in occupational settings, presented as a dermal acute potential dose rate (APDR). The APDRs are then used to calculate acute retained doses (AD), intermediate average daily doses (IADD), and average daily doses (ADD) for chronic non-cancer risks. 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 less than one day) from workplace inhalation exposures for, per Equation_Apx A-1.

Equation_Apx A-1.

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

Where:

- AD = Acute dose (mg/kg/day)
- C = Contaminant concentration in air (TWA mg/m³)
- ED = Exposure duration (hr/day)
- BR = Breathing rate (m³/hr)
- BW = 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:

- IADD = Intermediate average daily dose (mg/kg/day)
- EF_{int} = Intermediate exposure frequency (day)
- ID = 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:

- ADD = Average daily dose for chronic non-cancer risk calculations

EF = Exposure frequency (day/year)
WY = Working years per lifetime (yr)

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:

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

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

Equation_Apx A-5.

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

Where:

IADD = Intermediate average daily dose (mg/kg-day)
EF_{int} = Intermediate exposure frequency (day)
ID = 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.

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

Where:

ADD = Average daily dose for chronic non-cancer risk calculations
EF = Exposure frequency (day/year)
WY = 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.

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

Where:

AD_{Dermal} = Dermal exposure acute retained dose (mg/kg-day)
AD_{Inhalation} = Inhalation exposure acute retained dose (mg/kg-day)
AD_{Aggregate} = Aggregated 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. Where EPA calculated exposures using probabilistic modeling, EPA integrated the calculations into a Monte Carlo simulation. The EF and EF_{int} 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 A.1 and A.2 and summarized in Table_Apx A-1.

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

Parameter Name	Symbol	Value	Unit
Exposure Duration	ED	8	hr/day
Breathing Rate	BR	1.25	m ³ /hr
Exposure Frequency	EF	50th percentile: 250 ^a , 235 ^b , 234 ^c , 232 ^d , 223 ^e , 219 ^f , or 208 ^g 95th percentile: 250 in the case of all OES	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 All OES except for those in the subsequent footnotes. ^b The OES of Use of laboratory chemicals. ^c The OES of Rubber manufacturing (for the compounding portion of the process). ^d The OES of Application of adhesives and sealants. ^e The OES of Plastics compounding, Recycling, and Waste handling, treatment, and disposal. ^f The OES of Plastics converting and Rubber manufacturing (for the converting portion of the process). ^g The OES of Repackaging into Large and Small Containers.			

A.4.1 Exposure Duration (ED)

EPA generally used an exposure duration of eight 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 ([U.S. EPA, 1991b](#)).

A.4.3 Exposure Frequency (EF)

EPA estimated a maximum exposure frequency of 250 days per year. However, for some OES where a range of exposure frequency was 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 (day/year)
- AWD = annual working days, the number of days per year a worker works (day/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 COUs 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-digit, 5-digit, or 6-digit). EPA converted the working hours per employee to working days per year per employee assuming employees work an average of eight 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 DIBP-specific data, EPA assumed the parameter, f, is equal to one for all OES.

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

For DIBP, 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/week:

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 ADC 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 two years. The data are available by demographic characteristics and by generic industry sectors, but not by NAICS codes.

The U.S. Census' ([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 works (TJBIND1); worker age (TAGE); and years of work experience *with all employers* over the surveyed individual's lifetime⁵. 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 our 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.

⁵ To calculate the number of years of work experience EPA took the difference between the year first worked (TMAKMNYEAR) 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. Census Bureau, 2016a				
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 to 17 years	0.7	0.7	0.7	0.7
18 to 19 years	0.8	1.0	0.8	0.8
20 to 24 years	1.3	1.5	1.3	1.3
25 years and over	5.1	5.2	5.4	5.5
25 to 34 years	2.7	3.1	3.2	3.0
35 to 44 years	4.9	5.1	5.3	5.2
45 to 54 years	7.6	7.8	7.8	7.9
55 to 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 DOSES

Sample calculations for high-end and central tendency acute, intermediate, and chronic (non-cancer) doses for one COU, Processing – Incorporation into a Formulation, Mixture, or Reaction Product – Plasticizer in plastic product manufacturing, which corresponds to the plastics compounding OES, 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 total 8-hour TWA for all routes:

$$C_{HE} = C_{vapor_HE} + C_{particulate_HE}$$
$$C_{HE} = 1.83 \times 10^{-2} \frac{mg}{m^3} + 1.94 \times 10^{-3} \frac{mg}{m^3}$$
$$C_{HE} = 2.10 \times 10^{-2} \frac{mg}{m^3}$$

Calculating AD_{HE}:

$$AD_{HE} = \frac{C_{HE} \times ED \times BR}{BW}$$
$$AD_{HE} = \frac{2.1 \times 10^{-2} \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr}}{80 kg} = 2.6 \times 10^{-3} \frac{mg}{kg day}$$

Calculating IADD_{HE}:

$$IADD = \frac{C_{HE} \times ED \times BR \times EF_{int}}{BW \times SCD}$$
$$IADD_{HE} = \frac{2.1 \times 10^{-2} \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 1.25 \frac{m^3}{hr} \times 22 \frac{days}{year}}{80 kg \times 30 \frac{days}{year}} = 1.9 \times 10^{-3} \frac{mg}{kg day}$$

Calculating ADD_{HE}:

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

$$ADD_{HE} = \frac{2.1 \times 10^{-2} \frac{\text{mg}}{\text{m}^3} \times 8 \frac{\text{hr}}{\text{day}} \times 1.25 \frac{\text{m}^3}{\text{hr}} \times 250 \frac{\text{days}}{\text{year}} \times 40 \text{ years}}{80 \text{ kg} \times 365 \frac{\text{days}}{\text{year}} \times 40 \text{ years}} = 1.8 \times 10^{-3} \frac{\text{mg}}{\text{kg} \cdot \text{day}}$$

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

Calculating AD_{CT}:

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

$$AD_{CT} = \frac{4.2 \times 10^{-3} \frac{\text{mg}}{\text{m}^3} \times 8 \frac{\text{hr}}{\text{day}} \times 1.25 \frac{\text{m}^3}{\text{hr}}}{80 \text{ kg}} = 5.2 \times 10^{-4} \frac{\text{mg}}{\text{kg} \cdot \text{day}}$$

Calculating IADD_{CT}:

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

$$IADD_{CT} = \frac{4.2 \times 10^{-3} \frac{\text{mg}}{\text{m}^3} \times 8 \frac{\text{hr}}{\text{day}} \times 1.25 \frac{\text{m}^3}{\text{hr}} \times 22 \frac{\text{days}}{\text{year}}}{80 \text{ kg} \times 30 \frac{\text{days}}{\text{year}}} = 3.8 \times 10^{-4} \frac{\text{mg}}{\text{kg} \cdot \text{day}}$$

Calculating ADD_{CT}:

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

$$ADD_{CT} = \frac{4.2 \times 10^{-3} \frac{\text{mg}}{\text{m}^3} \times 8 \frac{\text{hr}}{\text{day}} \times 1.25 \frac{\text{m}^3}{\text{hr}} \times 250 \frac{\text{days}}{\text{year}} \times 31 \text{ years}}{80 \text{ kg} \times 365 \frac{\text{days}}{\text{year}} \times 31 \text{ years}} = 3.2 \times 10^{-4} \frac{\text{mg}}{\text{kg} \cdot \text{day}}$$

B.2 Dermal Exposures

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

Calculating AD_{HE} :

$$AD_{HE} = \frac{APDR}{BW}$$
$$AD_{HE} = \frac{5.05 \frac{mg}{day}}{80 \text{ kg}} = 0.063 \frac{mg}{kg-day}$$

Calculate $IADD_{HE}$:

$$IADD_{HE} = \frac{APDR \times EF_{int}}{BW \times SCD}$$
$$IADD_{HE} = \frac{5.05 \frac{mg}{day} \times 22 \frac{day}{yr}}{80 \text{ kg} \times 30 \frac{day}{yr}} = 0.046 \frac{mg}{kg-day}$$

Calculate ADD_{HE} (non-cancer):

$$ADD_{HE} = \frac{APDR \times EF \times WY}{BW \times 365 \frac{day}{yr} \times WY}$$
$$ADD_{HE} = \frac{5.05 \frac{mg}{day} \times 250 \frac{day}{yr} \times 40 \text{ years}}{80 \text{ kg} \times 365 \frac{day}{yr} \times 40 \text{ years}} = 0.043 \frac{mg}{kg-day}$$

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

Calculating AD_{CT} :

$$AD_{CT} = \frac{APDR}{BW}$$
$$AD_{CT} = \frac{2.53 \frac{mg}{day}}{80 \text{ kg}} = 0.032 \frac{mg}{kg-day}$$

Calculating IADD_{CT}:

$$IADD_{CT} = \frac{APDR \times EF_{int}}{BW \times 30 \frac{days}{yr}}$$

$$IADD_{CT} = \frac{2.53 \frac{mg}{day} \times 22 \frac{days}{yr}}{80 \text{ kg} \times 30 \frac{days}{yr}} = 0.023 \frac{mg}{kg \cdot day}$$

Calculate ADD_{CT} (non-cancer):

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

$$ADD_{CT} = \frac{2.53 \frac{mg}{day} \times 250 \frac{days}{yr} \times 31 \text{ years}}{80 \text{ kg} \times 365 \frac{day}{yr} \times 31 \text{ years}} = 0.022 \frac{mg}{kg \cdot day}$$

Appendix C DERMAL EXPOSURE ASSESSMENT METHOD

C.1 Dermal Dose Equation

As described in Section 2.4.3, occupational dermal exposures to DIBP are characterized using a flux-based approach to dermal exposure estimation. 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 (mg/cm ² /h);
S	=	Surface area of skin in contact with the chemical formulation (cm ²);
t_{abs}	=	Duration of absorption (h/day)
PF	=	Glove protection factor (unitless, $PF \geq 1$)

The inputs to the dermal dose equations are described in Section 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	J	Dermal Contact with Liquids: 5.9E-04 Dermal Contact with Solids: 1.7E-04	mg/cm ² /h	See Section C.2.1
Surface Area	S	Workers: 535 (central tendency) 1,070 (high-end) Females of reproductive age: 445 (central tendency) 890 (high-end) ONUs: 268 (central tendency)	cm ²	See Section C.2.2
Absorption time	t_{abs}	8	h	See Section C.2.3
Glove Protection Factor	PF	1; 5; 10; or 20	Unitless	See Section C.2.6

C.2.1 Absorptive Flux

Dermal data were sufficient to characterize occupational dermal exposures to liquids or formulations containing DIBP; however, dermal data were not sufficient to estimate dermal exposures to solids or articles containing DIBP. Therefore, modeling efforts were used to estimate dermal exposures to solids or articles containing DIBP. As described in Section 2.4.3.4, dermal exposures to DIBP vapors are not expected to be significant due to the protective effect of clean clothing on dermal uptake of DBP from

vapor demonstrated by Morrison *et al.* (2016). Therefore, vapor to skin exposures are not quantitatively included in the dermal exposure assessment of DIBP.

C.2.1.1 Dermal Contact with Liquids or Formulations Containing DIBP

As described in Section 2.4.3.2, EPA identified one study related to the dermal absorption of DIBP (Elsisi *et al.*, 1989), and the study was conducted *in vivo* with rat specimens. However, based on examinations of the difference of phthalate absorption between rats and humans (Beydon *et al.*, 2010; Scott *et al.*, 1987), the data reported by Elsisi *et al.* (1989) are expected to result in overestimation of human dermal absorption of DIBP. Alternatively, there are multiple studies of dermal absorption of DBP using human skin (Hopf *et al.*, 2024; Beydon *et al.*, 2010; Scott *et al.*, 1987), and specifically, the study of Beydon (2010) was identified as the most representative study for estimating dermal absorption of DBP in human skin. Because DIBP and DBP are isomers with similar physical and chemical properties and similar absorption profiles in rats (Elsisi *et al.*, 1989), human absorption data measured for DBP is used as surrogate to estimate the absorption potential of DIBP in humans. Therefore, EPA uses the steady-state flux of neat DBP over a 24-hour period of 5.9×10^{-4} mg/cm²/h estimated from Beydon *et al.* (Beydon *et al.*, 2010) as surrogate for estimating dermal exposure to DIBP in liquid materials. EPA assumes the same average absorptive flux would be representative of dermal contact with liquids or formulations containing DIBP that may occur in occupational settings over an 8-hour work shift.

C.2.1.2 Dermal Contact with Solids or Articles Containing DIBP

As described in Section 2.4.3.3, the average absorptive flux of DIBP from solid matrices is expected to vary between 0.17 and 0.47 µg/cm²/h for durations between 1-hour and 8-hours based on aqueous absorption modeling from U.S. EPA (2004b). Using Equation 2-1 from Section 2.4.3.3, the average absorptive flux of DBP over an 8-hour exposure period is calculated as 0.17 µg/cm²/h. Because it is assumed that DIBP must first migrate from the solid matrix to a thin film of moisture on the surface of the skin, and that solubility of DIBP by the moisture layer limits absorption, the 8-hour time weighted average aqueous flux value of 0.17 µg/cm²/h was chosen as a representative value for dermal exposures to solids or articles containing DBP. It is important to note that there are mass transfer limitations from powders and solid matrices to the aqueous phase. Therefore, aqueous absorption estimates serve as an upper bound of potential dermal uptake from solid materials containing DIBP.

C.2.2 Surface Area

Regarding surface area of occupational dermal exposure, EPA assumed a high-end value of 1070 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 one side of two 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). Regarding surface area of dermal exposure to ONUs experiencing incidental contact to mist or dust deposited on surfaces, EPA assumed a representative exposure surface area equivalent to the mean value for one palm (*i.e.*, 268 cm²) of adult males (U.S. EPA, 2011).

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 worker's 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

Though 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 DIBP does not rapidly evaporate, and the worker may contact the material multiple times throughout the workday, EPA assumes that absorption of DIBP in occupational settings may occur throughout the entirety of an 8-hour work shift ([U.S. EPA, 1991a](#)).

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 lowest weight fraction of DIBP for liquid materials among OES shown in Table Apx C-2 is 0.115, and the central tendency of dermal loading of liquid materials in occupational settings is 1.4 to 3.8 mg/cm². Therefore, the low-end of dermal loading of DIBP expected during occupational handling of liquids containing DBP is 0.16 to 0.44 mg/cm². The expected dermal flux of DIBP from liquid materials is 5.9×10^{-4} mg/cm²/h, which results in dermal uptake of 4.7×10^{-3} mg/cm² over an 8-hour duration. Consequently, dermal loading is not expected to be the limiting factor in occupational dermal exposure to DIBP, but rather the flux of DIBP from liquid materials is expected to limit dermal exposure.

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](#)).

The expected dermal flux of DIBP from solid materials, based on aqueous absorption modeling, is 1.7×10^{-4} mg/cm²/h. Therefore, for a two-hand exposure (*i.e.*, 1070 cm²) over an 8-hour duration, the maximum dermal uptake is estimated as 1.5 mg/day. The central tendency of dermal loading of solid materials in occupational settings is 900 mg/day, and the weight fraction of DIBP in most solid substances is greater than 0.002. Therefore, with the exception of handling solid laboratory chemicals, dermal loading is not expected to be the limiting factor in occupational dermal exposure to DIBP, but rather the flux of DIBP from liquid materials is expected to limit dermal exposure. Low levels of DIBP in solid laboratory chemicals may lead to overestimation in dermal exposure depending on the loading scenario.

C.2.5 DIBP Weight Fraction

EPA used the maximum weight fraction of DIBP in each OES to estimate potential dermal loading quantities. The details of the range of expected weight fractions of DIBP in each OES are described for

each OES in Section 3. Table Apx C-2 presents the weight fraction of DIBP used for estimating dermal loading of DIBP for each OES.

Table Apx C-2. Summary of DIBP Weight Fractions for Dermal Exposure Estimates

OES	Physical Form	Weight Fraction
Manufacturing	Liquid	1
Repackaging into large and small containers	Liquid	1
Incorporation into adhesives and sealants	Liquid	1
Incorporation into paints and coatings	Liquid	1
Use as a catalyst – Formulation of Pre-Catalyst	Liquid	0.99
Use as a catalyst – Polypropylene manufacturing	Liquid	0.115
Use as a catalyst – Polypropylene manufacturing	Liquid	1
	Solid	1.3E–06
Application of adhesives and sealants	Liquid	0.4
Application of paints and coatings	Liquid	0.6
Use of laboratory chemicals	Liquid	1
	Solid	0.001
Plastics compounding	Liquid	1
	Solid	0.074
Plastics converting	Solid	0.074
Recycling	Solid	0.074
Rubber manufacturing – Compounding	Liquid	1
	Solid	0.18
Rubber manufacturing – Converting	Solid	0.18
Fabrication of final product from articles	Solid	0.18
Waste handling, treatment, and disposal	Solid	0.18

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 – that is, 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 percent 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)
a. Any glove / gauntlet without permeation data and without employee training	Both industrial and professional users	0	1
b. Gloves with available permeation data indicating that the material of construction offers good protection for the substance		80	5
c. Chemically resistant gloves (<i>i.e.</i> , as b above) with “basic” employee training		90	10
d. 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 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 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. A Monte Carlo simulation (a type of stochastic simulation) was conducted to capture variability in the model input parameters. The simulation was conducted using the Latin Hypercube sampling method in @Risk Industrial Edition, Version 7.0.0. 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 the model 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. 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 Standard Models

This appendix discusses the standard models used by EPA to estimate environmental releases of chemicals and occupational inhalation exposures. All the models presented in this appendix 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 ([U.S. EPA, 1991b](#)), 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 are specific to calculating environmental releases and occupational inhalation exposures to DIBP.

The EPA Penetration Model 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 Penetration Model calculates the average vapor generation rate of the chemical from the exposed liquid surface using the following equation:

Equation_Apx D-1.

$$G_{activity} = \frac{(8.24 \times 10^{-8}) \times (MW_{DIBP}^{0.835}) \times F_{correction_factor} \times VP \times \sqrt{Rate_{air_speed}} \times (0.25\pi D_{opening}^2)^4 \sqrt{\frac{1}{29} + \frac{1}{MW_{DIBP}}}}{T^{0.05} \times \sqrt{D_{opening}} \times \sqrt{P}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity [g/s]
MW_{DIBP}	=	DIBP molecular weight [g/mol]
$F_{correction_factor}$	=	Vapor pressure correction factor [unitless]
VP	=	DIBP vapor pressure [torr]
$Rate_{air_speed}$	=	Air speed [cm/s]
$D_{opening}$	=	Diameter of opening [cm]
T	=	Temperature [K]
P	=	Pressure [torr]

The EPA Mass Transfer Coefficient Model estimates releases to air from the evaporation of a chemical from an open, exposed liquid surface. 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 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.

$$G_{activity} = \frac{(1.93 \times 10^{-7}) \times (MW_{DIBP}^{0.78}) \times F_{correction_factor} \times VP \times Rate_{air_speed}^{0.78} \times (0.25\pi D_{opening}^2)^3 \sqrt{\frac{1}{29} + \frac{1}{MW_{DIBP}}}}{T^{0.4} D_{opening}^{0.11} (\sqrt{T} - 5.87)^{2/3}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity [g/s]
MW_{DIBP}	=	DIBP molecular weight [g/mol]
$F_{correction_factor}$	=	Vapor pressure correction factor [unitless]
VP	=	DIBP 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. 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.

$$G_{activity} = \frac{F_{saturation_factor} \times MW_{DIBP} \times V_{container} \times 3785.4 \frac{cm^3}{gal} \times F_{correction_factor} \times VP \times \frac{RATE_{fill}}{3600 \frac{s}{hr}}}{R \times T}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity [g/s]
$F_{saturation_factor}$	=	Saturation factor [unitless]
MW_{DIBP}	=	DIBP molecular weight [g/mol]
$V_{container}$	=	Volume of container [gal/container]
$F_{correction_factor}$	=	Vapor pressure correction factor [unitless]
VP	=	DIBP vapor pressure [torr]
$RATE_{fill}$	=	Fill rate of container [containers/hr]
R	=	Universal gas constant [L×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 DIBP 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 DIBP in the liquid of interest. Using the mass fraction of DIBP 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 DIBP, 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 DIBP, the mass fraction of DIBP will be an overestimate of the mole fraction. If other components in the liquid of interest have much higher molecular weights than DIBP, the mass fraction of DIBP 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, Equation_Apx D-3) is then used along with an operating time to calculate the release amount:

Equation_Apx D-4.

$$Release_Year_{activity} = Time_{activity} \times G_{activity} \times 3600 \frac{s}{hr} \times 0.001 \frac{kg}{g}$$

Where:

$Release_Year_{activity}$	=	DIBP released for activity per site-year [kg/site-yr]
$Time_{activity}$	=	Operating time for activity [hr/site-yr]
$G_{activity}$	=	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 Small Container Residual Model

- EPA Drum Residual Model
- EPA Bulk Transport Residual Model
- EPA Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders
- EPA Multiple Process Vessel Residual Model
- EPA Single Process Vessel Residual Model
- EPA 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 DIBP for the given process. 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.

$$Release_Year_{activity} = PV \times F_{activity_loss}$$

Where:

$Release_Year_{activity}$	=	DIBP released for activity per site-year [kg/site-yr]
PV	=	Production volume throughput of DIBP [kg/site-yr]
$F_{activity_loss}$	=	Loss fraction for activity [unitless]

The EPA 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 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 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, 2021c](#)):

Equation_Apx D-6.

$$E_{local_dust_not_captured} = E_{local_dust_generation} \times (1 - F_{dust_capture})$$

Where:

$E_{local_dust_not_captured}$	=	Daily amount emitted from transfers/unloading that is not captured [kg not captured/site-day]
$E_{local_dust_generation}$	=	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

$$Elocal_{dust_cap_uncontrol} = Elocal_{dust_generation} \times F_{dust_capture} \times (1 - F_{dust_control})$$

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

$$Elocal_{dust_cap_control} = Elocal_{dust_generation} \times F_{dust_capture} \times F_{dust_control}$$

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]

The EPA Mass Balance Inhalation Model estimates a worker inhalation exposure to an estimated concentration of chemical vapors within the worker's breathing zone using a one box model. The model estimates the amount of chemical inhaled by a worker during an activity in which the chemical has volatilized and the airborne concentration of the chemical vapor is estimated as a function of the source vapor generation rate or the saturation level of the chemical in air. First, the applicable vapor generation rate model (Equation_Apx D-1, Equation_Apx D-2, Equation_Apx D-3) is used to calculate the vapor generation rate for the given activity. With this vapor generation rate, the EPA Mass Balance Inhalation Model calculates the volumetric concentration of DIBP using the following equation:

Equation_Apx D-9.

$$Cv_{activity} = Minimum: \left\{ \begin{array}{l} \left[\frac{170,000 \times T \times G_{activity}}{MW_{DIBP} \times Q \times k} \right] \\ \left[\frac{1,000,000 ppm \times F_{correction_factor} \times VP}{P} \right] \end{array} \right.$$

Where:

$Cv_{activity}$	=	Exposure activity volumetric concentration [ppm]
$G_{activity}$	=	Exposure activity vapor generation rate [g/s]
MW_{DIBP}	=	DIBP molecular weight [g/mol]
Q	=	Ventilation rate [ft ³ /min]
k	=	Mixing factor [unitless]
T	=	Temperature [K]
$F_{correction_factor}$	=	Vapor pressure correction factor [unitless]
VP	=	DIBP vapor pressure [torr]
P	=	Pressure [torr]

Mass concentration can be estimated by multiplying the volumetric concentration by the molecular weight of DIBP and dividing by molar volume at standard temperature and pressure.

EPA uses the above equations in the DIBP environmental release and occupational exposure models, and EPA references the model equations by model name and/or equation number within Appendix D.

D.2 Manufacturing Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the manufacturing OES. This approach utilizes the ESD on the Chemical Industry ([OECD, 2011c](#)) and CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on ESD on the Chemical Industry ([OECD, 2011c](#)), EPA identified the following release sources from manufacturing operations:

- Release source 1: Vented Losses to Air During Reaction/Separations/Other Process Operations.
- Release source 2: Process Waste from Reaction/Separations/Other Process Operations.
- Release source 3: Product Sampling Wastes.
- Release source 4: Open Surface Losses to Air During Product Sampling.
- Release source 5: Equipment Cleaning Wastes.
- Release source 6: Open Surface Losses to Air During Equipment Cleaning.
- Release source 7: Transfer Operation Losses to Air from Packaging Manufactured DIBP into Transport Containers.

Environmental releases for DIBP during manufacturing are a function of DIBP'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, DIBP concentration, 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 Section D.2.2. The Monte Carlo simulation calculated the total DIBP 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-10	$Q_{DIBP_day}; F_{DIBP_SPERC}$
Release source 2: Process Waste from Reaction/Separations/Other Process Operations.	See Equation_Apx D-11	$Q_{DIBP_day}; WS_{DIBP}$
Release source 3: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Section D.1)	$Q_{DIBP_day}; LF_{sampling}$
Release source 4: Open Surface Losses to Air During Product Sampling.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP}; MW; VP; RATE_{air_speed}; D_{sampling}; T; P$ Operating Time: $OH_{sampling}$
Release source 5: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model (Section D.1)	$Q_{DIBP_day}; LF_{equip_clean}$
Release source 6: Open Surface Losses to Air During Equipment Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP}; MW; VP; RATE_{air_speed}; D_{equip_clean}; T; P$ Operating Time: OH_{equip_clean}
Release source 7: Transfer Operation Losses to Air from Packaging Manufactured DIBP into Transport Containers.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: $F_{DIBP}; VP; f_{sat}; MW; R; T; RATE_{fill_drum}$ Operating Time: $N_{prodcont_yr}; RATE_{fill_cont}; RATE_{fill_drum}; OD$

Release source 1 daily release (Vented Losses to Air During Reaction/Separations/Other Process Operations) is calculated using the following equation:

Equation_Apx D-10.

$$Release_perDay_{RP1} = Q_{DIBP_day} \times F_{DIBP_SPERC}$$

Where:

$$\begin{aligned}
 Release_perDay_{RP1} &= \text{DIBP released for release source 1 [kg/site-day]} \\
 Q_{DIBP_day} &= \text{Facility throughput of DIBP [kg/site-day]} \\
 F_{DIBP_SPERC} &= \text{Loss fraction for unit operations [unitless]}
 \end{aligned}$$

Release source 2 daily release (Process Waste from Reaction/Separations/Other Process Operations) is calculated using the following equation:

Equation_Apx D-11

$$Release_perDay_{RP2} = Q_{DIBP_day} \times \frac{WS_{DIBP}}{1000}$$

Where:

$Release_perDay_{RP2}$	=	DIBP released for release source 2 [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
WS_{DIBP}	=	Water solubility for DIBP [g/L]

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	PV	kg/site-yr	1.8E05	—	—	—	—	See Section D.2.4
Manufactured DIBP Concentration	F _{DIBP}	kg/kg	—	0.9	1	—	Uniform	See Section D.2.7
Air Speed	RATE _{air_speed}	ft/min	19.7	2.6	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	55	20	100	55	Triangular	See Section D.2.11
Fraction of DIBP Lost During Sampling (Q _{DIBP_day} 200-5000 kg/site-day)	F _{sampling}	kg/kg	4.0E-03	5.0E-04	4.0E-03	4.0E-03	Triangular	See Section D.2.12
Operating Days	OD	days/year	250	—	—	—	—	See Section D.2.13
Vapor Pressure at 25C	VP	mmHg	4.8E-05	—	—	—	—	Physical property
Vapor Pressure at 140F	VP ₁₄₀	mmHg	2.6E-03	—	—	—	—	Physical property
Vapor Pressure at 250F	VP ₂₅₀	mmHg	0.50	—	—	—	—	Physical property
Vapor Pressure at 375F	VP ₃₇₅	mmHg	37	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	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	
Process Operation Emission Factor	$F_{\text{DIBP_SPERC}}$	kg/kg	1.0E-05	—	—	—	—	See Section D.2.14
Equipment Cleaning Loss Fraction	$LF_{\text{equip_clean}}$	kg/kg	2.0E-02	—	—	—	—	See Section D.2.15
Drum Fill Rate	$RATE_{\text{fill_drum}}$	drums/hr	20	—	—	—	—	See Section D.2.16
Water Solubility of DIBP	WS_{DIBP}	g/L	6.2E-03	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property

D.2.3 Number of Sites

EPA used 2020 CDR data ([U.S. EPA, 2020a](#)) to identify the number of sites that manufacture DIBP. In CDR, only one site reported domestic manufacturing of DIBP, Lanxess Corporation in Greensboro, NC. Therefore, EPA used one site for the release modeling.

D.2.4 Throughput Parameters

EPA used 2020 CDR data ([U.S. EPA, 2020a](#)) to identify annual facility PV. Lanxess Corporation reported 184,750 kg/site-year of DIBP manufactured.

The daily throughput of DIBP is calculated using Equation_Apx D-12 by dividing the annual PV by the number of operating days. The number of operating days is determined according to Section D.2.13.

Equation_Apx D-12.

$$Q_{DIBP_day} = \frac{PV}{OD}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
PV	=	Annual production volume [kg/site-yr]
OD	=	Operating days (see Section D.2.13) [days/year]

D.2.5 Number of Containers Per Year

The number of product containers filled with manufactured DIBP per year is calculated using the following equation:

Equation_Apx D-13.

$$N_{drum_load_yr} = \frac{PV}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{drum}}$$

Where:

$N_{drum_load_yr}$	=	Annual number of containers loaded [container/site-year]
PV	=	Facility production rate (see Section D.2.4) [kg/site-year]
RHO	=	DIBP density [kg/L]
V_{drum}	=	Product container volume (see Section D.2.11) [gal/container]

D.2.6 Operating Hours

EPA estimated operating hours using the ChemSTEER User Guide ([U.S. EPA, 2015](#)) and through calculation from other parameters, as discussed below for the relevant release points.

For product sampling (release point 4), the ChemSTEER User Guide provides an estimate of one hour per day for product sampling ([U.S. EPA, 2015](#)).

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](#)).

The operating hours for loading of DIBP into transport containers (release point 7) is calculated based on the number of product containers filled at the site and the fill rate using the following equation:

Equation_Apx D-14.

$$OH_{RP7} = \frac{N_{drum_load_yr}}{RATE_{fill_drum} \times OD}$$

Where:

OH_{RP7}	=	Operating time for release point 7 [hrs/site-day]
$N_{drum_load_yr}$	=	Annual number of product containers loaded (see Section D.2.5) [containers/site-year]
$RATE_{fill_drum}$	=	Fill rate of drums (see Section D.2.16) [containers/hr]
OD	=	Operating days (see Section D.2.13) [days/site-year]

D.2.7 Manufactured DIBP Concentration

EPA used the manufactured concentration range reported in CDR ([U.S. EPA, 2020a](#)) to make a uniform distribution of 90 to 100 percent DIBP.

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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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

EPA assumed that manufactured DIBP was packaged into drums, based on the reported PV of 184,750 kg/site-year. 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.

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, 2023c](#)). 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 (~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
$\geq 5,000$	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 Section D.2.4.

D.2.13 Operating Days

EPA was unable to identify DIBP-specific information for manufacturing operating days. Therefore, EPA assumes a constant value of 250 days/year, which assumes the manufacturing facility operates 5 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). DIBP has a vapor pressure of $4.8E-05$ mmHg at room temperature, with increased vapor pressure at elevated temperatures. ESIG's Specific Environmental Release Category for Industrial Substance Manufacturing (solvent-borne) states that a chemical with a vapor pressure <1 Pa ($7.5E-03$ mmHg) will have an emission factor of $1E-05$ (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 Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA 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.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 100 gallons of liquid.

D.3 Repackaging into Large and Small Containers Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the repackaging OES. This approach utilizes the GS for Chemical Repackaging (U.S. EPA, 2022) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the GS, EPA identified the following release sources from repackaging operations:

- Release source 1: Transfer Operation Losses to Air from Unloading DIBP.

- Release source 2: Product Sampling Wastes.
- Release source 3: Container Residue.
- Release source 4: Open Surface Losses to Air During Container Cleaning.
- Release source 5: Equipment Cleaning Wastes.
- Release source 6: Open Surface Losses to Air During Equipment Cleaning.
- Release source 7: Transfer Operation Losses to Air from Loading of DIBP.

Environmental releases for DIBP during repackaging are a function of DIBP'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: operating days, 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 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 Section D.3.2. The Monte Carlo simulation calculated the total DIBP 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: Transfer Operation Losses to Air from Unloading DIBP.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: F_{DIBP} ; VP ; f_{sat} ; MW ; R ; T ; V_{tote} ; $RATE_{fill_tote}$ Operating Time: $N_{tote_unload_yr}$; $RATE_{fill_tote}$; OD
Release source 2: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Section D.1)	Q_{DIBP_day} ; $LF_{sampling}$
Release source 3: Container Residue.	EPA Bulk Transport Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{bulk}
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP} ; MW ; VP ; $RATE_{air_speed}$; $D_{container}$; T ; P Operating Time: $N_{tote/drum_unload_yr}$; $RATE_{fill_tote}$; OD
Release source 5: Equipment Cleaning Wastes	EPA Multiple Process Vessel Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{equip_clean}
Release source 6: Open Surface Losses to Air During Equipment Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP} ; MW ; VP ; $RATE_{air_speed}$; D_{equip_clean} ; T ; P Operating Time: OH_{equip_clean}

Release source	Model(s) Applied	Variables Used
Release source 7: Transfer Operation Losses to Air from Loading of DIBP.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: F_{DIBP} ; VP ; f_{sat} ; MW ; R ; T ; V_{drum} ; $RATE_{fill_drum}$ Operating Time: $N_{drum_load_yr}$; $RATE_{fill_drum}$; OD

D.3.2 Model Input Parameters

Table_Apx D-5 summarizes the model parameters and their values for the Repackaging into Large and Small Containers 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 Repackaging 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	45,359	—	—	—	—	See Section D.3.4
Annual Use Rate of DIBP	$Q_{DIBP_site_year}$	kg/site-yr	7,000	1	315,479	7,000	Triangular	See Section D.3.4
Operating Days	OD	days/year	260	174	260	—	Discrete	See Section D.3.7
Manufactured DIBP Concentration	F_{DIBP}	kg/kg	1	—	—	—	—	See Section D.3.8
Air Speed	$RATE_{air_speed}$	ft/min	19.7	2.56	398	—	Lognormal	See Section D.3.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.3.10
Drum Size	V_{drum}	gal	55	20	100	55	Triangular	See Section D.3.11
Tote Size	V_{tote}	gal	550	100	1000	550	Triangular	See Section 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 Section D.3.12
Fraction of DIBP Lost During Sampling – 1 ($Q_{DIBP_day} < 50$ kg/site-day)	$F_{sampling_1}$	kg/kg	$2.0E-02$	$2.0E-03$	$2.0E-02$	$2.0E-02$	Triangular	See Section D.3.13
Fraction of DIBP Lost During Sampling – 2 ($Q_{DIBP_day} 50-200$ kg/site-day)	$F_{sampling_2}$	kg/kg	$5.0E-03$	$6.0E-04$	$5.0E-03$	$5.0E-03$	Triangular	See Section D.3.13
Fraction of DIBP Lost During Sampling – 3 ($Q_{DIBP_day} 200-5000$ kg/site-day)	$F_{sampling_3}$	kg/kg	$4.0E-03$	$5.0E-04$	$4.0E-03$	$4.0E-03$	Triangular	See Section D.3.13
Fraction of DIBP Lost During Sampling – 4 ($Q_{DIBP_day} > 5000$ kg/site-day)	$F_{sampling_4}$	kg/kg	$4.0E-04$	$8.0E-05$	$4.0E-04$	$4.0E-04$	Triangular	See Section D.3.13
Diameter of Opening – Container Cleaning	$D_{container}$	cm	5.08	—	—	—	—	See Section D.3.14
Diameter of Opening for Equipment Cleaning	D_{equip_clean}	cm	92	—	—	—	—	See Section D.3.14
Vapor Pressure at 25C	VP	mmHg	$4.76E-05$	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	2.0E-02	—	—	—	—	See Section D.3.15
Drum Fill Rate	RATE _{fill_drum}	drums/hr	20	—	—	—	—	See Section D.3.16
Tote Fill Rate	RATE _{fill_tote}	totes/hr	20	—	—	—	—	See Section D.3.16
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property

D.3.3 Number of Sites

In the 2016 CDR, one site, Sika Corp in Lyndhurst, NJ, reported repackaging of DIBP but their production volume was withheld ([U.S. EPA, 2019a](#)). EPA estimated the production volume for this site and any additional smaller repackaging sites that were not required to report to CDR based on the upper threshold for CDR reporting of 100,000 lb (43,359 kg) irrespective of sales. This estimation accounts for the potential operation of smaller DIBP repackaging sites that do not exceed the CDR reporting threshold requirements in addition to the known repackaging site. The estimated production volume for repackaging DIBP was 45,359 kg/year.

EPA estimated the number of theoretical sites that repackage DIBP, including the site identified in the 2016 CDR, using Equation_Apx D-15 by dividing the production volume by the annual facility throughput.

Equation_Apx D-15.

$$N_s = \frac{PV}{Q_{DIBP_site_yr}}$$

Where:

N_s	=	Number of sites [sites]
PV	=	Annual production volume [kg/site-yr]
$Q_{DIBP_site_yr}$	=	Annual facility throughput of DIBP (Section D.3.4) [kg/site-day]

D.3.4 Throughput Parameters

EPA estimated the annual facility throughput using the Chemical Repackaging GS ([U.S. EPA, 2022](#)). The GS estimates chemicals are repackaged at rates ranging from 1 to 315,479 kg/site-year, with a 50th percentile value of 7,000 kg/site-year. EPA estimated the annual facility throughput using a triangular distribution of 1 to 315,479 kg/site-year with a mode of 7,000 kg/site-year.

The daily throughput of DIBP is calculated using Equation_Apx D-16 by dividing the annual facility throughput by the number of operating days. The number of operating days is determined according to Section D.3.7.

Equation_Apx D-16.

$$Q_{DIBP_site_day} = \frac{Q_{DIBP_site_yr}}{OD}$$

Where:

$Q_{DIBP_site_day}$	=	Facility throughput of DIBP [kg/site-day]
$Q_{DIBP_site_yr}$	=	Annual facility throughput of DIBP [kg/site-yr]
OD	=	Operating days (see Section D.3.7) [days/year]

D.3.5 Number of Containers per Year

The number of totes unloaded and repackaged into drums per site per year is calculated using the following equation:

Equation_Apx D-17

$$N_{tote_unload_yr} = \frac{Q_{DIBP_site_yr}}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{tote}}$$

Where:

$N_{tote_unload_yr}$	=	Annual number of totes unloaded [tote/site-year]
$Q_{DIBP_site_yr}$	=	Annual facility throughput of DIBP (see Section D.3.4) [kg/site-yr]
RHO	=	DIBP density [kg/L]
V_{tote}	=	Tote container volume (see Section D.3.11) [gal/container]

The number of drums of repackaged DIBP loaded per site per year is calculated using the following equation:

Equation_Apx D-18

$$N_{drum_load_yr} = \frac{Q_{DIBP_site_yr}}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{drum}}$$

Where:

$N_{drum_load_yr}$	=	Annual number of drums loaded [drum/site-year]
$Q_{DIBP_site_yr}$	=	Annual facility throughput of DIBP (see Section D.3.4) [kg/site-yr]
RHO	=	DIBP density [kg/L]
V_{drum}	=	Drum container volume (see Section D.3.11) [gal/container]

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.

For unloading and container cleaning (release points 1 and 4), the operating hours are calculated based on the number of totes unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-19.

$$OH_{RP1/RP4} = \frac{N_{tote_unload_yr}}{RATE_{fill_tote} \times OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 [hrs/site-day]
$N_{tote_unload_yr}$	=	Annual number of totes unloaded (see Section D.3.5) [tote/site-year]
$RATE_{fill_tote}$	=	Fill rate of totes (see Section D.3.16) [containers/hr]
OD	=	Operating days (see Section D.3.7) [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 loading into transport containers (release point 7), the operating hours are calculated based on the number of product containers filled per year. The operating hours are calculated using the following equation:

Equation_Apx D-20.

$$OH_{RP7} = \frac{N_{drum_load_yr}}{RATE_{fill_drum} \times OD}$$

Where:

OH_{RP7}	=	Operating time for release point 7 [hrs/site-day]
$N_{drum_load_yr}$	=	Annual number of drums loaded (see Section D.3.5) [drum/site-year]
$RATE_{fill_drum}$	=	Fill rate of drums (see Section D.3.16) [containers/hr]
OD	=	Operating days (see Section D.3.7) [days/site-year]

D.3.7 Operating Days

EPA assessed the number of operating days associated with 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](#)). Therefore, dividing this time by an assumed working duration of 8 to 12 hours/day yields a number of operating days between 174 to 260 days/year. In order to account for differences in operating days, EPA assumed three types of shift durations with corresponding operating days per year: 8-hour, 10-hour, 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 Manufactured DIBP Concentration

In the 2020 CDR, one site, Sika Corp in Lyndhurst, NJ, reported the concentration of DIBP as greater than 90 percent. EPA assumed repackaging of neat DIBP, or 100 percent DIBP to model this parameter.

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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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

EPA assessed incoming containers as totes that were repackaged into drums. The container sizes for totes and drums are based on the ChemSTEER User Guide ([U.S. EPA, 2015](#)). Totes are defined as containing between 100 and 1,000 gallons, with a default of 550 gallons. Therefore, EPA modeled tote size using a triangular distribution with a lower bound of 100 gallons, an upper bound of 1,000 gallons, and a mode of 550 gallons. Drums are defined as containing between 20 and 100 gallons of liquid, and the default drum size is 55 gallons. 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.

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 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 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 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, 2023c](#)). 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 LVE). Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites (~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-6 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-6. 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 Section D.3.4

D.3.14 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](#)).

D.3.15 Equipment Cleaning Loss Fraction

EPA used the EPA 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.3.16 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 liquid.

D.4 Incorporation into Adhesives and Sealants Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the incorporation into formulation, mixture, or reaction product – incorporation into adhesives and sealants OES. This approach utilizes the Emission Scenario Document on Adhesive Formulation ([OECD, 2009a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD, EPA identified the following release sources from incorporation into adhesives and sealants:

- Release source 1: Transfer Operation Losses to Air from Unloading Adhesive Component.
- Release source 2: Dust Generation from Transfer Operations.
- Release source 3: Adhesive Component Container Residue Losses.
- Release source 4: Open Surface Losses to Air During Container Cleaning.
- Release source 5: Vented Losses During Dispersion and Blending/Process Operations.
- Release source 6: Product Sampling Wastes.
- Release source 7: Open Surface Losses to Air During Product Sampling.
- Release source 8: Equipment Cleaning Wastes.
- Release source 9: Open Surface Losses to Air During Equipment Cleaning.
- Release source 10: Transfer Operations Losses to Air for Packaging Adhesive/Sealant into Transport Containers.
- Release source 11: Off-Specification and Other Waste Adhesive.

Environmental releases for DIBP during incorporation into adhesives and sealants are a function of DIBP'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, DIBP concentrations, air speed, saturation factor, container size, loss fractions, diameters of openings, 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-7 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 incorporation 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 Section D.4.2. The Monte Carlo simulation calculated the total DIBP 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-7. Models and Variables Applied for Release Sources in the Incorporation into Adhesives and Sealants OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses to Air from Unloading the Adhesive Component	EPA/OAQPS AP-42 Loading Model (Section D.1)	$F_{DIBP_feed}; f_{sat}; MW; R; T; V_{cont};$ $RATE_{fill_drum_tote}$ Operating Time: $N_{cont_unload_yr};$ $RATE_{fill_drum_tote}; OD$
Release source 2: Dust Generation from Transfer Operations.	Not Assessed for liquid DIBP.	N/A
Release source 3: Container Cleaning Wastes.	EPA Drum Residual Model (Section D.1)	$Q_{DIBP_year}; LF_{drum}; V_{cont}; RHO; OD$
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_feed}; MW;$ $VP; RATE_{air_speed}; D_{cont_clean}; T; P; OD$ Operating Time: $N_{cont_unload_yr};$ $RATE_{fill_drum_tote}; OD$
Release source 5: Vented Losses to Air During Dispersion and Blending.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_final}; MW;$ $VP; RATE_{air_speed}; D_{blend}; T; P; OD$ Operating Time: OH_{blend}
Release source 6: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Section D.1)	$Q_{DIBP_day}; LF_{sampling}$
Release source 7: Open Surface Losses to Air During Product Sampling.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_final}; MW;$ $VP; RATE_{air_speed}; D_{sampling}; T; P$ Operating Time: $OH_{sampling}$
Release source 8: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model (Section D.1)	$Q_{DIBP_day}; LF_{equip_clean}$
Release source 9: Open Surface Losses to Air During Equipment Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_final}; MW;$ $VP; RATE_{air_speed}; D_{equip_clean}; T; P$ Operating Time: OH_{equip_clean}
Release source 10: Transfer Operation Losses to Air from Packaging Adhesive/ Sealant into Transport Containers.	EPA/OAQPS AP-42 Loading Model (Section D.1)	$F_{DIBP_final}; VP; f_{sat}; MW; R; T;$ $V_{cont_packaged}; RATE_{fill_cont}$ Operating Time: $N_{cont_load_yr};$ $RATE_{fill_cont}; OD$
Release source 11: Off-Spec and Other Waste Adhesive.	See Equation_Apx D-21	$Q_{DIBP_day}; LF_{offspec}$

Release source 11 daily release (Off-Spec and Other Waste Adhesive) is calculated using the following equation:

Equation_Apx D-21.

$$Release_perDay_{RP11} = Q_{DIBP_day} \times LF_{offspec}$$

Where:

$Release_perDay_{RP11}$	=	DIBP released for release source 11 [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
$LF_{offspec}$	=	Loss fraction for off-spec and waste adhesive [unitless]

D.4.2 Model Input Parameters

Table_Apx D-8 summarizes the model parameters and their values for the Incorporation 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-8. Summary of Parameter Values and Distributions Used in the Incorporation 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 DIBP	PV _{total}	kg/year	3,694	—	—	—	—	See Section D.4.4
Feed DIBP Concentration	F _{DIBP_feed}	kg/kg	1	0.9	1	—	Uniform	See Section D.4.7
Final DIBP Concentration	F _{DIBP_final}	kg/kg	0.3	1.0E-03	0.75	0.3	Triangular	See Section D.4.8
Air Speed	RATE _{air_speed}	ft/min	19.7	2.56	398	—	Lognormal	See Section D.4.9
Saturation Factor	f _{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.4.10
Feed Container Size	V _{cont}	gal	55	20	100	55	Triangular	See Section D.4.11
Packaged Container Size	V _{cont_packaged}	gal	1	0.10	20	1	Triangular	See Section D.4.11
Drum Residual Loss Fraction	LF _{drum}	kg/kg	3.0E-03	3.0E-04	6.0E-03	3.0E-03	Triangular	See Section D.4.12
Fraction of DIBP Lost During Sampling – 1 (Q _{DIBP_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.4.13
Fraction of DIBP Lost During Sampling – 2 (Q _{DIBP_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.4.13
Fraction of DIBP Lost During Sampling – 3 (Q _{DIBP_day} 200-5000 kg/site-day)	F _{sampling_3}	kg/kg	4.0E-03	5.0E-04	4.0E-03	4.0E-03	Triangular	See Section D.4.13
Fraction of DIBP Lost During Sampling – 4 (Q _{DIBP_day} > 5000 kg/site-day)	F _{sampling_4}	kg/kg	4.0E-04	8.0E-5	4.0E-04	4.0E-04	Triangular	See Section D.4.13
Diameter of Opening-Blending	D _{blend}	cm	10	10	169	—	Uniform	See Section D.4.14
Diameter of Opening – Sampling	D _{sampling}	cm	2.5	2.5	10	—	Uniform	See Section D.4.14

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Diameter of Opening – Container Cleaning	D _{cont_clean}	cm	5.08	—	—	—	—	See Section D.4.14
Diameter of Opening – Equipment Cleaning	D _{equip_clean}	cm	92	—	—	—	—	See Section D.4.14
Hours per Batch for Equipment Cleaning	OH _{batch_equip_clean}	hours/batch	3	1	4	3	Triangular	See Section D.4.6
Vapor Pressure at 25C	VP	mmHg	4.76E-05	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Operating Days	OD	days/year	250	—	—	—	—	See Section D.4.15
Batch Size	Q _{batch}	kg/batch	4,000	—	—	—	—	See Section D.4.16
Drum and Tote Fill Rate	RATE _{fill_drum_tote}	containers/hr	20	—	—	—	—	See Section D.4.17
Small Container Fill Rate	RATE _{fill_cont}	containers/hr	60	—	—	—	—	See Section D.4.17
Sampling Duration	OH _{sampling}	hr/day	1	—	—	—	—	See Section D.4.6
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	2.0E-02	—	—	—	—	See Section D.4.18
Off-Spec and Waste Loss Fraction	LF _{offspec}	kg/kg	1.0E-02	—	—	—	—	See Section D.4.19

D.4.3 Number of Sites

In 2016 CDR, only one site, Sika Corp in Lyndhurst, NJ, reported adhesives manufacturing, but listed the PV as CBI ([U.S. EPA, 2021a](#)). In the 2020 CDR, Sika Corp did not report adhesives manufacturing ([U.S. EPA, 2020a](#)). EPA assessed one total site for the incorporation into adhesives and sealants manufacturing.

D.4.4 Throughput Parameters

EPA estimated the total production volume for the one known site as a deterministic value of 3,694 kg/year. The production volume is based on CDR data ([U.S. EPA, 2020a](#)) and the 2003 Danish EPA Restriction Report on DIBP ([ECHA, 2011](#)). The Danish EPA estimated that six percent of the DIBP produced goes to non-polymer end use categories. EPA split this production volume percentage evenly between three DIBP uses, adhesive and sealant manufacturing, paints and coatings manufacturing, and incorporation into other formulations mixtures or reaction products. CDR states that the total U.S. national production volume of DIBP is 407,303 lbs/year. Multiplying this value by two percent results in 8,146 lbs/year (3,694 kg/year). The annual throughput of DIBP is equal to the total production volume for the one known site.

The daily throughput of DIBP is calculated using Equation_Apx D-22 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section D.4.15.

Equation_Apx D-22.

$$Q_{DIBP_day} = \frac{Q_{DIBP_year}}{OD}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
OD	=	Operating days (see Section D.4.15) [days/year]

D.4.5 Number of Containers per Year

The number of DIBP raw material containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-23.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{cont}}$$

Where:

$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.4.4) [kg/site-yr]
RHO	=	DIBP density [kg/L]
V_{cont}	=	Feed container volume (see Section D.4.11) [gal/container]

The number of product containers loaded by a site per year is calculated using the following equation:

Equation_Apx D-24.

$$N_{cont_load_yr} = \frac{Q_{DIBP_year}}{RHO * \left(3.79 \frac{L}{gal}\right) * V_{cont_packaged} * F_{DIBP_final}}$$

Where:

$N_{cont_load_yr}$	=	Annual number of containers loaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.4.4) [kg/site-yr]
RHO	=	DIBP density [kg/L]
$V_{cont_packaged}$	=	Product container volume (see Section D.4.11) [gal/container]
F_{DIBP_final}	=	Post-Formulation DIBP concentration [kg/kg]

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 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-25.

$$OH_{RP1/RP4} = \frac{N_{cont_unload_yr}}{RATE_{fill_drum_tote} \times OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 [hrs/site-day]
$N_{cont_unload_yr}$	=	Annual number of containers unloaded (see Section D.4.5) [container/site-year]
$RATE_{fill_drum_tote}$	=	Fill rate of drums and totes (see Section D.4.17) [containers/hr]
OD	=	Operating days (see Section D.4.15) [days/site-year]

For blending/process operations (release point 5), the ESD for Adhesive Formulation ([OECD, 2009a](#)) recommends using the following equation:

Equation_Apx D-26.

$$OH_{RP5} = \left(\frac{Q_{DIBP_year}}{Q_{batch} * OD} \right) \times 8 \frac{hrs}{day}$$

Where:

OH_{RP5}	=	Operating time for release point 5 [hrs/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.4.4) [kg/site-yr]
Q_{batch}	=	Average batch size (see Section D.4.16) [kg/batch]
OD	=	Operating days (see Section D.4.15) [days/site-year]

For product sampling (release point 7), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) indicates a value of 1 hour/day.

For equipment cleaning (release point 9), the ESD for Adhesive Formulation ([OECD, 2009a](#)) provides an estimate of four hours per batch based on the value for cleaning multiple vessels from the ChemSTEER User Guide ([U.S. EPA, 2015](#)). The ESD for Adhesive Formulation also states that a case study conducted by the Pollution Prevention Assistance Division indicated a range of equipment cleaning times between one and three hours per batch. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on a lower bound, upper bound, and mode for equipment cleaning operating hours. EPA assigned the lower bound as one hour based on the lower end cleaning time observed in the case study ([OECD, 2009a](#)) and the upper bound as four hours based on the ChemSTEER User Guide default value for this worker activity. For the mode, EPA assigned three hours based on the ESD for Adhesive Formulation ([OECD, 2009a](#)). EPA calculated the equipment cleaning operating hours using the following equation:

Equation_Apx D-27.

$$OH_{RP9} = \left(\frac{Q_{DIBP_year}}{Q_{batch} \times OD} \right) \times OH_{batch_equip_clean}$$

Where:

OH_{RP9}	=	Operating time for release point 9 [hrs/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.4.4) [kg/site-yr]
Q_{batch}	=	Average batch size (see Section D.4.16) [kg/batch]
OD	=	Operating days (see Section D.4.15) [days/site-year]
$OH_{batch_equip_clean}$	=	Duration for batch equipment cleaning (see above) [hrs/batch]

For loading into transport containers (release point 10), 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-28.

$$OH_{RP10} = \begin{cases} \frac{N_{cont_load_yr}}{RATE_{fill_cont} \times OD}, & \frac{N_{cont_load_yr}}{RATE_{fill_cont} \times OD} \leq [24 - OH_{RP1/RP4}] \\ 24 - OH_{RP1/RP4}, & \frac{N_{cont_load_yr}}{RATE_{fill_cont} \times OD} > [24 - OH_{RP1/RP4}] \end{cases}$$

Where:

OH_{RP10}	=	Operating time for release point 10 [hrs/site-day]
$RATE_{fill_cont}$	=	Fill rate of containers (see Section D.4.17) [containers/hr]
$N_{cont_load_yr}$	=	Annual number of containers loaded (see Section D.4.5) [container/site-year]
OD	=	Operating days (see Section D.4.15) [days/site-year]
$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 [hrs/site-day]

D.4.7 Feed DIBP Concentration

EPA used the manufactured concentration range reported in CDR ([U.S. EPA, 2020a](#)) of 90 to 100 percent to make a uniform distribution.

D.4.8 Final DIBP Concentration

EPA modeled final, post-formulation, DIBP concentration in adhesives and sealants using a triangular distribution with a lower bound of 0.1 percent, upper bound of 75 percent, and mode of 30 percent. The assessed range is based on compiled SDS information for adhesives and sealant products containing DIBP. EPA did not have information on the prevalence or market share of different adhesive/sealant products in commerce; therefore, EPA assumed a triangular distribution of concentrations. From the compiled data, the minimum concentration was 0.1 percent, the maximum was 75 percent, and the mode of product concentrations was 30 percent (see Appendix E for EPA identified DIBP-containing products for this OES).

D.4.9 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.4.10 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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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.4.11 Container Size

EPA assumed that adhesive and sealant manufacturing sites would receive DIBP in drums. According to the ESD for Adhesive Formulation ([OECD, 2009a](#)), 55-gallon drums are expected to be the default container size for adhesives and sealant components. 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 the incoming 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.

For packaging of adhesives and sealants after formulation, EPA identified products in bottles as small as 0.1 gallons, and small containers. According to the ChemSTEER User Guide, bottles and small containers are defined as containing between 1 and 5 or 5 and 20 gallons of liquid respectively. The default container sizes are 1 and 5 gallons respectively ([U.S. EPA, 2015](#)). Therefore, EPA modeled finished adhesive container size using a triangular distribution with a lower bound of 0.1 gallons, an upper bound of 20 gallons, and a mode of 1 gallon based on the ChemSTEER user guide default for bottles.

D.4.12 Drum Residue Loss Fraction

For drums, 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 Drum 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 Drum 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 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 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 pouring.

D.4.13 Sampling Loss Fraction

Sampling loss fractions were estimated using the March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes ([U.S. EPA, 2023c](#)). 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% 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-9 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-9. 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.4.4.

D.4.14 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 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 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 Section D.4.16:

Equation_Apx D-29.

$$D_{blending_max} = \left[\frac{4 \times V_{batch} \times 3785.41 \frac{cm^3}{gal}}{\pi} \right]^{1/3}$$

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 and upper bound 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](#)).

For equipment cleaning operations, the ChemSTEER User Guide indicates a single default value of 92 cm ([U.S. EPA, 2015](#)).

D.4.15 Operating Days

EPA was unable to identify DIBP-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.4.16 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.4.17 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-30.

$$\text{if } 24 < (OH_{RP1/RP4} + OH_{RP10}), RATE_{fill_adjusted} = \frac{N_{cont_load_yr}}{(24 - OH_{RP1/RP4}) \times OD}$$

Where:

$RATE_{fill_adjusted}$	=	Corrected fill rate for product containers [containers/hr]
$N_{cont_load_yr}$	=	Annual number of product containers [containers/site-year]
OH_n	=	Operating time for release point “n” [hrs/site-day]
OD	=	Operating days [days/site-year]

D.4.18 Equipment Cleaning Loss Fraction

EPA used the EPA Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA 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.4.19 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 Incorporation into Paints and Coatings Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the incorporation into formulation, mixture, or reaction product – incorporation into paints and coatings OES. This approach utilizes the GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) 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 incorporation into paints and coatings:

- Release source 1: Transfer Operation Losses to Air from Unloading Paint Component.
- Release source 2: Dust Generation from Transfer Operations.
- Release source 3: Container Residue Wastes.
- Release source 4: Open Surface Losses to Air During Container Cleaning.
- Release source 5: Vented Losses to Air During Blending/Process Operations.
- Release source 6: Product Sampling Wastes.
- Release source 7: Open Surface Losses to Air During Product Sampling.
- Release source 8: Equipment Cleaning Wastes.
- Release source 9: Open Surface Losses to Air During Equipment Cleaning.
- Release source 10: Filter Waste Losses.
- Release source 11: Open Surface Losses to Air During Filter Media Replacement.
- Release source 12: Transfer Operation Losses to Air from Packaging Paint/Coating into Transport Containers.
- Release source 13: Off-Spec and Other Waste Paint/Coatings.

Environmental releases for DIBP during incorporation into paints and coatings are a function of DIBP'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, DIBP concentrations, air speed, saturation factor, container size, loss fractions, diameters of openings, 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-10 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 incorporation 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 Section D.5.2. The Monte Carlo simulation calculated the total DIBP 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-10. Models and Variables Applied for Release Sources in the Incorporation into Paints and Coatings OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses to Air from Unloading Paint Component.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: F_{DIBP_feed} ; VP ; f_{sat} ; MW ; R ; T ; V_{cont} ; $RATE_{fill_drum}$ Operating Time: Q_{DIBP_year} ; RHO ; V_{cont} ; $RATE_{fill_drum}$; OD
Release source 2: Dust Generation from Transfer Operations.	Not Assessed for liquid DIBP.	N/A
Release source 3: Container Residue Wastes.	EPA Drum Residual Model (Section D.1)	LF_{drum} ; V_{cont} ; Q_{DIBP_year} ; V_{cont} ; RHO ; OD
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP_feed} ; MW ; VP ; $RATE_{air_speed}$; D_{cont_clean} ; T ; P Operating Time: Q_{DIBP_year} ; RHO ; V_{cont} ; $RATE_{fill_drum}$; OD
Release source 5: Vented Losses to Air During Blending/Process Operations.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP_final} ; MW ; VP ; $RATE_{air_speed}$; D_{blend} ; T ; P Operating Time: OH_{blend} ; OD
Release source 6: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Section D.1)	Q_{DIBP_day} ; $LF_{sampling}$; OD
Release source 7: Open Surface Losses to Air During Product Sampling.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP_feed} ; MW ; VP ; $RATE_{air_speed}$; D_{cont_clean} ; T ; P Operating Time: $OH_{sampling}$
Release source 8: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{equip_clean} ; OD
Release source 9: Open Surface Losses to Air During Equipment Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP_final} ; MW ; VP ; $RATE_{air_speed}$; D_{equip_clean} ; T ; P Operating Time: $OH_{batch_equip_clean}$; Q_{DIBP_year} ; Q_{DIBP_batch} ; OD
Release source 10: Filter Waste Losses.	No available data or models for estimation.	N/A
Release source 11: Open Surface Losses to Air During Filter Media Replacement	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP_final} ; MW ; VP ; $RATE_{air_speed}$; D_{filter} ; T ; P Operating Time: OH_{filter} ; OD

Release Source	Model(s) Applied	Variables Used
Release source 12: Transfer Operation Losses to Air from Packaging Paint/Coating into Transport Containers.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: F_{DIBP_final} ; VP ; f_{sat} ; MW ; R ; T ; $V_{cont_packaged}$ Operating Time: Q_{DIBP_year} ; $V_{cont_packaged}$; $RATE_{fill_cont}$; RHO ; OD ; $RATE_{fill_adjusted}$; F_{DIBP_final}
Release source 13: Off-Spec and Other Waste Paint/Coating.	See Equation_Apx D-31	Q_{DIBP_day} ; $LF_{offspec}$

Release source 13 daily release (Off-Spec and Other Waste Paint/Coating) is calculated using the following equation:

Equation_Apx D-31.

$$Release_perDay_{RP13} = Q_{DIBP_day} \times LF_{offspec}$$

Where:

$Release_perDay_{RP13}$	=	DIBP released for release source 13 [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP (see Section D.5.4) [kg/site-day]
$LF_{offspec}$	=	Loss fraction for off-spec and waste adhesive (see Section D.5.19) [kg/kg]

D.5.2 Model Input Parameters

Table_Apx D-11 summarizes the model parameters and their values for the Incorporation 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-11. Summary of Parameter Values and Distributions Used in the Incorporation 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	
Total PV of DIBP	PV	kg/year	3,694	—	—	—	—	See Section D.5.4
Feed DIBP Concentration	F _{DIBP_feed}	kg/kg	1	0.9	1	—	Uniform	See Section D.5.7
Post-Formulation DIBP Concentration	F _{DIBP_final}	kg/kg	5.0E-02	1.0E-03	0.6	5.0E-03	Triangular	See Section D.5.8
Air Speed	RATE _{air_speed}	ft/min	19.7	2.56	398	—	Lognormal	See Section D.5.9
Saturation Factor	f _{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.5.10
Feed Container Size	V _{cont}	gal	55	20	100	55	Triangular	See Section D.5.11
Drum Residual Loss Fraction	LF _{drum}	kg/kg	3.0E-03	3.0E-04	6.0E-03	3.0E-03	Triangular	See Section D.5.12
Fraction of DIBP Lost During Sampling – 1 (Q _{DIBP_day} < 50 kg/site-day)	F _{sampling_1}	kg/kg	2.0E-02	—	—	—	—	See Section D.5.13
Fraction of DIBP Lost During Sampling – 2 (Q _{DIBP_day} 50-200 kg/site-day)	F _{sampling_2}	kg/kg	5.0E-03	—	—	—	—	See Section D.5.13
Fraction of DIBP Lost During Sampling – 3 (Q _{DIBP_day} 200-5000 kg/site-day)	F _{sampling_3}	kg/kg	4.0E-03	—	—	—	—	See Section D.5.13
Fraction of DIBP Lost During Sampling – 4 (Q _{DIBP_day} > 5000 kg/site-day)	F _{sampling_4}	kg/kg	4.0E-04	—	—	—	—	See Section D.5.13
Diameter of Opening-Blending	D _{blend}	cm	10	10	168.92	—	Uniform	See Section D.5.14
Diameter of Opening – Sampling	D _{sampling}	cm	2.5	2.5	10	—	Uniform	See Section D.5.14
Diameter of Opening – Container Cleaning	D _{cont_clean}	cm	5.08	—	—	—	—	See Section D.5.14

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Diameter of Opening – Equipment Cleaning	D _{equip_clean}	cm	92	—	—	—	—	See Section D.5.14
Diameter of Opening – Filter Media Replacement	D _{filter}	cm	182.4	—	—	—	—	See Section D.5.14
Hours per Batch for Equipment Cleaning	OH _{batch_equip_clean}	hours/batch	3	1	4	3	Triangular	See Section D.5.6
Packaged Container Size	V _{cont_packaged}	gal	1	0.10	20	1	Triangular	See Section D.5.11
Vapor Pressure at 25C	VP	mmHg	4.76E-05	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Operating Days	OD	days/year	250	—	—	—	—	See Section D.5.15
Drum Fill Rate	RATE _{fill_drum}	containers/hr	20	—	—	—	—	See Section D.5.17
Small Container Fill Rate	RATE _{fill_cont}	containers/hr	60	—	—	—	—	See Section D.5.17
Sampling Duration	OH _{sampling}	hr/day	1	—	—	—	—	See Section D.5.6
Filter Media Replacement Duration	OH _{filter}	hr/day	1	—	—	—	—	See Section D.5.6
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	2.0E-02	—	—	—	—	See Section D.5.18
Off-Spec and Waste Loss Fraction	LF _{offspec}	kg/kg	1.2E-02	—	—	—	—	See Section D.5.19

D.5.3 Number of Sites

No facilities reported manufacturing paints and coatings to the 2020 CDR ([U.S. EPA, 2020a](#)). EPA identified a total of five DIBP-containing paint and coatings products formulated by five different manufacturers (see Appendix E for EPA identified DIBP-containing products). Two of the five manufacturers (IKO PLC and ITW Plexus) maintain at least one plant in the United States. Therefore, EPA assessed the number of sites using a discrete distribution of one to two total sites, with equal probability of each.

D.5.4 Throughput Parameters

EPA estimated the total production volume for incorporation into paints and coatings as a deterministic value of 3,694 kg/year, as described previously in Section D.4.4. The annual throughput of DIBP is calculated using Equation_Apx D-32 by dividing total production volume by the number of sites.

Equation_Apx D-32.

$$Q_{DIBP_year} = \frac{PV}{Ns}$$

Where:

Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
PV	=	Production Volume (see above) [kg/site-yr]
Ns	=	Number of paint and coating manufacturing sites (see Section D.5.3) [sites]

The daily throughput of DIBP is calculated using Equation_Apx D-33 by dividing the annual facility throughput by the number of operating days. The number of operating days is determined according to Section D.5.15.

Equation_Apx D-33.

$$Q_{DIBP_day} = \frac{Q_{DIBP_year}}{OD}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
OD	=	Operating days (see Section D.5.15) [days/year]

D.5.5 Number of Containers per Year

The number of DIBP raw material containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-34.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{RHO * \left(3.79 \frac{L}{gal}\right) \times V_{cont} \times F_{DIBP_feed}}$$

Where:

$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.5.4) [kg/site-yr]

V_{cont}	=	Feed container volume (see Section D.5.11) [gal/container]
RHO	=	DIBP density [kg/L]
F_{DIBP_feed}	=	Feed DIBP concentration (see Section D.5.7) [kg/kg]

The number of product containers loaded by a site per year is calculated using the following equation:

Equation_Apx D-35.

$$N_{cont_load_yr} = \frac{Q_{DIBP_year}}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{cont_packaged} \times F_{DIBP_final}}$$

Where:

$N_{cont_load_yr}$	=	Annual number of containers loaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.5.4) [kg/site-yr]
$V_{cont_packaged}$	=	Product container volume (see Section D.5.11) [gal/container]
RHO	=	DIBP density [kg/L]
F_{DIBP_final}	=	Post-formulation DIBP concentration (see Section D.5.8) [kg/kg]

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 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-36.

$$OH_{RP1/RP4} = \frac{N_{cont_unload_yr}}{RATE_{fill_drum} \times OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 [hrs/site-day]
$N_{cont_unload_yr}$	=	Annual number of containers unloaded (see Section D.5.5) [container/site-year]
$RATE_{fill_drum}$	=	Fill rate of drums (see Section D.5.17) [containers/hr]
OD	=	Operating days (see Section D.5.15) [days/site-year]

For blending/process operations (release point 5), the ESD for Adhesive Formulation ([OECD, 2009a](#)) recommends using the following equation:

Equation_Apx D-37.

$$OH_{RP5} = \left(\frac{Q_{DIBP_year}}{Q_{batch} * OD} \right) * 8 \frac{hrs}{day}$$

Where:

OH_{RP5}	=	Operating time for release point 5 [hrs/site-day]
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Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.5.4) [kg/site-yr]
Q_{batch}	=	Average batch size (see Section D.5.16) [kg/batch]
OD	=	Operating days (see Section D.5.15) [days/site-year]

For product sampling (release point 7), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) indicates a value of one hour/day.

For equipment cleaning (release point 9), the GS for Formulation of Waterborne Coatings ([U.S. EPA, 2014a](#)) provides an estimate of four hours per batch based on the value for cleaning multiple vessels from the ChemSTEER User Guide ([U.S. EPA, 2015](#)). The ESD for Adhesive Formulation also states that a case study conducted by the Pollution Prevention Assistance Division indicated a range of equipment cleaning times between one and three hours per batch. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on a lower bound, upper bound, and mode for equipment cleaning operating hours. EPA assigned the lower bound as one hour based on the lower end cleaning time observed in the case study ([OECD, 2009a](#)) and the upper bound as four hours based on the ChemSTEER User Guide default value for this worker activity. For the mode, EPA assigned three hours based on the ESD for Adhesive Formulation ([OECD, 2009a](#)). EPA calculated the equipment cleaning operating hours using the following equation:

Equation_Apx D-38.

$$OH_{RP9} = \left(\frac{Q_{DIBP_year}}{Q_{batch} \times OD} \right) \times OH_{batch_equip_clean}$$

Where:

OH_{RP9}	=	Operating time for release point 9 [hrs/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.5.4) [kg/site-yr]
Q_{batch}	=	Average batch size (see Section D.5.16) [kg/batch]
OD	=	Operating days (see Section D.5.15) [days/site-year]
$OH_{batch_equip_clean}$	=	Batch duration for equipment cleaning [hrs/batch]

For filter media changeout (release point 11), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) indicates a single value of one hour/day.

For loading into transport containers (release point 12), 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-39.

$$OH_{RP12} = \begin{cases} \frac{N_{cont_load_yr}}{RATE_{fill_cont} \times OD}, & \frac{N_{cont_load_yr}}{RATE_{fill_cont} \times OD} \leq [24 - OH_{RP1/RP4}] \\ 24 - OH_{RP1/RP4}, & \frac{N_{cont_load_yr}}{RATE_{fill_cont} \times OD} > [24 - OH_{RP1/RP4}] \end{cases}$$

Where:

OH_n	=	Operating time for release point “n” [hrs/site-day]
$RATE_{fill_cont}$	=	Fill rate of containers, dependent on volume (see Section D.5.17)

		[containers/hr]
$N_{cont_load_yr}$	=	Annual number of containers loaded (see Section D.5.5)
		[container/site-year]
OD	=	Operating days (see Section D.5.15) [days/site-year]

D.5.7 Feed DIBP Concentration

EPA used the manufactured concentration range reported in CDR ([U.S. EPA, 2020a](#)) of 90 to 100 percent to make a uniform distribution.

D.5.8 Final DIBP Concentration

EPA modeled final, post-formulation DIBP concentration in paints and coatings using a triangular distribution with a lower bound of 0.1 percent, upper bound of 60 percent, and mode of 5 percent. This is based on compiled SDS information for paint and coating products containing DIBP. 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 DIBP-containing products for this OES).

D.5.9 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.5.10 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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA,](#)

[1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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.5.11 Container Size

EPA assumed that paint and coating manufacturing sites would receive DIBP 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.

For packaging of paints and coatings after production, EPA identified products in bottles as small as 0.1 gallons, and in small containers as large as 20 gallons. However, one-gallon containers are the default packaged container size for bottles in ChemSTEER User Guide ([U.S. EPA, 2015](#)). Therefore, EPA modeled finished paint/coating container size using a triangular distribution with a lower bound of 0.1 gallons, an upper bound of 20 gallons, and a mode of one gallon.

D.5.12 Drum Residue Loss Fraction

For drums, 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 Drum 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 Drum 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 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 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 pouring.

D.5.13 Sampling Loss Fraction

Sampling loss fractions were estimated using the *March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes* ([U.S. EPA, 2023c](#)). 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% 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-12 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-12. 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
$\geq 5,000$	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 as a deterministic value equal to the 95th percentile value as the upper bound. The sampling loss fraction was chosen based on the calculation of daily throughput, as shown in Section D.5.4.

D.5.14 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 ten 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 ten 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 Section D.5.16:

Equation_Apx D-40.

$$D_{blending_max} = \left[\frac{4 \times V_{batch} \times 3785.41 \frac{cm^3}{gal}}{\pi} \right]^{1/3}$$

D.5.15 Operating Days

EPA was unable to identify DIBP-specific information for operating days in the production of adhesives and sealants. 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 2 weeks down for turnaround.

D.5.16 Batch Size

EPA assumed the number of batches completed per year was equal to the number of facility operating days, with one batch/day. EPA calculated the batch size using the following equation:

Equation_Apx D-41.

$$Q_{Batch} = \left(\frac{Q_{DIBP_year}}{OD} \right)$$

Where:

Q_{Batch}	=	Batch size [kg/batch]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.5.4) [kg/site-yr]
OD	=	Operating days (see Section D.5.15) [days/site-year]

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 12).

Equation_Apx D-42.

$$\text{if } 24 < (OH_{RP1/RP4} + OH_{RP12}), RATE_{fill_adjusted} = \frac{N_{cont_load_yr}}{(24 - OH_{RP1/RP4}) \times OD}$$

Where:

OH_n	=	Operating time for release point “n” [hrs/site-day]
$RATE_{fill_adjusted}$	=	Corrected fill rate for product containers [containers/hr]
$N_{cont_load_yr}$	=	Annual number of product containers [containers/site-year]
OD	=	Operating days [days/site-year]

D.5.18 Equipment Cleaning Loss Fraction

EPA used the EPA Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA 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.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 Use as a Catalyst Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the use as a catalyst – incorporation into pre-catalyst and intermediate in polypropylene manufacturing OES. This approach utilizes the ESD on Adhesive Formulation ([OECD, 2009a](#)), CDR data ([U.S. EPA, 2020a](#)), industry provided process information, combined with Monte Carlo simulation (a type of stochastic simulation).

EPA identified the following release sources from formulation of pre-catalyst:

- Release source 1: Transfer Operation Losses to Air from Unloading Raw DIBP.
- Release source 2: Container Residue Losses.
- Release source 3: Open Surface Losses to Air During Container Cleaning.
- Release source 4: Vented Losses to Air During Dispersion and Process Operations.
- Release source 5: Product Sampling Wastes.
- Release source 6: Open Surface Losses to Air During Product Sampling.
- Release source 7: Equipment Cleaning Losses.
- Release source 8: Open Surface Losses to Air During Equipment Cleaning.
- Release source 9: Open Surface Losses to Air During Loading Pre-Catalyst Mixtures.

EPA identified the following release sources from intermediate in polypropylene manufacturing:

- Release source 1: Open Surface Losses to Air from Unloading Raw Materials.
- Release source 2: Container Residue Losses.
- Release source 3: Vented Losses to Air During Reaction/Separation/Other Process Operations.
- Release source 4: Product Sampling Wastes.
- Release source 5: Equipment Cleaning Losses.
- Release source 6: Dust Emissions from Loading Polypropylene Powders/Pellets.

Environmental releases for DIBP during incorporation into pre-catalyst and intermediate in polypropylene manufacturing are a function of DIBP'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, number of sites, DIBP concentrations, air speed, saturation factor, container size, loss fractions, diameters of openings, 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.6.1 Model Equations

Table_Apx D-13 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 as a catalyst OES. The OES modeled two scenarios for environmental releases of DIBP, release during the formulation of pre-catalyst and an intermediate in polypropylene (PP) manufacturing. 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 Section D.6.1. The Monte Carlo simulation calculated the total DIBP 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-13. Models and Variables Applied for Release Sources in the Use as a Catalyst OES

Release Source	Model(s) Applied	Variables Used
Formulation of pre-catalyst		
Release source 1: Transfer Operation Losses to Air from Unloading Raw DIBP.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: F_{DIBP_feed} ; VP ; f_{sat} ; MW ; R ; T ; V_{drum} ; V_{tote} ; $RATE_{fill_cont}$ Operating Time: Q_{DIBP_year} ; $RATE_{fill_cont}$; V_{drum} ; V_{tote} ; RHO ; F_{DIBP_feed} ; OD
Release source 2: Container Residue Losses.	EPA Drum Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{drum} ; LF_{tote}
Release source 3: Open Surface Losses to Air During Container Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP} ; MW ; VP ; $RATE_{air_speed}$; D_{cont_clean} ; T ; P Operating Time: Q_{DIBP_year} ; $RATE_{fill_cont}$; V_{drum} ; V_{tote} ; RHO ; F_{DIBP_feed} ; OD
Release source 4: Vented Losses During Dispersion and Process Operations.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_catalyst}$; MW ; VP ; $RATE_{air_speed}$; D_{vent} ; T ; P Operating Time: OH_{vent}
Release source 5: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Section D.1)	Q_{DIBP_day} ; $LF_{sampling}$
Release source 6: Open Surface Losses During Product Sampling.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_catalyst}$; MW ; VP ; $RATE_{air_speed}$; D_{cont_clean} ; T ; P Operating Time: $OH_{sampling}$
Release source 7: Equipment Cleaning Losses.	EPA Multiple Process Vessel Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{equip_clean}
Release source 8: Open Surface Losses During Equipment Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_catalyst}$; MW ; VP ; $RATE_{air_speed}$; D_{cont_clean} ; T ; P

Release Source	Model(s) Applied	Variables Used
	Coefficient Model, based on air speed (Section D.1)	Operating Time: OH_{equip_clean}
Release source 9: Transfer Operation Losses from Packaging Pre-Catalyst into Transport Containers	N/A – Not assessed – see discussion below table.	N/A
Intermediate in polypropylene manufacturing		
Release source 1: Transfer Operation Losses from Unloading Raw Materials	N/A – Not assessed – see discussion below table.	N/A
Release source 2: Container Residue Losses.	EPA Drum Residual Model (Section D.1)	$Q_{DIBP_day}; LF_{drum}$
Release source 3: Vented Losses During Dispersion and Process Operations.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP_catalyst}; MW; VP; RATE_{air_speed}; D_{cont_clean}; T; P$ Operating Time: $Q_{DIBP_year}; RATE_{fill_cont}; V_{cont}; RHO; F_{DIBP_catalyst}; OD$
Release source 4: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Section D.1)	$Q_{DIBP_day}; LF_{sampling}; EOR$
Release source 5: Equipment Cleaning Losses.	EPA Multiple Process Vessel Residual Model (Section D.1)	$Q_{DIBP_day}; LF_{equip_clean}; EOR$
Release source 6: Dust Emissions from Loading Polypropylene Powders/Pellets.	EPA Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Section D.1)	$Q_{DIBP_day}; F_{dust_generation}; F_{dust_capture}; F_{dust_control}; EOR$

An industry provided process description indicated that loading and unloading of pre-catalyst formulations is conducted under nitrogen blanket due to the sensitivity of the product. Therefore, EPA assumed no environmental releases for these sources (release source 9 for formulation of pre-catalyst and release source 1 for intermediate in polypropylene manufacturing respectively) ([Company Withheld](#)). Furthermore, the process description indicated that DIBP is residual in polypropylene. Therefore, to estimate releases of DIBP post-formulation of PP, EPA multiplied all post-formulation release sources by the inverse of the extent of reaction ([Company Withheld](#)). See Section D.6.4 for discussion of Extent of Reaction.

D.6.1 Model Input Parameters

Table_Apx D-14 summarizes the model parameters and their values for the Use of Catalyst Monte Carlo simulations. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx D-14. Summary of Parameter Values and Distributions Used in the Use as a Catalyst Models

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Production Volume	PV	kg/site-yr	76,500	19,125	76,500	—	Uniform	See Section D.6.3
Feed DIBP Concentration	F _{DIBP_feed}	kg/kg	0.99	—	—	—	—	See Section D.6.7
Pre-Catalyst DIBP Concentration	F _{DIBP_Catalyst}	kg/kg	0.12	6.24E-02	0.12	—	Uniform	See Section D.6.8
Residual DIBP in PP Polymer	F _{DIBP_PP}	kg/kg	4.6E-07	1.60E-07	1.33E-06	4.60E-07	Triangular	See Section D.6.9
Operating Days	OD	days/year	250	—	—	—	—	See Section D.6.17
Number of Sites – Pre-Catalyst Formulation	N _{spre-catalyst}	sites	5	2	5	—	Uniform	See Section D.6.1
Air Speed	RATE _{air_speed}	ft/min	19.7	2.56	398	—	Lognormal	See Section D.6.11
Saturation Factor	f _{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.6.12
Drum Size	V _{drum}	gal	55	20	100	55	Triangular	See Section D.6.10
Tote Size	V _{tote}	gal	550	100	1,000	550	Triangular	See Section D.6.10
Drum Residual Loss Fraction	LF _{drum}	kg/kg	2.5E-02	1.7E-02	3.0E-02	2.5E-02	Triangular	See Section D.6.13
Tote Residual Loss Fraction	LF _{tote}	kg/kg	7.0E-04	2.0E-04	2.0E-03	7.0E-04	Triangular	See Section D.6.14
Fraction of DIBP Lost During Sampling – 1 (Q _{DIBP_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.6.15
Fraction of DIBP Lost During Sampling – 2 (Q _{DIBP_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.6.15

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Fraction of DIBP Lost During Sampling – 3 ($Q_{\text{DIBP_day}}$ 200-5000 kg/site-day)	$F_{\text{sampling_3}}$	kg/kg	4.0E-03	5.0E-04	4.0E-03	4.0E-03	Triangular	See Section D.6.15
Fraction of DIBP Lost During Sampling – 4 ($Q_{\text{DIBP_day}}$ > 5000 kg/site-day)	$F_{\text{sampling_4}}$	kg/kg	4.0E-04	8.0E-5	4.0E-04	4.0E-04	Triangular	See Section D.6.15
Diameter of Opening – Sampling	D_{sampling}	cm	2.5	2.5	10	—	Uniform	See Section D.6.16
Diameter of Opening – Vented Processes	D_{vent}	cm	10	10	169	—	Uniform	See Section D.6.16
Solid Powder Loss Fraction	LF_{dust}	kg/kg	5.0E-03	1.0E-03	3.0E-02	5.0E-03	Triangular	See Section D.6.18
Vapor Pressure at 25C	VP	mmHg	4.76E-05	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Drum and Tote Fill Rate	$RATE_{\text{fill_drum}}$	containers/hr	20	—	—	—	—	See Section D.6.19
Diameter of Opening – Container Cleaning	$D_{\text{cont_clean}}$	cm	5.08	—	—	—	—	See Section D.6.16
Diameter of Opening – Equipment Cleaning	$D_{\text{equip_clean}}$	cm	92	—	—	—	—	See Section D.6.16

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Sampling Duration	OH _{sampling}	hr/day	1	—	—	—	—	See Section D.6.6
Equipment Cleaning Duration	OH _{batch_equip_clean}	hr/day	3	1	4	3	Triangular	See Section D.6.6
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	1.0E-02	—	—	—	—	See Section D.6.20
Number of Batches Completed	N _{batches}	batches/day	1	—	—	—	—	See Section D.6.21
Efficiency for Dust Capture	F _{dust_capture}	kg/kg	0.963	0	1	0.963	Triangular	See Section D.6.18
Efficiency for Dust Control	F _{dust_control}	kg/kg	0.79	0	1	0.79	Triangular	See Section D.6.18
Polypropylene Facility Throughput	Q _{PP_yr}	kg/site-yr	4.0E08	2.0E08	4.0E08	—	Uniform	See Section D.6.3
Polypropylene Production Volume	PV _{PP}	kg/year	7.65E09	—	—	—	—	See Section D.6.3

D.6.2 Number of Sites

EPA estimated the number of sites for the formulation of pre-catalyst based on industry provided or readily sources indicating that W.R. Grace and Company and LyondellBasell manufacture DIBP-containing pre-catalyst ([Lyondell Chemical Co., 2022](#); [W.R. Grace & Co, 2022](#)). One readily available source indicates that LyondellBasell has a single catalyst manufacturing site in the US ([Lyondell Chemical Co., 2022](#)). EPA estimated up to four W.R. Grace sites could manufacture DIBP catalyst ([W.R. Grace & Co, 2024](#)). Therefore, EPA assessed the number of pre-catalyst formulation sites as a uniform distribution range of 2 to 5 total sites.

The number of sites for intermediate in PP manufacturing is calculated using the following equation:

Equation_Apx D-43.

$$N_{s_PP} = \frac{PV_{PP}}{Q_{PP_yr}}$$

Where:

N_{s_PP}	=	Number of PP manufacturing sites [sites]
PV_{PP}	=	Production volume of polypropylene (see Section D.6.3) [kg/year]
Q_{PP_yr}	=	Facility annual throughput of polypropylene (see Section D.6.3) [kg/site-yr]

D.6.3 Throughput Parameters

EPA estimated the production volume for the use as a catalyst OES using the 2019 U.S. polypropylene (PP) production volume ([Jaganmohan, 2020](#)), the reported concentration of DIBP as residual in the produced PP (see Section D.6.9), and assumed that all PP produced in the U.S. uses DIBP-containing catalyst.

The estimated 2019 production volume of PP in the U.S. was 7.65 million tonnes ([Jaganmohan, 2020](#)). According to the industry provided process description of DIBP use in pre-catalyst, DIBP is present in the final formulation polypropylene at weight fractions ranging from 2.5 to 10 ppm ([W.R. Grace & Co, 2022](#)). Therefore, EPA assessed the total production volume of DIBP using a uniform distribution of 19,125 to 76,500 kg/year.

The annual throughput of DIBP in the Formulation of Pre-Catalyst is calculated using the below equation by dividing the production volume of DIBP by the number of sites.

Equation_Apx D-44.

$$Q_{DIBP_yr} = \frac{PV}{Ns_{catalyst}}$$

Where:

Q_{DIBP_yr}	=	Facility annual throughput of DIBP [kg/site-yr] (see above)
PV	=	Production Volume of DIBP [kg/year] (see above)
$Ns_{catalyst}$	=	Number of pre-catalyst formulation sites [sites] (see Section D.6.1)

The daily throughput of DIBP is calculated using the below equation by dividing the annual production volume by the number of operating days.

Equation_Apx D-45.

$$Q_{DIBP_day} = \frac{Q_{DIBP_year}}{OD}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
OD	=	Operating days [days/year] (see Section D.6.17)

EPA estimated the polypropylene facility throughput using readily available industry reports on polypropylene technology from the two known U.S. manufacturers of PP, W.R. Grace and Company and LyondellBasell. Based on the industry reports, EPA assessed the annual PP facility throughput using a uniform distribution ranging from 200 to 400 million kg/site-year.

However, EPA adjusted the annual facility throughput to prevent the lower bound of the number of PP manufacturing sites falling below one total site. EPA adjusted the annual facility throughput using Equation_Apx D-46:

Equation_Apx D-46.

$$Q_{PP_yr_adj} = \frac{PV_{PP}}{N_{s_PP}}$$

Where:

$Q_{PP_yr_adj}$	=	Adjusted facility annual throughput of polypropylene [kg/site-yr] (see above)
PV_{PP}	=	Production volume of polypropylene [kg/year] (see above)
N_{s_PP}	=	Number of PP manufacturing sites [sites] (see Section D.6.1)

The annual throughput of DIBP in Intermediate in PP manufacturing is calculated using Equation_Apx D-47 by dividing the production volume of DIBP by the number of sites.

Equation_Apx D-47.

$$Q_{DIBP_PP_yr} = \frac{PV}{N_{s_PP}}$$

Where:

$Q_{DIBP_PP_yr}$	=	Facility annual throughput of DIBP [kg/site-yr] (see above)
PV	=	Production Volume of DIBP [kg/year] (see above)
N_{s_PP}	=	Number of PP manufacturing sites [sites] (see Section D.6.1)

The daily throughput of DIBP in Intermediate in PP manufacturing is calculated using Equation_Apx D-48 by dividing the annual production volume by the number of operating days.

Equation_Apx D-48.

$$Q_{DIBP_PP_day} = \frac{Q_{DIBP_PP_year}}{OD}$$

Where:

$Q_{DIBP_PP_day}$	=	Facility throughput of DIBP [kg/site-day]
$Q_{DIBP_PP_year}$	=	Facility annual throughput of DIBP [kg/site-yr]
OD	=	Operating days [days/year] (see Section D.6.17)

D.6.4 Extent of Reaction

The extent of reaction of DIBP use as an intermediate in PP manufacturing is calculated using the below equation:

Equation_Apx D-49.

$$EOR = \frac{Q_{DIBP_PP_year} - Q_{PP_yr_adj} \times F_{DIBP_PP}}{Q_{DIBP_PP_year}}$$

Where:

EOR	=	Extent of Reaction [kg/site-day]
$Q_{DIBP_PP_year}$	=	Facility annual throughput of DIBP [kg/site-yr] (see Section D.6.3)
$Q_{PP_yr_adj}$	=	Adjusted facility annual throughput of polypropylene [kg/site-yr] (see Section D.6.3)
F_{DIBP_PP}	=	Weight fraction of residual DIBP in PP polymer (see Section D.6.9) [kg/kg]

For the intermediate in PP manufacturing release sources 4, 5, and 6, the associated environmental release models were multiplied by the inverse of the extent or reaction (1-EOR) as DIBP is present as residual.

D.6.5 Number of Containers per Year

The number of DIBP raw material containers received and unloaded by a pre-catalyst formulation site per year is calculated using the following equation:

Equation_Apx D-50.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{RHO * \left(3.79 \frac{L}{gal} \right) \times V_{drum/tote} \times F_{DIBP_feed}}$$

Where:

$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.6.3) [kg/site-yr]
RHO	=	DIBP density [kg/L]
$V_{drum/tote}$	=	Feed drum or tote volume (see Section D.6.10) [gal/container]
F_{DIBP_feed}	=	Feed DIBP concentration (see Section D.6.7) [kg/kg]

The number of DIBP raw material containers received and unloaded by a PP manufacturing site per year is calculated using the following equation:

Equation_Apx D-51.

$$N_{cont_unload_PP_yr} = \frac{Q_{DIBP_PP_year}}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{drum} \times F_{DIBP_catalyst}}$$

Where:

V_{drum}	=	Drum volume (see Section D.6.10) [gal/container]
$Q_{DIBP_PP_year}$	=	Facility annual throughput of DIBP in PP manufacturing (see Section D.6.3) [kg/site-yr]
RHO	=	DIBP density [kg/L]
$F_{DIBP_catalyst}$	=	Pre-catalyst DIBP concentration (see D.6.8) [kg/kg]
$N_{cont_unload_PP_yr}$	=	Annual number of containers unloaded in PP manufacturing [container/site-year]

D.6.6 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, product sampling, and equipment cleaning.

For unloading and container cleaning (release points 1 and 3 in formulation of pre-catalyst), 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-52.

$$OH_{RP1/RP3} = \frac{N_{cont_unload_yr}}{RATE_{fill_drum_tote} \times OD}$$

Where:

$OH_{RP1/RP3}$	=	Operating time for release points 1 and 3 [hrs/site-day]
$RATE_{fill_drum_tote}$	=	Fill rate of drums and totes (see Section D.6.19) [containers/hr]
$N_{cont_unload_yr}$	=	Annual number of containers unloaded (see Section D.6.5) [container/site-year]
OD	=	Operating days (see Section D.6.17) [days/site-year]

For process operations (release point 4 in formulation of pre-catalyst and release point 3 in intermediate of PP manufacturing), the ESD for Adhesive Formulation ([OECD, 2009a](#)) recommends using the following equation:

Equation_Apx D-53.

$$OH_{RPn} = (N_{batch_day}) \times 8 \frac{hrs}{day}$$

Where:

OH_{RPn}	=	Operating time for release point “n” [hrs/site-day]
N_{batch_day}	=	Number of batches completed per day (see Section D.6.21)

[batches/site-day]

For product sampling (release point 6 in formulation of pre-catalyst), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) indicates a value of one hour/day.

For equipment cleaning (release point 8 in formulation of pre-catalyst), the ESD for Adhesive Formulation ([OECD, 2009a](#)) provides an estimate of four hours per batch based on the value for cleaning multiple vessels from the ChemSTEER User Guide ([U.S. EPA, 2015](#)). The ESD for Adhesive Formulation also states that a case study conducted by the Pollution Prevention Assistance Division indicated a range of equipment cleaning times between one and three hours per batch. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on a lower bound, upper bound, and mode for equipment cleaning operating hours. EPA assigned the lower bound as one hour based on the lower end cleaning time observed in the case study ([OECD, 2009a](#)) and the upper bound as four hours based on the ChemSTEER User Guide default value for this worker activity. For the mode, EPA assigned three hours based on the ESD for Adhesive Formulation ([OECD, 2009a](#)). EPA calculated the equipment cleaning operating hours using the following equation:

Equation_Apx D-54.

$$OH_{RP8} = (N_{batch_day}) \times OH_{batch_equip_clean}$$

Where:

OH_{RP8}	=	Operating time for release point 8 [hrs/site-day]
N_{batch_day}	=	Number of batches completed per day (see Section D.6.21) [batches/site-day]
$OH_{batch_equip_clean}$	=	Batch duration for equipment cleaning [hrs/batch]

D.6.7 Feed DIBP Concentration

EPA modeled the feed DIBP concentration using a deterministic value of 0.99 based on information provided by W.R. Grace and Co. for purchased raw DIBP for use in pre-catalyst formulations ([W.R. Grace & Co, 2022](#)).

D.6.8 Pre-Catalyst DIBP Concentration

EPA modeled the pre-catalyst DIBP concentration using a uniform distribution with a lower bound of 6.24 percent and an upper bound of 11.5 percent based on information provided by W.R. Grace and Co. for DIBP in pre-catalyst formulations ([W.R. Grace & Co, 2022](#)).

D.6.9 Residual DIBP in PP Concentration

EPA modeled the pre-catalyst DIBP concentration using a triangular distribution with a lower bound of 0.16 ppm, an upper bound of 1.33 ppm, and a mode of 0.46 ppm based on information provided by W.R. Grace and Co. for residual DIBP in manufactured polypropylene ([W.R. Grace & Co, 2022](#)).

D.6.10 Container Size

EPA assumed that pre-catalyst formulation sites would receive DIBP in drums or totes. EPA modeled container size using a discrete distribution with equal probability of the site receiving the feed in drums or totes. 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](#)). For drums, EPA modeled 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. Totes are defined as containing between 100 and 1,000 gallons of liquid, and the default tote size is 550 gallons ([U.S. EPA, 2015](#)). For totes, EPA modeled container size using a triangular distribution with a lower bound of 100 gallons, an upper bound of 1,000 gallons, and a mode of 550 gallons.

For packaging of pre-catalyst after formulation, EPA assumed that sites package pre-catalyst in drums. This packaged pre-catalyst would then be received by PP manufacturing sites for use as an intermediate. EPA used the same drum size triangular distribution described above.

D.6.11 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.6.12 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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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.6.13 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 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 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 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.6.14 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 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 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 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.6.15 Sampling Loss Fraction

Sampling loss fractions were estimated using the March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes ([U.S. EPA, 2023c](#)). 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% 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-15 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-15. 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
$\geq 5,000$	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 as a deterministic value equal to the 95th percentile value as the upper bound. The sampling loss fraction was chosen based on the calculation of daily throughput, as shown in Section D.6.3.

D.6.16 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 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 venting process operations, the ESD for Adhesive Formulation ([OECD, 2009a](#)) assumes a closed vessel with a 4-inch diameter process vent, corresponding to ten cm in diameter. In addition, EPA considered the potential for open process vessels used for venting as mentioned the ESD for Adhesive Formulation ([OECD, 2009a](#)), with diameters of the open vessel calculated based on the batch volume for the simulation iteration and the assumption in the ESD 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](#)). 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:

Equation_Apx D-55.

$$D_{blending_max} = \left[\frac{4 \times V_{batch} \times 3785.41 \frac{cm^3}{gal}}{\pi} \right]^{1/3}$$

D.6.17 Operating Days

EPA was unable to identify DIBP-specific information for operating days in the formulation of pre-catalyst or intermediate in PP manufacturing. EPA assumed a constant value of 250 days/year, which corresponds to a production site that operates 5 days per week and 50 weeks per year, with 2 weeks down for turnaround.

D.6.18 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA 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, 2021c](#)).

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, 2021c](#)).

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 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 controlled based on the average of all estimated control efficiency values for all control technologies presented in the model, since potential control technologies are unknown. EPA assigned 0 for the lower bound because there is potential for some sites to have no control technology in operation ([U.S. EPA, 2021c](#)).

D.6.19 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 liquid.

D.6.20 Equipment Cleaning Loss Fraction

EPA used the EPA Single Vessel Residual Model to estimate the releases from equipment cleaning. The EPA Single Vessel Residual Model, as detailed in the ChemSTEER User Guide ([U.S. EPA, 2015](#)), provides an overall loss fraction of one percent from equipment cleaning.

D.6.21 Number of Batches per Year

EPA assumed the number of batches completed per year was equal to the number of facility operating days, equal to one batch/day.

D.7 Application of Paints and Coatings Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP 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).

Based on the ESD, EPA identified the following release sources from the application of paints and coatings:

- Release source 1: Transfer Operation Losses to Air from Unloading Paint.
- 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 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 DIBP during the application of paints and coatings are a function of DIBP'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, throughput, DIBP concentrations, air speed, saturation factor, container size, loss fractions, diameters of openings, 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.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 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 Section D.7.2. The Monte Carlo simulation calculated the total DIBP 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 Application of Paints and Coatings OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses to Air from Unloading Paint.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: F_{DIBP} ; VP ; f_{sat} ; MW ; R ; T ; V_{cont} ; $RATE_{fill_cont}$ Operating Time: Q_{DIBP_year} ; $RATE_{fill_cont}$; V_{cont} ; RHO ; F_{DIBP} ; OD
Release source 2: Open Surface Losses to Air During Raw Material Sampling.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section x D.1)	Vapor Generation Rate: F_{DIBP} ; MW ; VP ; $RATE_{air_speed}$; $D_{sampling}$; T ; P Operating Time: $OH_{sampling}$
Release source 3: Container Cleaning Wastes.	EPA Small Container Residual Model (Section D.1)	Q_{DIBP_day} ; $F_{residue}$
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP} ; MW ; VP ; $RATE_{air_speed}$; D_{cont_clean} ; T ; P Operating Time: Q_{DIBP_year} ; $RATE_{fill_cont}$; V_{cont} ; RHO ; F_{DIBP} ; OD
Release source 5: Process Releases During Operations.	See Equation_Apx D-56 through Equation_Apx D-60	Q_{DIBP_day} ; $F_{transfer_eff}$; $F_{capture_eff}$; $F_{solidrem_eff}$; OD
Release source 6: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{equip_clean}
Release source 7: Open Surface Losses to Air During Equipment Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP} ; MW ; VP ; $RATE_{air_speed}$; D_{equip_clean} ; T ; P Operating Time: OH_{equip_clean}
Release source 8: Raw Material Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Section D.1)	Q_{DIBP_day} ; $LF_{sampling}$

Release source 5 (Process Releases During Operations) is partitioned out by release media. In order to calculate the releases to each media, the total release is calculated first using the following equation:

Equation_Apx D-56.

$$Release_perDay_{RP5_total} = Q_{DIBP_day} \times (1 - F_{transfer_eff})$$

Where:

$Release_perDay_{RP5_total}$	=	DIBP released for release source 5 to all release media [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP (see Section D.7.4) [kg/site-day]
$F_{transfer_eff}$	=	Paint/coating transfer efficiency fraction (see Section D.7.15) [unitless]

The percent of release 5 that is released to water is calculated using the following equation:

Equation_Apx D-57.

$$\%_{water} = F_{capture_eff} \times (1 - F_{solidrem_eff})$$

Where:

$\%_{water}$	=	Percent of release 5 that is released to water [unitless]
$F_{capture_eff}$	=	Booth capture efficiency for spray-applied paints/ coatings (see Section D.7.18) [kg/kg]
$F_{solidrem_eff}$	=	Fraction of solid removed in the spray mist of sprayed paints/ coatings (see Section D.7.19) [kg/kg]

The percent of release 5 that is released to air is calculated using the following equation:

Equation_Apx D-58.

$$\%_{air} = (1 - F_{capture_eff})$$

Where:

$\%_{air}$	=	Percent of release 5 that is released to air [unitless]
$F_{capture_eff}$	=	Booth capture efficiency for spray-applied paints/ coatings (see Section D.7.18) [kg/kg]

The percent of release 5 that is released to land is calculated using the following equation:

Equation_Apx D-59.

$$\%_{land} = F_{capture_eff} \times F_{solidrem_eff}$$

Where:

$\%_{land}$	=	Percent of release 5 that is released to land [unitless]
$F_{capture_eff}$	=	Booth capture efficiency for spray-applied paints/ coatings (see Section D.7.18) [kg/kg]
$F_{solidrem_eff}$	=	Fraction of solid removed in the spray mist of sprayed paints/ coatings (see Section D.7.19) [kg/kg]

Finally, the release amounts to each media are calculated using the following equation:

Equation_Apx D-60.

$$Release_perDay_{RP5_media} = Release_perDay_{RP5_total} \times \%_{media}$$

Where:

$Release_perDay_{RP5_media}$	=	Amount of release 5 that is released to water, air, or land [kg/site-day]
$Release_perDay_{RP5_total}$	=	DIBP 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.7.2 Model Input Parameters

Table_Apx D-17 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-17. 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	
Annual Facility Throughput of Paint/Coating	Q_{coat_yr}	kg/site-yr	3,694	2,494	3,694	—	Uniform	See Section D.7.4
Production Volume	PV	kg/site-yr	3,694	—	—	—	—	See Section D.7.4
Paint/Coating DIBP Concentration	F_{DIBP}	kg/kg	5.0E-02	1.0E-02	0.6	5.0E-02	Triangular	See Section D.7.7
Operating Days	OD	days/year	250	225	300	250	Triangular	See Section D.7.8
Air Speed	$RATE_{air_speed}$	ft/min	19.7	2.56	398	—	Lognormal	See Section D.7.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.7.10
Container Size	V_{cont}	gal	5	0.1	5	5	Triangular	See Section D.7.11
Small Container Loss Fraction	$F_{residue}$	kg/kg	3.0E-04	3.0E-03	6.0E-03	3.0E-03	Triangular	See Section D.7.12
Fraction of DIBP Lost During Sampling – 1 ($Q_{DIBP_day} < 50$ kg/site-day)	$F_{sampling_1}$	kg/kg	2.0E-02	2.0E-03	2.0E-02	2.0E-02	Triangular	See Section D.7.13
Fraction of DIBP Lost During Sampling – 2 (Q_{DIBP_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.7.13
Fraction of DIBP Lost During Sampling – 3 (Q_{DIBP_day} 200-5000 kg/site-day)	$F_{sampling_3}$	kg/kg	4.0E-03	5.0E-04	4.0E-03	4.0E-03	Triangular	See Section D.7.13
Fraction of DIBP Lost During Sampling – 4 ($Q_{DIBP_day} > 5000$ kg/site-day)	$F_{sampling_4}$	kg/kg	4.0E-04	8.0E-5	4.0E-04	4.0E-04	Triangular	See Section D.7.13
Diameter of Opening – Sampling	$D_{sampling}$	cm	2.5	2.5	10	—	Uniform	See Section D.7.14
Transfer Efficiency Fraction	$F_{transfer_eff}$	unitless	0.65	0.2	0.8	0.65	Triangular	See Section D.7.15

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	4.76E-05	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Small Container Fill Rate	RATE _{fill_cont}	containers/hr	60	—	—	—	—	See Section D.7.16
Diameter of Opening – Container Cleaning	D _{cont_clean}	cm	5.08	—	—	—	—	See Section D.7.14
Diameter of Opening – Equipment Cleaning	D _{equip_clean}	cm	92	—	—	—	—	See Section D.7.14
Sampling Duration	OH _{sampling}	hr/day	1	—	—	—	—	See Section D.7.6
Equipment Cleaning Duration	OH _{equip_clean}	hr/day	4	—	—	—	—	See Section D.7.6
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	0.02	—	—	—	—	See Section D.7.17
Capture Efficiency for Spray Booth	F _{capture_eff}	kg/kg	0.9	—	—	—	—	See Section D.7.18
Fraction of Solid Removed in Spray Mist	F _{solidrem_eff}	kg/kg	1	—	—	—	—	See Section D.7.19

D.7.3 Number of Sites

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 the following equation:

Equation_Apx D-61.

$$N_s = \frac{PV}{Q_{DIBP_{year}}}$$

Where:

N_s	=	Number of sites [sites]
PV	=	Production volume [kg/year] (see Section D.7.4)
$Q_{DIBP_{year}}$	=	Facility annual throughput of DIBP [kg/site-yr] (see Section D.7.4)

D.7.4 Throughput Parameters

EPA estimated the total production volume for application of paints and coatings as a deterministic value of 3,694 kg/year, as described previously in Section D.4.4. The annual throughput of paint and coating product is modeled using a uniform distribution with a lower bound of 2,494 kg/year, and an upper bound of 3,694 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](#)). The ESD provides a range of 2,694 to 265,000 kg of radiation curable coatings produced per site, per year. The lower bound was taken from this range. The upper bound is equal to the production volume, such that the facility throughput does not exceed the maximum DIBP produced.

The annual throughput of DIBP is calculated using Equation_Apx D-62 by multiplying the annual throughput of all paints and coatings by the concentration of DIBP found in the paints and coatings.

Equation_Apx D-62.

$$Q_{DIBP_{year}} = Q_{coat_{yr}} \times F_{DIBP}$$

Where:

$Q_{DIBP_{year}}$	=	Facility annual throughput of DIBP [kg/site-yr]
$Q_{coat_{yr}}$	=	Facility annual throughput of all paints/ coatings [kg/site-yr]
F_{DIBP}	=	Concentration of DIBP in paints/ coatings (see Section D.7.7) [kg/kg]

The daily throughput of DIBP is calculated using Equation_Apx D-63 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section D.7.8.

Equation_Apx D-63.

$$Q_{DIBP_{day}} = \frac{Q_{DIBP_{year}}}{OD}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
OD	=	Operating days (see Section D.7.8) [days/year]

D.7.5 Number of Containers per Year

The number of DIBP raw material containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-64.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{RHO \times \left(3.79 \frac{L}{gal} \right) \times V_{cont} \times F_{DIBP}}$$

Where:

$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.7.4) [kg/site-yr]
V_{cont}	=	Container volume (see Section D.7.11) [gal/container]
RHO	=	DIBP density [kg/L]
F_{DIBP}	=	Concentration of DIBP in paints and coatings (see Section D.7.7) [kg/kg]

D.7.6 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 these sources include unloading, product sampling, and equipment cleaning.

For unloading and container cleaning (release point 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-65.

$$OH_{RP1/RP4} = \frac{N_{cont_unload_yr}}{RATE_{fill_cont} \times OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 [hrs/site-day]
$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year] (see Section D.7.5)
$RATE_{fill_cont}$	=	Container fill rate [containers/hr] (see Section D.7.16)
OD	=	Operating days [days/site-year] (see Section D.7.8)

For product sampling (release point 2), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) indicates a single value of one hour/day.

For equipment cleaning (release point 7), the ChemSTEER User Guide provides an estimate of four hours per day for cleaning multiple vessels ([U.S. EPA, 2015](#)).

D.7.7 Paint/Coating DIBP Concentration

EPA modeled final DIBP concentration in paints and coatings using a triangular distribution with a lower bound of one percent, upper bound of 60 percent, and mode of five percent. This is based on compiled SDS information for paint and coating products containing DIBP. 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 Table_Apx E-1 for EPA identified DIBP-containing products for this OES).

D.7.8 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 and 300 days/year. The lower bound is based on ESIG's Specific Environmental Release Category Factsheet for Industrial Application of Coatings by Spraying ([ESIG, 2020a](#)). The factsheet estimates 225 days/year as the number of emission days. The upper bound is based on the European Risk Report for DIDP ([ECJRC, 2003](#)) which provided a default of 300 days/year. The mode is based on the GS for Automobile Spray Coating ([U.S. EPA, 1996](#)) which estimates 250 days/year, based on 5 days/week operation that takes place 50 weeks/year.

D.7.9 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.7.10 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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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.7.11 Container Size

EPA modeled the container size of received paints and coatings using a triangular distribution with a lower bound of 0.1 gallons, and upper bound of five gallons, and a mode of five gallons. The lower bound is based on all product sizes available for purchase for DIBP-containing paints and coatings. The upper bound is based on the ChemSTEER User Guide for the largest relative size of the product containers identified, known as bottles. The mode is based on the ChemSTEER User Guide for the largest container volume size of bottles ([U.S. EPA, 2015](#)).

D.7.12 Small Container Loss Fraction

EPA used data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) and the EPA 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 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 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.7.13 Sampling Loss Fraction

Sampling loss fractions were estimated using the March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes ([U.S. EPA, 2023c](#)). 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 (~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-18 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx D-18. 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
$\geq 5,000$	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 Section D.7.4.

D.7.14 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 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.7.15 Transfer Efficiency Fraction

EPA modeled 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 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 of 30 to 80 percent. Therefore, EPA used 0.8 as the upper bound.

D.7.16 Small Container Unloading Rate

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical unloading rate of 60 containers per hour for containers with less than 20 gallons of liquid.

D.7.17 Equipment Cleaning Loss Fraction

EPA used the EPA Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA 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.7.18 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 Automobile Refinish Coating Overspray Loss Model to estimate releases from spray coating. This model assumes a spray booth capture efficiency of 90 percent.

D.7.19 Fraction of Solid Removed in Spray Mist

The ESD on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating ([OECD, 2011b](#)) uses the EPA Automobile Refinish Coating Overspray Loss Model to estimate releases from spray coating. This model assumes a solid removal efficiency of 100 percent.

D.8 Application of Adhesives and Sealants Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the application of adhesives and sealants OES. This approach utilizes the ESD on Use of Adhesives ([OECD, 2015b](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD, EPA identified the following release sources from the application of adhesives and sealants:

- Release source 1: Container Cleaning Wastes.
- Release source 2: Open Surface Losses to Air During Container Cleaning.
- Release source 3: Transfer Operation Losses from Unloading Adhesive Formulation.
- Release source 4: Equipment Cleaning Wastes.
- Release source 5: Open Surface Losses to Air During Equipment Cleaning.
- Release source 6: Process Releases During Adhesive Application.
- Release source 7: Open Surface Losses to Air During Curing/Drying.
- Release source 8: Trimming Wastes.

Environmental releases for DIBP during use of adhesives and sealants are a function of DIBP'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, product throughput, DIBP concentrations, air speed, saturation factor, 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.8.1 Model Equations

Table_Apx D-19 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 Section D.8.2. The Monte Carlo simulation calculated the total DIBP 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-19. 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: Container Cleaning Wastes.	EPA Small Container Residual Model (Section D.1)	$Q_{DIBP_year}; F_{residue}; V_{cont}; RHO; OD; F_{DIBP}$
Release source 2: Open Surface Losses to Air During Container Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP}; MW; VP; RATE_{air_speed}; D_{cont_clean}; T; P$ Operating Time: $RATE_{fill_cont}; RHO; V_{cont}; Q_{DIBP_year}$
Release source 3: Transfer Operation Losses from Unloading Adhesive Formulation.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: $F_{DIBP}; VP; f_{sat}; MW; R; T; RATE_{fill_cont}; V_{cont}$ Operating Time: $RATE_{fill_cont}; RHO; V_{cont}; Q_{DIBP_year}$
Release source 4: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model (Section D.1)	$Q_{DIBP_day}; F_{equipment_cleaning}$
Release source 5: Open Surface Losses to Air During Equipment Cleaning.	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: $F_{DIBP}; MW; VP; RATE_{air_speed}; D_{equip_clean}; T; P$ Operating Time: OH_{equip_clean}
Release source 6: Process Releases 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 the required data for release estimation of volatilization during curing not being available.	N/A
Release source 8: Trimming Wastes.	See Equation_Apx D-66	$Q_{DIBP_day}; F_{trimming}$

Release source 8 daily release (Trimming Wastes) is calculated using the following equation:

Equation_Apx D-66.

$$Release_perDay_{RP8} = Q_{DIBP_day} \times F_{trimming}$$

Where:

$Release_perDay_{RP8}$	=	DIBP released for release source 8 [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day] (see Section D.8.4)
$F_{trimming}$	=	Fraction of DIBP released as trimming waste [kg/kg] (see Section D.8.13)

D.8.2 Model Input Parameters

Table_Apx D-20 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-20. 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	
Annual Facility Throughput of Adhesive/ Sealant	$Q_{\text{product_yr}}$	kg/year	2,300	1,500	3,694	2,300	Triangular	See Section D.8.4
Adhesive/Sealant DIBP Concentration	F_{DIBP}	kg/kg	0.3	1.0E-03	0.6	0.3	Triangular	See Section D.8.7
Operating Days	OD	days/year	250	50	365	260	Triangular	See Section D.8.8
Air Speed	$\text{RATE}_{\text{air_speed}}$	ft/min	19.7	2.56	398	—	Lognormal	See Section D.8.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.8.10
Small Container Volume	V_{cont}	gal	1	1	5	1	Triangular	See Section D.8.11
Small Container Residual Loss Fraction	F_{residue}	kg/kg	3.0E-03	3.0E-04	6.0E-03	3.0E-03	Triangular	See Section D.8.12
Fraction of DIBP Released as Trimming Waste	F_{trimming}	kg/kg	4.0E-02	0	4.0E-02	4.0E-02	Triangular	See Section D.8.13
Vapor Pressure at 25 °C	VP	mmHg	4.76E-05	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Small Container Fill Rate	$\text{RATE}_{\text{fill_cont}}$	containers/hr	60	—	—	—	—	See Section D.8.14
Diameter of Opening – Container Cleaning	$D_{\text{cont_clean}}$	cm	5.08	—	—	—	—	See Section D.8.15

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Diameter of Opening – Equipment Cleaning	D _{equip_clean}	cm	92	—	—	—	—	See Section D.8.15
Operating Hours for Equipment Cleaning	OH _{equip_clean}	hr/day	4	—	—	—	—	See Section D.8.6
Equipment Cleaning Loss Fraction	F _{equipment_cleaning}	kg/kg	2.0E-02	—	—	—	—	See Section D.8.16

D.8.3 Number of Sites

Per 2020 U.S. Census Bureau data for the NAICS codes identified in the ESD on Use of Adhesives ([OECD, 2015b](#)), 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 the following equation.:

Equation_Apx D-67.

$$N_s = \frac{PV}{Q_{DIBP_{year}}}$$

Where:

N_s	=	Number of sites [sites]
PV	=	Production volume (see Section D.8.4) [kg/year]
$Q_{DIBP_{year}}$	=	Facility annual throughput of DIBP (see Section D.8.4) [kg/site-yr]

D.8.4 Throughput Parameters

EPA estimated the total production volume for application of adhesives and sealants as a deterministic value of 3,694 kg/year, as described previously in Section D.4.4. 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 3,694 kg/year, and mode of 2,300 kg/year. This is based on the ESD on Use of Adhesives ([OECD, 2015b](#)). 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. The relevant end-use categories included general assembly, motor and non-motor vehicle, vehicle parts, and tire manufacturing (except retreading). The lower bound adhesive use rates for these categories were 1,500 kg/year. The mode is based on the ESD default for unknown end-use markets. The upper bound is equal to the production volume, such that the facility throughput does not exceed the maximum DIBP produced.

The annual throughput of DIBP in adhesives/sealants is calculated Equation_Apx D-68 by multiplying the annual throughput of all adhesives and sealants by the concentration of DIBP in the adhesives/sealants.

Equation_Apx D-68.

$$Q_{DIBP_{year}} = Q_{product_{yr}} \times F_{DIBP}$$

Where:

$Q_{DIBP_{year}}$	=	Facility annual throughput of DIBP [kg/site-yr]
$Q_{product_{yr}}$	=	Facility annual throughput of all adhesives/ sealants [kg/site-yr]
F_{DIBP}	=	Concentration of DIBP in adhesive/ sealant (see Section D.8.7) [kg/kg]

The daily throughput of DIBP is calculated using Equation_Apx D-69 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section D.8.8.

Equation_Apx D-69.

$$Q_{DIBP_day} = \frac{Q_{DIBP_year}}{OD}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
OD	=	Operating days (see Section D.8.8) [days/year]

D.8.5 Number of Containers per Year

The number of DIBP raw material containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-70.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{cont}}$$

Where:

$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.8.4) [kg/site-yr]
RHO	=	DIBP density [kg/L]
V_{cont}	=	Product container volume (see Section D.8.11) [gal/container]

D.8.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the ESD on Use of Adhesives ([OECD, 2015b](#)), ChemSTEER User Guide ([U.S. EPA, 2015](#)), and/or through calculation from other parameters. Release points with operating hours provided from these sources include container cleaning, container unloading, and equipment cleaning.

For container cleaning and unloading (release points 2 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-71.

$$OH_{RP2/RP3} = \frac{N_{cont_unload_yr}}{RATE_{fill_cont} \times OD}$$

Where:

$OH_{RP2/RP3}$	=	Operating time for release points 2 and 3 [hrs/site-day]
$N_{cont_unload_yr}$	=	Annual number of containers unloaded (see Section D.8.5) [container/site-year]
$RATE_{fill_cont}$	=	Container fill rate (see Section D.8.14) [containers/hr]
OD	=	Operating days (see Section D.8.8) [days/site-year]

For equipment cleaning (release point 5), the ChemSTEER User Guide ([U.S. EPA, 2015](#)) states that the default operating hours for equipment cleaning is four hours/batch multiplied by the number of batches

per day for multiple vessels. Per the ESD on Use of Adhesives ([OECD, 2015b](#)), the default number of batches per day is one. Therefore, EPA assumes that equipment cleaning occurs for four hours/day.

D.8.7 Adhesive/ Sealant DIBP Concentration

EPA modeled DIBP concentration in adhesives and sealants using a triangular distribution with a lower bound of 0.1 percent, upper bound of 60 percent, and mode of 30 percent. The upper bound, lower bound, and mode is based on compiled SDS information for adhesives and sealant products containing DIBP. EPA did not have information on the prevalence or market share of different adhesive/ sealant products in commerce; therefore, EPA assumed a triangular distribution of concentrations. From the compiled data, the minimum concentration was 0.1 percent and the mode of high-end product concentrations was 30 percent (see Table_Apx E-1 for EPA identified DIBP-containing products for this OES).

D.8.8 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 ESD on Use of Adhesives ([OECD, 2015b](#)). The ESD provides operating days for several end-use categories, as listed in Section 3.6. 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.8.9 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.8.10 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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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.8.11 Container Size

EPA assumed that use sites would receive adhesives and sealants in bottles. According to the ChemSTEER User Guide, bottles are defined as containing between one and five gallons of liquid, and the default bottle size is one gallon ([U.S. EPA, 2015](#)). Therefore, EPA modeled container size using a triangular distribution with a lower bound and mode of one gallon, an upper bound of five gallons.

D.8.12 Small Container Residue Loss Fraction

EPA used data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) and the EPA 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 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 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.8.13 Fraction of DIBP Released as Trimming Waste

EPA modeled the fraction of DIBP released as trimming waste using a triangular distribution with a lower bound of 0 and upper bound of 0.04. This is based on the ESD on Use of Adhesives ([OECD, 2015b](#)). The ESD states that trimming losses should only be assessed if trimming losses are expected for the end-use being assessed. Since not all adhesive and sealant end uses will result in trimming losses, EPA assigned a lower bound of 0. The upper bound is based on the ESD's default waste fraction of 0.04 kg chemical in trimmings/kg chemical applied. The mode is based on the ESD's default waste fraction.

D.8.14 Container Unloading Rates

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.8.15 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](#)).

D.8.16 Equipment Cleaning Loss Fraction

EPA used the EPA Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA 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.9 Use of Laboratory Chemicals Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the use of laboratory chemicals OES. This approach utilizes the GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)) and CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation). The model was run separately for liquid and solid laboratory chemicals.

Based on the GS, EPA identified the following release sources from use of laboratory chemicals:

- Release source 1: Transfer Operation Losses to Air from Unloading Laboratory Chemicals (liquids only).
- Release source 2: Dust Emissions from Transferring Powders (solids only).
- Release source 3: Container Cleaning Wastes.
- Release source 4: Open Surface Losses to Air During Container Cleaning (liquids only).
- Release source 5: Equipment Cleaning Wastes.
- Release source 6: Open Surface Losses to Air During Equipment Cleaning (liquids only).
- Release source 7: Releases During Laboratory Analysis (liquids only).
- Release source 8: Laboratory Waste Disposal.

Environmental releases for DIBP during the use of laboratory chemicals are a function of DIBP'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, DIBP concentrations, air speed, saturation factor, container size, loss fractions, and diameters of 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.9.1 Model Equations

Table_Apx D-21 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 these variables are provided in D.9.2. The Monte Carlo simulation calculated the total DIBP 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-21. Models and Variables Applied for Release Sources in the Use of Laboratory Chemicals OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses to Air from Unloading laboratory chemicals (liquids only).	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: F_{DIBP-L} ; VP ; f_{sat} ; MW ; R ; T ; V_{cont} ; $RATE_{fill}$ Operating Time: Q_{DIBP_day} ; V_{cont} ; $RATE_{fill}$; RHO ; OD ; F_{DIBP-L}
Release source 2: Dust Emissions from Transferring Powders (solids only).	EPA Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Section D.1)	Q_{DIBP_day} ; $F_{dust_generation}$; $F_{dust_capture}$; $F_{dust_control}$
Release source 3: Container Cleaning Wastes.	EPA Small Container Residual Model or EPA Solid Residuals in Transport Containers Model, based on physical form (Appendix D.1)	Q_{DIBP_day} ; $F_{residue_S}$; $F_{residue_L}$; V_{cont} ; RHO ; F_{DIBP-S} ; F_{DIBP-L} ; LF_{cont} ; OD ; Q_{cont_solid}
Release source 4: Open Surface Losses to Air During Container Cleaning (liquids only).	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP-L} ; MW ; VP ; $RATE_{air_speed}$; $D_{cleaning}$; T ; P Operating Time: Q_{DIBP_day} ; V_{cont} ; $RATE_{fill}$; RHO ; OD ; F_{DIBP-L}
Release source 5: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model or EPA Solids Residuals in Transport Container Model, based on physical form (Section D.1)	Q_{DIBP_day} ; $F_{lab_residue_L}$; $F_{lab_residue_S}$
Release source 6: Open Surface Losses to Air During Equipment Cleaning (liquids only).	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP-L} ; MW ; VP ; $RATE_{air_speed}$; $D_{cleaning}$; T ; P Operating Time: $OH_{cleaning}$
Release source 7: Releases During Laboratory Analysis (liquids only).	EPA Penetration Model or EPA Mass Transfer Coefficient Model, based on air speed (Section D.1)	Vapor Generation Rate: F_{DIBP-L} ; MW ; VP ; $RATE_{air_speed}$; $D_{testing}$; T ; P Operating Time: $OH_{testing}$
Release source 8: Laboratory Waste Disposal.	See Equation_Apx D-72 and Equation_Apx D-73	Q_{DIBP_day} ; $F_{residue}$; LF_{cont} ; $F_{lab_residue_L}$; $F_{lab_residue_S}$; $F_{dust_generation}$; Release Points 1, 4, 6, and 7

For liquid DIBP, release source 8 (Laboratory Waste Disposal) is calculated via a mass-balance, via the following equation:

Equation_Apx D-72.

$$\begin{aligned}
 & \text{Release_perDay}_{RP8-L} \\
 &= \left(Q_{DIBP_day_L} - \text{Release_perDay}_{RP1} - \text{Release_perDay}_{RP4} - \text{Release_perDay}_{RP6} - \text{Release_perDay}_{RP7} \right) \\
 & \quad * (1 - F_{\text{residue_L}} - F_{\text{lab_residue_L}})
 \end{aligned}$$

Where:

$\text{Release_perDay}_{RP8-L}$	=	Liquid DIBP released for release source 8 [kg/site-day]
$Q_{DIBP_day_L}$	=	Facility throughput of liquid DIBP (see Section D.9.4) [kg/site-day]
$\text{Release_perDay}_{RP1}$	=	DIBP released for release source 1 [kg/site-day]
$\text{Release_perDay}_{RP4}$	=	DIBP released for release source 4 [kg/site-day]
$\text{Release_perDay}_{RP6}$	=	DIBP released for release source 6 [kg/site-day]
$\text{Release_perDay}_{RP7}$	=	DIBP released for release source 7 [kg/site-day]
$F_{\text{residue_L}}$	=	Fraction of DIBP remaining in liquid transport containers (see Section D.9.12) [kg/kg]
$F_{\text{lab_residue_L}}$	=	Fraction of liquid DIBP remaining in lab equipment (see Section D.9.16) [kg/kg]

For solids containing DIBP, release source 8 (Laboratory Waste Disposal) is calculated via a mass-balance, via the following equation:

Equation_Apx D-73.

$$\text{Release_perDay}_{RP8-S} = Q_{DIBP_day_S} \times (1 - F_{\text{dust_generation}} - LF_{\text{cont_S}} - F_{\text{lab_residue_S}})$$

Where:

$\text{Release_perDay}_{RP8-S}$	=	Solid DIBP released for release source 8 [kg/site-day]
$Q_{DIBP_day_S}$	=	Facility throughput of solid DIBP (see Section D.9.4) [kg/site-day]
$F_{\text{dust_generation}}$	=	Fraction of DIBP lost during unloading of solid powder (see Section D.9.13) [kg/kg]
$LF_{\text{cont_S}}$	=	Fraction of DIBP remaining in solid transport containers (see Section D.9.12) [kg/kg]
$F_{\text{lab_residue_S}}$	=	Fraction of solid DIBP remaining in lab equipment (see Section D.9.16) [kg/kg]

D.9.2 Model Input Parameters

Table_Apx D-22 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-22. 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	
Facility Throughput of Liquid DIBP	Q _{stock_site_day_L}	mL/site-day	4,000	1.55	4,000	—	Uniform	See Section D.9.4
Liquid DIBP Concentration	F _{DIBP-L}	kg/kg	0.95	0.9	1	0.95	Triangular	See Section D.9.7
Solid DIBP Concentration	F _{DIBP-S}	kg/kg	1.0E-03	—	—	—	—	See Section D.9.7
Operating Days	OD	days/year	260	174	260	260	Triangular	See Section D.9.8
Air Speed	RATE _{air_speed}	ft/min	19.7	2.56	398	—	Lognormal	See Section D.9.9
Saturation Factor	f _{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.9.10
Liquid Container Size	V _{cont}	gal	1	2.6E-02	5	1	Triangular	See Section D.9.11
Solid Container Mass	Q _{cont_solid}	kg	1	5.0E-03	5	1	Triangular	See Section D.9.11
Small Container Loss Fraction	F _{residue}	kg/kg	3.0E-03	3.0E-04	6.0E-03	3.0E-03	Triangular	See Section D.9.12
Solid Container Loss Fraction	LF _{cont}	kg/kg	1.0E-02	—	—	—	—	See Section D.9.12
Fraction of chemical lost during transfer of solid powders	F _{dust_generation}	kg/kg	5.0E-03	—	—	—	—	See Section D.9.13
Fraction of dust captured and controlled by control technology	F _{dust_control}	kg/kg	2.6E-01	0	1	2.6E-01	Triangular	See Section D.9.13
Fraction of dust captured by captured technology	F _{dust_capture}	kg/kg	3.2E-01	0	1	3.2E-01	Triangular	See Section D.9.13

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	4.76E-05	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property
Temperature	T	K	298	—	—	—	—	Process parameter
Pressure	P	atm	1	—	—	—	—	Process parameter
Small Container Fill Rate	RATE _{fill}	containers/hr	60	—	—	—	—	See Section D.9.14
Diameter of Opening – Container Cleaning	D _{cleaning}	cm	5.08	—	—	—	—	See Section D.9.15
Lab Testing Duration	OH _{testing}	hr/day	1	—	—	—	—	See Section D.9.6
Equipment Cleaning Duration	OH _{cleaning}	hr/day	4	—	—	—	—	See Section D.9.6
Equipment Cleaning Loss Fraction—Liquid	F _{lab_residue_L}	kg/kg	0.02	—	—	—	—	See Section D.9.16
Equipment Cleaning Loss Fraction—Solid	F _{lab_residue_S}	kg/kg	0.01	—	—	—	—	See Section D.9.16

D.9.3 Number of Sites

Per 2020 U.S. Census Bureau data for the NAICS codes identified in GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)), there are 36,873 laboratory use sites ([U.S. BLS, 2016](#)). Therefore, this value is used as a bounding limit, not to be exceeded by the calculation. For releases associated with solid laboratory chemicals, this value was used deterministically due to the minimal weight fraction of DIBP present in solid laboratory chemical resulting in a number of sites exceeding this value for every model iteration. Number of sites for liquid DIBP laboratory chemicals is calculated using the following equation:

Equation_Apx D-74.

$$N_s = \frac{PV}{Q_{DIBP_{year}}}$$

Where:

N_s	=	Number of sites [sites]
PV	=	Production volume (see Section D.9.4) [kg/year]
$Q_{DIBP_{year}}$	=	Facility annual throughput of DIBP (see Section D.9.4) [kg/site-yr]

D.9.4 Throughput Parameters

No sites reported the use of DIBP-containing laboratory chemicals in the 2020 CDR. Instead, EPA estimated the total production volume of DIBP 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. The single site that reported to 2020 CDR for DIBP, Lanxess Corp, reported production volume of 407,303 pounds. Therefore, the total production volume for this OES was 9,327 kg/year.

The GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)) provides daily throughput of DIBP 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 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, 2023d](#)). For this scenario, EPA assumes stock solutions are prepared daily per GS. EPA initially 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.

However, the proposed distributions resulted in a calculated number of sites that exceeded the number of sites identified in the GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)), which was used as a bounding limit as previously described. Therefore, for liquid stock solutions, EPA modified the lower bound to 1.55 mL. This lower bound was calculated using the minimum operating days of 174 days/year and the lowest known weight fraction of DIBP in liquid laboratory chemicals (0.9 kg/kg). The daily throughput of DIBP in liquid laboratory chemicals is calculated using Equation_Apx D-75 by multiplying the daily throughput of all laboratory solutions by the concentration of DIBP in the solutions and converting volume to mass.

Equation_Apx D-75.

$$Q_{DIBP_day} = Q_{stock_site_day_L} \times F_{DIBP-L} \times RHO \times \frac{0.001L}{mL}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
$Q_{stock_site_day_L}$	=	Facility annual throughput of liquid laboratory chemicals [mL/site-day]
F_{DIBP-L}	=	Concentration of DIBP in liquid laboratory chemicals (Section D.9.7) [kg/kg]
RHO	=	Density of DIBP [kg/L]

For solids, EPA used a deterministic value calculated using the maximum operating days of 260 days/year and the weight fraction of solid laboratory chemicals (0.001 kg/kg). This parameter is calculated using Equation_Apx D-76 below:

Equation_Apx D-76.

$$Q_{stock-site-day-s} = \frac{PV}{Ns_{max} \times F_{DIBP-S} \times 0.001 \frac{kg}{g} \times OD}$$

Where:

$Q_{stock_site_day_S}$	=	Facility annual throughput of solid laboratory chemicals [g/site-day]
PV	=	Production volume of DIBP [kg/year]
Ns_{max}	=	Number of sites identified in GS (see Section D.9.3) [36,873 sites]
F_{DIBP-S}	=	Concentration of DIBP in solid laboratory chemicals (see Section D.9.7) [kg/kg]
OD	=	Operating Days (see Section D.9.8) [days/year]

The daily throughput of DIBP in solid laboratory chemicals is calculated using Equation_Apx D-77 by multiplying the daily throughput of all laboratory solids by the concentration of DIBP in the solids.

Equation_Apx D-77.

$$Q_{DIBP_day} = Q_{stock_site_day_S} \times F_{DIBP-S} \times \frac{0.001kg}{g}$$

Where:

Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
$Q_{stock_site_day_S}$	=	Facility annual throughput of solid laboratory chemicals [g/site-day]
F_{DIBP-S}	=	Concentration of DIBP in solid laboratory chemicals (see Section D.9.7) [kg/kg]

The annual throughput of DIBP is calculated using Equation_Apx D-78 by multiplying the daily throughput by the number of operating days. The number of operating days is determined according to Section D.9.8.

Equation_Apx D-78.

$$Q_{DIBP_year} = Q_{DIBP_day} \times OD$$

Where:

Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
Q_{DIBP_day}	=	Facility throughput of DIBP [kg/site-day]
OD	=	Operating days [days/year] (see Section D.9.8)

D.9.5 Number of Containers per Year

The number of liquid DIBP laboratory containers unloaded by a site per year is calculated using the following equation:

Equation_Apx D-79.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{F_{DIBP-L} \times RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{cont}}$$

Where:

$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.9.4) [kg/site-yr]
F_{DIBP-L}	=	Mass fraction of DIBP in liquid (see Section D.9.7) [kg/kg]
RHO	=	DIBP density [kg/L]
V_{cont}	=	Container volume (see Section D.9.11) [gal/container]

The number of laboratory containers containing solids with DIBP unloaded by a site per year is calculated using the following equation:

Equation_Apx D-80.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{F_{DIBP-S} \times Q_{cont_solid}}$$

Where:

$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.9.4) [kg/site-yr]
F_{DIBP-S}	=	Mass fraction of DIBP in solid (see Section D.9.7) [kg/kg]
Q_{cont_solid}	=	Mass in container of solids (see Section D.9.7) [kg/container]

D.9.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)), 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, equipment cleaning, and product sampling.

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-81.

$$OH_{RP1/RP4} = \frac{N_{cont_unload_yr}}{RATE_{fill} \times OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 [hrs/site-day]
$N_{cont_unload_yr}$	=	Annual number of containers unloaded (see Section D.9.5) [container/site-year]
$RATE_{fill}$	=	Container fill rate (see Section D.9.14) [containers/hr]
OD	=	Operating days (see Section D.9.8) [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 one hour/day.

D.9.7 DIBP Concentration in Laboratory Chemicals

EPA modeled DIBP concentration in liquid laboratory chemicals using a triangular distribution with a lower bound of 90 percent, upper bound of 100 percent, and mode of 95 percent. The GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)) states that most laboratory chemicals are sold as reagent grade equal to or higher than 95 percent purity. EPA built the triangular distribution by using this value as the mode and including concentrations five percent lower and higher than the mode to be the lower and upper bounds. For solid laboratory chemicals, EPA used the weight fraction from the single identified SDS (0.1 percent DIBP by mass) as a deterministic value (see Table_Apx E-1 for EPA identified DIBP-containing products for this OES).

D.9.8 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 of 260 days/year. These values were 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 eight or 12 hours/day yields 174 or 260 days/year. To ensure that only integer values of this parameter were selected, EPA modeled a discrete distribution that listed each integer between (and including) 174 and 260 days/year.

D.9.9 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.9.10 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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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.9.11 Container Size

The GS on Use of Laboratory Chemicals ([U.S. EPA, 2023d](#)) states that laboratory chemicals are packaged in bottles, typically one gallon in size (liquids) or one kilogram in capacity (solids). According to the ChemSTEER User Guide, bottles are defined as containing between one and five gallons of liquid ([U.S. EPA, 2015](#)). EPA identified laboratory products containing DIBP as having available container sizes as small as 100 mL (liquids) or five grams (solids). EPA built a triangular distribution for liquid volumes with a lower bound of 0.02642 gallons (100 mL) based on the identified products, an upper bound of five gallons based on the ChemSTEER User Guide, and mode of one gallon based on the GS. EPA similarly built a triangular distribution for solid quantities with a lower bound of 0.005 kilograms, an upper bound of five kilograms, and mode of one kilogram.

D.9.12 Container Loss Fractions

EPA used data from the PEI Associates Inc. study ([PEI Associates, 1988](#)) and the EPA 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 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 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 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA 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. The model recommends a default dust generation loss fraction of 0.5 percent ([U.S. EPA, 2021c](#)).

For the fraction of dust captured, EPA assigned a range of 0 to 1.0 with a mode of 0.32 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 default capture efficiency for unknown capture technology, which has a safety factor built in.

For the fraction of captured dust that is removed/controlled, EPA assigned a range of 0 to 1.0 with a mode of 0.23 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 default control efficiency for unknown control technology, which has a safety factor built in.

D.9.14 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.9.15 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](#)).

D.9.16 Equipment Cleaning Loss Fraction

For liquids, EPA used the EPA Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA 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.

For solids, EPA used the EPA Solid Residuals in Transport Containers Model to estimate the releases from equipment cleaning. The EPA 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 equipment cleaning.

D.10 Plastic Compounding and Converting Model Approaches and Parameters for Releases

This appendix presents the modeling approach, and equations used to estimate environmental releases for DIBP during the plastics compounding and plastics converting OESs. This approach utilizes the GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)), the GS for the Use of Additives in Plastic Converting ([U.S. EPA, 2021e](#)), and CDR data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)), EPA identified the following release sources from plastic compounding:

- Release source 1: Transfer Operation Losses to Air from Unloading Plastics Additives.
- Release source 2: Container Cleaning Wastes.
- Release source 3: Vapor Emissions from Compounding.
- Release source 4: Equipment Cleaning Wastes.
- Release source 5: Direct Contact Cooling Water Losses.
- Release source 6: Transfer Operations Losses to Air from Loading Compounded Plastic.

Based on the GS for the Use of Additives in Plastic Converting ([U.S. EPA, 2021e](#)), EPA identified the following release sources from plastic converting:

- Release source 1: Transfer Operation Losses to Air from Unloading Plastics Additives.
- Release source 2: Container Cleaning Wastes.
- Release source 3: Vapor Emissions from Converting.
- Release source 4: Particulate Emissions from Converting.
- Release source 5: Equipment Cleaning Wastes.
- Release source 6: Direct Contact Cooling Water Losses.
- Release source 7: Solid Wastes from Trimming Operations.

Environmental releases for DIBP during plastic materials production are a function of DIBP'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, DIBP concentrations, operating days, air speed, saturation factor, container size, loss fractions, and dust control/capture efficiencies. 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 plastic compounding and converting OESs. 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 Section D.10.2. The Monte Carlo simulation calculated the total DIBP 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 Plastic Compounding and Converting OESs

Release source	Model(s) Applied	Variables Used
Plastics Compounding		
Release source 1: Transfer Operation Losses to Air from Unloading Plastics Additives.	EPA/OAQPS AP-42 Loading Model (Section D.1)	Vapor Generation Rate: $F_{DIBP_additive}$; VP ; f_{sat} ; MW ; R ; T ; $V_{additive_cont}$; $RATE_{fill_drum_tote}$ Operating Time: Q_{DIBP_year} ; $V_{additive_cont}$; $RATE_{fill_drum_tote}$; RHO ; OD_{comp}
Release source 2: Container Cleaning Wastes.	EPA Drum Residual Model or EPA Bulk Transport Residual Model, based on container size (Section D.1)	Q_{DIBP_year} ; LF_{drum} ; $V_{additive_cont}$; LF_{bulk} ; V_{bulk} RHO ; OD_{comp}
Release source 3: Vapor Emissions During Compounding.	See Equation_Apx D-82	Q_{DIBP_day} ; $F_{vapor_emissions}$
Release source 4: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{equip_clean}
Release source 5: Direct Contact Cooling Water Losses.	See Equation_Apx D-82	Q_{DIBP_day} ; $F_{cooling_water}$
Release source 6: Transfer Operations Losses to Air from Loading Compounded Plastic.	EPA Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Section D.1)	Q_{DIBP_day} ; $F_{dust_generation}$; $F_{dust_capture}$; $F_{dust_control}$
Plastics Converting		
Release source 1: Transfer Operation Losses to Air from Unloading Plastics Additives.	EPA Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Section D.1)	Q_{DIBP_day} ; $F_{dust_generation}$; $F_{dust_capture}$; $F_{dust_control}$
Release source 2: Container Cleaning Wastes.	EPA Solid Residuals in Transport Containers Model (Section D.1)	Q_{DIBP_year} ; LF_{cont} ; V_{prod_cont} ; RHO ; $N_{cont_unload_day}$; OD_{conv}
Release source 3: Vapor Emissions from Converting.	See Equation_Apx D-82	Q_{DIBP_day} ; $F_{vapor_emissions}$
Release source 4: Particulate Emissions from Converting.	See Equation_Apx D-83	Q_{DIBP_day} ; $F_{particulate_emissions}$
Release source 5: Equipment Cleaning Wastes.	EPA Multiple Process Vessel Residual Model (Section D.1)	Q_{DIBP_day} ; LF_{equip_clean}
Release source 6: Direct Contact Cooling Water Losses.	See Equation_Apx D-84	Q_{DIBP_day} ; $F_{cooling_water}$
Release source 7: Solid Wastes from Trimming Operations.	See Equation_Apx D-85	Q_{DIBP_day} ; $F_{trimming}$

Compounding and converting release source 3 daily release (vapor emissions during compounding/converting) is calculated using the following equation:

Equation_Apx D-82.

$$Release_perDay_{RP5/3} = Q_{DIBP_day} \times F_{vapor_emissions}$$

Where:

$Release_perDay_{RP5/3}$	=	DIBP released for release source 5 (compounding) and 3 (converting) [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP (see Section D.10.4) [kg/site-day]
$F_{vapor_emissions}$	=	Fraction of DIBP lost from volatilization during compounding/converting operations (see Section D.10.17) [kg/kg]

Converting release source 4 daily release (Particulate Emissions from Converting) is calculated using the following equation:

Equation_Apx D-83.

$$Release_perDay_{RP4} = Q_{DIBP_day} \times F_{particulate_emissions}$$

Where:

$Release_perDay_{RP4}$	=	DIBP released for converting release source 4 [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP (see Section D.10.4) [kg/site-day]
$F_{particulate_emissions}$	=	Fraction of DIBP lost as particulates during converting operations (see Section D.10.19) [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-84.

$$Release_perDay_{RP7/6} = Q_{DIBP_day} \times F_{cooling_water}$$

Where:

$Release_perDay_{RP7/6}$	=	DIBP released for release source 7 (compounding) and 6 (converting) [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP (see Section D.10.4) [kg/site-day]
$F_{cooling_water}$	=	Cooling water loss fraction (see Section D.10.16) [kg/kg]

Converting release source 7 daily release (Solid Wastes from Trimming Operations) is calculated using the following equation:

Equation_Apx D-85.

$$Release_perDay_{RP7} = Q_{DIBP_day} \times F_{trimming}$$

Where:

$Release_perDay_{RP7}$	=	DIBP released for release source 7 [kg/site-day]
Q_{DIBP_day}	=	Facility throughput of DIBP (see Section D.10.4) [kg/site-day]

$F_{trimming}$ = Trimming loss fraction (see Section D.10.18) [kg/kg]

D.10.2 Model Input Parameters

Table_Apx D-24 summarizes the model parameters and their values for the Plastic Compounding and Converting 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 Plastic Compounding and Converting Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Total PV of DIBP at all Sites	PV _{total}	kg/year	184,750	—	—	—	—	See Section D.10.4
Initial DIBP Concentration	F _{DIBP_additive}	kg/kg	0.9	0.9	1	1	Triangular	See Section D.10.6
Plastic DIBP Concentration	F _{DIBP_resin}	kg/kg	7.4E-02	6.5E-03	7.4E-02	—	Uniform	See Section D.10.7
Operating Days – Compounding	OD _{comp}	days/year	246	148	264	246	Triangular	See Section D.10.9
Operating Days – Converting	OD _{conv}	days/year	253	137	254	253	Triangular	See Section D.10.9
Saturation Factor	f _{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section D.10.10
Container Size of Additive Received Onsite	V _{additive_cont}	gal	55	20	100	55	Triangular	See Section D.10.11
Resin Product Container Size	V _{prod_cont}	kg	25	25	499	25	Triangular	See Section D.10.11
Drum Residual Loss Fraction	LF _{drum}	kg/kg	2.5E-02	3.0E-03	3.0E-02	2.5E-02	Triangular	See Section D.10.12
Fraction of chemical lost during transfer of solid powders	F _{dust_generation}	kg/kg	5.0E-03	6.0E-06	4.5E-02	5.0E-03	Triangular	See Section D.10.8
Capture efficiency for dust capture methods	F _{dust_capture}	kg/kg	0.321	0	1	0.321	Triangular	See Section D.10.8
Control efficiency for dust filter	F _{dust_control}	kg/kg	0.26	0	1	0.26	Triangular	See Section D.10.8
Fraction of the chemical of interest lost	F _{vapor_emissions_open}	kg/kg	1.0E-04	—	—	—	—	See Section D.10.17

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
from volatilization 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 Section D.10.17
Fraction of the chemical of interest lost from volatilization during blending/compounding operations	F _{vapor_emissions}	kg/kg	2.0E-05	—	—	—	—	See Section D.10.17
Fraction of DIBP 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 Section D.10.19
Number of Plastic Compounding Sites	N _{sites_comp}	sites	1	1	9	—	Uniform	See Section D.10.3

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Number of Plastic Converting Sites	N _{sites_conv}	sites	6	6	70	—	Uniform	See Section D.10.3
Small Container Fill Rate	RATE _{fill_cont}	cont/hr	30	—	—	—	—	See Section D.10.12
Drum and Tote Fill Rate	RATE _{fill_drum_tote}	drums/hr	20	—	—	—	—	See Section D.10.12
Ambient Pressure	P	atm	1	—	—	—	—	Process parameter
Ambient Temperature	T	K	298	—	—	—	—	Process parameter
Vapor Pressure at 25C	VP	mmHg	4.76E-05	—	—	—	—	Physical property
Molecular Weight	MW	g/mol	278.35	—	—	—	—	Physical property
Gas Constant	R	atm-cm ³ /gmol-L	82.05	—	—	—	—	Universal constant
Density of DIBP	RHO	kg/L	1.0386	—	—	—	—	Physical property
Equipment Cleaning Loss Fraction	LF _{equip_clean}	kg/kg	2.0E-02	—	—	—	—	See Section D.10.15
Cooling Water Loss Fraction	F _{cooling_water}	kg/kg	1.0E-02	—	—	—	—	See Section D.10.16
Solid container Loss Fraction	LF _{cont}	kg/kg	1.0E-02	—	—	—	—	See Section D.10.14
Trimming Loss Fraction	F _{trimming}	kg/kg	2.5E-02	—	—	—	—	See Section D.10.18

D.10.3 Number of Sites

The singular entry in the 2020 CDR (Lanxess Corp) reports < 10 downstream industrial sites to receive the manufactured DIBP for plastic product manufacturing ([U.S. EPA, 2020a](#)). Based on this reporting, EPA assessed the number of plastic compounding sites as a uniform distribution with an upper bound of nine sites and a lower bound of one site.

The number of sites for plastic converting sites was calculated using the equation below:

Equation_Apx D-86.

$$N_{sites_conv} = \frac{PV}{Q_{additives} \times (F_{DIBP_resin} / F_{all_additives})}$$

Where:

N_{sites_conv}	=	Number of sites plastic converting [sites]
PV	=	Production volume [kg/year]
$Q_{additives}$	=	Facility annual throughput of DIBP [kg/site-yr]
F_{DIBP_resin}	=	Resin product DIBP concentration [kg/kg]
$F_{all_additives}$	=	Concentration of all additives in product [kg/kg]

EPA calculated the range of the number of sites using Equation_Apx D-86 and set the range as a uniform distribution with a lower bound of six sites and an upper bound of 70 sites.

D.10.4 Throughput Parameters

EPA estimated the total production volume for all sites using a constant value of 407,303 lbs/year (184,750 kg/year) based on the 2020 CDR reporting data for Lanxess Corp ([U.S. EPA, 2020a](#)). This production volume is used for both plastic compounding and converting since EPA assumes 100 percent of the compounded plastic goes to the converting process.

For compounding and converting, the annual throughput of DIBP is calculated using Equation_Apx D-87 by dividing the annual total production volume assessed (discussed in the paragraph above) by the number of sites (see Section D.10.3).

Equation_Apx D-87.

$$Q_{DIBP_year} = \frac{PV_{total}}{N_{sites_comp\ or\ conv}}$$

Where:

Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
PV_{total}	=	Total PV assessed [kg/year]
$N_{sites_comp\ or\ conv}$	=	Number of plastic compounding or converting sites (see Section D.10.3) [sites]

D.10.5 Number of Containers per Year

The number of DIBP raw material containers received and unloaded by a site per year is calculated

using the following equation:

Equation_Apx D-88.

$$N_{cont_unload_yr} = \frac{Q_{DIBP_year}}{RHO \times \left(3.79 \frac{L}{gal}\right) \times V_{cont} \times F_{DIBP}}$$

Where:

V_{cont}	=	Feed container volume (see Section D.10.11) [gal/container]
Q_{DIBP_year}	=	Facility annual throughput of DIBP (see Section D.10.4) [kg/site-yr]
RHO	=	DIBP density [kg/L]
F_{DIBP}	=	Concentration of DIBP in Additive/Resin (see Section D.10.6) [kg/kg]
$N_{cont_unload_yr}$	=	Annual number of containers unloaded [container/site-year]

D.10.6 Plastic Additive DIBP Concentration

EPA modeled the concentration of DIBP in the plasticizer additive received onsite based on the 2020 CDR reporter for plastic product manufacturing ([U.S. EPA, 2020a](#)). Based on this data, EPA assessed the parameter using a uniform distribution with an upper bound of 1 and a lower bound of 0.9.

D.10.7 Fraction of DIBP in Compounded Plastic Resin Product

EPA modeled the concentration of DIBP in the compounded plastic product based on product data from the European Industry Reports ([ECHA, 2011](#)). Based on this data, EPA assessed the parameter using a uniform distribution with an upper bound of 0.074 and a lower bound of 0.0065.

D.10.8 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA 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. The model recommends a default dust generation loss fraction of 0.5 percent ([U.S. EPA, 2021c](#)).

For the fraction of dust captured, EPA assigned a range of 0 to 1.0 with a mode of 0.32 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 default capture efficiency for unknown capture technology, which has a safety factor built in.

For the fraction of captured dust that is removed/controlled, EPA assigned a range of 0 to 1.0 with a mode of 0.23 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 default control efficiency for unknown control technology, which has a safety factor built in.

D.10.9 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 264 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 and 264 days/year. The lower bound and upper bound are based on the 2014 Plastics Compounding Draft GS ([U.S. EPA, 2014c](#)), which states that a typical range of 148 to 264 days/year are expected. The mode is based on the GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)), 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 and 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, 2014d](#)), which states 137 to 254 days/year should be assumed. The mode is based on the GS on the Use of Additives in Plastics Converting ([U.S. EPA, 2021e](#)), which states that an average value of 253 days/year should be used as a default.

D.10.10 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 ([U.S. EPA, 1991b](#)). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 ([U.S. EPA, 1991b](#)). 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 ([U.S. EPA, 1991b](#)). 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.10.11 Container Size

EPA assumed that plastic manufacturing sites would receive DIBP 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](#)). EPA modeled a triangular distribution for containers using these values, with the lower and upper bounds corresponding to the range of volumes for drums, and the mode corresponding to the default container size for drums.

For packaging of compounded plastics, 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 GS on the Use of Additives in Plastics Converting ([U.S. EPA, 2021e](#)), which states that compounded plastics in pellet form are routinely shipped in containers ranging from 25 kg bags to 500 kg gaylords. EPA converted the mass of the container to volume assuming a compounded plastic density of 1 kg/L. The volumetric distribution contains a lower bound and mode of seven gallons, and an upper bound of 132 gallons.

D.10.12 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.

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.

Equation_Apx D-89.

$$\text{if } (24 - OH_{\text{unload_cont}}) < OH_{\text{load}}, RATE_{\text{fill_adjusted}} = \frac{N_{\text{cont_load_yr}}}{(24 - OH_{\text{unload_cont}}) \times OD}$$

Where:

OH_{load}	=	Daily operating hours for loading [hrs/site-day]
$RATE_{\text{fill_adjusted}}$	=	Corrected fill rate for product containers [containers/hr]
$N_{\text{cont_load_yr}}$	=	Annual number of product containers [containers/site-year]
OD	=	Operating days [days/site-year]
$OH_{\text{unload_cont}}$	=	Daily unloading operating hours [hrs/site-day]

D.10.13 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 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 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 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.10.14 Solids Container Loss Fractions

EPA used the EPA Solid Residuals in Transport Containers Model to estimate residual releases from solid container cleaning. The EPA 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.10.15 Equipment Cleaning Loss Fractions

EPA used the EPA Multiple Process Residual Model to estimate the releases from equipment cleaning. The EPA 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.10.16 Cooling Water Loss Fraction

EPA GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)) and GS for the Use of Additives in Plastics Converting ([U.S. EPA, 2021e](#)) state that if direct contact cooling water is used for compounding/converting, that the EPA Single Vessel Residual Model should be used to estimate releases. The EPA 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, 2014d](#)).

D.10.17 Process Operations Vapor Loss Fractions

The GS for the Use of Additives in Plastics Converting ([U.S. EPA, 2021e](#)) provides a breakdown of vapor emission rates during converting. The loss rates are based on plastic additive type and volatility of the chemical. DIBP is a plasticizer with a low volatility (less than 0.2 torr at 200°C). According to the GS, a loss rate of 0.01 percent is expected for open processes, and a loss rate of 0.002 percent is expected for closed processes. Within the Monte Carlo model, each loss rate has an equal probability of being selected during each iteration of the simulation for plastic converting. For plastic compounding, vapor emissions are assessed assuming a closed process operation, utilizing a loss rate of 0.01 percent for vapor emissions

D.10.18 Trimming Loss Fraction

The GS for the Use of Additives in Plastics Converting ([U.S. EPA, 2021e](#)) recommends a default trimming loss fraction of 0.025 kg/kg.

D.10.19 Fraction of DIBP Lost as Particulate during Converting

EPA modeled the loss fraction of particulate DIBP during converting using a triangular distribution with a lower bound of 2.0E-05 kg/kg, upper bound of 1.0E-04 kg/kg, and mode of 6.0E-05 kg/kg. This is based on the GS for the Use of Additives in Plastics Converting ([U.S. EPA, 2021e](#)). The GS presents loss fractions for “Other or unknown unreacted additive types” for three types of converting: open process (1.0E-04 kg/kg), partially open process (6.0E-05 kg/kg), or closed process (2.0E-05 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.11 Recycling Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the recycling OES. This approach utilizes the same equations and assumptions presented for the plastic compounding and plastic converting OESs in Section D.10 for the release points listed below. Therefore, only the parameters that differ between approaches, including throughput parameters, number of sites, container size, and container unloading rate, will be presented in this appendix for brevity.

Based on the GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)) and GS for the Use of Additives in Plastic Converting ([U.S. EPA, 2021e](#)), EPA identified the following release sources that are applicable to recycling:

- Release source 1: Transfer Operations Losses to Air, Water, Incineration, or Landfill from Unloading Plastics Additives.
- Release source 2: Container Residue Losses to Water, Incineration, or Landfill
- Release source 3: General Processing
- Release source 4: Direct Contact Cooling Water Losses to Water
- Release source 5: Equipment Cleaning Losses to Water, Landfill, or Incineration
- Release source 6: Loaded into Hopper/Feedstock Storage of Plastics Compounding or Converting Line or Transport Containers for External Shipment

D.11.1 Number of Sites

EPA estimated the number of recycling sites based on the ENF Recycling plastic recycling database which reports 59 plastic recyclers as of January 22, 2024 ([ENF Plastic, 2024](#)). Since the proportion of plastic recycling sites which receive DIBP-containing plastics is unknown, EPA assessed this OES using the entire 59 sites.

D.11.2 Throughput Parameters

EPA estimated the total production volume for all recycling sites using a constant value of 5,543 kg/year based on 2020 CDR reporting data ([U.S. EPA, 2020a](#)) and industry data from Milbrandt ([Milbrandt et al., 2022](#)). The Milbrandt article indicates that three percent of plastic products produced during the plastic compounding and converting OESs will be recycled. Based on this, EPA assessed the PV for recycling as three percent of the plastic compounding and converting production volume.

For recycling, the annual throughput of DIBP is calculated using Equation_Apx D-90 by dividing the annual total production volume assessed (discussed in the paragraph above) by the number of recycling sites (see Section D.11.1).

Equation_Apx D-90.

$$Q_{DIBP_year} = \frac{PV}{N_{sites}}$$

Where:

Q_{DIBP_year}	=	Facility annual throughput of DIBP [kg/site-yr]
PV	=	Total PV assessed [kg/year]
N_{sites}	=	Number of recycling sites [sites] (see Section D.11.1)

D.11.1 Container Size

EPA assessed the container size for plastics to be recycled using data from the Association of Plastics Recyclers (APR) technical report ([APR, 2023](#)). The report indicates plastics for recycling are transported in bales that are 15 to 20 lb/ft³. Standard bales have dimensions of 30 × 42 × 48 inches or 30 × 48 × 60 inches, and a single truck load is typically 35,000 lbs (15,875 kg). Based on these standard dimensions, EPA calculated a uniform distribution to assess the recycling bale size with a lower bound of 240 kg and an upper bound of 453 kg.

D.11.2 Container Unloading Rate

The ChemSTEER User Guide ([U.S. EPA, 2015](#)) provides a typical unloading rate of 20 containers per hour for containers with more than 20 gallons and less than 1,000 gallons of capacity.

D.11.3 Dust Capture and Control

EPA assessed dust capture and control for this OES using the parameters outlined in Section D.10.8. EPA does not expect dust capture or control for the unloading of plastics; however, dust capture and control is expected to be implemented during the loading of recycled plastic material.

D.12 Rubber Manufacturing Model Approaches and Parameters for Releases

This appendix presents the modeling approach and equations used to estimate environmental releases for DIBP during the rubber manufacturing OES. This approach utilizes the same release points, equations, and assumptions presented for the plastic compounding and plastic converting OESs in Section D.10.

Therefore, only the parameters that differ between approaches, including throughput parameters and DIBP concentrations, will be presented in this section for brevity.

D.12.1 Throughput Parameters

EPA estimated the total production volume for all sites using a combination of reported national production volume of DIBP from the 2020 CDR ([U.S. EPA, 2020a](#)) and industry data from the Annex XV Restriction Report ([ECHA, 2011](#)). The national PV from CDR is 407,303 lbs/year, and the percentage of PV from the Annex report assigned to each COU under the rubber manufacturing OES is 2 percent. Based on these values, the EPA assessed the total PV for the rubber manufacturing OES as 7,388 kg/year. Since there are two sites associated with the rubber manufacturing OES, the facility annual throughput of DIBP is 3,694 kg/site-year.

D.12.2 Rubber Additive DIBP Concentration

EPA modeled the concentration of DIBP in the rubber additive received onsite based on the 2020 CDR reporter for plastic product manufacturing and concentration of DIBP manufactured ([U.S. EPA, 2020a](#)). Based on this data, EPA assessed the parameter using a uniform distribution with an upper bound of 1 and a lower bound of 0.9.

D.12.3 Mass Fraction of DIBP in Rubber Product

EPA modeled the mass fraction of DIBP in rubber products using both the GS on the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)) and the 2004 ESD on Additives in the Rubber Industry ([OECD, 2004](#)). The ESD estimates that the chemical of interest concentration in rubber products ranges from 10 to 20 percent, and the GS estimates that plasticizers contain a concentration ranging from one to five percent in products. Therefore, EPA assessed the mass fraction of DIBP in rubber products with a uniform distribution with a lower bound of 0.01 and an upper bound of 0.2.

D.12.4 Number of Sites

The number of sites for rubber manufacturing was calculated using the equation below:

Equation_Apx D-91.

$$N_{sites_conv} = \frac{PV}{Q_{additives} \times (F_{DIBP_resin} / F_{all_additives})}$$

Where:

N_{sites_conv}	=	Number of sites [sites]
PV	=	Production volume (see Section D.12.1) [kg/year]
$Q_{additives}$	=	Facility annual throughput of DIBP (see Section D.12.1) [kg/site-yr]
F_{DIBP_resin}	=	Rubber product DIBP concentration (see Section D.12.3) [kg/kg]
$F_{all_additives}$	=	Concentration of all additives in product [kg/kg]

EPA calculated the range of the number of sites using Equation_Apx D-91, which resulted in a total number of two sites for the rubber manufacturing OES.

D.12.5 Operating Days

For rubber 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 and 300 days/year. The lower bound is based on the 2014 Plastics Compounding Draft GS ([U.S. EPA, 2014c](#)), which states that a typical range of 148 to 264 days/year are expected. The upper bound is based on ESIG's Specific Environmental Release Category for Rubber Production and Processing ([ESIG, 2020b](#)). The mode is based on the GS for the Use of Additives in Plastic Compounding ([U.S. EPA, 2021d](#)), which states that 246 days/year should be used as a default.

D.13 Spray Inhalation Exposure Model Approach and Parameters

This section presents the modeling approach and equations used to estimate occupational inhalation exposures for DIBP during the application of paints and coatings and application of adhesives and sealants OESs. 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 DIBP in the paint, coating, adhesive, or sealant to estimate the central tendency and high-end inhalation exposures, respectively.

D.13.1 Model Design Equations

The Automotive Refinishing Spray Coating Mist Inhalation Model calculates the 8-hour TWA exposure to DIBP present in mist and particulates using the following equation:

Equation_Apx D-92.

$$C_{DIBP,8hr-TWA} = \frac{C_{mist} \times F_{DIBP,solids} \times ED}{8\ hrs}$$

Where:

$C_{DIBP,8hr-TWA}$	=	8-hour TWA inhalation exposure to DIBP (mg/m ³)
C_{mist}	=	Over sprayed product mist concentration in the air within worker's breathing zone (mg/m ³)
$F_{DIBP,solids}$	=	Mass fraction of DIBP in the non-volatile portion of the spray (mg DIBP/mg nonvolatile components)
ED	=	Exposure duration (hr)

D.13.2 Model Parameters

Table_Apx D-25 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-25. 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	Application of paints and coatings	3.38	22.1	See Section D.13.2.1

Input Parameter	Symbol	Unit	OES	Parameter Value		Rationale/ Basis
				Central Tendency	High-End	
			Application of adhesives and sealants			
DIBP Concentration in Product	F _{DIBP_prod}	kg/kg	Application of paints and coatings	0.05	0.60	See Section D.13.2.2
			Application of adhesives and sealants	0.30	0.60	
Concentration of Nonvolatile Solids in the Spray Product	F _{solids_prod}	kg/kg	Application of paints and coatings	0.5	0.25	See Section D.13.2.3
			Application of adhesives and sealants			
DIBP Concentration of Nonvolatile Components	F _{DIBP_solids}	mg/mg	Application of paints and coatings	0.10	1.00	See Section D.13.2.4
			Application of adhesives and sealants	0.60	1.00	
Exposure Duration	ED	hr	Application of paints and coatings	8		See Section D.13.2.5
			Application of adhesives and sealants			

D.13.2.1 Concentration of Mist

EPA assessed the concentrations of mists to be equal to all of the mist concentration data that is given in Appendix E of the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry ([OECD, 2011a](#)). The mist concentration data of this appendix are PBZ worker monitoring data that are associated with three types of spray booths (downdraft, cross draft, or semi-downdraft) and two types of spray guns (conventional or high-volume low-pressure). These mist concentration data were obtained through a search of available OSHA In-Depth Surveys of the Automotive Refinishing Shop Industry and other relevant studies, as mentioned in the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry ([OECD, 2011a](#)). EPA determined the central tendency and high-end values of the set of data that includes all of the mist concentration data of Appendix E of the ESD and these values are 3.38 mg/m³ and 22.1 mg/m³, respectively. Therefore, these central tendency and high-end values are not associated with any particular type of spray booth and spray gun.

D.13.2.2 DIBP Product Concentration

EPA obtained DIBP product concentration data from the safety data sheets or technical data sheets of products that are listed in Appendix E and are associated with these two categories of products: (a) paint and coating, and (b) adhesive and sealant., EPA then determined the mode and the maximum of the DIBP product concentration data in the case of each of these two categories of products. EPA assessed the central tendency and high-end concentrations to be equal to the mode and maximum concentrations

respectively. For paints and coatings, the central tendency value is 0.05 and the high-end is 0.60. For adhesives and sealants, the central tendency value is 0.30 and the high-end is 0.60.

D.13.2.3 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 an auto refinishing 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 0.25 mg/mg and the upper bound of the underlying distribution of 0.50 mg/mg for the high-end and central tendency parameters, respectively ([OECD, 2011a](#)).

D.13.2.4 DIBP Concentration in Nonvolatile Components

The mass fraction of DIBP in the nonvolatile portion of the sprayed product is calculated using the following equation:

Equation_Apx D-93.

$$F_{DIBP_solids} = \frac{F_{DIBP_prod}}{F_{solids_prod}}$$

Where:

F_{DIBP_solids}	=	Mass fraction of DIBP in the nonvolatile portion of the sprayed product (mg DIBP/mg nonvolatile components)
F_{DIBP_prod}	=	Mass fraction of DIBP in the paint, coating, adhesive, or sealant product, spray-applied (mg DIBP/mg sprayed product)
F_{solids_prod}	=	Mass fraction of nonvolatile components within the sprayed product (mg nonvolatile components/mg sprayed product)

If this equation results in $F_{DIBP_solids} > 1$, then the value of F_{DIBP_solids} is assessed at a value of 1. The results of this equation were a central tendency DIBP concentration in solids of 0.10 for paints and coatings and 0.60 for adhesives and sealants. For both scenarios, the results were a high-end concentration of 1.00.

D.13.2.5 Exposure Duration

EPA did not identify DIBP-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 eight-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 eight-hour duration for spraying is used and assumed to be protective of any contribution to exposures from vapors.

D.14 Inhalation Exposure Modeling for Vapor Exposures

This appendix presents the modeling approach and model equations used in the occupational inhalation vapor exposure modeling for the DIBP manufacturing OES. EPA determined that DIBP manufacturing had the highest vapor inhalation exposure potential for all OES based on the summation of results of environmental fugitive releases to air and their associated exposure durations for each OES (to see environmental releases by OES, refer to Section 3). Therefore, EPA only estimated worker vapor inhalation exposures for the DIBP manufacturing OES to represent the most protective exposure

outcome of all possible vapor exposure OESs. The results of this modeling showed no risks to workers from inhalation exposures to vapor, including when aggregated with dermal exposures, due to the MOE values exceeding the benchmark by multiple orders of magnitude.

EPA developed the model to estimate worker inhalation exposures to vapor during manufacturing using the ESD on the Chemical Industry ([OECD, 2011c](#)) and 2020 CDR reporting data ([U.S. EPA, 2020a](#)) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD on the Chemical Industry ([OECD, 2011c](#)), EPA identified the following exposure activities from manufacturing operations:

- Exposure activity A: Product Sampling.
- Exposure activity B: Equipment Cleaning.
- Exposure activity C: Loading Manufactured DIBP into Transport Containers.

Occupational inhalation exposures to vapor DIBP during manufacturing are a function of DIBP's physical properties, DIBP mass fractions, vapor generation rates, 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: vapor generation rate, mixing factor, ventilation rate, and working years. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate exposure concentrations for this OES.

EPA determined that the potential for vapor inhalation exposure is greatest in the case of the OES of DIBP manufacturing. EPA accomplished this determination by considering the following determinants of inhalation exposure: fugitive emission rates and their respective duration, and worker exposure frequency. Specifically, EPA calculated an index of exposure potential by multiplying the emission rate of each source fugitive air emissions and the duration of emission from this source and then summing these products. This index was calculated for each OES that includes fugitive air emissions, and the value of this index is greatest in the case of the OES of DIBP manufacturing. EPA then considered the exposure frequency that EPA assessed in the case of each OES; these exposure frequencies are all of similar value and therefore the OES of manufacture is confirmed as the worst-case of vapor inhalation exposure. EPA notes that other exposure determinants (*i.e.*, mixing factor, ventilation rate, and working years) do not vary by OES and are therefore not relevant to the determination of the worst-case. Based on this, EPA only modeled vapor exposures for the DIBP manufacturing OES and used these modeled estimates as surrogate for all OES with vapor exposure potential. For each OES, EPA used this modeled vapor exposure estimate from the manufacturing OES in conjunction with the exposure frequency specific to each OES to calculate the risks as discussed in Appendix A.

D.14.1 Model Design Equations

Table_Apx D-26 provides the models and associated variables used to calculate inhalation exposure for each exposure activity within each iteration of the Monte Carlo simulation. EPA used these calculations to develop a distribution of exposure 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 Section D.14.2. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end exposures, respectively.

Table_Apx D-26. Models and Variables Applied for Exposure Activities in the Manufacturing OES

Exposure Activity	Model(s) Applied	Variables Used ^a
Exposure activity A: Product Sampling	EPA Mass Balance Inhalation Model (Section D.1)	$F_{DIBP}; VP; OH_{sampling}; MW; T; OH_{sampling}; RATE_{ventilation}; F_{mixing} Release_perDay_{RP4}$
Exposure activity B: Equipment Cleaning	EPA Mass Balance Inhalation Model (Section D.1)	$F_{DIBP}; VP; OH_{equip_clean}; MW; T; OH_{equip_clean}; RATE_{ventilation}; F_{mixing} Release_perDay_{RP6}$
Exposure activity C: Loading Manufactured DIBP into Transport Containers	EPA Mass Balance Inhalation Model (Section D.1)	$F_{DIBP}; VP; OH_{load}; MW; T; OH_{load}; RATE_{ventilation}; F_{mixing} Release_perDay_{RP7}$
All activities	8-hr TWA (see Equation_Apx D-94 below)	
^a Parameters such as release rate and operating hours were calculated and outlined in Section D.2 which covers the release assessment for the manufacturing OES.		

Worker eight-hour TWA exposure is calculated using the following equation:

Equation_Apx D-94.

$$C_{8-hr,TWA} = \frac{OH_{sampling} \times C_{mA} + OH_{equip_clean} \times C_{mB} + OH_{load} \times C_{mC}}{ED}$$

Where:

$C_{8-hr,TWA}$	=	Mass 8-hour TWA [mg/m ³]
$OH_{sampling}$	=	Sampling operating hours [hours/day]
OH_{equip_clean}	=	Equipment cleaning operating hours [hours/day]
OH_{load}	=	Product loading operating hours [hours/day]
ED	=	Exposure duration [hrs/day]
C_{mA}	=	Mass concentration of DIBP for Activity A [mg/m ³]
C_{mB}	=	Mass concentration of DIBP for Activity B [mg/m ³]
C_{mC}	=	Mass concentration of DIBP for Activity C [mg/m ³]

D.14.2 Model Parameters

Table_Apx D-27 summarizes the model parameters for the vapor inhalation exposure modeling for the manufacturing OES. Each parameter is discussed in further detail in the following subsections.

Table_Apx D-27. Summary of Parameter Values Used in the Surrogate Manufacturing OES Exposure Assessment

Input Parameter	Symbol	Unit	Constant Value ⁶	Variable Model Parameter Values				Rationale
				Lower Bound	Upper Bound	Mode	Distribution Type	
Mixing Factor	F _{mixing}	dimensionless	—	0.1	1	0.5	Triangular	See Section D.14.2.1
Ventilation Rate	RATE _{ventilation}	ft ³ /min	—	500	10,000	3,000	Triangular	See Section D.14.2.2
Working Years	WY	years	—	10.4	44	36	Triangular	See Section D.14.2.3
Exposure Frequency	EF	days/year	250	—	—	—	—	Assumption based on 50 weeks worked per year
Molar Volume	V _m	L/mol	24.45	—	—	—	—	Universal constant
Lifetime Years	LT	years	78	—	—	—	—	See Section D.14.2.4
Exposure Duration	ED	hours/day	8	—	—	—	—	See Section D.14.2.5

⁶ Each parameter is represented either by a constant value or a distribution.

D.14.2.1 Mixing Factor

The CEB Manual ([U.S. EPA, 1991b](#)) indicates mixing factors may range from 0.1 to 1, with 1 representing ideal mixing. The CEB Manual references the 1988 ACGIH Ventilation Handbook, which suggests the following factors and descriptions: 0.67 to 1 for best mixing; 0.5 to 0.67 for good mixing; 0.2 to 0.5 for fair mixing; and 0.1 to 0.2 for poor mixing ([U.S. EPA, 1991b](#)). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the defined lower and upper bound and estimated mode of the parameter. The mode for this distribution was not provided; therefore, EPA assigned a mode value of 0.5 based on the typical value provided in the ChemSTEER User Guide for the EPA Mass Balance Inhalation Model ([U.S. EPA, 2015](#)).

D.14.2.2 Ventilation Rate

The CEB Manual ([U.S. EPA, 1991b](#)) indicates general ventilation rates in industry range from 500 to 10,000 ft³/min, with a typical value of 3,000 ft³/min. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on an estimated lower bound, upper bound, and mode from the CEB Manual ([U.S. EPA, 1991b](#)).

D.14.2.3 Working Years

EPA assessed working years for this OES using the approach outlined in Section A.4.6.

D.14.2.4 Lifetime Years

EPA assumes a lifetime of 78 years for all worker demographics.

D.14.2.5 Exposure Duration

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

D.15 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, 2021c](#)) 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) dataset. 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 DIBP in the particulates, EPA assumed DIBP 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 DIBP present in dust and particulates using the following equation:

Equation_Apx D-95.

$$C_{DIBP,8hr-TWA} = C_{PNOR,8hr-TWA} \times F_{DIBP}$$

Where:

$C_{DIBP,8hr-TWA}$	=	8-hour TWA exposure to DIBP [mg/m ³]
$C_{PNOR,8hr-TWA}$	=	8-hour TWA exposure to PNOR [mg/m ³]
F_{DIBP}	=	Mass fraction of DIBP in PNOR [mg/mg]

Table_Apx D-28 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, 2021c](#)) along with the associated NAICS code, PNOR 8-hour TWA exposures, DIBP mass fraction, and DIBP 8-hour TWA exposures assessed for each OES.

Table_Apx D-28. Summary of DIBP Exposure Estimates for OESs Using the Generic Model for Exposure to PNOR

OES	NAICS Code Assessed	Respirable PNOR 8-hour TWA from Model (mg/m ³)		DIBP Mass Fraction Assessed	DIBP 8-Hour TWA (mg/m ³)	
		Central Tendency	High-End		Central Tendency	High-End
Use as a catalyst – formulation of pre-catalyst	325 – Chemical Manufacturing	0.48	5	1.33E-06	6.4E-07	6.7E-06
Use in laboratory chemicals	54 – Professional, Scientific, and Technical Services	0.19	2.7	1.0E-03	1.9E-04	2.7E-03
Fabrication of articles	337 – Furniture and Related Product Manufacturing	0.2	1.8	0.2	4.0E-02	0.36
	23 – Construction	0.37	5	5.0E-07	1.9E-07 ^a	2.5E-06 ^a
Plastics compounding	325 – Chemical Manufacturing	0.48	5	7.4E-02	3.6E-02	0.37
Plastics converting	326 – Plastics and Rubber Manufacturing	0.23	4.7	7.4E-02	1.7E-02	0.35
Recycling	56 – Administrative and Support and Waste Management and Remediation Services	0.24	3.5	0.2	4.8E-02	0.7
	326 – Plastics and Rubber Manufacturing	0.23	4.7	5.0E-07	1.2E-07 ^b	2.4E-06 ^b
Waste handling	56 – Administrative and Support and Waste Management and Remediation Services	0.24	3.5	0.2	4.8E-02	0.7
Rubber manufacturing – Compounding	325 – Chemical Manufacturing	0.48	5	0.2	9.6E-02	1.0
Rubber manufacturing – Converting	326 – Plastics and Rubber Manufacturing	0.23	4.7	0.2	4.6E-02	0.94
^a These results are associated with the specific case of use of tire crumb rubber in artificial sports turf and were not incorporated into the occupational risk calculator because these results are less than the other results calculated for the Fabrication of articles OES. See Section 3.9 for information related to tire crumb rubber and the Fabrication of articles OES. ^b These results are associated with the specific case of production of tire crumb rubber and were not incorporated into the occupational risk calculator because these results are less than the other results calculated for the Recycling OES. See Section 3.12 for information related to tire crumb rubber and the Recycling OES.						

Appendix E Products Containing DIBP

This appendix contains information about specific products that contain DIBP. All of the specific products that EPA has information about are mentioned in Table_Apx E-1 but this table is not a comprehensive list of products containing DIBP. In addition, mention of manufacturers' names in Table_Apx E-1 does not imply anything about the market share of these manufacturers. The mention of these manufacturers may mean that they are more likely to disclose product ingredients online than other manufacturers.

EPA associated each of the products mentioned in Table_Apx E-1 with one of the various OESs as shown in this table. If the concentration of DIBP in the product is lacking, then EPA did not assume a value and therefore did not incorporate concentration information about this product into the assessment. If the concentration units are not specified, then EPA assumed units of mass fraction. EPA incorporated all of the concentration data of Table_Apx E-1 that are associated with the OES of Application of Adhesives/Sealants into the assessment except for Azo-Cat 25 as noted in the table. EPA accomplished this by determining central tendency and high-end concentration values to represent the data in the table as discussed in Section D.8.7. EPA similarly incorporated all of the concentration data of Table_Apx E-1 that are associated with the OES of Application of Paints/Coatings into the assessment – see Section D.7.7. The table also contains concentration data that are associated with other OESs but EPA did not create distributions of DIBP concentration in products in the case of those OESs as discussed in the various relevant sections of Section 3.

Table_Apx E-1. Products Containing DIBP

OES	Product	Manufacturer	DIBP Concentration	Source
Application of adhesives and sealants	Lord Accelerator 17	Lord Corporation	<25%, by weight	(Lord Corporation, 2000)
Application of adhesives and sealants	Flexible Accelerator	Multiurethanes Ltd.	≥50 – ≤75%, by weight	(MME, 2018a)
Application of adhesives and sealants	Universal Accelerator	Multiurethanes Ltd.	≥50 – ≤75%, by weight	(MME, 2018b)
Application of adhesives and sealants	Blue Label Washable PVA Adhesive	Colorlord Ltd.	Unknown	(Colorlord Ltd, 2009)
Application of adhesives and sealants	Chem-Set C-19 Seaming Adhesive – All Colors	Chemical Concepts Inc.	15–40%, by weight	(Chemical Concepts Inc, 2014)
Application of adhesives and sealants	Mondo PU-105 - Part A	MAPEI	1 – 5%, unspecified	(MAPEI, 2009)
Application of adhesives and sealants	STA'-PUT 2-Component Solid Surfacing Adhesive (10:1 Ratio) - All Colors	ITW TACC	25–50%, by weight	(ITW TACC, 2012)
Application of adhesives and sealants	Wilsonart® 8215 Adhesive and Activator - SK200	Wilsonart LLC	30–60%, by weight	(Wilsonart, 2013b)

OES	Product	Manufacturer	DIBP Concentration	Source
Application of adhesives and sealants	Wilsonart® Hard Surface Adhesive	Wilsonart LLC	25–50%, by weight	(Wilsonart, 2013a)
Application of adhesives and sealants	Clear Welder Activator	ITW	30–40%, by weight	(ITW Performance Polymers, 2015)
Application of adhesives and sealants	CornerSealant Adhesive (TI-550 activator)	Tower Industries	10–30%, by weight	(Tower Industries, 2012)
Application of adhesives and sealants	Velstone Activator	Velstone International Ltd.	30–60%, by weight	(Velstone International Ltd, 2003)
Fabrication of final product from articles	Centerfire Pistol & Revolver and Rifle Cartridges – All Calibers up to .500	Companhia Brasileira de Cartuchos (CBC)	0.1–0.6%, unspecified	(CBC, 2014)
Application of adhesives and sealants	AT (AT10, AT13, AT30, AT)	Simpson Strong-Tie Company Inc.	20–30%, by weight	(Simpson Strong-Tie, 2014)
Application of adhesives and sealants	CP310	Abesco Fire LLC	5–10%, unspecified	(LLC, 2015)
Application of paints and coatings	Formica Solid Surfacing Activator	ITW Plexus	30–60%, by weight	(ITW Plexus, 2004)
Application of paints and coatings	BK-NitroEmail	Banja Komerc Bekament d.o.o.	2 to <5%, unspecified	(Bekament, 2019)
Application of adhesives and sealants	Butanox LPT	Akzo Nobel Polymer Chemicals	60%, by weight	(Chemicals, 2008)
Application of adhesives and sealants	Akperox BP 15, 17, 20, 25, 50 Pastes	Akpa Kimya Ambalaj Sanayi Ve Ticaret Anonim Şirketi	1–5%, unspecified	(AKPA, 2023a, b, 2017)
Application of adhesives and sealants	Perkadox® 40E	Akzo Nobel Polymer Chemicals	Unknown	(AzkoNobel, 2011)
Application of adhesives and sealants	Jowacoll 110.60	Jowat Corporation	2.5 to <5%, unspecified	(Jowat Corporation, 2016)
Application of adhesives and sealants	Polyester Filler Hardener Paste	Chemical Specialties Ltd.	0–30%, unspecified	(Chemical Specialties Ltd, 2017)
Fabrication of final product from articles	Glitter Boards	DJECO	Unknown	(DJECO, 2018b)

OES	Product	Manufacturer	DIBP Concentration	Source
Application of adhesives and sealants	Azo-Grout 443	Azon USA Inc.	<30%, unspecified	(Inc, 2015)
Application of adhesives and sealants	Azo-Grout 447	Azon USA Inc.	<50%, unspecified	(Azon, 2015c)
Application of adhesives and sealants	Azo-Grout 552	Azon USA Inc.	<50%, unspecified	(Azon, 2015d)
Application of adhesives and sealants	Azo-Grout 553	Azon USA Inc.	<50%, unspecified	(Azon, 2015e)
Application of adhesives and sealants	Universal Resin	Multiurethanes Ltd.	≥25 to ≤50%, by weight	(MME, 2018c)
Application of adhesives and sealants	Azo-Cat™ 24	Azon USA Inc.	<60%, unspecified	(Azon, 2015a)
Application of adhesives and sealants	Azo-Cat™ 48	Azon USA Inc.	<60%, unspecified	(Azon, 2015b)
Use of laboratory chemicals	33227 / EPA Method 8061A Phthalate Esters Mixture	Restek Corporation	0.1%, unspecified	(Restek, 2019)
Use of laboratory chemicals	Custom 8061 Phthalates Mix	Phenova	0.1%, unspecified	(Phenova, 2017)
Use of laboratory chemicals	DIBP	Sigma-Aldrich Inc.	≤100 %, unspecified	(Sigma-Aldrich, 2020)
Use of laboratory chemicals	DIBP	SPEX CertiPrep, LLC	0.1%, unspecified	(SPEX CertiPrep, 2015)
Use of laboratory chemicals	DIBP	SPEX CertiPrep, LLC	0.1%, unspecified	(SPEX CertiPrep, 2016)
Use of laboratory chemicals	Phthalate Esters Mix	SPEX CertiPrep, LLC	0.2%, unspecified	(AccuStandard, 2023)
Use of laboratory chemicals	Phthalic acid diisobutyl ester	SPEX CertiPrep, LLC	0.1%, unspecified	(SPEX CertiPrep, 2015)
Application of paints and coatings	Painting - Oh, It's Magic	DJECO	Unknown	(DJECO, 2018a)
Application of paints and coatings	Simoniz Black Paints	Holt Lloyd	1–5%, unspecified	(Lloyd, 2005)
Plastics compounding ^a	TMCH-HA-M2	United Initiators, Inc.	≥25 to <30%, by weight	(United Initiators, 2019)
Application of adhesives and sealants	RESFOAM SS 75	MAPEI	25–50%, unspecified	(MAPEI, 2018)

OES	Product	Manufacturer	DIBP Concentration	Source
Application of adhesives and sealants	IVS 150	IDEAL (VS) LTD	1–5%, unspecified	(Ideal (VS) Ltd, 2010)
Use of laboratory chemicals	DIBP	Veritas House	99%, unspecified	(Veritas House, 2015)
Use of laboratory chemicals	DIBP, 99+% (GC)	Acros Organics N.V.	>99%, unspecified	(NV, 2013)
Application of adhesives and sealants ^b	Azo-Cat™ 25	Azon USA Inc.	50–75%, unspecified	(Azon, 2017)
^a This product is expected to be mixed with other material in the plastic compounding process and fall within the current DIBP product distribution outlined in Section D.10.7. ^b This product is expected to be mixed Azo-Grout 443 as a two-part adhesive before use. Thus, the listed concentration for this product was not used for this assessment.				

Appendix F List of Supplemental Documents

A list of the supplemental documents that are mentioned in the *Environmental Release and Occupational Exposure Assessment for DIBP* and a brief description of each of these documents is given below. These supplemental documents are spreadsheets that contains model equations, parameter values and the results of the probabilistic (stochastic) or deterministic calculations and are available in Docket [EPA-HQ-OPPT-2018-0434](https://www.regulations.gov/document/EPA-HQ-OPPT-2018-0434).

1. *Manufacturing OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
2. *Manufacturing OES Occupational Inhalation Exposure Modeling Results for Diisobutyl Phthalate (DIBP)*. The Manufacturing OES was used as a surrogate for all other OESs that involve exposure to DIBP vapor.
3. *Container Repackaging OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
4. *Incorporation into Adhesives and Sealants OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
5. *Incorporation into Paints and Coatings OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
6. *Use as a Catalyst, Formulation of Pre-Catalyst OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
7. *Use as a Catalyst, Intermediate in PP Manufacturing OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
8. *Application of Paints and Coatings OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
9. *Application of Adhesives and Sealants OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
10. *Use of Laboratory Chemicals OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
11. *Plastic Manufacturing OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
12. *Recycling OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
13. *Rubber Manufacturing OES Environmental Release Modeling Results for Diisobutyl Phthalate (DIBP)*.
14. *Occupational Particulate Inhalation Exposure Modeling Results for Diisobutyl Phthalate (DIBP)*.
15. *Occupational Spray Application Mist Inhalation Exposure Modeling Results for Diisobutyl Phthalate (DIBP)*.