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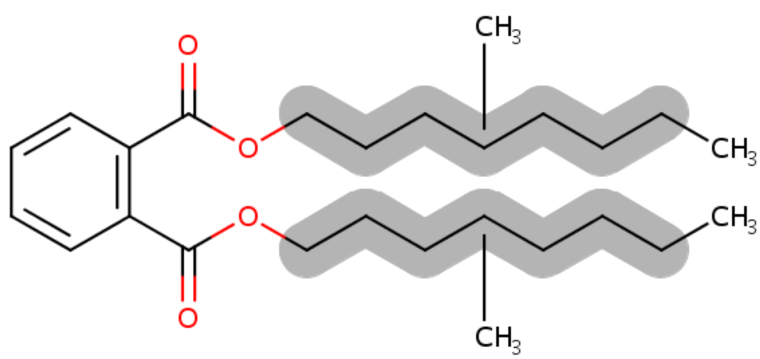
Pollution Prevention

Environmental Release and Occupational Exposure Assessment for Diisononyl Phthalate (DINP)

Technical Support Document for the Risk Evaluation

CASRNs: 28553-12-0 and 68515-48-0



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KEY ABBREVIATIONS AND ACRONYMS

AC	Acute exposure concentration
ACGIH	American Conference of Governmental Industrial Hygienists
AD	Acute retained dose
ADC	Average daily concentration
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
AWD	Annual Working Days
BLS	Bureau of Labor Statistics
BR	Breathing rate
BW	Body weight
C	Contaminant concentration in air
CASRN	Chemical Abstracts Service Registry Number
CBI	Confidential business information
CDR	Chemical Data Reporting
CEB	Chemical Engineering Branch
CEC	Commission for Environmental Cooperation
CEHD	Chemical Exposure Health Database
CFR	Code of Federal Regulations
CPS	Current Population Survey
CPSC	Consumer Product Safety Commission (U.S.)
CT	Central tendency

DD	Dermal Daily Dose
DIDP	Diisodecyl phthalate
DINP	Diisononyl 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. or the Agency)
ESD	Emission Scenario Document
ETIMEOFF	Months When Not Working (CPS data)
f	Fractional number of working days per year a worker works
G	Vapor generation rate
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
J	Absorptive flux
k	Mixing factor
LADC	Lifetime average daily concentration
LOD	Limit of detection
LT	Lifetime years
LVE	Low volume exception
MW	Molecular weight of DINP
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
OD	Operating days
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
P	Pressure
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
Q	Facility throughput
R	Universal Gas Constant
RD	Release days
REL	Recommended Exposure Limits
$\rho_{product}$	Product density
ρ_{DINP}	DINP density
RQ	Reportable Quantity
S	Surface area
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
SOC	Standard Occupational Classification (codes)
SRRP	Source Reduction Research Partnership
SUSB	Statistics of U.S. Businesses
T	Temperature
T_{AGE}	Worker age in SIPP
TDS	Technical data sheets
TSD	Technical support document
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
TWA	Time-weighted average
Vm_{DINP}	Molar volume of DINP
VP	DINP vapor pressure
W	Workers
WEEL	Workplace Environmental Exposure Level
WWT	Wastewater treatment
WY	Working Years per Lifetime
S	Surface area

SUMMARY

This technical support document (TSD) is for the Toxic Substances Control Act (TSCA) *Risk Evaluation for Diisononyl Phthalate (DINP)* (U.S. EPA, 2025) (also called the "risk evaluation for DINP"). DINP is a common chemical name for the category of chemical substances that includes the following substances: 1,2-benzenedicarboxylic acid, 1,2-isononyl ester (Chemical Abstracts Service Registration Number (CASRN] 28553-12-0) and 1,2-benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C9-rich (CASRN 68515-48-0). Both CASRNs contain mainly C_9 dialkyl phthalate esters. DINP is not a Toxics Release Inventory (TRI)-reportable substance; however, it is included in the TSCA Inventory and reported under the Chemical Data Reporting (CDR) rule. This TSD describes the use of reasonably available information to estimate environmental releases of DINP and to evaluate occupational exposure to workers. See the risk evaluation for DINP (U.S. EPA, 2025) for a complete list of all the TSDs and other supplemental files for DINP.

Environmental Release and Occupational Exposure Assessment

During scoping, EPA considered all known TSCA uses for DINP. The 2016 CDR report indicate that 100 to 250 million pounds (lb) of CASRN 28553-12-0 and 100to 250 million lb of CASRN 68515-48-0 were manufactured or imported in the United States in 2015 (U.S. EPA, 2019). The 2020 CDR report indicates a reduction in the manufacture/import of CASRN 28553-12-0 (range: 50–100 million lb). The manufacture/import volume of CASRN 68515-48-0 was between 100 million to 1 billion lb. The largest use of DINP is as a plasticizer in polyvinyl chloride (PVC) plastics. Secondary uses include use as a plasticizer in adhesives, sealants, paints, coatings, rubbers, and non-PVC plastics as well as other applications/uses.

Industrial, commercial, and consumer uses of DINP and DINP-containing articles might result in releases to air, water, or land and subsequent exposures to workers, consumers, general populations, and ecological species. Also, workers and occupational non-users (ONUs) may be exposed to DINP during specific worker activities for all conditions of use (COUs; also called TSCA COUs) such as sampling, loading and unloading, or the direct use of DINP-containing products. Exposure to the general population and ecological species might occur from industrial and commercial releases related to the manufacture, import, processing, distribution, and use of DINP. This TSD provides the details of the assessment of the environmental releases and occupational exposures from each condition of use of DINP.

Approach for Assessing Environmental Releases and Occupational Exposures in this Risk Evaluation

EPA evaluated environmental releases of DINP to air, water, and land from the TSCA COUs assessed in the risk evaluation for DNIP. EPA used release data from literature sources, where available, and modeling approaches where release data were not available.

EPA evaluated acute, intermediate, and chronic exposures to workers and ONUs for each condition of use. The Agency used inhalation monitoring data from literature sources where available, and exposure models where monitoring data were not available, or these data were deemed insufficient for capturing actual exposure within the condition of use (COU). EPA also used *in vivo* rat absorption data along with modeling approaches to estimate dermal exposures to workers.

Results for Environmental Releases and Occupational Exposures in the Risk Evaluation

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) (TSCA COUs) 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 DINP to air, water, and/or land for 14 OESs assessed in this risk evaluation. The Agency did not quantitatively assess environmental releases for some OESs due to a lack of readily available, process-specific and DINP-specific data. The OES with the highest expected release was Manufacturing, followed by Import/repackaging, and then Non-PVC compounding. 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. 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. Due to the low rate of dermal absorption of DINP, the occupational exposure assessment has shown that dermal exposures to DINP from industrial and commercial COUs are not expected to be significant under typical working conditions. However, the occupational exposure assessment has also shown that some inhalation exposures can be elevated under certain conditions for occupational applications of adhesives/sealants and paints/coatings. Detailed exposure results for each OES and exposure route can be found in Section 3.

Uncertainties of the Assessment

Uncertainties exist with the monitoring and modeling approaches used to assess DINP environmental releases and occupational exposures. For example, the lack of DINP facility production volume data and use of throughput estimates based on CDR reporting thresholds may result in production volume estimates that are not representative of the actual production volume of DINP in the United States. The Agency also used generic EPA models and default input parameter values when site-specific data were not available. In addition, site-specific differences in use practices and engineering controls exist but are largely unknown. This represents another source of variability that EPA could not quantify in this assessment.

Environmental and Exposure Pathways Considered in the Assessment

EPA assessed environmental releases to air, water, and land to estimate exposures to both the general population as well as ecological species for each condition of use. The Agency used these environmental release estimates to assess the presence of DINP in the environment and biota as well as to evaluate environmental hazards. EPA used the release estimates to model exposures to the general population and ecological species where environmental monitoring data were not available.

The Agency assessed risks for acute, intermediate, and chronic exposure scenarios in workers (those directly handling DINP) and ONUs (workers not directly involved with the manufacture or use of DINP) for DINP COUs. EPA assumed that workers and ONUs could be individuals of both sexes (aged 16+ years, including pregnant workers), based upon occupational work permits—although exposures to younger workers in occupational settings cannot be ruled out. An objective of this exposure assessment was to provide separate exposure 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

On May 24, 2019, EPA received a request, pursuant to 40 CFR 702.37, from ExxonMobil Chemical Company, through the American Chemistry Council's High Phthalates Panel (ACC HPP), to conduct a risk evaluation for DINP (CASRNs 28553-12-0 and 68515-48-0) (ACC HPP, 2019). The Agency determined that these two CASRNs should be treated as a category of chemical substances as defined in 15 U.S.C. 2625(c). On August 19, 2019, EPA opened a 45-day public comment period to gather information relevant to the requested risk evaluation. EPA reviewed the request (along with additional information received during the public comment period) and assessed whether the circumstances identified in the request constitute conditions of use under 40 CFR 702.33, and whether those COUs warrant inclusion within the scope of a risk evaluation for DINP. EPA determined that the request meets the applicable regulatory criteria and requirements, as prescribed under 40 CFR 702.37. The Agency granted the request on December 2, 2019.

DINP is a common chemical name for the category of chemical substances that includes the following substances: 1,2-benzenedicarboxylic acid, 1,2-isononyl ester (CASRN 28553-12-0) and 1,2-benzenedicarboxylic acid, di-C9-11-branched alkyl esters, C9-rich (CASRN 68515-48-0). Both CASRNs contain mainly C_9 dialkyl phthalate esters. DINP is a low volatility liquid that is used primarily as a plasticizer in PVC plastics—although it is also used in adhesives, sealants, paints, coatings, rubbers, and non-PVC plastics as well as for other applications. DINP is not a Toxics Release Inventory (TRI)-reportable substance; however, it is on the TSCA Inventory and reported under the CDR rule.

1.2 Scope

EPA assessed environmental releases and occupational exposures for COUs as described in Table 2-2 of the *Final Scope of the Risk Evaluation for Di-isononyl Phthalate (DINP); CASRNs 28553-12-0 and 68515-48-0* (U.S. EPA, 2021b). To estimate environmental releases and occupational exposures, EPA first developed occupational exposure scenarios (OESs) related to the COUs of DINP. An OES is based on a set of facts, assumptions, and inferences that describe how releases and exposures take place within an occupational condition of use. Release/exposure mechanisms may be similar across multiple COUs, or there may be several ways in which releases/exposures takes place for a given COU. Table 1-1 provides a crosswalk between the COUs from the *Risk Evaluation for Diisononyl Phthalate (DINP)* (U.S. EPA, 2025) and the OES assessed in this TSD.

In general, EPA mapped OESs to conditions of use using professional judgment based on available data and information. Several of the 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 OESs based on expected differences in process equipment and/or differences in associated release/exposure potential between facilities. EPA assessed environmental releases and occupational exposures for the following DINP OESs:

1. Manufacturing
2. Import and repackaging
3. Incorporation into adhesives and sealants
4. Incorporation into paints and coatings
5. Incorporation into other formulations, mixtures, and reaction products not covered elsewhere
6. PVC plastics compounding

7. PVC plastics converting
8. Non-PVC material compounding
9. Non-PVC material converting
10. Application of adhesives and sealants
11. Application of paints and coatings
12. Use of laboratory chemicals
13. Use of lubricants and functional fluids
14. Fabrication and final use of products or articles
15. Recycling
16. Disposal

Table 1-1. Crosswalk of Conditions of Use to Occupational Exposure Scenarios Assessed in the Risk Evaluation of DINP

Life Cycle Stage	Category	Subcategory	OES
Manufacturing	Domestic manufacturing	Domestic manufacturing	Manufacturing
	Importing	Importing	Import and repackaging
Processing	Repackaging	Plasticizer (all other chemical product and preparation manufacturing; wholesale and retail trade; laboratory chemicals manufacturing)	Import and repackaging
	Other uses	Miscellaneous processing (petroleum refineries; wholesale and retail trade)	Incorporation into other formulations, mixtures, or reaction products
	Incorporation into formulation, mixture, or reaction product	Heat stabilizer and processing aid in basic organic chemical manufacturing	Incorporation into other formulations, mixtures, or reaction products
		Plasticizers (adhesives manufacturing, custom compounding of purchased resin; paint and coating manufacturing; plastic material and resin manufacturing; synthetic rubber manufacturing; wholesale and retail trade; all other chemical product and preparation manufacturing; ink, toner, and colorant manufacturing [including pigment])	Incorporation into adhesives and sealants; Incorporation into paints and coatings; Incorporation into other formulations, mixtures, or reaction products; PVC material compounding; Non-PVC material compounding
	Incorporation into articles	Plasticizers (playground and sporting equipment manufacturing; plastics products manufacturing; rubber product manufacturing; wholesale and retail trade; textiles, apparel, and leather manufacturing; electrical equipment, appliance, and component manufacturing; ink, toner, and colorant manufacturing [including pigment])	PVC plastics converting; Non-PVC material converting
	Recycling	Recycling	Recycling
Disposal	Disposal	Disposal	Disposal
Distribution in Commerce	Distribution in commerce	Distribution in commerce	Distribution in commerce
Industrial Uses	Adhesive and sealant chemicals	Adhesive and sealant chemicals (sealant (barrier) in machinery manufacturing; computer and electronic product manufacturing; electrical equipment, appliance, component manufacturing; and adhesion/cohesion promoter in transportation equipment manufacturing)	Application of adhesives and sealants
	Construction, paint, electrical, and metal products	Building/construction materials (roofing, pool liners, window shades, flooring, water supply piping)	Fabrication or use of final product or articles
		Paints and coatings	Application of paints and coatings
	Other Uses	Hydraulic fluids	Use of lubricants and functional fluids
		Pigment (leak detection)	Application of paints and coatings
		Automotive articles	Fabrication or use of final product or articles

Life Cycle Stage	Category	Subcategory	OES
Commercial Use	Construction, paint, electrical, and metal products	Adhesives and sealants	Application of adhesives and sealants
		Plasticizer in building/construction materials (roofing, pool liners, window shades, water supply piping); construction and building materials covering large surface areas, including paper articles; metal articles; stone, plaster, cement, glass and ceramic articles	Fabrication or use of final product or articles
		Electrical and electronic products	Fabrication or use of final product or articles
		Paints and coatings	Application of paints and coatings
	Furnishing, cleaning, treatment/care products	Foam seating and bedding products; furniture and furnishings including plastic articles (soft); leather articles	Fabrication or use of final product or articles
		Air care products	Incorporation into other formulations, mixtures, or reaction products
		Floor coverings; plasticizer in construction and building materials covering large surface areas including stone, plaster, cement, glass and ceramic articles; fabrics, textiles and apparel (vinyl tiles, resilient flooring, PVC-backed carpeting)	Fabrication or use of final product or articles
		Fabric, textile, and leather products (apparel and footwear care products)	Fabrication or use of final product or articles
	Packaging, paper, plastic, hobby products	Arts, crafts, and hobby materials	Fabrication or use of final product or articles
		Ink, toner, and colorant products	Application of paints and coatings
		Packaging, paper, plastic, hobby products (packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft))	Fabrication or use of final product or articles
		Plasticizer (plastic and rubber products; tool handles, flexible tubes, profiles, and hoses)	Fabrication or use of final product or articles
		Toys, playground, and sporting equipment	Fabrication or use of final product or articles
	Other uses	Laboratory chemicals	Use of laboratory chemicals
		Automotive articles	Fabrication or use of final product or articles
	Solvents (for cleaning or degreasing)	Solvents (for cleaning or degreasing)	Use of lubricants and functional fluids

EPA's assessment included quantifying annual and daily releases of DINP to air, water, and land. Releases to air include both fugitive and stack air emissions and emissions resulting from on-site waste treatment equipment (*e.g.*, incinerators). For purposes of this assessment/TSD, 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. The Agency considered 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 DINP to landfills, land treatment, surface impoundments, or other land applications. The purpose of this TSD 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 Diisononyl Phthalate (DINP)* (U.S. EPA, 2025) describes how these factors were considered when determining risk.

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

2 COMPONENTS OF RELEASE AND OCCUPATIONAL EXPOSURE ASSESSMENT

EPA describes the assessed COUs for DINP in the *Risk Evaluation for Diisononyl Phthalate (DINP)* (U.S. EPA, 2025); however, some COUs are very broad and encompass multiple many different processes and associated exposure/release scenarios. Therefore, Table 1-1 provides a crosswalk that maps the DINP COUs to the more specific OESs. The following components comprise the environmental release and occupational exposure assessments for each OES:

- **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 DINP 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 DINP 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 points of worker and ONU exposures.
    - **Number of Workers and ONUs:** An estimate of the number of workers and ONUs potentially exposed to the chemical for the given OES.
    - **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, the Agency 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 steps;
- Information on receiving and shipping containers; and
- Ultimate destination of chemical leaving the facility.

Where DINP-specific process descriptions were unclear or unavailable, EPA referenced generic process descriptions from literature, including relevant Emission Scenario Documents (ESD) or Generic Scenarios (GS). EPA developed process descriptions that include facility throughputs or hypothetical scenarios assessed, key process steps, and a description of where DINP is present (*e.g.*, physical state, concentration) throughout the process. Sections 3.1 through 3.17 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 program data and top-down analyses of U.S. economic data and industry-specific data. Generally, the Agency used the following steps to develop facility estimates:

1. Identify or "map" each facility that reported for DINP in the 2016 and 2020 CDR to an OES (U.S. EPA, 2020b, 2019). Mapping consisted 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 the facilities within the OES. If so, the Agency assessed the total number of facilities in the OES as equal to the number 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 method:
    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 U.S. Businesses (SUSB) data on total sites by 6-digit NAICS.
    c. Use market penetration data to estimate the percentage of sites likely to be using DINP instead of other chemicals.
    d. Combine the data generated in Steps 3.a through 3.c to produce an estimate of the number of facilities using DINP 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 encompasses 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 DINP 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, the Agency used stochastic modeling to provide a range of estimates for the number of facilities within an 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 (*i.e.*, via monitoring), calculations based on empirical data, and/or assumptions and models. For each OES, the Agency attempted to provide annual releases, high-end and central tendency daily releases, and the number of release days per year for each media of release (*i.e.*, air, water, and land).

EPA used the following hierarchy in selecting data and approaches for assessing environmental releases:

1. Monitoring and measured data:

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

EPA described the final release results as either a point estimate (*i.e.*, a single descriptor or statistic, such as central tendency or high-end) or a full distribution. The Agency considered three general approaches to estimate 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. The Agency documented the method and rationale for selecting parametric combinations, to be 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 statistical distributions for each input parameter to calculate a full distribution of the final release results. The Agency 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 but point estimates of the remaining parameters. For example, the Agency used Monte Carlo modeling to estimate annual throughputs and emission factors, but only had point estimates of release frequency and production volume. In such cases, 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 3.17.

2.3.1 Identifying Release Sources

EPA performed a literature search to identify process operations that could potentially result in releases of DINP to air, water, or land from each OES. For each OES, the Agency identified the release sources and the associated media of release. Where information on DINP-specific release sources was unclear or unavailable, EPA referenced relevant ESDs or GSs. Sections 3.1 through 3.17 describe the release sources for each OES.

2.3.2 Estimating Release Days per Year

EPA assumed that the number of release days per year for a given release source was equal to the number of operating days at a given facility, unless the Agency identified information indicating otherwise. 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, the Agency used data for other facilities within the same OES, if possible, and 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: Days/year = Estimated Annual Use Rate for the facility (kg/year) / 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, the Agency used a value of 250 days per year. This assumes the plant manufactures the chemical five days per week and 50 weeks per year (with 2 weeks down for turnaround).
5. **Other Chemical Plant OES (*e.g.*, processing into formulation and repackaging):** For these OES, EPA assumed that a facility does not always use the chemical of interest, even if the facility operates 24 hours/day, 7 days/week. Therefore, the Agency used a value of 300 days/year, based on the assumption that the facility operates 6 days/week and 50 weeks/year (with 2 weeks for turnaround). However, in instances where the OES uses a low volume of the chemical of interest, EPA used 250 days per year as a lower estimate based on the assumption that the facility operates 5 days/week and 50 weeks/year (with 2 weeks for turnaround).
6. **POTWs:** Although EPA expects POTWs to operate continuously 365 days per year, the discharge frequency of the chemical of interest from a POTW will depend on the discharge patterns of the chemical from upstream facilities discharging to the POTW. However, there can be multiple upstream facilities (possibly with different OESs) discharging to the same POTW and information on when the discharges from each facility occur (*e.g.*, on the same day or separate days) is typically unavailable. Since EPA could not determine the exact number of days per year that the POTW discharges the chemical of interest, the Agency 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 OESs.

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. The Agency used the following these 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 software with 100,000 iterations and the Latin Hypercube sampling method. Appendix E provides detailed descriptions of the model approaches that the Agency used for each OES as well as model equations, input parameter values, and associated distributions.

2.3.4 Estimating Releases Using Literature Data

Where available, EPA used data from literature sources to estimate releases. Literature data may include directly measured release data or other information related to release modeling. Therefore, the Agency's approach to literature data differed depending on the type of available literature data. For example, if facility-specific release data are available, EPA may use that data to estimate releases for that facility. If facility-specific data are available for a subset of the facilities within an OES, the Agency may build a distribution from these data and estimate releases from facilities within the OES using central tendency and high-end values from this distribution. If facility-specific data are unavailable, but industry- or chemical-specific emission factors are available, EPA may use these emission factors to calculate releases for an OES or incorporate the emission factors into release models to develop a distribution of potential releases for the OES. Sections 3.1 through 3.17 provide a detailed description of how the Agency incorporated literature data into the release estimates for each OES.

2.4 Occupational Exposure Approach and Methodology

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

EPA provided occupational exposure results representative of central tendency and high-end exposure conditions. The Agency expects the central tendency exposure value to represent occupational exposures in the center of the distribution for a given COU. For risk evaluation, EPA used the 50th percentile (median), mean (arithmetic or geometric), mode, or midpoint value of the exposure distribution to represent the central tendency. The Agency 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.

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

For occupational exposures, EPA used measured or estimated air concentrations to calculate the exposure concentration metrics required for risk assessment, such as average daily concentration (ADC) and lifetime average daily concentration (LADC). These calculations require additional parameter inputs, such as years of exposure, exposure duration and frequency, and lifetime years. 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, lifetime years) may be a point estimate (*i.e.*, a single descriptor or statistic, such as central tendency or high-end) or a full distribution. The Agency considered three general approaches for estimating the final exposure result metrics:

- **Deterministic calculations:** EPA used a combination of point estimates of each parameter to estimate both 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. The Agency selected the 50th and 95th percentiles of the 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, the Agency used Monte Carlo modeling to estimate exposure concentrations, but only had point estimates of exposure duration, exposure frequency, and lifetime years.

Appendix B 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). The Agency 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; for example, there is only one manufacturer who provides their internal OEL(s) 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 B describes the approach that EPA used for 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, the Agency referenced relevant ESDs or GSs. Sections 3.1 through 3.17 provide worker activities for each OES.

2.4.2 Estimating Number of Workers and Occupational Non-users

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

1. Identify the NAICS codes for the industry sectors associated with these uses.
2. Estimate total employment by industry/occupation combination using the Bureau of Labor Statistics' 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 DINP instead of other chemicals.
5. Where market penetration data are not available, use the estimated number of 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 data. For DMR, 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 DINP in each industry/occupation combination and sum these to arrive at a total estimate of the number of employees with exposure within the OES.

2.4.3 Estimating Inhalation Exposures

2.4.3.1 Inhalation Monitoring Data

To assess inhalation exposure, EPA reviewed workplace inhalation monitoring data collected by government agencies such as OSHA and NIOSH, monitoring data found in published literature (*i.e.*, personal exposure monitoring data and area monitoring data), and monitoring data submitted via public comments. Studies were evaluated using the strategies laid out in the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances, Version 1.0: A Generic TSCA Systematic Review Protocol with Chemical-Specific Methodologies* (also called the "Draft Systematic Review Protocol") (U.S. EPA, 2021a).

EPA calculated exposures from the monitoring datasets provided in the sources discussed above, using different methodologies depending on the size of the dataset. For datasets with six or more data points, the Agency estimated central tendency and high-end exposures using the 50th and 95th percentile values, respectively. For datasets with three to five data points, EPA estimated the central tendency and high-end exposures using the median and maximum values, respectively. For datasets with two data points, the Agency presented the midpoint and the maximum value. Finally, the Agency presented datasets with only one data point as-is. For datasets that included exposure data reported as below the limit of detection (LOD), EPA estimated exposure concentrations following guidance in *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. EPA, 1994). The Agency combined the exposure data from all studies applicable to a given OES into a single dataset.

For exposure assessment, EPA used personal breathing zone (PBZ) monitoring data and applicable area monitoring data to determine the TWA exposure concentration. Table 2-1 presents the data quality rating of the monitoring data that the Agency used to assess occupational exposures. EPA evaluated monitoring data using the evaluation strategies laid out in the Draft Systematic Review Protocol (U.S. EPA, 2021a).

Table 2-1. Data Evaluation of Sources Containing Occupational Exposure Monitoring Data

Source Reference	Data Type	Data Quality Rating	Occupational Exposure Scenario(s)
(ExxonMobil, 2022a)	PBZ Monitoring	Medium	Manufacturing
(Irwin, 2022)	PBZ Monitoring	Medium	PVC plastics converting

2.4.3.2 Inhalation Exposure Modeling

If EPA expected inhalation exposures for an OES, but monitoring data were either unavailable or did not sufficiently capture exposures, the Agency attempted to utilize models to estimate inhalation exposures. These models apply deterministic calculations, stochastic calculations, or a combination of both deterministic and stochastic calculations to estimate inhalation exposures. EPA used the following steps to estimate exposures for each OES:

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

For exposure models that utilize stochastic calculations, EPA performed a Monte Carlo simulation using the Palisade @Risk software with 100,000 iterations and the Latin Hypercube sampling method. Appendix E provides detailed descriptions of the model approaches used for each OES, model equations, and input parameter values and associated distributions.

2.4.4 Estimating Dermal Exposures

This section summarizes the available dermal absorption data related to DINP (Section 2.4.4.1), the interpretation of the dermal absorption data (Section 2.4.4.1.1), dermal absorption modeling efforts (Section 2.4.4.2), and uncertainties associated with dermal absorption estimation (Section 2.4.4.3). Dermal data were sufficient to characterize occupational dermal exposures to liquids or formulations containing DINP (Section 2.4.4.1); however, dermal data were not sufficient to estimate dermal exposures to solids or articles containing DINP. Therefore, modeling efforts described in Section 2.4.4.2 were utilized to estimate dermal exposures to solids or articles containing DINP. Dermal exposures to vapors are not expected to be significant due to the extremely low volatility of DINP, and therefore, are not included in the dermal exposure assessment of DINP. The flux-based dermal exposure approach used for estimating occupational dermal exposures to DINP is further explained in Appendix D.

2.4.4.1 Dermal Absorption Data

Dermal absorption data related to DINP were limited. Specifically, EPA identified only one acceptable study directly related to the dermal absorption of DINP (Midwest Research Institute, 1983), which was an *in vivo* absorption study using male F344 rats. For each *in vivo* dermal absorption experiment, neat DINP was applied to a freshly shaven area of 3 cm × 4 cm at doses varying from approximately 8 mg/cm^2 (*i.e.*, 0.1 mL of neat DINP per rat) to 16 mg/cm^2 (*i.e.*, 0.2 mL of neat DINP per rat) and the site of application was covered with a styrofoam cup lined with aluminum foil. Rats were then monitored for durations of 1, 3, and 7 days to determine the quantity of DINP absorbed during those durations.

Because EPA expects finite dose exposures (*i.e.*, <10 µL/cm^2 for liquids (OECD, 2004c)) in occupational settings, only data from finite dose experiments (*i.e.*, ≈8 mg/cm^2 doses) were considered for the occupational dermal exposure assessment. Also, to provide the most protective assessment, the highest absorptive flux value calculated from the finite dose experiments was utilized for occupational dermal exposure assessment of liquids containing DINP. More specifically, the highest average absorptive flux value from the finite dose experiments was measured from the 7-day exposure period finite dose experiment, where there was 3.06 percent absorption of ~8 mg/cm^2 over the 7-day duration (i.e., 1.46×10^{-3} mg/cm^2/h). For all dermal absorption experiments with DINP, material recovery fell within the OECD 156 (2022) guidelines of 90 to 110 percent for non-volatile chemicals.

2.4.4.1.1 Dermal Absorption Data Interpretation

With respect to interpretation of the DINP dermal absorption data reported in Midwest Research Institute (1983), it is important to consider the relationship between the applied dermal load and the rate of dermal absorption. Specifically, the work of Kissel (2011) suggests the dimensionless term N_{derm} to assist with interpretation of dermal absorption data. The term N_{derm} represents the ratio of the experimental load (*i.e.*, application dose) to the steady-state absorptive flux for a given experimental duration as shown in the following equation.

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

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

Kissel (2011) indicates that high values of N_{derm} (>>1) suggest that supply of the material is in surplus and that the dermal absorption is considered “flux-limited,” whereas lower values of N_{derm} indicate that absorption is limited by the experimental load and would be considered “delivery-limited.” Furthermore, Kissel (2011) indicates that values of percent absorption for flux-limited scenarios are highly dependent on the dermal load and should not be assumed transferable to conditions outside of the experimental conditions. Rather, the steady-state absorptive flux should be utilized for estimating dermal absorption of flux-limited scenarios.

Using an estimate of 3.06 percent absorption of 8 mg/cm^2 of DINP over a 7-day period, the steady-state flux of neat DINP is estimated as 1.46×10^{-3} mg/cm^2/h. The application of N_{derm} to the DINP dermal absorption data reported in Midwest Research Institute (1983) is shown below.

$$N_{derm} = \frac{8\ mg/cm^2}{1.46E-03\frac{mg}{cm^2 \cdot hr} \times 7\ days\ \times 24\frac{hr}{day}} = 33$$

Because N_{derm} >> 1 for the experimental conditions of Midwest Research Institute (1983), it is shown that the absorption of DINP is considered flux-limited even at finite doses (*i.e.*, <10 µL/cm^2 (OECD, 2004c)) and that percent absorption should not be considered transferrable across exposure conditions. The range of estimated steady-state fluxes of DINP presented in this section, based on the results of Midwest Research Institute (1983), is representative of exposures to liquid materials or formulations only. Dermal exposures to liquids containing DINP are characterized in Section 4.2 and 4.2Appendix D.

Regarding dermal exposures to solids containing DINP, there were no available data and dermal exposures to solids are modeled as described in Section 2.4.4.2.

2.4.4.2 Dermal Absorption Modeling

It is expected that dermal exposure to solid matrices would result in far less absorption, but there are no studies that report dermal absorption of DINP from a solid matrix. For cases of dermal absorption of DINP from a solid matrix, EPA assumes that DINP will first migrate from the solid matrix to a thin layer of moisture on the skin surface. Therefore, absorption of DINP 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/h). EPA utilized the Consumer Exposure Model (CEM) (U.S. EPA, 2023a) to estimate the steady-state aqueous permeability coefficient of DINP. 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, 2004a), which characterizes dermal uptake (through and into skin) for aqueous organic compounds. Specifically, Equation 3.2 from U.S. EPA (2004a) was used to estimate the dermally absorbed dose (DA_{event}, mg/cm^2) for an absorption event occurring some duration (t_{abs}, hours) as shown below.

Equation 2-2. Dermal Absorption Dose During Absorption Event

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

Where:

DA_{event}	=	Dermally absorbed dose during absorption event t_{abs} (mg/cm^2)
FA	=	Effect of stratum corneum on quantity absorbed = 0.75 [see Exhibit A-5 of U.S. EPA (2004a)]
K_p	=	Permeability coefficient = 0.0081cm/hour (calculated using CEM (U.S. EPA, 2023a))
S_w	=	Water solubility = 0.20 mg/L (NLM, 2015; Howard et al., 1985)
t_{lag}	=	$0.105*10^{0.0056MW} = 0.105 \times 10^{0.0056*446.68}$ = 23.2 hours [calculated from A.4 of U.S. EPA (2004a)]
t_{abs}	=	Duration of absorption event (hours)

By dividing the dermally absorbed dose (DA_{event}) by the duration of absorption (t_{abs}), the resulting expression yields the average absorptive flux. Figure 2-1 illustrates the relationship between the average absorptive flux and the absorption time.

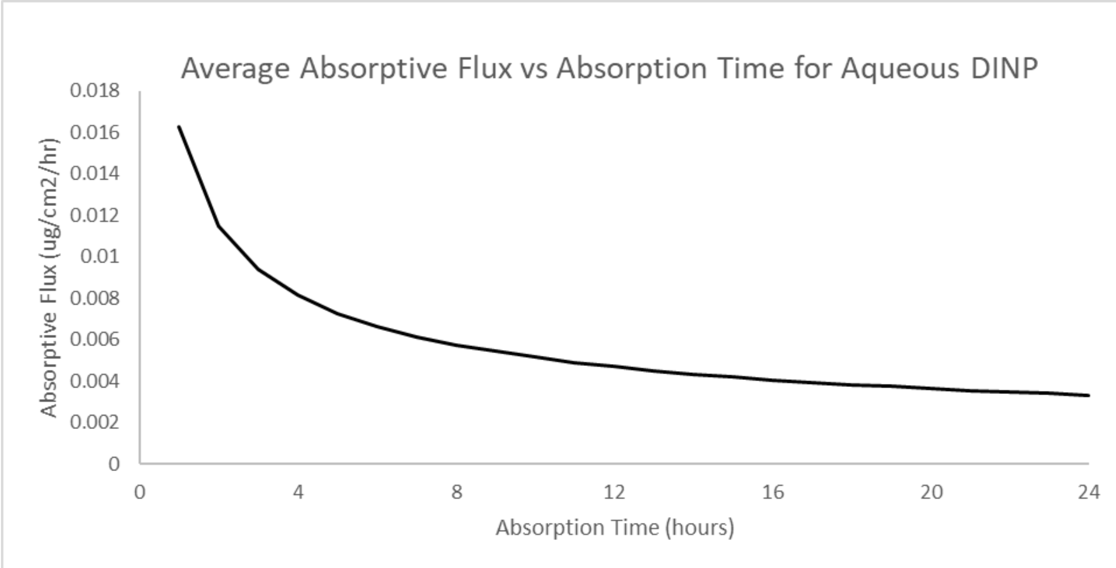

Figure 2-1. Average Absorptive Flux Absorbed into and through Skin as a Function of Absorption Time

Figure 2-1 shows that the average absorptive flux for aqueous DINP is expected to vary between 0.003 and 0.016 µg/cm^2/hour for durations between 1-hour and 1-day, and the average absorptive flux for an 8-hour exposure is 0.00575 µg/cm^2/h. The estimation of average flux of aqueous material through and into the skin is dependent on the duration of absorption and must be determined based on the scenario under assessment. The range of estimated steady-state fluxes of DINP presented in this section, based on modeling from (U.S. EPA, 2004a), is considered representative of dermal exposures to solid materials or articles containing DINP. Dermal exposures to solids containing DINP are characterized in Appendix D.

2.4.4.3 Uncertainties in Dermal Absorption Estimation

As noted above in Section 2.4.4.1, EPA identified only one set of experimental data related to the dermal absorption of neat DINP (Midwest Research Institute, 1983). This dermal absorption study was conducted *in vivo* using male F344 rats. There have been additional studies conducted to determine the difference in dermal absorption between rat skin and human skin. Specifically, Scott et al. (1987) examined the difference in dermal absorption between rat skin and human skin for four different phthalates (*i.e.*, DMP, DEP, DBP, and DEHP) using *in vitro* dermal absorption testing. Results from the *in vitro* dermal absorption experiments showed that rat skin was more permeable than human skin for all four phthalates examined. For example, rat skin was up to 30 times more permeable than human skin for DEP, and rat skin was up to 4 times more permeable than human skin for DEHP. Although there is uncertainty regarding the magnitude of difference between dermal absorption through rat skin vs. human skin for DINP, EPA is confident that the *in vivo* dermal absorption data using male F344 rats (Midwest Research Institute, 1983) provides an upper bound of dermal absorption of DINP based on the findings of Scott et al. (1987).

Another source of uncertainty regarding the dermal absorption of DINP from products or formulations stems from the varying concentrations and co-formulants that exist in products or formulations containing DINP. For purposes of this risk evaluation, EPA assumes that the absorptive flux of neat DINP measured from *in vivo* rat experiments serves as an upper bound of potential absorptive flux of chemical into and through the skin for dermal contact with all liquid products or formulations, and that the modeled absorptive flux of aqueous DINP serves as an upper bound of potential absorptive flux of chemical into and through the skin for dermal contact with all solid products. However, dermal contact with products or formulations that have lower concentrations of DINP may exhibit lower rates of flux since there is less material available for absorption. Conversely, co-formulants or materials within the products or formulations may lead to enhanced dermal absorption, even at lower concentrations. Therefore, it is uncertain whether the products or formulations containing DINP would result in decreased or increased dermal absorption. Based on the available dermal absorption data for DINP, EPA has made assumptions that result in exposure assessments that are the most human health protective in nature.

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

2.4.5 Estimating Acute, Intermediate, and Chronic (Non-cancer) Exposures

For each OES, EPA used the estimated exposures 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 frequency, and lifetime years.

For the final exposure result metrics, each of the input parameters (*e.g.*, air concentrations, dermal doses, working years, exposure frequency, lifetime years) 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. The equations and input parameter values used to estimate each exposure metric are provided in Appendix B.

2.5 Consideration of Engineering Controls and Personal Protective Equipment

OSHA and NIOSH recommend that employers utilize the hierarchy of controls 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 first, which is to 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 workers from exposures. OSHA and NIOSH recommend the use of personal protective equipment (*e.g.*, respirators, gloves) as the last means of control, when the other control measures cannot reduce workplace exposures to an acceptable level.

2.5.1 Respiratory Protection

OSHA's Respiratory Protection Standard (29 CFR 1910.134) requires employers in certain industries to address workplace hazards by implementing engineering control measures and, if these are not feasible, provide 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 are 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 2-2) and refer to the level of respiratory protection that a respirator or class of respirators is expected to provide to employees when the employer implements a continuing, effective respiratory protection program according to the requirements of OSHA's Respiratory Protection Standard.

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

Table 2-2. 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 (*e.g.*, open/closed circuit)			10,000	10,000	
Source: 29 CFR 1910.134(d)(3)(i)(A)					

NIOSH and BLS conducted a voluntary survey of U.S. employers regarding the use of respiratory protective devices between August 2001 and January 2002 (NIOSH, 2003). The survey was sent to a sample of 40,002 sites designed to represent all private sector sites and had a 75.5 percent response rate (NIOSH, 2003). A voluntary survey may not be representative of all private industry respirator use patterns as some sites with low or no respirator use may choose to not respond to the survey. Therefore, results of the survey may potentially be biased towards higher respirator use.

NIOSH and BLS estimated that about 619,400 sites used respirators for voluntary or required purposes (including emergency and non-emergency uses). About 281,800 sites (45%) used respirators for required purposes in the 12 months prior to the survey. NIOSH and BLS estimated that the 281,800 sites that used respirators for required purposes comprised approximately 4.5 percent of all private industry sites in the United States at the time of the survey (NIOSH, 2003).

The survey found that the sites that required respirator use had the following respirator program characteristics (NIOSH, 2003):

- 59 percent provided training to workers on respirator use;
- 34 percent had a written respiratory protection program;
- 47 percent performed an assessment of the employees' medical fitness to wear respirators; and
- 24 percent included air sampling to determine respirator selection.

The survey report does not provide statistics for respirator fit testing or identify if fit testing was included in one of the other program characteristics.

Of the sites that had respirator use for a required purpose within the 12 months prior to the survey, NIOSH and BLS found (NIOSH, 2003) the following:

- non-powered air purifying respirators are most common, 94 percent overall and varying from 89 to 100 percent across industry sectors;
- powered air-purifying respirators represent a minority of respirator use, 15 percent overall and varying from 7 to 22 percent across industry sectors; and
- supplied air respirators represent a minority of respirator use, 17 percent overall and varying from 4 to 37 percent across industry sectors.

Of the sites that used non-powered air-purifying respirators for a required purpose within the 12 months prior to the survey, NIOSH and BLS found (NIOSH, 2003)

- a majority use dust masks, 76 percent overall and varying from 56 to 88 percent across industry sectors;
- varying fractions use half-mask respirators, 52 percent overall and varying from 26 to 66 percent across industry sectors; and
- varying fractions use full-facepiece respirators, 23 percent overall and varying from 4 to 33 percent across industry sectors.

Table 2-3 summarizes the number and percent of all private industry sites and employees that used respirators for a required purpose within the 12 months prior to the survey and includes a breakdown by industry sector (NIOSH, 2003).

Table 2-3. Number and Percent of Sites and Employees Using Respirators within 12 Months Prior to Survey

Industry	Sites		Employees	
	Number	% of Sites	Number	% of Employees
Total Private Industry	281,776	4.5	3,303,414	3.1
Agriculture, Forestry, and Fishing	13,186	9.4	101,778	5.8
Mining	3,493	11.7	53,984	9.9
Construction	64,172	9.6	590,987	8.9
Manufacturing	48,556	12.8	882,475	4.8
Transportation and Public Utilities	10,351	3.7	189,867	2.8
Wholesale Trade	31,238	5.2	182,922	2.6
Retail Trade	16,948	1.3	118,200	0.5
Finance, Insurance, and Real Estate	4,202	0.7	22,911	0.3
Services	89,629	4.0	1,160,289	3.2

2.5.2 Glove Protection

Data on the frequency of effective glove use (*i.e.*, the proper use of effective gloves) in industrial settings is very limited. An initial literature review suggests that it is unlikely that there is sufficient data to justify a specific probability distribution for effective glove use for DINP or a given industry. Instead, EPA explored the impact of effective glove use by considering different percentages of effectiveness (*e.g.*, 25 vs. 50% effectiveness).

EPA also made assumptions about glove use and associated protection factors. When workers wear gloves, they may be exposed to DINP-based products that penetrate the gloves. This may occur though seepage at the cuff from improper donning of the gloves. When workers do not wear gloves, they are exposed through direct dermal contact with DINP-based products.

Gloves only offer barrier protection until the chemical breaks through the glove material. Using a conceptual model, Cherrie et al. (2004) proposed a workplace glove protection factor, defined as the ratio of estimated uptake through the hands without gloves to the estimated uptake though the hands while wearing gloves. This protection factor is driven by flux, and thus the protection factor varies with time. The ECETOC TRA model represents the glove protection factor as a fixed, assigned value equal to 5, 10, or 20 (Marquart et al., 2017). Like the APR for respiratory protection, the inverse of the protection factor is the fraction of the chemical that penetrates the glove. Table 2-4 presents dermal doses without glove use, with the potential impacts of these protection factors presented as what-if scenarios in the dermal exposure summary.

Table 2-4. Glove Protection Factors for Different Dermal Protection Strategies

Dermal Protection Characteristics	Setting	Protection Factor (PF)
a. No gloves used, or any glove/gauntlet without permeation data and without employee training	Industrial and Commercial Uses	1
b. Gloves with available permeation data indicating that the material of construction offers good protection for the substance		5
c. Chemically resistant gloves (*i.e.*, as b. above) with "basic" employee training		10
d. Chemically resistant gloves in combination with specific activity training (*e.g.*, procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur	Industrial Uses Only	20
Source: (Marquart et al., 2017)		

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 the Agency 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. The Agency did not use data and information rated as uninformative in exposure evidence integration. In general, the Agency gave preference to higher rankings over lower rankings; however, the Agency 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 dataset that precisely matches the OES of interest over a higher ranked study that does not match the OES of interest as closely.
2. **Data Hierarchy:** EPA used both measured and modeled data to obtain accurate and representative estimates (*e.g.*, central tendency, high-end) of the environmental releases and occupational exposures resulting directly from a specific source, medium, or product. If available, measured release and exposure data are given preference over modeled data, with the highest preference given to data that are both chemical-specific and directly representative of the OES/exposure source.

EPA considered both data quality and data hierarchy when determining evidence integration strategies. For example, 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 monitoring data and worker activity information from standard engineering sources and systematic review. The Agency estimated COU-specific assessment approaches where supporting data existed and documented uncertainties where supporting data were only applicable for broader assessment approaches.

3 ENVIRONMENTAL RELEASE AND OCCUPATIONAL EXPOSURE ASSESSMENTS BY OES

3.1 Manufacturing

3.1.1 Process Description

At a typical manufacturing site, DINP is formed through the reaction of phthalic anhydride and isononyl alcohol using an acid catalyst. DINP is manufactured in two forms. The first form, CASRN 28553-12-0, is manufactured from a C9 alcohol, which is n-butene based. The second form, CASRN 68515-48-0, is manufactured from a C8-C10 alcohol fraction (ExxonMobil, 2022b). Typical manufacturing operations consist of reaction, followed by a crude filtration, where the product is distilled or separated, and final filtration. Manufacturing operations may also include quality control sampling of the DINP product. Additionally, manufacturing operations include equipment cleaning/reconditioning and product transport to other areas of the manufacturing facility or offsite shipment for downstream processing or use. No changes to chemical composition occur during transportation (ExxonMobil, 2022b). Figure 3-1 provides an illustration of the manufacturing process.

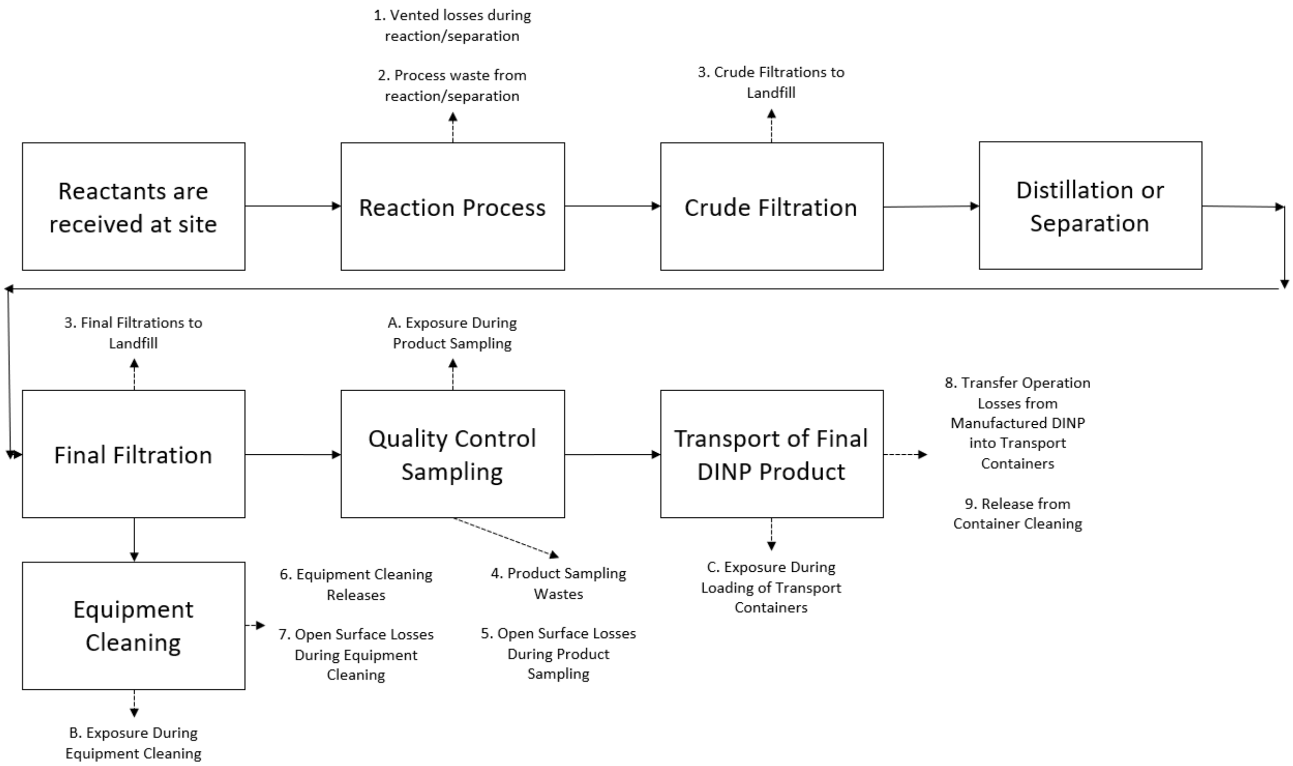

Figure 3-1. DINP Manufacturing Flow Diagram

3.1.2 Facility Estimates

In the 2020 CDR, two sites reported domestic manufacturing of DINP (CASRN 68515-48-0) and one site of DINP (CASRN 28553-12-0). Three additional sites withheld site activity or claimed this information as confidential business information (CBI); therefore, EPA could not use site activity to distinguish between manufacturing and import sites. A singular site, Gehring Montgomery in Warminster, Pennsylvania, reported a production volume of 88,607 kg for CASRN 28553-12-0 in the 2019 reporting year. The remaining two sites reported their production volumes as CBI (U.S. EPA, 2020a). EPA did not identify other data on current manufacturing or volumes from systematic review.

EPA evaluated the production volume for sites that claimed this information as CBI by subtracting known production volumes from other manufacturing and import sites from the total DINP production volume reported to the 2020 CDR. The Agency considered production volumes for both import and manufacturing sites, because the annual DINP production volume in the CDR includes both domestic manufacture and importation.[1] The 2020 CDR reported a range of national production volume for DINP, therefore EPA provided the manufacturing production volume as a range. The Agency split the remaining production volume range evenly across all sites that reported this information as CBI. The calculated production volume range for the unknown sites under the CASRN 28553-12-0 was 951,673 to 3,219,635 kg-average site/year. The production volume for CASRN 68515-48-0 was 8,889,194 to 90,535,820 kg-average site/year.

EPA did not identify site- or chemical-specific manufacturing facility throughput operating data; therefore, EPA assessed facility throughput information using a Monte Carlo model (see Appendix E.2 for details). The modeled 50th to 95th percentile range was 11,587 to 17,257 kg/site-day and 276,180 to 480,295 kg/site-day for CASRN 28553-12-0 and 68515-48-0, respectively. A published report from ExxonMobil indicated a continuous half-year operation dedicated to the manufacture of DINP. Therefore, EPA assessed 180 days per year of continuous DINP manufacturing operations (ExxonMobil, 2022b). The ExxonMobil report also indicated that DINP is transported via marine vessels, rail cars, and trucks to/from the ExxonMobil facility. Based on CDR and systematic review information, DINP is manufactured in liquid form at a concentration of 90 to 100 percent (ExxonMobil, 2022b; U.S. EPA, 2020a; NICNAS, 2012; ECJRC, 2003b).

3.1.3 Release Assessment

3.1.3.1 Environmental Release Points

ExxonMobil provided EPA with a walkthrough presentation of their Baton Rouge (Louisiana) manufacturing facility and identified non-air releases but did not quantify releases to protect their CBI claim on production volume. Each release point and suspected fugitive air release point were assigned a default EPA model to quantify potential releases. The Agency expects stack air releases from vented losses to air during process operations, and fugitive air releases from sampling, equipment cleaning, and container loading. It also expects releases to onsite wastewater treatment, incineration, or landfill from equipment cleaning, process wastes, and sampling wastes. EPA further expects landfill releases from crude and final filtration steps, and onsite wastewater releases from container cleaning. Fugitive emissions may occur at loading racks and during container filling due to equipment leaks and displaced vapors as containers are filled.

[1] For specific values of the known site production volumes belonging to the Import OES, see the import facility estimates (Section 3.2.2).

3.1.3.2 Environmental Release Assessment Results

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

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
88,607 lb production volume	Fugitive Air	2.98E−04	6.81E−04	180		1.66E−06	3.78E−06
	Stack Air	4.02E01				2.23E−01	
	Wastewater to Onsite Treatment or Discharge to POTW	5.13	9.26			2.05E−01	3.70E−01
	Onsite Wastewater, Incineration, or Landfill	1.24E02	1.62E02			5.13	5.34
	Landfill	2.07E02	3.60E02			2.16	3.75
2,098,080–7,098,080 lb production volume	Fugitive Air	3.23E−04	7.12E−04	180		1.80E−06	3.95E−06
	Stack Air	2.09E03	3.11E03	180		1.16E01	1.73E01
	Wastewater to Onsite Treatment or Discharge to POTW	2.52E02	5.65E02			1.01E01	2.26E01
	Onsite Wastewater, Incineration, or Landfill	8.14E02	1.39E03			2.35E02	3.50E02
	Landfill	9.62E03	2.29E04			1.00E02	2.38E02
19,597,318–199,597,318 lb production volume	Fugitive Air	7.99E−04	1.43E−03	180		4.44E−06	7.92E−06
	Stack Air	4.97E04	8.65E04			2.76E02	4.80E02
	Wastewater to Onsite Treatment or Discharge to POTW	5.78E03	1.52E04			2.31E02	6.08E02
	Onsite Wastewater, Incineration, or Landfill	1.93E04	3.84E04			5.61E03	9.75E03
	Landfill	8.34E04				8.69E02	

3.1.4 Occupational Exposure Assessment

3.1.4.1 Workers Activities

During manufacturing, worker exposures to DINP occur during product sampling. Additionally, worker exposures may occur via inhalation of vapors or dermal contact with liquids during equipment cleaning, container cleaning, and packaging and loading of DINP into transport containers for shipment. Workers that manufacture DINP at ExxonMobil sites wear standard PPE during filtration; however, EPA did not identify additional information on the extent to which engineering controls and required PPE are used at any other manufacturing sites or throughout the remainder of the process at ExxonMobil sites (ExxonMobil, 2022b).

ONUs include employees (*e.g.*, supervisors, managers) that work at the manufacturing facility, but do not directly handle DINP. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. For the worker activities within the Manufacturing

OES, it is expected that workers are exposed through inhalation of vapors and dermal contact with concentrated liquids. However, ONUs are not expected to encounter dermal contact with liquids containing DINP; therefore, only inhalation exposures were estimated for ONUs under the Manufacturing OES.

3.1.4.2 Numbers of Workers and Occupational Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs that are potentially exposed to DINP during manufacturing. This approach involved the identification of relevant Standard Occupational Classification (SOC) codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details on the methodology that EPA used to estimate the number of workers and ONUs per site. The Agency assigned the NAICS codes 325110, 325199, and 325998 for this OES, based on the Emission Scenario Document on the Chemical Industry and CDR reported NAICS codes for DINP manufacturers (U.S. EPA, 2020a; OECD, 2011c). Table 3-2 summarizes the per site estimates for this OES. As discussed in Section 3.1.2, EPA did not identify site-specific data for the number of facilities in the United States that manufacture DINP.

Table 3-2. Estimated Number of Workers Potentially Exposed to DINP During the Manufacturing of DINP

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
325110 – Petrochemical Manufacturing	1–2	64		30	
325199 – All Other Basic Organic Chemical Manufacturing	1	39	N/A	18	N/A
325998 – All Other Miscellaneous Chemical Product and Preparation Manufacturing	1	14		5	
Total/Average[c]	3–6	39	116–258	18	53–118

[a] The result is expressed as a range between the central tendency and the high-end value representing the 50th and 95th percentile results.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs is rounded to the nearest integer.
[c] Included in the count for total number of sites, workers, and ONUs are three sites that did not have one of the mapped NAICS codes for the manufacturing OES.

3.1.4.3 Occupational Inhalation Exposure Results

EPA identified inhalation monitoring data for the manufacture of DINP during systematic review of literature sources. The Agency used monitoring data provided in an exposure study conducted by ExxonMobil at their DINP manufacturing site to estimate inhalation exposure for this OES (ExxonMobil, 2022b). ExxonMobil collected PBZ samples via an American Industrial Hygiene Association (AIHA) validated method involving polytetrafluoroethylene (PTFE) Teflon filters, extraction with acetonitrile, and high-performance liquid chromatography (HPLC) analysis with UV detection. ExxonMobil took PBZ samples from plasticizer assistant operators, laboratory technicians, and maintenance operators (ExxonMobil, 2022b). EPA used the samples taken during filter change-out from maintenance operators to represent this OES as this activity was determined to best represent the activities that occur during manufacturing. The study included 12 PBZ data points for DINP. All data points were below the limit of detection (LOD). Therefore, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. To estimate high-end exposures to workers, the Agency used the LOD reported in the study. To estimate central tendency worker exposures, EPA used half of the LOD.

Table 3-3 summarizes the estimated 8-hour TWA concentration, acute dose (AD), intermediate average daily dose (IADD), and chronic average daily dose (ADD) for worker exposures to DINP during the manufacture of DINP. Regarding the number of exposure days per year, ExxonMobil indicated a continuous half-year operation dedicated to the manufacture of DINP. Therefore, EPA assessed 180 days per year of continuous DINP manufacturing operations (ExxonMobil, 2022b). Accordingly, the central tendency and high-end exposures use 180 days per year as the exposure frequency.

Table 3-3: Summary of Estimated Worker Inhalation Exposures for Manufacture of DINP

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute (AD, mg/kg-day)	4.3E−03	8.6E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	6.3E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.1E−03	4.3E−03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute (AD, mg/kg-day)	4.8E−03	9.5E−03
	Intermediate (IADD, mg/kg-day)	3.5E−03	7.0E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.3E−03	4.7E−03
ONU	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	3.5E−02
	Acute (AD, mg/kg-day)	4.3E−03	4.3E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	3.2E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.1E−03	2.1E−03

EPA compared the exposures in Table 3-3 to Monte Carlo simulation results for the OES. The Agency applied the EPA Mass Balance Inhalation Model to release points with inhalation exposure potential (*e.g.*, those with fugitive air releases) and estimated an 8-hour TWA assuming no exposure occurred outside of the manufacturing activities. The results of this analysis were within two orders of magnitude of the high-end and central tendency inhalation exposure estimates developed from the ExxonMobil study, justifying the use of the ExxonMobil monitoring data for this OES.

3.1.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-4 are explained in Appendix B. Because dermal exposures to workers may occur in the neat liquid form during manufacturing of DINP, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Table 3-4 summarizes the summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age. Because there are no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed. Dermal exposure parameters are described in Appendix D.

Table 3-4. Summary of Estimated Worker Dermal Exposures for the Manufacturing of DINP

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	3.8E−02	7.7E−02
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	3.5E−02	7.1E−02

3.1.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B.3 to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-5. Summary of Estimated Worker Aggregate Exposures for Manufacture of DINP

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	8.2E−02	0.16
	Intermediate (IADD, mg/kg-day)	6.0E−02	0.12
	Chronic, Non-cancer (ADD, mg/kg-day)	4.1E−02	8.1E−02
Female of Reproductive Age	Acute (AD, mg/kg-day)	7.6E−02	0.15
	Intermediate (IADD, mg/kg-day)	5.6E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	3.8E−02	7.5E−02
ONU	Acute (AD, mg/kg-day)	4.3E−03	4.3E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	3.2E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.1E−03	2.1E−03

3.2 Import and Repackaging

3.2.1 Process Description

At a typical import and repackaging site, DINP arrive via water, air, land, or intermodal shipments on oceangoing chemical tankers, rail cars, tank trucks, or intermodal tank containers (Tomer and Kane, 2015). Sites unload the import containers and transfer DINP into smaller containers (drums or rail cars) for downstream processing, use within the facility, or offsite use. Operations may include quality control sampling of DINP product and equipment cleaning. No changes to chemical composition occur during transportation (U.S. EPA, 2022a). Figure 3-2 provides an illustration of the import and repackaging process.

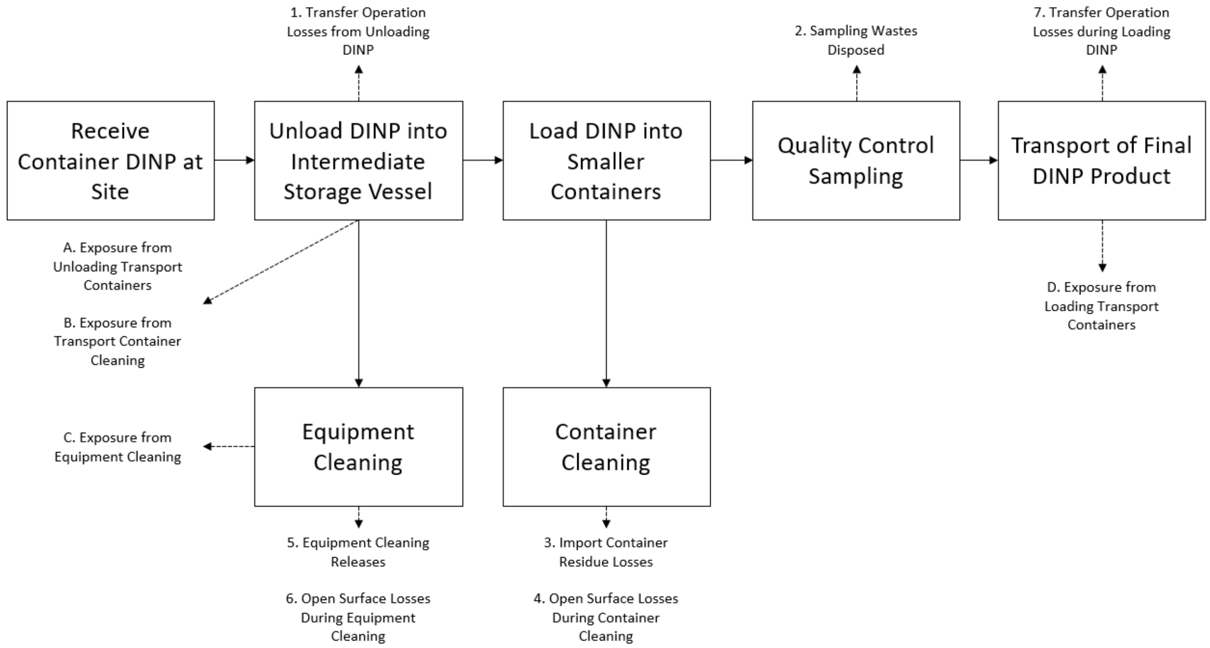

Figure 3-2. DINP Import and Repackaging Flow Diagram

3.2.2 Facility Estimates

In the 2020 CDR, 20 sites reported import of DINP CASRN 28553-12-0 and three sites reported import for CASRN 68515-48-0. Fourteen out of the 23 total sites that reported import activity provided a non-CBI production volume for the 2019 reporting year, with the other 9 reporting their production volumes as CBI. One site reported a site activity of import and repackaging but claimed both the site name and production volume as CBI. Five additional sites provided an import and repackaging production volume for previous years within the 2020 CDR reporting timeline, but volumes for the 2019 reporting year fell below the required reporting threshold or the site claimed that it no longer imported DINP (U.S. EPA, 2020a). Three additional sites withheld site activity or claimed this information as CBI; therefore, EPA could not determine whether these sites manufactured or imported DINP. The Agency did not identify other information on current DINP import sites or volumes from systematic review. Table 3-5 provides the location and reported 2019 production volume for identified DINP import and repackaging sites for CASRN 28553-12-0 (U.S. EPA, 2020a).

Table 3-5. Production Volume of DINP CASRN 28553-12-0 Import and Repackaging Sites, 2020 CDR

DINP Import Site, Site Location	2019 Reported Production Volume of DINP CASRN 28553-12-0 (kg/year)
BASF Imports, Florham Park, NJ	CBI
Henkel, Louisville, KY	11,189
Showa Denko Materials, San Jose, CA	CBI
Westlake Compounds LLC, Houston, TX	CBI
GEON Performance Solutions LLC, Louisville, KY	380,745
ALAC International LLC, New York, NY	11,349,540
Mercedes-Benz Inc. Vance, AL	140,614
DOW Chemical Co. Midland, MI	CBI
Univar Solutions LLC, Redmond, WA	239,157
Evonik Corp. Parsippany, NJ	CBI

DINP Import Site, Site Location	2019 Reported Production Volume of DINP CASRN 28553-12-0 (kg/year)
ICC Chemical Corp. New York, NY	CBI
Belt Concepts of America LLC, Spring Hope, NC	299,752
Greenchem, West Palm Beach, FL	CBI
Formosa Global Solutions Inc. Livingston, NJ	17,100
Harwick Standard Distribution Corp. Akron, OH	59,923
Tribute Energy Inc. Houston, TX	380,000
Superior Oil Company Inc. Indianapolis, IN	CBI
The Chemical Company, Jamestown, RI	CBI
CBI	97,514
Chemspec, LTD. Uniontown, OH	50,431
Silver Fern Chemical, Seattle, WA	97,184

Table 3-6 provides the location and reported 2019 production volume for identified DINP import and repackaging sites for CASRN 68515-48-0 (U.S. EPA, 2020a).

Table 3-6. Production Volume of DINP CASRN 68515-48-0 Import and Repackaging Sites, 2020 CDR

DINP Import Site, Site Location	2019 Reported Production Volume of DINP CASRN 68515-48-0 (kg/year)
Westlake Compounds LLC, Houston, TX	CBI
Univar Solutions Inc. Redmond, WA	239,157
CBI	CBI
Cascadia Columbia Distribution, Sherwood, OR	674,115

EPA evaluated the production volumes for sites that reported this information as CBI by subtracting known production volumes for other manufacturing and import sites from the total DINP production volume reported to the 2020 CDR. The Agency considered production volumes for both import and manufacturing sites because the annual DINP production volume in the CDR includes both domestic manufacture and importation.[2] Because the 2020 CDR reported a range of national production volume for DINP, EPA provided the import and repackaging production volume as a range. The Agency split the remaining production volume range evenly across all sites that reported this information as CBI. The calculated production volume range for the unknown sites under the CASRN 28553-12-0 was 951,673-3,219,635 kg-average site/year. The production volume for unknown sites under CASRN 68515-48-0 was 8,889,194-90,535,820 kg-average site/year.

EPA did not identify site- or chemical specific import and repackaging operating data (*e.g.*, facility throughput, operating days). The 2022 GS on Chemical Repackaging estimated the total number of operating days for import as 174 to 260 days per year based on the length of worker shifts (U.S. EPA, 2022a). The Agency assumed that import and repackaging facilities operate 24 hours/day, 7 days/week (*i.e.*, multiple shifts) for the given throughput scenario. Based on CDR reports, DINP is imported in liquid or pellet form with concentrations ranging from 1 to 100 percent DINP (U.S. EPA, 2021b, 2020a). EPA assessed facility throughput using a Monte Carlo model (see Appendix E.3 for details). The 50th to 95th percentile range was 9,733 to 16,527 kg/site-day and 232,238-450,567 kg/site-day for CASRN 28553-12-0 and 68515-48-0, respectively.

[2] For specific values of the known site production volumes belonging to the Import OES, see the Import facility estimates (Section 3.2.2).

3.2.3 Release Assessment

3.2.3.1 Environmental Release Points

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

3.2.3.2 Environmental Release Assessment

Table 3-7. Summary of Modeled Environmental Releases for Import and Repackaging of DINP

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
24,668 lb production volume	Fugitive Air	9.67E−08	1.84E−07	208	260	1.57E−08	2.90E−08
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	5.38E01	2.11E02			1.47	1.70
37,699 lb production volume	Fugitive Air	6.97E−07	8.86E−07	208	260	9.70E−08	1.02E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	7.00E01	9.02E01			2.03	2.52
111,182 lb production volume	Fugitive Air	1.31E−06	1.86E−06	208	260	1.00E−07	1.06E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	1.80E02	2.50E02			5.80	7.17
132,107 lb production volume	Fugitive Air	1.49E−06	2.14E−06	208	260	1.01E−07	1.07E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	2.02E02	2.58E02			6.89	8.52
214,255 lb production volume	Fugitive Air	1.56E−06	2.78E−06	208	260	7.75E−08	1.07E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	3.27E02	4.18E02			1.12E01	1.38E01
214,982 lb production volume	Fugitive Air	2.18E−06	3.25E−06	208	260	1.04E−07	1.12E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	3.28E02	4.20E02	208	260	1.12E01	1.39E01

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
310,000 lb production volume	Fugitive Air	1.39E−06	2.35E−06	208	260	5.13E−08	6.71E−08
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	4.74E02	6.05E02			1.62E01	2.00E01
527,252 lb production volume	Fugitive Air	2.24E−06	3.84E−06	208	260	5.55E−08	7.38E−08
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	8.07E02	1.03E03			2.75E01	3.40E01
660,840 lb production volume	Fugitive Air	5.90E−06	9.18E−06	208	260	1.22E−07	1.41E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	1.01E03	1.29E03			3.45E01	4.26E01
837,756 lb production volume	Fugitive Air	7.39E−06	1.15E−05	208	260	1.29E−07	1.53E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	1.29E03	1.64E03			4.37E01	5.40E01
839,400 lb production volume	Fugitive Air	3.46E−06	6.00E−06	208	260	6.15E−08	8.39E−08
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	1.29E03	1.65E03			4.38E01	5.41E01
1,486,170 lb production volume	Fugitive Air	1.28E−05	2.02E−05	208	260	1.54E−07	1.97E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	2.30E03	2.93E03			7.75E01	9.59E01
25,021,453 lb production volume	Fugitive Air	9.78E−05	1.72E−04	208	260	5.10E−07	9.15E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	1.66E04	2.52E04			1.16E03	1.42E03
2,098,080–7,098,080 lb production volume	Fugitive Air	2.57E−05	5.95E−05	208	260	1.93E−07	3.79E−07
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	1.83E03	3.48E03			2.07E02	3.51E02

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
19,597,318–199,597,318 lb production volume	Fugitive Air	5.73E−04	1.58E−03	208	260	2.77E−06	7.88E−06
	Wastewater to Onsite Treatment, Discharge to POTW, or Landfill	7.71E04	1.62E05			4.94E03	9.58E03

3.2.4 Occupational Exposure Assessment

3.2.4.1 Workers Activities

During import and repackaging, worker exposures to DINP occur when transferring DINP from the import vessels (*e.g.*, chemical tankers, rail cars, intermodal tank containers) into smaller containers. Worker exposures also occur via inhalation of vapors or dermal contact with liquids when cleaning import vessels, loading and unloading DINP, sampling, and cleaning equipment. EPA did not find any information on the extent to which engineering controls and worker PPE are used at facilities that repackage DINP from import vessels into smaller containers.

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

3.2.4.2 Number of Workers and Occupational Non-users

EPA used data from the BLS and the U.S. Census' SUSB specific (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs that are potentially exposed to DINP during DINP import and repackaging. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details on the methodology that EPA used to estimate the number of workers and ONUs per site. The Agency assigned the NAICS codes 424610, 424690, and 444120 for this OES, based on the Chemical Repackaging Generic Scenario and CDR reported NAICS codes for DINP importers (U.S. EPA, 2022a, 2020a). Table 3-8 summarizes the per site estimates for this OES. As discussed in Section 3.2.2, EPA did not identify site-specific data for the number of facilities in the United States that import and repackage DINP.

Table 3-8. Estimated Number of Workers Potentially Exposed to DINP During Import and Repackaging

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers	1	1	N/A	0	N/A
424690 – Other Chemical and Allied Products Merchant Wholesalers	15	1		0	
444120 – Paint and Wallpaper Stores	1	0.56		0.10	
Total/Average[c]	29–32	1	32–35	0.31	11–12

[a] The result is expressed as a range between the central tendency and the high-end value representing the 50th and 95th percentile results.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.
[c] Included in the count for total number of sites, workers, and ONUs are 12 sites that did not have one of the mapped NAICS codes for the import and repackaging OES in the central tendency scenario, and 15 sites in the high-end scenario.

3.2.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for import and repackaging from systematic review of literature sources. However, the Agency estimated inhalation exposures for this OES using monitoring data for DINP exposures during manufacturing (ExxonMobil, 2022b). The Agency expects that inhalation exposures during manufacturing are greater than inhalation exposures during import and repackaging.

EPA used surrogate monitoring data from an exposure study conducted by ExxonMobil at their DINP manufacturing site to estimate inhalation exposures for this OES. ExxonMobil collected PBZ samples via an AIHA validated method involving PTFE Teflon filters, extraction with acetonitrile, and HPLC analysis with UV detection. ExxonMobil took PBZ samples from plasticizer assistant operators, laboratory technicians, and maintenance operators (ExxonMobil, 2022a). EPA used the samples taken during filter change-out from maintenance operators to represent this OES, as this activity was determined to best represent the activities that occur during import and repackaging. The study included 12 PBZ data points for DINP. All data points were below the LOD. Therefore, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. To estimate high-end exposures to workers, the Agency used the LOD reported in the study. To estimate central tendency worker exposures, EPA used half of the LOD.

Table 3-9 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during the import and repackaging of DINP. The central tendency and high-end exposures use 208 days/year and 250 days/year, respectively, as the exposure frequencies to reflect the 50th and 95th percentile of operating days in the release assessment.

Table 3-9. Summary of Estimated Worker Inhalation Exposures for Import and Repackaging of DINP

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute (AD, mg/kg-day)	4.3E−03	8.6E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	6.3E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.5E−03	5.9E−03
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute (AD, mg/kg-day)	4.8E−03	9.5E−03
	Intermediate (IADD, mg/kg-day)	3.5E−03	7.0E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−03	6.5E−03
ONU	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	3.5E−02
	Acute (AD, mg/kg-day)	4.3E−03	4.3E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	3.2E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.5E−03	3.0E−03

3.2.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-10 are explained in Appendix B. Because dermal exposures to workers may occur in the neat liquid form during import and/or repackaging of DINP, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Table 3-10 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age. Because there are no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed. Dermal exposure parameters are described in Appendix D.

Table 3-10. Summary of Estimated Worker Dermal Exposures for Import and Repackaging of DINP

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.4E−02	0.11
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.1E−02	9.8E−02

3.2.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in Table 3-11 below.

Table 3-11. Summary of Estimated Worker Aggregate Exposures for Import and Repackaging of DINP

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	8.2E−02	0.16
	Intermediate (IADD, mg/kg-day)	6.0E−02	0.12
	Chronic, Non-cancer (ADD, mg/kg-day)	4.7E−02	0.11
Female of Reproductive Age	Acute (AD, mg/kg-day)	7.6E−02	0.15
	Intermediate (IADD, mg/kg-day)	5.6E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.4E−02	0.10
ONU	Acute (AD, mg/kg-day)	4.3E−03	4.3E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	3.2E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.5E−03	3.0E−03

3.3 Incorporation into Adhesives and Sealants

3.3.1 Process Description

DINP is a plasticizer in adhesive and sealant products for industrial and commercial use, including duct sealants and industrial adhesives for automotive care (see Appendix F for EPA identified DINP-containing products for this OES) (ACC, 2020; U.S. EPA, 2020a). Based on the 2009 ESD on the Manufacture of Adhesives, a typical adhesive incorporation site receives and unloads DINP and then incorporates it 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.*, DINP) during the mixing process. Blending or mixing operations can take up to 8 hours a day. Process operations may also include quality control sampling. EPA expects that sites will load DINP-containing products into bottles, small containers, or drums depending on the product type. Incorporation sites may dispose of off-specification product when the adhesive product does not meet quality or desired standards (OECD, 2009a). Figure 3-3 provides an illustration of the adhesive and sealant manufacturing process.

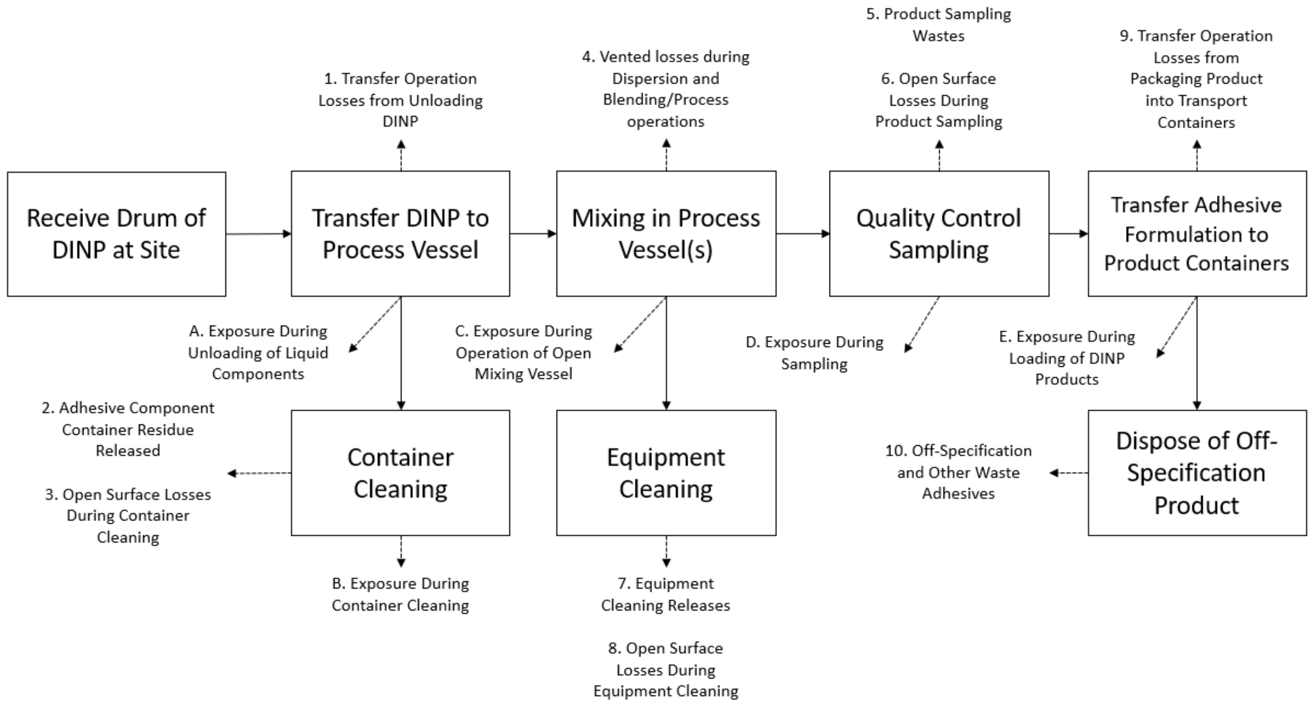

Figure 3-3. Incorporation into Adhesives and Sealants Flow Diagram

3.3.2 Facility Estimates

In the 2020 CDR, seven sites reported adhesive and sealant manufacturing for DINP, four of which reported their production volume as CBI (U.S. EPA, 2020a). EPA did not identify any other data on sites that use DINP in adhesives and sealants manufacturing or production volumes from systematic review. The 2003 *DINP Risk Assessment* published by the European Union reported that approximately 2.6 percent of the market share of DINP use was associated with non-polymer uses (ECJRC, 2003b). Furthermore, it was assumed that the percentage of non-polymer uses would be split equally between paints/coatings, adhesives/sealants, and inks, which was 0.87 percent for each non-polymer use. ACC indicated that the use rate of DINP in the EU is similar to the use rate of DINP in the United States (ACC, 2020). EPA estimated the production volume of DINP in adhesives and sealants as 0.87 percent of the total DINP production volume reported to CDR for both CASRN. The 2020 CDR reported the national production volume for DINP as a range; therefore, EPA also provided the adhesive and sealant production volume as a range. The total production volume for incorporation into adhesives and sealants was 589,670 to 4,340,879 kg/year.

EPA did not identify operating information for this OES (*i.e.*, batch size or number of batches per year). As a result, EPA assumed 4,000 kg for batch size and 250 batches per year based on the 2009 ESD on the Manufacture of Adhesives (OECD, 2009a). This is equivalent to a facility throughput of DINP of 1,000 to 400,000 kg-DINP/site-year and a DINP concentration in the adhesive/sealant product of 0.1 (40%) (see Appendix F for EPA identified DINP-containing products for this OES). Additionally, EPA assumed the number of operating days was equivalent to the number of batches per year or 250 days/year of 24 hours/day, 7 days/week (*i.e.*, multiple shifts) operations for the given site throughput scenario. Incorporation sites receive DINP in drums and totes ranging in size from 20 to 100 gallons with DINP concentrations of 30 to 60 percent (U.S. EPA, 2020a). Sites receive DINP as either a liquid or solid with material in drums transferred to mixing vessels during formulation (OECD, 2009a). EPA estimated the total number of sites that manufacture DINP-containing adhesives and sealants using a

Monte Carlo model (see Appendix E.4 for details). The modeled 50th to 95th percentile range of the number of sites was 15 to 59 sites. In contrast, the 2020 CDR only identified seven incorporation sites.

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). The Agency assigned default models to quantify release from each release point and suspected fugitive air release point. EPA expects fugitive air releases during the unloading of DINP containers, container cleaning, sampling, and equipment cleaning. The Agency 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, equipment cleaning, and off-specification trimming.

3.3.3.2 Environmental Release Assessment Results

Table 3-12. Summary of Modeled Environmental Releases for Incorporation into Adhesives and Sealants

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
1,300,000–9,570,000 lb production volume	Fugitive Air	1.30E−06	4.45E−06	250		5.19E−09	1.78E−08
	Stack Air	1.24E−06	1.03E−05			4.97E−09	4.10E−08
	Wastewater, Incineration, or Landfill	9.00E03	1.88E04			3.60E01	7.51E01

3.3.4 Occupational Exposure Assessment

3.3.4.1 Workers Activities

During the formulation of adhesives and sealants containing DINP, worker exposures may occur when transferring DINP from transport containers into process vessels, taking quality control (QC samples), and packaging formulated products into containers. Worker exposures may also occur via inhalation of vapor or dermal contact with liquids when cleaning residuals from transport containers or process vessels (OECD, 2009a). EPA did not identify information on engineering controls or worker PPE used at DINP-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 DINP that is received or processed onsite or handle the formulated product. ONUs are potentially exposed through the inhalation route while in the working area. However, dermal exposures to ONUs are not expected for this OES.

3.3.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs that are potentially exposed to DINP during the incorporation of DINP into adhesives and sealants. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details on the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 325199 – All Other Basic Organic Chemical Manufacturing and 325520 – Adhesive

Manufacturing for this OES, based on the CDR reported NAICS codes for incorporation into adhesives or sealants (U.S. EPA, 2020a). Table 3-13 summarizes the per site estimates for this OES. As discussed in Section 3.3.2, EPA did not identify site-specific data for the number of facilities in the United States that incorporate DINP into adhesives and sealants.

Table 3-13. Estimated Number of Workers Potentially Exposed to DINP During Incorporation into Adhesives and Sealants

<table>
<tr><th>NAICS Code</th><th>Number of Sites[a]</th><th>Exposed Workers per Site[b]</th><th>Total Number of Exposed Workers[a]</th><th>Exposed ONUs per Site[b]</th><th>Total Number of Exposed ONUs[a]</th></tr>
<tr><td>325199 – All Other Basic Organic Chemical Manufacturing</td><td rowspan="2">N/A</td><td>39</td><td rowspan="2">N/A</td><td>18</td><td rowspan="2">N/A</td></tr>
<tr><td>325520 – Adhesive Manufacturing</td><td>18</td><td>7</td></tr>
<tr><td>Total/Average</td><td>15–59</td><td>28</td><td>425–1,672</td><td>12</td><td>187–736</td></tr>
</table>

[a] The result is expressed as a range between the central tendency and the high-end value representing the 50th and 95th percentile results.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.3.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the incorporation of DINP into adhesives and sealants during systematic review. However, EPA estimated vapor inhalation exposures for this OES using monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. EPA expects that vapor inhalation exposures during plastics converting will represent a bounding range of exposures for other processing operations, such as incorporation into adhesives and sealants, because of the elevated temperature of converting operations and relatively high concentration of DINP present in PVC plastics.

The Irwin et al. (2022) study collected oil mist samples using NIOSH Method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three select stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were located above each process unit (*i.e.*, not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the concentrations of DINP in the stationary samples were similar to the concentrations in the PBZ samples. Because the PBZ oil mist samples were all below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. As a result, EPA used the LOD reported in the study to estimate high-end exposures and half of the LOD to estimate central tendency exposures.

Table 3-14 summarizes the estimated 10-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during the incorporation into adhesives and sealants. The central tendency and high-end exposures use 250 days per year as the exposure frequency.

Table 3-14. Summary of Estimated Worker Inhalation Exposures for Incorporation into Adhesives and Sealants

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05
Female of Reproductive Age	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	4.3E−05	8.6E−05
	Intermediate (IADD, mg/kg-day)	3.2E−05	6.3E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	3.0E−05	5.9E−05
ONU	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05

3.3.4.4 Occupational Dermal Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-15 are explained in Appendix B. Because dermal exposures to workers may occur in a concentrated liquid form during the incorporation of DINP into adhesives and sealants, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Table 3-15 summarizes the summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age. Because there are no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed. Dermal exposure parameters are described in Appendix D.

Table 3-15. Summary of Estimated Worker Dermal Exposures for Incorporation into Adhesives and Sealants

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02

3.3.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-16. 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)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02
ONU	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05

3.4 Incorporation into Paints and Coatings

3.4.1 Process Description

DINP is a plasticizer in paint and coating products for industrial and commercial use, including paints and brush on electrical tape (see Appendix F for EPA identified DINP-containing products for this OES) (ACC, 2020; U.S. EPA, 2020a). A typical incorporation site receives and unloads DINP into industrial mixing vessels and incorporates it into paints and coatings as a batch blending or mixing process, with no reactions or chemical changes occurring to the plasticizer (*i.e.*, DINP) during the mixing process. Blending or mixing operations can take up to 8 hours a day. Process operations may include quality control sampling. In the case of waterborne coatings, the formulator will transfer the blended formulation through an in-line filter. Following formulation, incorporation sites will load DINP-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 3-4 provides an illustration of the paint and coating manufacturing process.

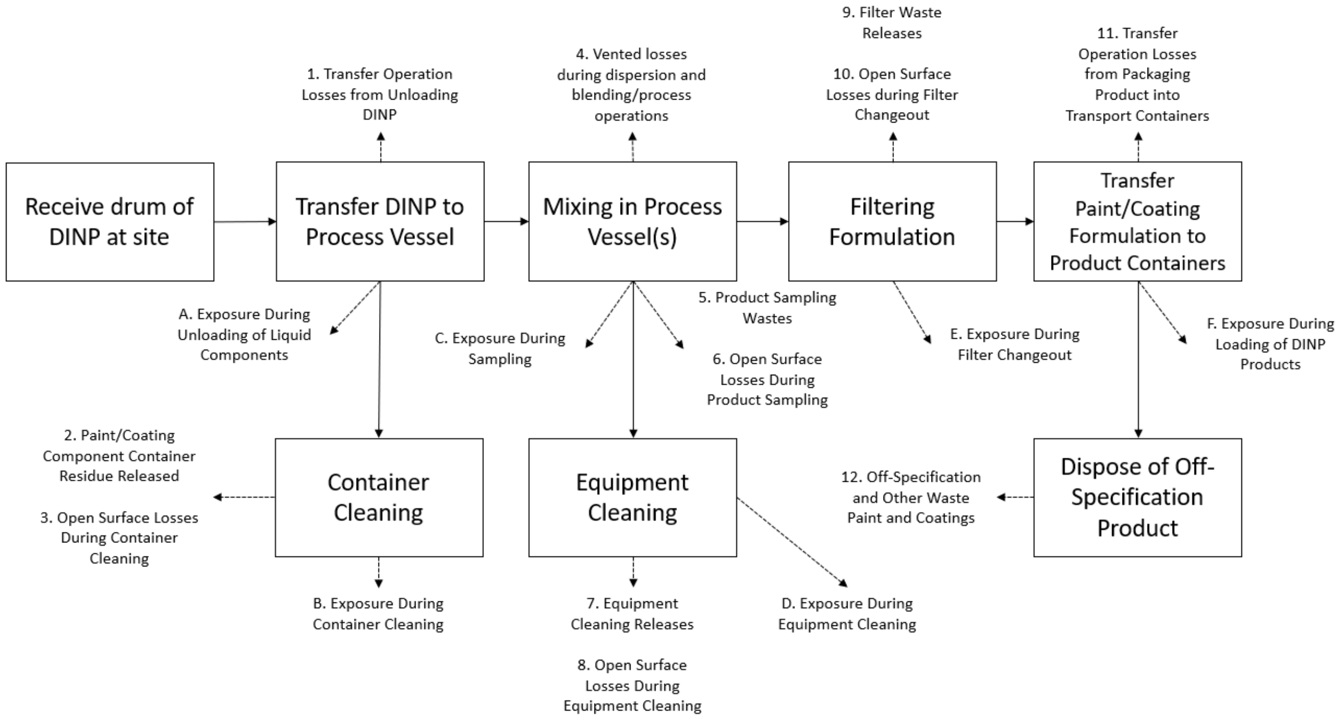

Figure 3-4. Incorporation into Paints and Coatings Flow Diagram

3.4.2 Facility Estimates

In the 2020 CDR, two sites reported paint and coating manufacturing, one of which claimed their production volume as CBI (U.S. EPA, 2020a). EPA did not identify any other data on sites that use DINP in paints or coatings or production volumes from systematic review. However, the Agency assessed the total production volume and the total number of sites from systematic review sources due to the limitations of CDR reporting for downstream processes and uses. The 2003 *DINP Risk Assessment* published by the European Union reported that approximately 2.6 percent of the market share of DINP use was associated with non-polymer uses (ECJRC, 2003b). Further, it was assumed that the percentage of non-polymer uses would be split equally between paints/coatings, adhesives/sealants, and inks, which was 0.87 percent for each non-polymer use. ACC indicated that the use rate of DINP in the EU is similar to the use rate of DINP in the United States (ACC, 2020). EPA estimated the production volume of DINP in paints and coatings as 0.87 percent of the total DINP production volume reported to CDR for both CASRN. The 2020 CDR reported a range of national production volume for DINP; therefore, EPA provided the paint and coating production volume as a range. The total production volume for incorporation into paints and coatings was 589,670 to 4,340,879 kg/year.

EPA did not identify paint and coating site operating data (*i.e.*, batch size or number of batches per year). As a result, the Agency assumed 5,030 kg per batch and 250 batches per year based on the 2014 GS on the Formulation of Waterborne Coatings (U.S. EPA, 2014a). This corresponds to a facility throughput of DINP of 1600 to 3,200,000 kg-DINP/site-year and a DINP concentration in the paint/coating product of 0.01 to 20 percent. Additionally, EPA assumed that the number of operating days was equivalent to the number of batches manufactured per year, or 250 days/year of 24 hours/day, 7 days/week operations (*i.e.*, multiple shifts) for the given site throughput scenario. Incorporation sites receive DINP in drums and totes ranging in size from 20 to 1,000 gallons with DINP concentrations of 30 to 90 percent (see Appendix F for EPA identified DINP-containing products for this OES) (U.S.

EPA, 2020a). Sites receive DINP as a liquid that is then incorporated into paints and coatings, with the DINP transferred from drums to mixing vessels during formulation (U.S. EPA, 2014a). EPA estimated the total number of sites that manufacture DINP-containing paints and coatings using a Monte Carlo model (see Appendix E.5 for details). The modeled 50th to 95th percentile range of the number of sites was 4 to 23 sites. In contrast, the 2020 CDR only identified two incorporation sites.

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). The Agency assigned a default model to quantify releases from each identified release point and fugitive air release point. EPA expects fugitive air releases from unloading DINP containers, container cleaning, sampling, equipment cleaning, and filter replacement as well as stack air releases from vented losses during process operations and from packaging paints and coatings into transport containers. The Agency expects releases to wastewater, incineration, or landfill from container residuals, sampling, equipment cleaning, filter wastes, and off-specification wastes.

3.4.3.2 Environmental Release Assessment Results

Table 3-17. Summary of Modeled Environmental Releases for Incorporation into Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
1,300,000–9,570,000 lb production volume	Fugitive Air	6.27E−06	2.12E−05	250		2.29E−06	2.06E−05
	Stack Air	2.51E−08	8.47E−08			9.15E−09	8.24E−08
	Wastewater, Incineration, or Landfill	7.14E04	2.53E05			3.00E02	1.01E03

3.4.4 Occupational Exposure Assessment

3.4.4.1 Worker Activities

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

ONUs include supervisors, managers, and other employees that work in the formulation area but do not directly contact DINP received or processed onsite or handle the formulated product. ONUs are potentially exposed through the inhalation route while in the working area. However, dermal exposures to ONUs are not expected for this OES.

3.4.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs that are potentially exposed to DINP during the incorporation of DINP into paints and coatings. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details on the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 325510 and 325613 for this OES based on the Generic Scenario on the Formulation of Waterborne Coatings and CDR reported NAICS codes for incorporation into paints and coatings (U.S. EPA, 2020a, 2014a). Table 3-18 summarizes the per site estimates for this OES. As discussed in Section 3.4.2, EPA did not identify site-specific data on the number of facilities in the United States that incorporate DINP into paints and coatings.

Table 3-18. Estimated Number of Workers Potentially Exposed to DINP During Incorporation into Paints and Coatings

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
325613 – Surface Active Agent Manufacturing	N/A	22	N/A	5	N/A
325510 – Paint and Coating Manufacturing		14		5	
Total/Average	4–23	18	72–415	5	21–119

[a] The result is expressed as a range between the central tendency and the high-end value representing the 50th and 95th percentile results.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as “0” are left unrounded.

3.4.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the incorporation of DINP into paints and coatings during systematic review. However, EPA estimated vapor inhalation exposures for this OES using monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. EPA expects that vapor inhalation exposures during plastics converting will represent a bounding range of exposures for other processing operations, such as incorporation into paints and coatings, because of the elevated temperature of converting operations and relatively high concentration of DINP present in PVC plastics.

The Irwin et al. (2022) study collected oil mist samples using NIOSH method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three select stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were located above each process unit (*i.e.*, not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the concentration of DINP in the stationary samples was similar to the concentration in the PBZ samples. Since the PBZ oil mist samples were all below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. As a results, EPA used the LOD reported in the study to estimate high-end exposures, and EPA used half of the LOD to estimate central tendency exposures.
Table 3-19 summarizes the estimated 10-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during incorporation into paints and coatings. The central tendency and high-end exposures use 250 days per year as the exposure frequency.

Table 3-19. Summary of Estimated Worker Inhalation Exposures for Incorporation into Paints and Coatings

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05
Female of Reproductive Age	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	4.3E−05	8.6E−05
	Intermediate (IADD, mg/kg-day)	3.2E−05	6.3E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	3.0E−05	5.9E−05
ONU	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05

3.4.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-20 are explained in Appendix B. Because dermal exposures to workers may occur in a concentrated liquid form during the incorporation of DINP into paints and coatings, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Table 3-20 summarizes the summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age. Because there are no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed. Dermal exposure parameters are described in Appendix D.

Table 3-20. Summary of Estimated Worker Dermal Exposures for Incorporation into Paints and Coatings

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02

3.4.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-21. Summary of Estimated Worker Aggregate Exposures for Incorporation into Paints and Coatings

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02
ONU	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05

3.5 Incorporation into Other Formulations, Mixtures, and Reaction Products

3.5.1 Process Description

The incorporation into other formulations, mixtures, and reaction products OES is broad and includes formulation of cleaning solvents, penetrants, and printing inks (see Appendix F for EPA identified DINP-containing products for this OES) (ACC, 2020; U.S. EPA, 2020a). EPA expects that each use case is small; therefore, the Agency assessed exposures as a group rather than individually. While EPA identified limited information on the formulation of these types of products, the Agency expects that formulation follows the same general processes regardless of end product type. Based on the 2014 GS on the Formulation of Waterborne Coatings, EPA expects that a typical site will unload DINP and incorporate it into other formulations, mixtures, and reaction products within industrial mixing vessels, using a batch blending or mixing process, with no reactions or chemical changes occurring to DINP during the mixing process. Blending or mixing operations can take up to 8 hours a day. Process operations may include quality control sampling and incorporation sites may transfer the blended formulation through an in-line filter. Following formulation, sites will load DINP-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 other formulations manufacturing process.

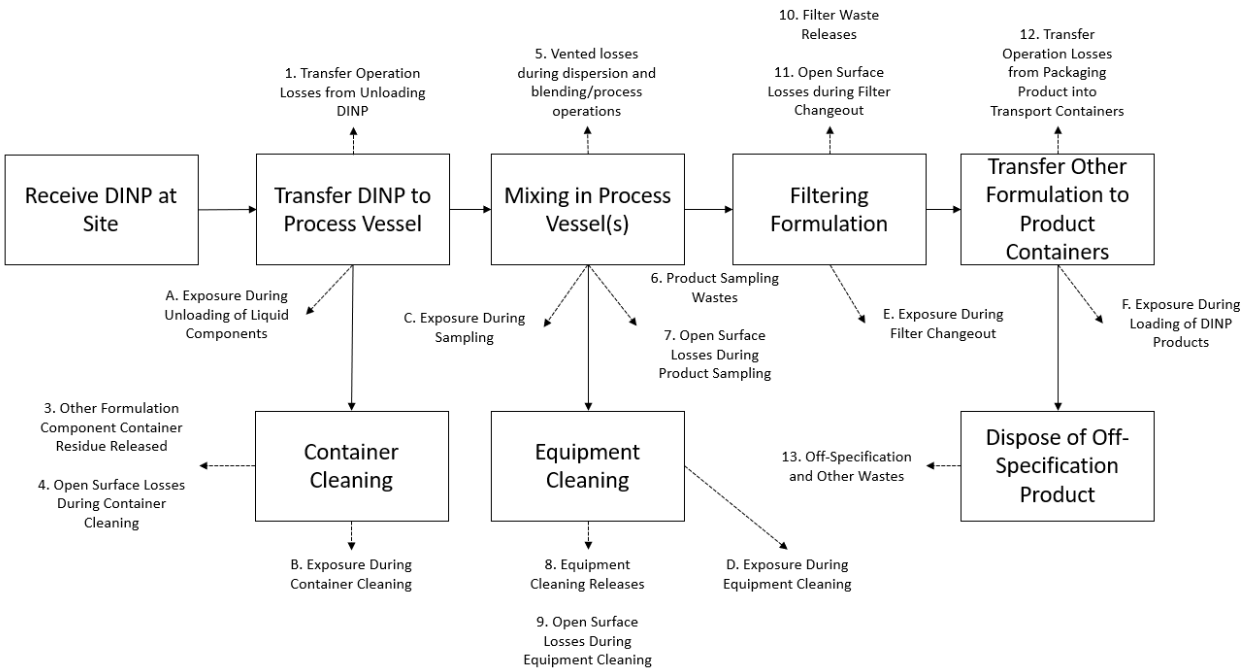

Figure 3-5. Incorporation into Other Formulations, Mixtures, and Reaction Products Flow Diagram

3.5.2 Facility Estimates

The 2020 CDR has one entry for incorporation into other formulations, mixtures, and reaction products for Univar Solutions in Redmond, WA, reported as "Petroleum Refineries" (U.S. EPA, 2020a). EPA assessed the total production volume and the total number of sites from systematic review due to the limitations of CDR reporting for downstream processes and uses. The 2003 *DINP Risk Assessment* published by the European Union reported that approximately 2.6 percent of the market share of DINP use was associated with non-polymer uses (ECJRC, 2003b). Further, it was assumed that the percentage of non-polymer uses would be split equally between paints/coatings, adhesives/sealants, and inks, which was 0.87 percent for each non-polymer use. ACC indicated that the use rate of DINP in the EU is similar to the use rate in the United States (ACC, 2020). Therefore, EPA estimated all OES that are not accounted for in the EU Risk Assessment as being less than or equal to 0.87 percent. As a result, EPA calculated the production volume of DINP in other formulations, mixtures, and reaction products as the remaining 0.87 percent of the yearly production volume of DINP for both CASRN reported to CDR. The total production volume for other formulations was 589,670 to 4,340,879 kg/year.

EPA did not identify other formulation operating information (*i.e.*, batch size or number of batches per year). The Agency assumed 5,030 kg/batch and 250 batches/year based on the 2014 ESD on the Formulation of Waterborne Coatings (U.S. EPA, 2014a). This corresponds to a DINP facility throughput of 8,000 to 8,000,000 kg-DINP/site-year, based on DINP product concentrations of 0.5 to 50 percent (see Appendix F for EPA identified DINP-containing products for this OES). Additionally, the Agency assumed that the number of operating days is equivalent to the number of batches per year, or 250 days/year with 24 hours/day and 7 days/week operations (*i.e.*, multiple shifts) for the given site throughput scenario. According to CDR reports, other formulation sites receive DINP in drums and totes ranging in size from 20 to 1,000 gallons, with DINP concentrations of 30 to 90 percent (U.S. EPA, 2020a). These sites receive DINP as either a liquid or a solid paste with material in drums transferred to mixing vessels during formulation (U.S. EPA, 2014a). EPA estimated the total number of sites that manufacture other formulations using a Monte Carlo model (see Appendix E.6 for details). The modeled 50th to 95th percentile range of the number of sites was 1 to 7 sites. This is in contrast to 2020 CDR reports, which identify a sole incorporation site.

3.5.3 Release Assessment

3.5.3.1 Environmental Release Points

EPA assigned release points based on the 2014 Generic Scenario on the Formulation of Waterborne Coatings(U.S. EPA, 2014a) and assigned default models to quantify potential releases from each release point and suspected fugitive air release point. The Agency expects fugitive air releases from unloading of DINP containers, container cleaning, sampling, equipment cleaning, and filter replacements. EPA also expects stack air releases from vented losses during process operations and from packaging products into transport containers. EPA further expects releases to wastewater, incineration, or landfill from container residue, sampling and equipment cleaning wastes, filter wastes, and off-specification wastes.

3.5.3.2 Environmental Release Assessment Results

Table 3-22. Summary of Modeled Environmental Releases for Incorporation into Other Formulations, Mixtures, and Reaction Products

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
1,300,000-9,570,000 lb production volume	Fugitive Air	2.34E−05	7.89E−05	250		9.35E−08	3.16E−07
	Stack Air	1.96E−05	1.45E−04			7.83E−08	5.81E−07
	Wastewater, Incineration, or Landfill	2.16E05	6.71E05			8.64E02	2.68E03

3.5.4 Occupational Exposure Assessment

3.5.4.1 Worker Activities

During the formulation of other articles that contain DINP, worker exposures to DINP vapors may occur during the packaging of final products. Worker exposures may also occur via inhalation of vapors or dermal contact with liquids when unloading DINP, cleaning transport containers, product sampling, equipment cleaning, and during filter media change out (U.S. EPA, 2014a). EPA did not identify information on engineering controls or worker PPE used at other formulation sites.

ONUs include supervisors, managers, and other employees that work in the formulation area but do not directly contact DINP received or processed onsite or handle of formulated product. ONUs are potentially exposed through the inhalation route while in the working area. However, dermal exposures to ONUs are not expected for this OES.

3.5.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs potentially exposed to DINP during the incorporation of DINP into other formulations, mixtures, or reaction products not covered elsewhere. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details on the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 325110, 424690, and 424910 for this OES based on the Generic Scenario on the Formulation of Waterborne Coatings and CDR reported NAICS codes for incorporation into paints and coatings (U.S. EPA, 2020a, 2014a). Table 3-23 summarizes the per site estimates for this OES. As discussed in Section 3.5.2, EPA did not identify site-specific data for the number of facilities in the United States that incorporate DINP into other formulations, mixtures, or reaction products not covered elsewhere.

Table 3-23. Estimated Number of Workers Potentially Exposed to DINP During Incorporation into Other Formulations, Mixtures, or Reaction Products not Covered Elsewhere

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
325110 – Petrochemical Manufacturing		64		30	
424690 – Other Chemical and Allied Products Merchant Wholesalers	N/A	1	N/A	0.45	N/A
424910 – Farm Supplies Merchant Wholesalers		1		0.10	
Total/Average	1–7	22	22–153	10	10–71

[a] The result is expressed as a range between the central tendency and the high-end value representing the 50th and 95th percentile results. Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.5.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the incorporation of DINP into other formulations, mixtures, and reaction products not covered elsewhere during systematic review. However, the Agency estimated vapor inhalation exposures for this OES using monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. EPA expects that vapor inhalation exposures during plastics converting will represent a bounding range of exposures for other processing operations, such as incorporation into other formulations, mixtures, and reaction products not covered elsewhere, because of the elevated temperature of converting operations and relatively high concentration of DINP present in PVC plastics.

The Irwin et al. (2022) study collected oil mist samples using NIOSH Method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three select stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were located above each process unit (*i.e.*, not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the concentration of DINP in the stationary samples was similar to the concentration in the PBZ samples. Since the PBZ oil mist samples were all below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. As a results, EPA used the LOD reported in the study to estimate high-end exposures, and EPA used half of the LOD to estimate central tendency exposures.

Table 3-24 summarizes the estimated 10-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during incorporation into other formulations, mixtures, and reaction products. The central tendency and high-end exposures use 250 days per year as the exposure frequency.

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

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05
Female of Reproductive Age	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	4.3E−05	8.6E−05
	Intermediate (IADD, mg/kg-day)	3.2E−05	6.3E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	3.0E−05	5.9E−05
ONU	10-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05

3.5.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-25 are explained in Appendix B. Because dermal exposures to workers may occur in a concentrated liquid form during the incorporation of DINP into other formulations, mixtures, and reaction products, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Table 3-25 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age. Because there are no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed. Dermal exposure parameters are described in Appendix D.

Table 3-25. Summary of Estimated Worker Dermal Exposures for Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02

3.5.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-26. Summary of Estimated Worker Aggregate Exposures for Incorporation into Other Formulations, Mixtures, or Reaction Products Not Covered Elsewhere

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02
ONU	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05

3.6 PVC Plastics Compounding

3.6.1 Process Description

DINP is used in PVC plastics to increase flexibility and is found in floor and wall coverings, electrical tape, coated fiberglass fabrics, and sporting equipment (see Appendix F for EPA identified DINP-containing products for this OES) (ACC, 2020). Compounding involves the mixing of the polymer with the plasticizer and other chemical such as, fillers and heat stabilizers. The plasticizer needs to be absorbed into the particle to impart flexibility to the polymer. For PVC compounding, compounding occurs through mixing of ingredients to produce a powder (dry blending) or a liquid (Plastisol blending). The most common process for dry blending involves heating the ingredients in a high intensity mixer and transfer to a cold mixer. The Plastisol blending is done at ambient temperature using specific mixers that allow for the breakdown of the PVC agglomerates and the absorption of the plasticizer into the resin particle. EPA expects that a typical compounding site receives DINP as a pure liquid at 25°C, in drums and totes ranging in size from 20-1,000 gallons (U.S. EPA, 2021d). The site unloads and transfers DINP into mixing vessels to produce a compounded resin masterbatch. Following completion of the masterbatch, the site transfers the solid resin to an extruder that shapes and sizes the plastic and packages the final product for shipment to downstream conversion sites after cooling. Figure 3-6 provides an illustration of the PVC plastic compounding process (U.S. EPA, 2021d).

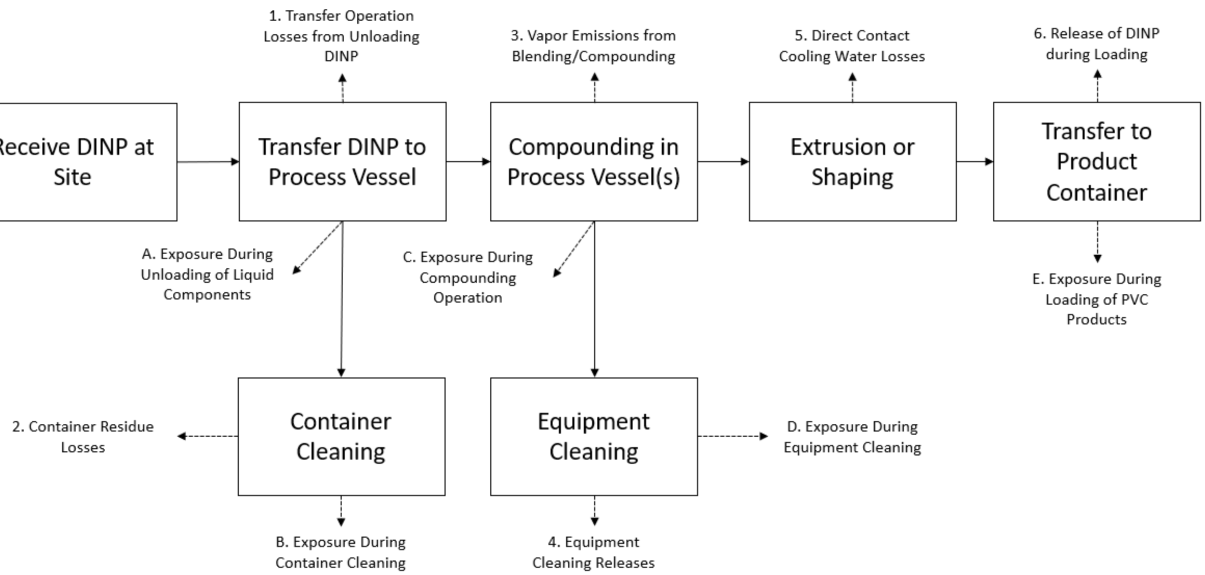

Figure 3-6. PVC Plastics Compounding Flow Diagram

3.6.2 Facility Estimates

In the 2020 CDR, twenty-nine sites reported using DINP as a plasticizer in several PVC plastics industrial sectors, including custom compounding of purchased resins, plastic material and resin manufacturing, and wholesale and retail trade. Of those twenty-nine sites, thirteen sites reported their production volume as CBI (U.S. EPA, 2020a). Due to the limitations of CDR reporting data for downstream processes and uses, EPA relied on data from the European Union and the American Chemistry Council to assess the total production volume. The 2003 *DINP Risk Assessment* published by the European Union stated that the market share of DINP used in PVC plastics is equal to 94.9 percent of the annual chemical production volume (ECJRC, 2003b). ACC indicated that the use rate of DINP in the EU is similar to the use rate in the United States (ACC, 2020). As a result, EPA calculated the production volume of DINP in PVC plastics compounding as 94.9 percent of the yearly production volume of DINP under both CASRN or 64,568,873 to 473,505,075 kg/year. The 2020 CDR reported the national production volume of DINP as a range; therefore, EPA also provided the plastics compounding production volume as a range. In addition, the Royal Society of Chemistry published a book chapter that stated that, “In 2008, more than 5 million tonnes of phthalates were used as plasticizers worldwide. Of the phthalates used 16 percent are used in North America… In 2008 DINP and DIDP had a market share of 38 percent and 21 percent, respectively” (Koch and Angerer, 2011). The annual North American DINP production volume used in PVC plastics based on these market share values is 304,000,000 DINP kg/year, which is generally consistent with the production volume range calculated based on the 2020 CDR data and *EU Risk Assessment* (U.S. EPA, 2020a; ECJRC, 2003b). Based on the 2021 Generic Scenario on Plastic Compounding the mass fraction of DINP as a plasticizer in PVC products is 30 to 45 percent (U.S. EPA, 2021d).

EPA did not identify site- or chemical-specific operating data for PVC plastics compounding (*i.e.*, facility production rate, number of batches, or operating days); EPA estimated an annual facility throughput of 1,489,327 to 4,146,286 kg/site-year based on the 2021 Generic Scenario on Plastic Compounding throughput of plastic additives, the mass fraction of DINP in PVC products, and the mass fraction of all additives in compounded plastic resin (U.S. EPA, 2021d). EPA assessed the total number of operating days as 148 to 264 days/year, with 24 hours/day, 7 days/week (*i.e.*, multiple shifts) operations for the given site throughput scenario. Additionally, EPA assumed the number of batches per site per year was equivalent to the number of operating days, or one batch per day. EPA estimated the total number of PVC plastics compounding sites using a Monte Carlo model (see Appendix E.8 for details). The modeled 50th to 95th percentile range of the number of sites was 110 to 215 sites. In contrast, Table 3-27 provides the reported number of industrial sites in the 2020 CDR (U.S. EPA, 2020a) but does not include any sites that reported the number of industrial sites as NKRA.

Table 3-27. 2020 CDR Reported Downstream Industrial Sites for PVC Plastics Compounding

Site Name, Location[a]	Number of Downstream Sites
ICC Chemical Corp, New York, NY	<10
Alac International Inc. New York, NY	25–99
Formosa Global Solutions, Livingston, NJ	<10
Teknor Apex, Brownsville, TN	<10
Westlake Compounds LLC. Houston, TX	CBI
BASF Imports, Florham, NJ	<10
Evonik Corp. Parsippany, NJ	100–249
ExxonMobil, Baton Rouge, LA	<10
Gehring Montgomery, Warminster, PA	<10
Geon Performance Solutions LLC	<10
Alac International Inc. New York, NY	25–99
Alac International Inc. New York, NY	10–24
Alac International Inc. New York, NY	25–99

[a] Sites may be included multiple times if they reported to several industrial sectors falling under the PVC plastics compounding OES

3.6.3 Release Assessment

3.6.3.1 Environmental Release Points

EPA assigned release points based on the 2021 Generic Scenario on Plastic Compounding (U.S. EPA, 2021d). EPA assigned a default model to quantify releases at each release point and suspected fugitive air release point. EPA expects fugitive or stack air releases from unloading plastic 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. Sites may utilize air capture technology. 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 pollution control technology, EPA expects releases to fugitive air, wastewater, incineration, or landfill, as described above.

3.6.3.2 Environmental Release Assessment Results

Table 3-28. Summary of Modeled Environmental Releases for PVC Plastics Compounding

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
142,349,998–1,043,900,000 lb production volume	Fugitive or Stack Air	7.20E03	3.13E04	223	254	3.30E01	1.46E02
	Fugitive Air, Wastewater, Incineration, or Landfill	1.80E04	5.84E04			8.23E01	2.74E02
	Wastewater, Incineration, or Landfill	9.35E04	1.41E05			4.28E2	6.81E02
	Wastewater	2.38E04	3.38E04			1.09E02	1.64E02
	Incineration or Landfill	4.86E03	2.39E04			2.23E01	1.11E02

3.6.4 Occupational Exposure Assessment

3.6.4.1 Worker Activities

Worker exposures during the compounding process may occur via inhalation of DINP-containing dusts. Dermal exposures to liquids may occur during equipment cleaning. Worker exposures may also occur via dermal contact with liquids and inhalation of vapors during DINP unloading and loading 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 formulation area but do not directly contact DINP received or processed onsite or handle compounded product. ONUs are potentially exposed through the inhalation route while in the working area. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.6.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs that are potentially exposed to DINP during PVC plastics compounding. This approach involved the identification of relevant SOC codes within the BLS data for the select NAICS codes. Section 2.4.2 provides additional details on the methodology EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS code 325211 – Plastics Material and Resin Manufacturing for this OES based on the CDR reported NAICS codes for PVC plastics compounding (U.S. EPA, 2020a). Table 3-29 summarizes the per site estimates for this OES. As discussed in Section 3.6.2, EPA did not identify site-specific data for the number of facilities in the United States that compound PVC plastics.

Table 3-29. Estimated Number of Workers Potentially Exposed to DINP During PVC Plastics Compounding

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed Occupation Non-users per Site[b]	Total Number of Exposed ONUs[a]
325211 – Plastics Material and Resin Manufacturing	110–215	27	3,022–5,907	12	1,328–2,595

[a] The result is expressed as a range between the central tendency and the high-end value representing the 50th and 95th percentile results.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.6.4.3 Occupational Inhalation Exposure Results

EPA identified inhalation monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. Irwin et al. collected total respirable dust PBZ samples using personal sampling pumps with cyclones, during five separate worker activities at a manufacturing site that both compounds and converts PVC plastic. Irwin et al. used these samples to calculate five, 10-hour TWAs for airborne particulate and an adjusted 10-hour TWA based on the expected concentration of DINP in the process. Since these samples were not direct measurements of DINP, EPA assessed occupational 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). This model relies on a more robust dataset of dust measurements from relevant processes at different industrial facilities. To estimate PVC particulate concentrations in the air, EPA used a subset of the model's dust data for facilities with NAICS codes starting with 326 (Plastics and Rubber Manufacturing). This dataset consisted of 237 measurements. EPA used the maximum expected concentration of DINP in PVC plastic products to estimate the concentration of DINP in airborne PVC particulates. For this OES, EPA selected 45 percent by mass as the highest expected DINP concentration, based on estimated plasticizer concentrations in flexible PVC in the Use of Additives in Plastic Compounding Generic Scenario (U.S. EPA, 2021d). The estimated DINP concentrations assume that DINP is present in PVC particulate at this fixed concentration throughout the working shift. The Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) uses an 8-hour TWA for particulate concentrations and assumes exposures outside the sample duration are zero. The model does not evaluate exposures during individual worker activities. EPA estimated bounding exposures for ONUs using the worker central tendency of the PNOR model results.

Irwin et al. (2022) also collected oil mist samples using NIOSH method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three stationary locations near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were above each process unit (*i.e.*, not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the DINP concentration in the stationary samples was similar to the DINP concentration in the PBZ samples. Since the PBZ oil mist samples were below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. EPA used the LOD reported in the study to estimate high-end exposures. EPA used half of the LOD to estimate central tendency exposures.

EPA converted the 10-hour vapor exposures (estimated from the oil mist sampling results) and the 8-hour dust exposures (estimated 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)) to an aggregated 24 hour acute dose to assess DINP exposures to both vapor and dust for the full work shift. Specifically, EPA added the 24-hour acute dose from the vapor monitoring data to the 24-hour acute dose from the PNOR model to calculate aggregate DINP exposures. Table 3-30 summarizes the estimated 8-hour and 10-hour TWA concentrations, and the aggregated AD, IADD, and ADD for worker inhalation exposures to DINP during PVC plastic 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 223 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment.

Table 3-30. Summary of Estimated Worker Inhalation Exposures for PVC Plastics Compounding

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	0.10	2.1
	Acute (AD, mg/kg-day)	1.3E−02	0.26
	Intermediate (IADD, mg/kg-day)	9.5E−03	0.19
	Chronic, Non-cancer (ADD, mg/kg-day)	7.9E−03	0.18
Female of Reproductive Age	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	0.10	2.1
	Acute (AD, mg/kg-day)	1.4E−02	0.29
	Intermediate (IADD, mg/kg-day)	1.1E−02	0.21
	Chronic, Non-cancer (ADD, mg/kg-day)	8.8E−03	0.20
ONU	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	0.10	0.10
	Acute (AD, mg/kg-day)	1.3E−02	1.3E−02
	Intermediate (IADD, mg/kg-day)	9.5E−03	9.5E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.9E−03	8.9E−03

3.6.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-31 are explained in Appendix B. Because dermal exposures of DINP to workers may occur in the neat form during PVC plastics compounding, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-31 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

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

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.8E−02	0.11
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.4E−02	9.8E−02
ONU	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.9E−04	2.1E−04

3.6.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

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

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	9.1E−02	0.42
	Intermediate (IADD, mg/kg-day)	6.7E−02	0.31
	Chronic, Non-cancer (ADD, mg/kg-day)	5.6E−02	0.29
Female of Reproductive Age	Acute (AD, mg/kg-day)	8.6E−02	0.44
	Intermediate (IADD, mg/kg-day)	6.3E−02	0.32
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.30
ONU	Acute (AD, mg/kg-day)	1.3E−02	1.3E−02
	Intermediate (IADD, mg/kg-day)	9.7E−03	9.8E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	8.1E−03	9.1E−03

3.7 PVC Plastics Converting

3.7.1 Process Description

DINP is used in PVC plastics to increase flexibility and is found in floor and wall coverings, electrical tape, coated fiberglass fabrics, and sporting equipment (see Appendix F for EPA identified DINP-containing products for this OES)(ACC, 2020). DINP arrives at a typical converting site as a solid in containers ranging in size from 6-132 gallons (U.S. EPA, 2021e). A typically converting site will unload DINP in solid form, as a masterbatch, from PVC 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 3-7 provides an illustration of the plastic converting process (U.S. EPA, 2021e).

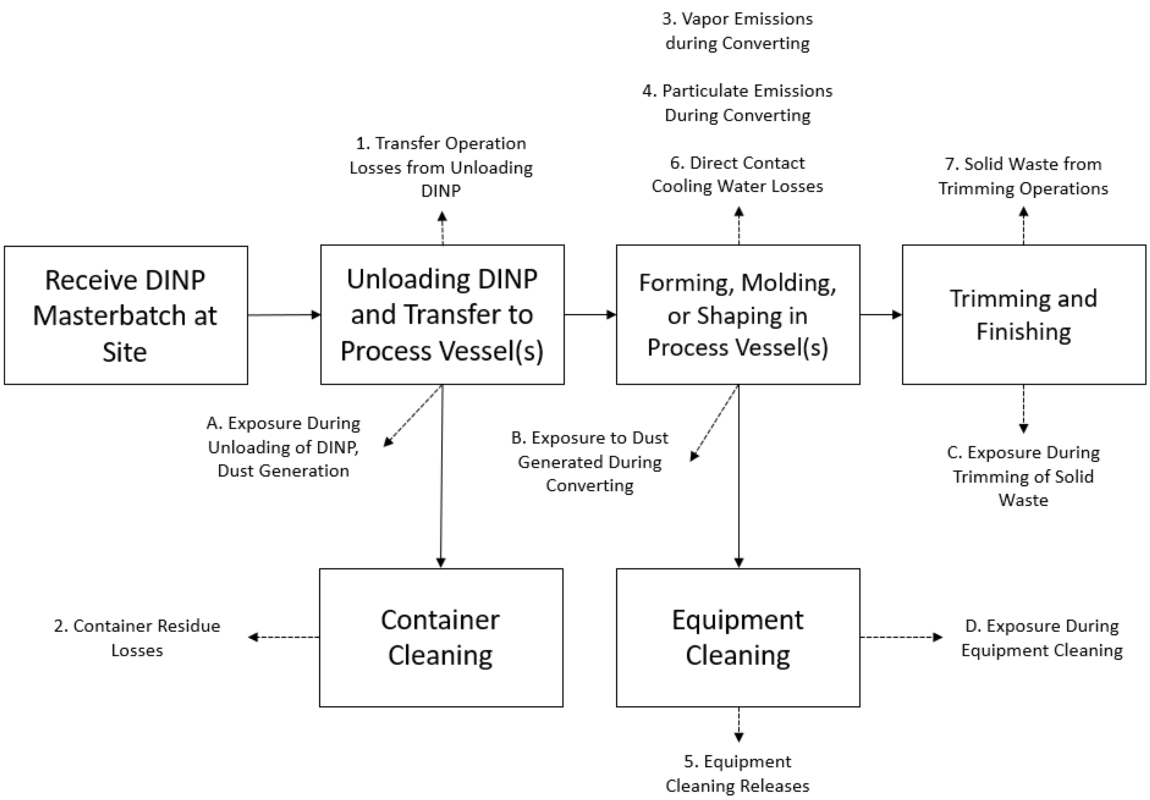

Figure 3-7. PVC Plastic Converting Flow Diagram

3.7.2 Facility Estimates

Since converting occurs immediately downstream of compounding, EPA expects the production volume for PVC plastic converting to be identical to the production volume for the PVC plastics compounding OES. The production volume of DINP in PVC plastics compounding under both CASRN was 64,568,873 to 473,505,075 kg/year (see Section 3.6.2 for details). Based on the 2021 Generic Scenario on Plastic Compounding the mass fraction of DINP as a plasticizer in PVC products is 30 to 45 percent (U.S. EPA, 2021d).

EPA did not identify PVC plastic converting site operating data (*i.e.*, facility production rate, number of batches, or operating days); EPA estimated an annual facility throughput of 68,542 to 190,822 kg/site-year based on the 2021 Revised Draft GS on the Use of Additives in the Thermoplastics Converting Industry throughput of plastic additives, the mass fraction of DINP in PVC 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 hours/day, 7 days/week (*i.e.*, multiple shifts) operations for the given site throughput scenario. Additionally, EPA assumed the number of batches completed per site per year was equivalent to the number of operating days, or one completed batch per day. EPA estimated the total number of PVC plastics converting sites using a Monte Carlo model (see Appendix E.8 for details). The modeled 50th to 95th percentile range of the number of sites was 2,386 to 4,662 sites. In contrast, Table 3-33 provides the reported number of industrial sites from the 2020 CDR (U.S. EPA, 2020a). Table 3-33 does not include any sites that reported the number of industrial sites as NKRA.

Table 3-33. 2020 CDR Reported Downstream Industrial Sites for PVC Plastics Compounding

Site Name, Location[a]	Number of Downstream Sites
ICC Chemical Corp, New York, NY	<10
Alac International Inc. New York, NY	25–99
Formosa Global Solutions, Livingston, NJ	<10
Teknor Apex, Brownsville, TN	<10
Westlake Compounds LLC. Houston, TX	CBI
BASF Imports, Florham, NJ	<10
Evonik Corp. Parsippany, NJ	100–249
ExxonMobil, Baton Rouge, LA	<10
Gehring Montgomery, Warminster, PA	<10
Geon Performance Solutions LLC	<10
Alac International Inc. New York, NY	25–99
Alac International Inc. New York, NY	10–24
Alac International Inc. New York, NY	25–99

[a] Sites may be included multiple times if they reported to several industrial sectors falling under the PVC plastics compounding OES.

3.7.3 Release Assessment

3.7.3.1 Environmental Release Points

EPA assigned release points based on the 2021 Revised Draft GS on the Use of Additives in the Thermoplastics Converting Industry (U.S. EPA, 2021e). The Agency assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects fugitive or stack air releases and particulate emissions to fugitive air, wastewater, incineration, or landfill from converting operations. EPA also expects releases to wastewater, incineration, or landfill from container residues, and equipment cleaning. The Agency further expects releases to wastewater from direct contact cooling and incineration, and landfill releases from solid waste trimming. Converting sites may utilize air pollution capture and control technology. If a site uses air pollution control technology, EPA expects dust releases from plastic 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 pollution control technology, EPA expects plastic unloading releases to fugitive air, wastewater, incineration, or landfill as described above.

3.7.3.2 Environmental Release Assessment Results

Table 3-34. Summary of Modeled Environmental Releases for PVC Plastics Converting

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
142,349,998–1,043,900,000 lb production volume	Fugitive or Stack Air	3.36E02	1.44E03	219	251	1.58	6.94
	Fugitive Air, Wastewater, Incineration, or Landfill	8.36E02	2.70E03			3.92	1.30E01
	Wastewater, Incineration, or Landfill	3.29E03	4.67E03			1.54E01	2.35E01
	Wastewater	1.10E03	1.56E03			5.14	7.85
	Incineration or Landfill	3.05E03	4.51E03			1.43E01	2.27E01

3.7.4 Occupational Exposure Assessment

3.7.4.1 Worker Activities

Workers are potentially exposed to DINP via dust inhalation during the converting process and via dermal contact with liquids during equipment cleaning. Additionally, workers may be exposed to DINP via dermal contact with liquids and inhalation of vapors during unloading and loading, transport container cleaning, and trimming of excess plastic (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 formulation area but do directly contact DINP that is received or processed onsite or handle the finished product. ONUs are potentially exposed through the inhalation route while in the working area. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.7.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during PVC plastics converting. This approach involved the identification of relevant SOC codes withing the BLS data for select NAICS codes. Section 2.4.2 provides additional details regarding the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS code 326100 – Plastics Product Manufacturing for this OES based on the CDR reported NAICS codes for PVC plastics converting (U.S. EPA, 2020a). Table 3-35 summarizes the per site estimates for this OES. As discussed in Section 3.7.2, EPA did not identify site-specific data for the number of facilities in the United States that convert PVC plastics.

Table 3-35. Estimated Number of Workers Potentially Exposed to DINP During PVC Plastics Converting

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
326100 – Plastics Product Manufacturing	2,386–4,662	18	43,777–85,536	5	12,389–24,206

[a] The result is expressed as a range between the central tendency and the high-end value representing the 50th and 95th percentile results.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.7.4.3 Occupational Inhalation Exposure Results

EPA identified inhalation monitoring data for DINP during PVC plastics compounding and converting in a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. Irwin et al. collected total respirable dust PBZ samples using personal sampling pumps with cyclones, during five separate worker activities at a manufacturing site that both compounds and converts PVC plastic. Irwin et al. used these samples to calculate five, 10-hour TWAs for airborne particulate and an adjusted 10-hour TWA based on the expected concentration of DINP in the process. Since these samples were not direct measurements of DINP, EPA assessed occupational 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). This model relies on a more robust dataset of dust measurements from relevant processes at different industrial facilities. To estimate PVC particulate concentrations in the air, EPA used a subset of the model's dust data for facilities with NAICS codes starting with 326 (Plastics and Rubber Manufacturing). This dataset consisted of 237 measurements. EPA used the maximum expected concentration of DINP in PVC plastic products to estimate the concentration of DINP in airborne PVC particulates. For this OES, EPA selected 45 percent by mass as the highest expected DINP concentration, based on estimated plasticizer concentrations in flexible PVC in the Use of Additives in Plastic Compounding Generic Scenario (U.S. EPA, 2021d). The estimated DINP concentrations assume that DINP is present in PVC particulate at this fixed concentration throughout the working shift. The Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) uses an 8-hour TWA for particulate concentrations and assumes exposures outside the sample duration are zero. The model does not evaluate exposures during individual worker activities. EPA estimated bounding exposures for ONUs using the worker central tendency of the PNOR model results.

Irwin et al. also collected oil mist samples using NIOSH method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were above each process unit (*i.e.*, not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the DINP concentration in the stationary samples was similar to the DINP concentration in the PBZ samples. Since the PBZ oil mist samples were below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. EPA used the LOD reported in the study to estimate high-end exposures. EPA used half of the LOD to estimate central tendency exposures.

EPA converted the 10-hour vapor exposures (estimated from the oil mist sampling results) and the 8-hour dust exposures (estimated 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)) to an aggregated 24-hour acute dose to assess DINP exposures to both vapor and dust for the full work shift. Specifically, EPA added the 24-hour acute dose from the vapor monitoring data to the 24-hour acute dose from the PNOR model to calculate aggregate DINP exposures. Table 3-36Table 3-30 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during PVC plastic 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 3-36. Summary of Estimated Worker Inhalation Exposures for PVC Plastics Converting

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	0.10	2.1
	Acute (AD, mg/kg-day)	1.3E−02	0.26
	Intermediate (IADD, mg/kg-day)	9.5E−03	0.19
	Chronic, Non-cancer (ADD, mg/kg-day)	7.8E−03	0.18
Female of Reproductive Age	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	0.10	2.1
	Acute (AD, mg/kg-day)	1.4E−02	0.29
	Intermediate (IADD, mg/kg-day)	1.1E−02	0.21
	Chronic, Non-cancer (ADD, mg/kg-day)	8.6E−03	0.20
ONU	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	0.10	0.10
	Acute (AD, mg/kg-day)	1.3E−02	1.3E−02
	Intermediate (IADD, mg/kg-day)	9.5E−03	9.5E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.8E−03	8.9E−03

3.7.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-37 are explained in Appendix B. Because dermal exposures of DINP to workers is expected to occur through contact with solids or articles for this OES, EPA assessed the absorptive flux of DINP according to dermal absorption modeling approach for solids outlined in Appendix D.2.1.2. Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-37 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-37. Summary of Estimated Worker Dermal Exposures for PVC Plastics Converting

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5E−02	4.9E−02
	Acute (AD, mg/kg-day)	3.1E−04	6.2E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	4.5E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.8E−04	4.2E−04
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.0E−02	4.1E−02
	Acute (AD, mg/kg-day)	2.8E−04	5.7E−04
	Intermediate (IADD, mg/kg-day)	2.1E−04	4.1E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.7E−04	3.9E−04
ONU	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.8E−04	2.1E−04

3.7.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-38. Summary of Estimated Worker Aggregate Exposures for PVC Plastics Converting

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.3E−02	0.27
	Intermediate (IADD, mg/kg-day)	9.7E−03	0.19
	Chronic, Non-cancer (ADD, mg/kg-day)	8.0E−03	0.18
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.5E−02	0.29
	Intermediate (IADD, mg/kg-day)	1.1E−02	0.21
	Chronic, Non-cancer (ADD, mg/kg-day)	8.8E−03	0.20
ONU	Acute (AD, mg/kg-day)	1.3E−02	1.3E−02
	Intermediate (IADD, mg/kg-day)	9.7E−03	9.8E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	8.0E−03	9.1E−03

3.8 Non-PVC Material Compounding

3.8.1 Process Description

The 2021 *Scope of the Risk Evaluation for Di-isononyl Phthalate* (U.S. EPA, 2021b) and CDR reports for rubber product manufacturing and petroleum refineries indicate DINP use in non-PVC polymers, such as polyurethane resin, rubber erasers, and synthetic rubber (see Appendix F for EPA identified DINP-containing products for this OES)(ACC, 2020; U.S. EPA, 2020a). DINP is used as a plasticizer in rubber products (ACC, 2020).

EPA expects that a typical non-PVC material compounding site operates like a PVC plastic compounding site. Based on the 2021 Generic Scenario on Plastic Compounding, typical compounding sites receive DINP as a pure liquid at 25 °C in drums and totes ranging from 20 to 1,000 gallons in size. Typical compounding sites receive and unload DINP and transfer it into mixing vessels to produce a compounded resin masterbatch. Following completion of the masterbatch, sites transfer the solid resin to extruders that shape and size the plastic and package the final product for shipment to downstream conversion sites after cooling (U.S. EPA, 2021d). Figure 3-8 provides an illustration of the plastic compounding process (U.S. EPA, 2021d).

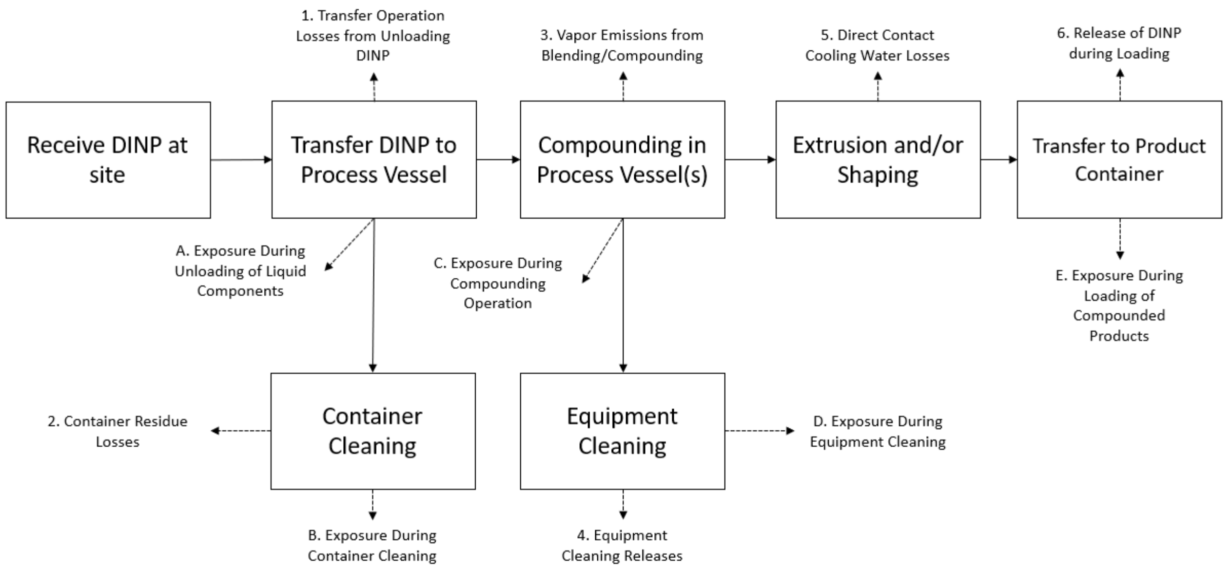

Figure 3-8. Non-PVC Material Compounding Flow Diagram

Note that manufactures of some materials, such as rubbers, may consolidate compounding and converting operations as described in the *SpERC Fact Sheet on Rubber Production and Processing*. Figure 3-9 provides an illustration of the rubbers formulation process (ESIG, 2020b; OECD, 2004a). Since the rate of consolidated operations for non-PVC materials is unknown, EPA assessed all formulations considering separate compounding and converting steps per Figure 3-8.

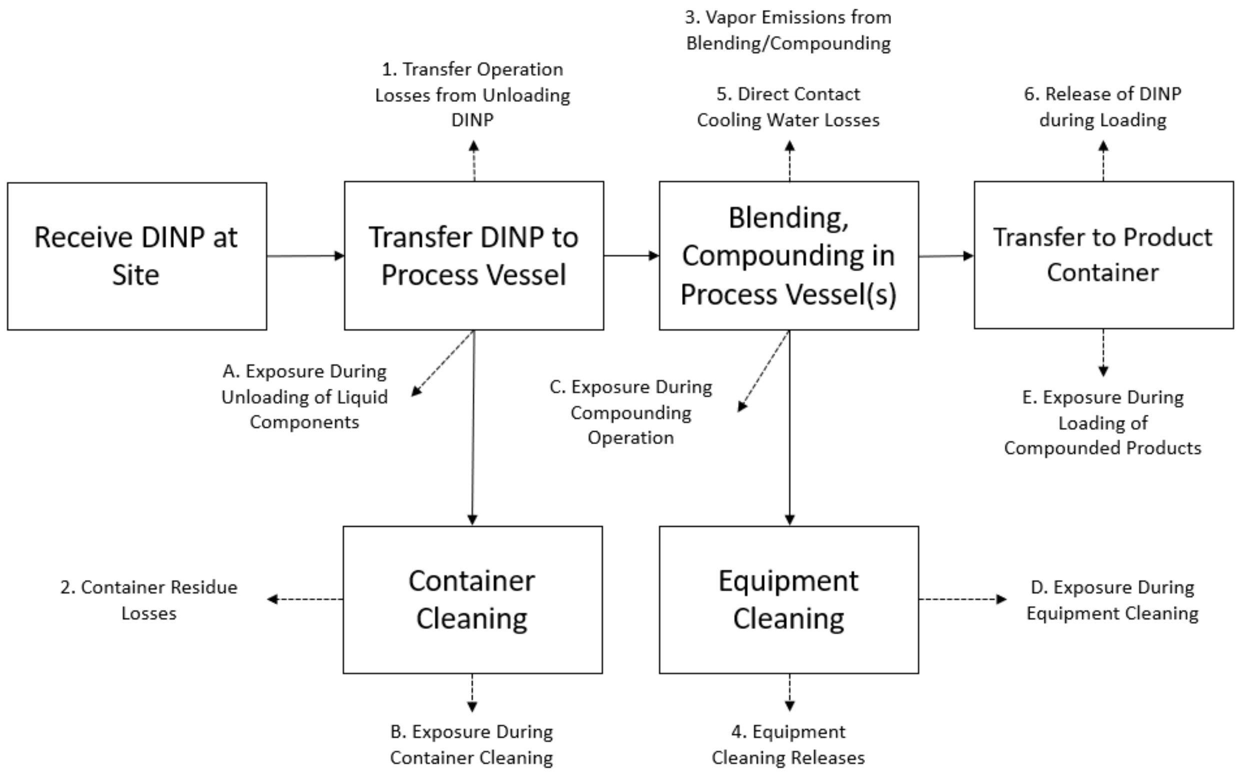

Figure 3-9. Consolidated Compounding and Converting Flow Diagram

3.8.2 Facility Estimates

In the 2020 CDR, four manufacturing sites reported production volume for the formulation of rubbers and petroleum OES. One additional site, ICC Chemical in New York, NY reported rubber product manufacturing activity but claimed their production volume as CBI (U.S. EPA, 2020a). Many sites reported plastic compounding activity; however, CDR does not allow reporters to specify PVC or non-PVC plastic compounding. Therefore, EPA assessed all plastic compounding sites as PVC compounding, based on the majority use case. Due to additional limitations associated with using CDR data for downstream processes, EPA relied on data from the European Union and the American Chemistry Council to assess the total production volume. The 2003 *DINP Risk Assessment* published by the European Union reported that approximately 5.1 percent of the market share of DINP was used was in non-PVC end uses, including both polymer and non-polymer uses (ECJRC, 2003b). Further, it was assumed that the non-PVC end uses would be split equally between polymer related and non-polymer related uses, resulting in approximately 2.6 percent of the market share being associated with non-PVC polymer uses (*e.g.*, rubber manufacturing). ACC indicated that the use rate of DINP in the EU is similar to the use rate in the United States (ACC, 2020). The 2020 CDR reported a national production volume range for DINP; therefore, EPA also provided the non-PVC material compounding production volume as a range, using the 2.6 percent estimated by the EU to calculate the non-PVC polymer production volume for DINP. Since EPA was unable to further refine this production volume into non-PVC materials and rubber, the OES were assessed together due to similarities in their respective production processes. EPA calculated the production volume of DINP under both CASRN as 1,769,010 to 12,972,742 kg/year.

EPA did not identify site- or DINP-specific non-PVC material compounding operating data (*i.e.*, facility production rate, number of batches, or operating days). The Agency assessed non-PVC material compounding operating data based on PVC compounding operating data, as the operations are expected to be similar. EPA based the DINP facility use rate on the 2021 Generic Scenario on Plastic Compounding product throughput of plastic additives (U.S. EPA, 2021d). EPA also considered the 2004 ESD on Additives in the Rubber Industry but determined that the Generic Scenario on Plastic Compounding was more representative of the COUs covered under the OES (OECD, 2004a). The Generic Scenario on Plastic Compounding based the facility use rate on the mass fraction of DINP in non-PVC products of 1 to 40 percent, and the mass fraction of all additives in compounded plastic resin (U.S. EPA, 2021d). EPA estimated the annual facility DINP throughput using Monte Carlo modeling (see Appendix E.7 for details) with the 50th to 95th percentile range as 2,536,239 to 4,478,366 kg/site-year. The Generic Scenario on Plastic Compounding estimated the total number of operating days as 148 to 300 days/year, with 24 hours/day, 7 days/week (*i.e.*, multiple shifts) operations for the given site throughput scenario. The number of batches completed per site year was equivalent to the number of operating days, or one batch per day (U.S. EPA, 2021d). EPA estimated the total number of sites that participate in non-PVC material compounding using Monte Carlo modeling (see Appendix E.7 for details). The modeled 50th to 95th percentile range of the number of sites was 5 to 9. In contrast, in the 2020 CDR reports, two sites reported the number of industrial use sites to be less than 10. The remaining three sites reported the number of industrial sites as NKRA.

3.8.3 Release Assessment

3.8.3.1 Environmental Release Points

EPA assigned release points based on the 2021 Generic Scenario on Plastic Compounding (U.S. EPA, 2021d). The Agency assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects fugitive or stack air releases from unloading plastic additives and process operations. EPA also expects releases to wastewater, incineration, or landfill from container residues and equipment cleaning wastes. The Agency expects releases to wastewater from direct contact cooling. Sites may utilize air pollution capture and control technology. If a site uses air pollution capture and control technology, EPA expects dust releases from product loading to be controlled and released to disposal facilities for incineration or landfill. The Agency expects the remaining uncontrolled dust to be released to stack air. If the site does not use air control technology, EPA expects releases to fugitive air, wastewater, incineration, or landfill as described above.

3.8.3.2 Environmental Release Assessment Results

Table 3-39. Summary of Modeled Environmental Releases for Non-PVC Material Compounding

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,900,000–28,600,000 lb production volume	Fugitive or Stack Air	1.25E04	5.02E04	234	280	5.47E01	2.15E02
	Fugitive Air, Wastewater, Incineration, or Landfill	1.09E03	4.36E03			4.77	1.86E01
	Wastewater, Incineration, or Landfill	2.73E05	6.16E05			1.20E03	2.60E03
	Wastewater	2.54E04	4.48E04			1.11E02	1.86E02
	Incineration or Landfill	1.83E04	6.60E04			7.96E01	2.81E02

3.8.4 Occupational Exposure Assessment

3.8.4.1 Worker Activities

Worker exposures to DINP dust may occur through inhalation during the compounding process, while dermal exposures to liquids may occur during equipment cleaning. Worker exposures may also occur via dermal contact with liquids and inhalation of vapors during the unloading and loading of DINP 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 formulation area but do not directly contact DINP that is received or processed onsite or handle compounded product. ONUs are potentially exposed through the inhalation route while in the working area. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.8.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during the compounding of non-PVC material. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details regarding the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 326200, 424610, and 424690 for this OES based on the Generic Scenario on the Use of Additives in Plastic Compounding and CDR reported NAICS codes for non-PVC material compounding (U.S. EPA, 2021d, 2020a). Table 3-40 summarizes the per site estimates for this OES. As addressed in Section 3.8.2, EPA did not identify site-specific data for the number of facilities in the United States that compound non-PVC material.

Table 3-40. Estimated Number of Workers Potentially Exposed to DINP During Non-PVC Material Compounding

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
326200 – Rubber Product Manufacturing	N/A	42	N/A	7	N/A
424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers		1		0.39	
424690 – Other Chemical and Allied Products Merchant Wholesalers		1		0.45	
Total/Average	5–9	15	74–132	3	13–23

[a] The result is expressed as a range between the central tendency and the high-end value. Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.8.4.3 Occupational Inhalation Exposure Results

EPA identified inhalation monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. Irwin et al. collected total respirable dust PBZ samples using personal sampling pumps with cyclones, during five separate worker activities at a manufacturing site that both compounds and converts PVC plastic. Irwin et al. used these samples to calculate five, 10-hour TWAs for airborne particulate and an adjusted 10-hour TWA based on the expected concentration of DINP in the process. Since these samples were not direct measurements of DINP, EPA assessed occupational 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). This model relies on a more robust dataset of dust measurements from relevant processes at different industrial facilities. To estimate PVC particulate concentrations in the air, EPA used a subset of the model's dust data for facilities with NAICS codes starting with 326 (Plastics and Rubber Manufacturing). This dataset consisted of 237 measurements. EPA used the maximum expected concentration of DINP in PVC plastic products to estimate the concentration of DINP in airborne PVC particulates. For this OES, EPA selected 40 percent by mass as the highest expected DINP concentration, based on compiled SDS information for non-PVC plastic materials containing DINP. The estimated DINP concentrations assume that DINP is present in PVC particulate at this fixed concentration throughout the working shift. The Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) uses an 8-hour TWA for particulate concentrations and assumes exposures outside the sample duration are zero. The model does not evaluate exposures during individual worker activities. EPA estimated bounding exposures for ONUs using the worker central tendency of the PNOR model results.

Irwin et al. also collected oil mist samples using NIOSH method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were above each process unit (i.e., not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the DINP concentration in the stationary samples was similar to the DINP concentration in the PBZ samples. Since the PBZ oil mist samples were below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. EPA used the LOD reported in the study to estimate high-end exposures. EPA used half of the LOD to estimate central tendency exposures.

EPA converted the 10-hour vapor exposures (estimated from the oil mist sampling results) and the 8-hour dust exposures (estimated 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)) to an aggregated 24 hour acute dose to assess DINP exposures to both vapor and dust for the full work shift. Specifically, EPA added the 24-hour acute dose from the vapor monitoring data to the 24-hour acute dose from the PNOR model to calculate aggregate DINP exposures. Table 3-41 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during non-PVC material 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.

Table 3-41. Summary of Estimated Worker Inhalation Exposures for Non-PVC Material Compounding

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	9.2E−02	1.9
	Acute (AD, mg/kg-day)	1.2E−02	0.24
	Intermediate (IADD, mg/kg-day)	8.5E−03	0.17
	Chronic, Non-cancer (ADD, mg/kg-day)	7.4E−03	0.16
Female of Reproductive Age	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	9.2E−02	1.9
	Acute (AD, mg/kg-day)	1.3E−02	0.26
	Intermediate (IADD, mg/kg-day)	9.3E−03	0.19
	Chronic, Non-cancer (ADD, mg/kg-day)	8.2E−03	0.18
ONU	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	9.2E−02	9.2E−02
	Acute (AD, mg/kg-day)	1.2E−02	1.2E−02
	Intermediate (IADD, mg/kg-day)	8.5E−03	8.5E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.4E−03	7.9E−03

3.8.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-42 are explained in Appendix B. Because dermal exposures of DINP to workers may occur in the neat form during non-PVC material compounding, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-42 summarizes the summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-42. Summary of Estimated Worker Dermal Exposures for Non-PVC Material Compounding

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.0E−02	0.11
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.6E−02	9.8E−02
ONU	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	2.0E−04	2.1E−04

3.8.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-43. Summary of Estimated Worker Aggregate Exposures for Non-PVC Material Compounding

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	9.0E−02	0.39
	Intermediate (IADD, mg/kg-day)	6.6E−02	0.29
	Chronic, Non-cancer (ADD, mg/kg-day)	5.7E−02	0.27
Female of Reproductive Age	Acute (AD, mg/kg-day)	8.4E−02	0.40
	Intermediate (IADD, mg/kg-day)	6.2E−02	0.30
	Chronic, Non-cancer (ADD, mg/kg-day)	5.4E−02	0.28
ONU	Acute (AD, mg/kg-day)	1.2E−02	1.2E−02
	Intermediate (IADD, mg/kg-day)	8.7E−03	8.7E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.6E−03	8.1E−03

3.9 Non-PVC Material Converting

3.9.1 Process Description

EPA identified several relevant SDSs and CDR reports for rubber product manufacturing and petroleum refineries that indicate DINP use in non-PVC polymers, such as polyurethane resin, rubber erasers, and synthetic rubber (see Appendix F for EPA identified DINP-containing products for this OES)(ACC, 2020; U.S. EPA, 2020a). DINP is used as a plasticizer in rubber products (ACC, 2020).

EPA expects that non-PVC material converting sites have similar operations to PVC plastic converting sites. A typical converting site receives and unloads DINP in solid form, as a masterbatch from compounding sites. The converting site then transfers the masterbatch to a shaping unit operation, such as an extruder, injection molding unit, or blow molding unit, to achieve the final product shape. The converting site may trim excess material from the final product after it cools. Figure 3-10 provides an illustration of the non-PVC material converting process (U.S. EPA, 2021e).

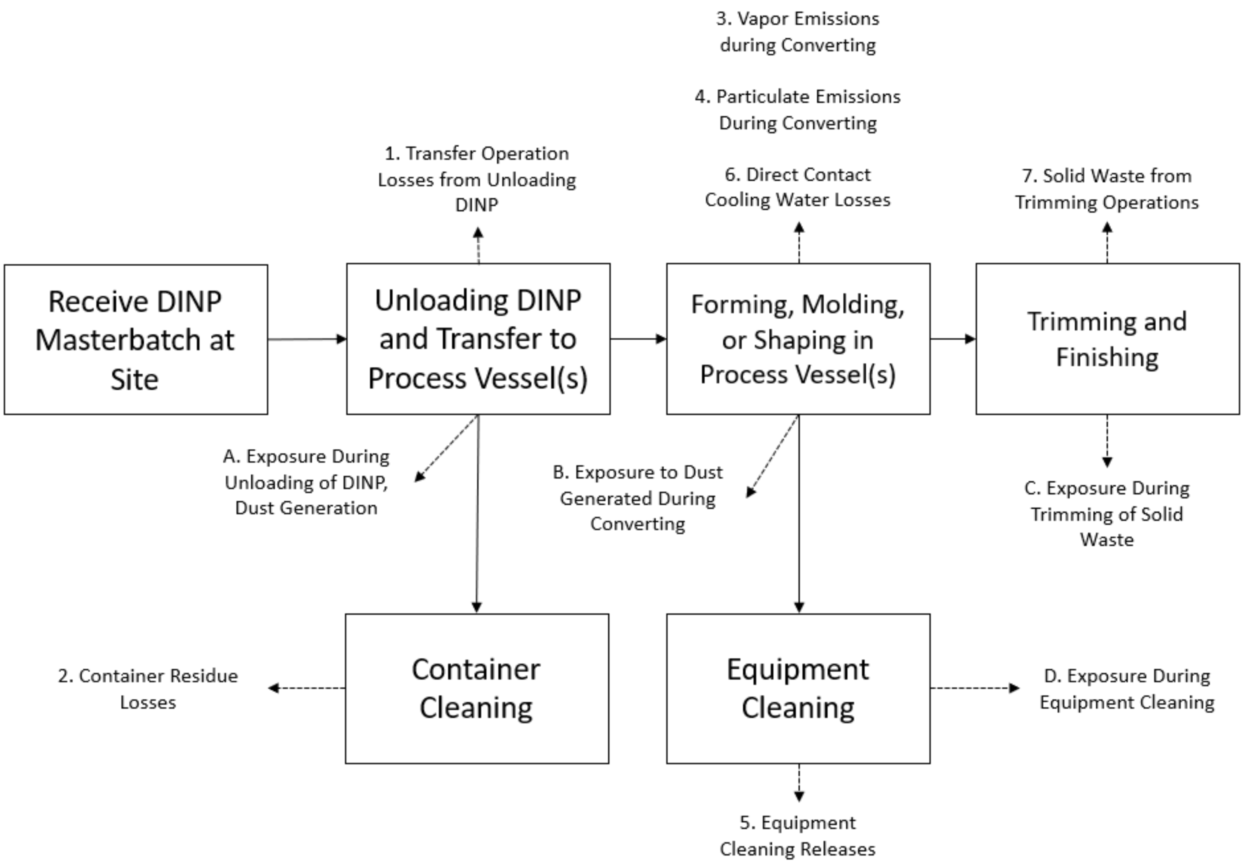

Figure 3-10. Non-PVC Material Converting Flow Diagram

3.9.2 Facility Estimates

Since converting occurs immediately downstream of compounding, EPA expects the production volume for non-PVC material converting to be identical to the production volume for the non-PVC material compounding OES. The production volume of DINP for use in non-PVC material converting under both CASRN is 1,769,010 to 12,972,742 kg/year (see Section 3.8.2 for details).

EPA did not identify site- or chemical-specific plastic converting operating data (*i.e.*, facility production rate, number of batches, or operating days). EPA based the DINP facility use rate on the 2021 Revised Generic Scenario on Plastic Converting product throughput of plastic additives, the mass fraction of DINP in non-PVC products of 1 to 40 percent, and the mass fraction of all additives in plastic resin. The estimated annual facility DINP throughput is 68,542 to 190,822 kg/site-year. The GS estimated the total number of operating days as 137 to 254 days/year, with 24 hours/day, 7 days/week (*i.e.*, multiple shifts) operations for the given site throughput scenario. The number of batches per site year was equivalent to the number of operating days, or one batch per day (U.S. EPA, 2021e). EPA estimated the total number of sites that participate in non-PVC material converting using a Monte Carlo model (see Appendix E.7 for details). The modeled 50th to 95th percentile range of the number of sites was 122 to 190. This is in contrast to 2020 CDR reports, in which two sites reported the number of industrial use sites to be less than 10. The remaining three sites reported the number of industrial sites as NKRA.

3.9.3 Release Assessment

3.9.3.1 Environmental Release Points

EPA assigned release points based on the 2021 Revised Draft GS on the Use of Additives in the Thermoplastics Converting Industry (U.S. EPA, 2021e). EPA assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects fugitive or stack air releases and particulate emissions to fugitive air, wastewater, incineration, or landfill from converting operations. 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. Sites may utilize air capture and control technology. If a site uses air capture technology, EPA expects dust releases from plastic unloading to be controlled and released to disposal facilities for incineration or landfill. EPA expects the remaining uncontrolled dust to be released to stack air. If the site does not use air control technology, EPA expects releases to fugitive air, wastewater, incineration, or landfill, as described above.

3.9.3.2 Environmental Release Assessment Results

Table 3-44. Summary of Modeled Environmental Releases for Non-PVC Material Converting

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
3,900,000–28,600,000 lb production volume	Fugitive or Stack Air	2.96E02	1.19E03	219	251	1.39	5.72
	Fugitive Air, Wastewater, Incineration, or Landfill	2.93E01	1.09E02			1.37E−01	5.22E−01
	Wastewater, Incineration, or Landfill	1.96E03	3.51E03			9.65	1.76E01
	Wastewater	5.93E02	1.08E03			2.77	5.32
	Incineration or Landfill	1.98E03	3.93E03			9.23	1.93E01

3.9.4 Occupational Exposure Assessment

3.9.4.1 Worker Activities

Worker exposures to DINP dust may occur via inhalation during the converting process. Dermal exposures may occur during equipment cleaning. Additionally, worker exposures may occur via dermal contact with liquids and inhalation of vapors during DINP unloading and loading, transport container cleaning, and trimming of excess plastic (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 may work in the formulation area but do not directly contact DINP that is received or processed onsite or handle the finished converted product. ONUs are potentially exposed through the inhalation route while in the working area. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.9.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during the converting of non-PVC material. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details regarding the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 326200, 424610, and 424690 for this OES based on the Generic Scenario on the Use of Additives in the Thermoplastic Converting Industry and CDR reported NAICS codes for non-PVC material converting (U.S. EPA, 2020a, 2014d). Table 3-45 summarizes the per site estimates for this OES. As addressed in Section 3.9.2, EPA did not identify site-specific data for the number of facilities in the United States that convert non-PVC material.

Table 3-45. Estimated Number of Workers Potentially Exposed to DINP During Non-PVC Material Converting

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
326200 – Rubber Product Manufacturing	N/A	42	N/A	7	N/A
424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers		1		0.39	
424690 – Other Chemical and Allied Products Merchant Wholesalers		1		0.45	
Total/Average	122–190	15	1,793–2,793	3	307–477

[a] The result is expressed as a range between the central tendency and the high-end value. Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.9.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the non-PVC material compounding OES during systematic review. However, EPA estimated inhalation exposures for this OES using monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site 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).

Irwin et al. collected total respirable dust PBZ samples using personal sampling pumps with cyclones, during five separate worker activities at a manufacturing site that both compounds and converts PVC plastic. Irwin et al. used these samples to calculate five, 10-hour TWAs for airborne particulate and an adjusted 10-hour TWA based on the expected concentration of DINP in the process. Since these samples were not direct measurements of DINP, EPA assessed occupational 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). This model relies on a more robust dataset of dust measurements from relevant processes at different industrial facilities. To estimate PVC particulate concentrations in the air, EPA used a subset of the model's dust data for facilities with NAICS codes starting with 326 (Plastics and Rubber Manufacturing). This dataset consisted of 237 measurements. EPA used the maximum expected concentration of DINP in PVC plastic products to estimate the concentration of DINP in airborne PVC particulates. For this OES, the Agency selected 40 percent by mass as the highest expected DINP concentration, based on compiled SDS information for non-PVC plastic materials containing DINP. The estimated DINP concentrations assume that DINP is present in PVC particulate at this fixed concentration throughout the working shift. The Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) uses an 8-hour TWA for particulate concentrations and assumes exposures outside the sample duration are zero. The model does not evaluate exposures during individual worker activities. EPA estimated bounding exposures for ONUs using the worker central tendency of the PNOR model results.

Irwin et al. also collected oil mist samples using NIOSH method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were above each process unit (*i.e.*, not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the DINP concentration in the stationary samples was similar to the DINP concentration in the PBZ samples. Since the PBZ oil mist samples were below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. EPA used the LOD reported in the study to estimate high-end exposures. EPA used half of the LOD to estimate central tendency exposures.

EPA converted the 10-hour vapor exposures (estimated from the oil mist sampling results) and the 8-hour dust exposures (estimated 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)) to an aggregated 24-hour acute dose to assess DINP exposures to both vapor and dust for the full work shift. Specifically, EPA added the 24-hour acute dose from the vapor monitoring data to the 24-hour acute dose from the PNOR model to calculate aggregate DINP exposures. Table 3-46 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during non-PVC material 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 3-46. Summary of Estimated Worker Inhalation Exposures for Non-PVC Material Converting

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	9.2E−02	1.9
	Acute (AD, mg/kg-day)	1.2E−02	0.24
	Intermediate (IADD, mg/kg-day)	8.5E−03	0.17
	Chronic, Non-cancer (ADD, mg/kg-day)	6.9E−03	0.16
Female of Reproductive Age	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	9.2E−02	1.9
	Acute (AD, mg/kg-day)	1.3E−02	0.26

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
	Intermediate (IADD, mg/kg-day)	9.3E−03	0.19
	Chronic, Non-cancer (ADD, mg/kg-day)	7.6E−03	0.18
ONU	10-hour TWA Exposure Concentration – Vapor (mg/m^3)	2.5E−04	5.0E−04
	8-hour TWA Exposure Concentration – Dust (mg/m^3)	9.2E−02	9.2E−02
	Acute (AD, mg/kg-day)	1.2E−02	1.2E−02
	Intermediate (IADD, mg/kg-day)	8.5E−03	8.5E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	6.9E−03	7.9E−03

3.9.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-47 are explained in Appendix B. Because dermal exposures of DINP to workers is expected to occur through contact with solids or articles for this OES, The Agency assessed the absorptive flux of DINP according to dermal absorption modeling approach for solids outlined in Appendix D.2.1.2. Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-47 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-47. Summary of Estimated Worker Dermal Exposures for Non-PVC Material Converting

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5E−02	4.9E−02
	Acute (AD, mg/kg-day)	3.1E−04	6.2E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	4.5E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.8E−04	4.2E−04
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.0E−02	4.1E−02
	Acute (AD, mg/kg-day)	2.8E−04	5.7E−04
	Intermediate (IADD, mg/kg-day)	2.1E−04	4.1E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.7E−04	3.9E−04
ONU	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.8E−04	2.1E−04

3.9.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-48. Summary of Estimated Worker Aggregate Exposures for Non-PVC Material Converting

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.2E−02	0.24
	Intermediate (IADD, mg/kg-day)	8.7E−03	0.17
	Chronic, Non-cancer (ADD, mg/kg-day)	7.1E−03	0.16
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.3E−02	0.26
	Intermediate (IADD, mg/kg-day)	9.6E−03	0.19
	Chronic, Non-cancer (ADD, mg/kg-day)	7.8E−03	0.18
ONU	Acute (AD, mg/kg-day)	1.2E−02	1.2E−02
	Intermediate (IADD, mg/kg-day)	8.7E−03	8.7E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.1E−03	8.1E−03

3.10 Application of Adhesives and Sealants

3.10.1 Process Description

DINP is a plasticizer in adhesive and sealant products for industrial and commercial use, including duct sealants and industrial adhesives for automotive care products (see Appendix F for EPA identified DINP-containing products for this OES) (ACC, 2020; U.S. EPA, 2020a). Workers apply adhesives and sealants that contain DINP incorporated as a plasticizer. Adhesives and sealants (which could also be fillers and putties) are highly malleable materials used to repair, smooth over or fill minor cracks in holds and buildings. EPA identified several adhesive and sealant product SDSs indicating that adhesive and sealant products containing DINP may arrive at end use sites in containers ranging in size from 1 to 5 gallons, at concentrations of 0.1 to 40 percent DINP. The application site transfers the adhesive/sealant from the shipping container to the application equipment, such as a caulk gun or syringe, and applies the sealant to the substrate (OECD, 2015a). The majority of the 29 DINP-containing commercial adhesive and sealant products identified by EPA are applied via syringe or bead, with two applied via brush or trowel and one applied via roller. There were two DINP-containing adhesive and sealant products identified for industrial use, and these two industrial products contain DINP concentrations that are comparable to the commercial adhesive and sealant products identified. The two DINP-containing industrial adhesive and sealant products are used in Insulated Glass unit manufacturing, where the adhesive and sealant products are precision applied rather than spray applied. However, the product search is not exhaustive, and per the OECD guidelines, application methods include bead, roll, dip, and syringe application. Application may occur over the course of an 8-hour workday for 1 or 2 days at a given site, accounting for drying or curing times and application of additional coats, if necessary. The site may trim excess adhesive/sealant from the applied substrate area. Figure 3-11 provides an illustration of the process of applying adhesives and sealants (OECD, 2015a).

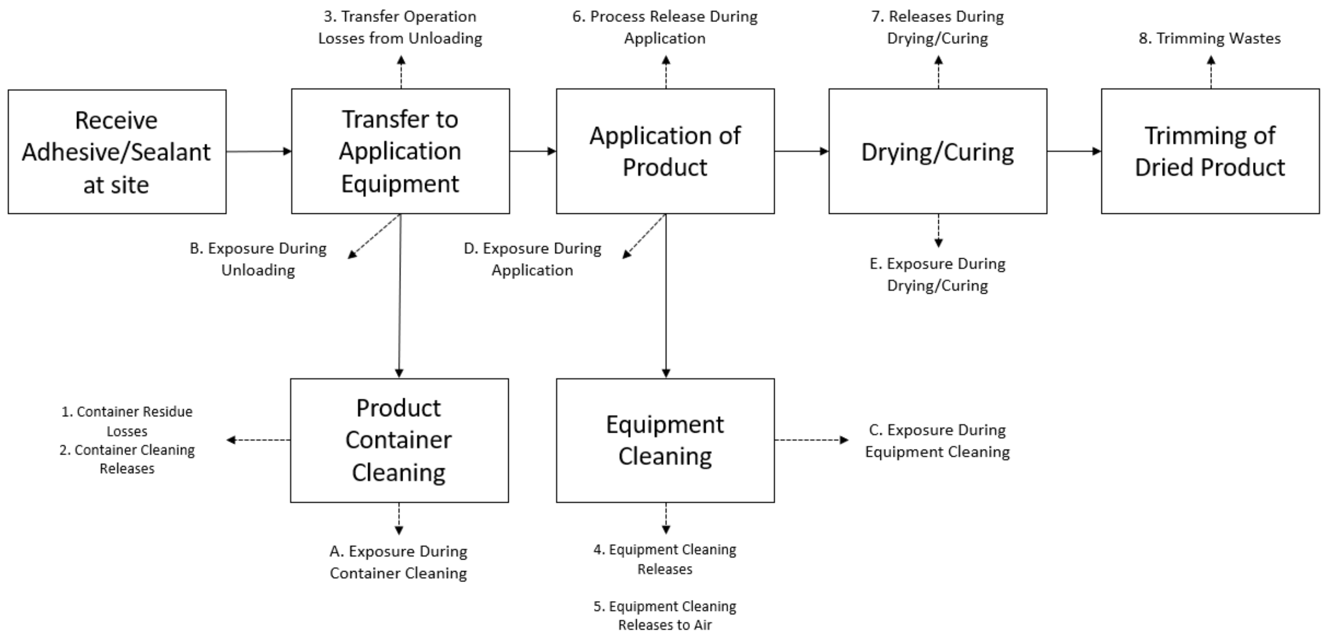

Figure 3-11. Application of Adhesives and Sealants Flow Diagram

3.10.2 Facility Estimates

Since the application of adhesives and sealants occurs immediately downstream of incorporation into adhesive and sealants, EPA expects the same production volume for the two OES. The production volume for adhesives and sealants under both CASRN is 589,670 to 4,340,879 kg/year (see Section 3.3.2 for details).

EPA did not identify site- or chemical-specific adhesive and sealant application operating data (*i.e.*, facility use rates, operating days). However, the 2015 Emission Scenario Document on the Use of Adhesives estimated an adhesive use rate of 2,300 to 141,498 kg/site-year. Based on a DINP concentration range in the product of 0.1 to 40 percent, EPA estimated a DINP use rate of 2.3 to 56,599 kg/site-year. Additionally, the ESD estimated the number of operating days as 50 to 365 days/year of 8 hours/day operations for the given throughput scenario (OECD, 2015a). EPA did not identify estimates on the number of sites that may apply adhesive and sealant products that contain DINP. Therefore, EPA estimated the total number of application sites that use DINP-containing adhesives and sealants using a Monte Carlo model (see Appendix E.9 for details). The modeled 50th to 95th percentile range of the number of sites was 345 to 2,383.

3.10.3 Release Assessment

3.10.3.1 Environmental Release Points

EPA assigned release points based on the 2015 Emission Scenario Document on the Use of Adhesives (OECD, 2015a). The Agency assigned default models to quantify releases from each release point and suspected fugitive air release point. EPA expects fugitive or stack air releases from unloading of adhesives, container cleaning, equipment cleaning, and drying or curing processes. EPA further expects releases to wastewater, incineration, or landfill from small container residue, equipment cleaning waste, adhesive application process waste, and trimming waste.

3.10.3.2 Environmental Release Assessment Results

Table 3-49. Summary of Modeled Environmental Releases Environmental Releases for Application of Adhesives and Sealants

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
1,300,000–9,570,000 lb production volume	Fugitive or Stack Air	1.06E−06	3.16E−06	232	325	4.97E−09	1.30E−08
	Wastewater, Incineration, or Landfill	3.21E02	1.22E03			1.48	6.46

3.10.4 Occupational Exposure Assessment

3.10.4.1 Worker Activities

During the use of adhesives and sealants containing DINP, workers exposures to DINP mist may occur during spray application. Also, worker exposures may also 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 identify information on engineering controls or worker PPE used at DINP-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 through the inhalation route while in the application area. For spray-applied adhesives and sealants, dermal exposures from contact with surfaces where mist has been deposited were assessed for ONUs.

3.10.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during the application of adhesives and sealants. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides additional details regarding the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 322220, 334100, 334200, 334300, 334400, 334500, 334600, 335100, 335200, 335300, 335900, 336100, 336200, 336300, 336400, 336500, 336600, 336900, and 327910 for this OES based on the Emission Scenario Document on the Use of Adhesives and CDR reported NAICS codes for application of adhesives and sealants (U.S. EPA, 2020a; OECD, 2015b). Table 3-50 summarizes the per site estimates for this OES. As discussed in Section 3.10.2, EPA did not identify site-specific data for the number of facilities in the United States that apply adhesives and sealants.

Table 3-50. Estimated Number of Workers Potentially Exposed to DINP During Application of Adhesives and Sealants

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed Occupational Non-users per Site[b]	Total Number of Exposed ONUs[a]
322220 – Paper Bag and Coated and Treated Paper Manufacturing	N/A	35	N/A	5	N/A
334100 – Computer and Peripheral Equipment Manufacturing		19		27	
334200 – Communications Equipment Manufacturing		13		14	
334300 – Audio and Video Equipment Manufacturing		10		7	
334400 – Semiconductor and Other Electronic Component Manufacturing		30		27	
334500 – Navigational, Measuring, Electromedical, and Control Instruments		17		18	
334600 – Manufacturing and Reproducing Magnetic and Optical Media		5		5	
335100 – Electric Lighting Equipment Manufacturing		17		5	
335200 – Household Appliance Manufacturing		102		20	
335300 – Electrical Equipment Manufacturing		28		12	
335900 – Other Electrical Equipment and Component Manufacturing		23		8	
336100 – Motor Vehicle Manufacturing		447		59	
336200 – Motor Vehicle Body and Trailer Manufacturing		40		5	
336300 – Motor Vehicle Parts Manufacturing		51		15	
336400 – Aerospace Product and Parts Manufacturing		75		64	
336500 – Railroad Rolling Stock Manufacturing		35		15	
336600 – Ship and Boat Building		36		11	
336900 – Other Transportation Equipment Manufacturing		16		4	
327910 – Abrasive Product Manufacturing		24		5	
Total/Average	345–2,383	54	18,576–128,306	17	5,885–40,646

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed Occupational Non-users per Site[b]	Total Number of Exposed ONUs[a]
[a] The result is expressed as a range between the central tendency and the high-end value. Results were not assessed by NAICS code for this scenario. [b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.					

3.10.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data specific to DINP for the use of adhesives and sealants during systematic review of literature sources. To account for the variety of potential application methods EPA assessed two application scenarios: spray application and non-spray application. For the spray application scenario, EPA assessed using the Automotive Refinishing Spray Coating Mist Inhalation Model from the Emission Scenario Document on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a) to estimate inhalation exposure to mist. For the non-spray application scenario, EPA assessed worker inhalation exposures from the volatilization of DINP in the adhesives or sealants during application via brush, trowel, or other non-spray method.

EPA assessed exposures from spray application using 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 concentrations along with the concentration of DINP in the adhesives and sealants to estimate the central tendency and high-end inhalation exposures, respectively.

EPA estimated vapor inhalation exposures from non-spray application using monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. EPA expects that vapor inhalation exposures during plastics converting will represent a bounding range of exposures for other processing operations, such as non-spray application of adhesives and sealants, because of the elevated temperature of converting operations and relatively high concentration of DINP present in PVC plastics.

The Irwin et al. (2022) study collected oil mist samples using NIOSH method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three select stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were located above each process unit (i.e., not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the concentrations of DINP in the stationary samples were similar to the concentrations in the PBZ samples. Since the PBZ oil mist samples were all below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. As a result, EPA used the LOD reported in the study to estimate high-end exposures, and EPA used half of the LOD to estimate central tendency exposures.

Table 3-51 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during the use of adhesives and sealants. 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 232 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix B describes the approach for estimating AD, IADD, and ADD.

Table 3-51. Summary of Estimated Worker Inhalation Exposures for Spray and Non-spray Application of Adhesives and Sealants

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Spray Application	8-hour TWA Exposure Concentration (mg/m^3)	1.4	18
	Acute (AD, mg/kg-day)	0.17	2.2
	Intermediate (IADD, mg/kg-day)	0.12	1.6
	Chronic, Non-cancer (ADD, mg/kg-day)	0.11	1.5
Female of Reproductive Age – Spray Application	8-hour TWA Exposure Concentration (mg/m^3)	1.4	18
	Acute (AD, mg/kg-day)	0.19	2.4
	Intermediate (IADD, mg/kg-day)	0.14	1.8
	Chronic, Non-cancer (ADD, mg/kg-day)	0.12	1.7
ONU – Spray Application	8-hour TWA Exposure Concentration (mg/m^3)	1.4	1.4
	Acute (AD, mg/kg-day)	0.17	0.17
	Intermediate (IADD, mg/kg-day)	0.12	0.12
	Chronic, Non-cancer (ADD, mg/kg-day)	0.11	0.12
Average Adult Worker – Non-spray Application	8-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.5E−05	5.4E−05
Female of Reproductive Age – Non-spray Application	8-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	4.3E−05	8.6E−05
	Intermediate (IADD, mg/kg-day)	3.2E−05	6.3E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.9E−05
ONU – Non-spray Application	8-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.5E−05	5.4E−05

3.10.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-52 are explained in Appendix B. Because dermal exposures of DINP to workers may occur in a concentrated liquid form during the application of adhesives or sealants, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). The dermal exposure potential for average adult workers and female workers of reproductive age are estimated similarly across both spray and non-spray application methods. However, EPA only assessed ONU exposures from spray application since mist may be deposited on surfaces for spray application. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with liquids containing DINP were assumed representative of ONU dermal exposure for spray applications.

Table 3-52 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-52. Summary of Estimated Worker Dermal Exposures for Spray and Non-spray Application of Adhesives and Sealants

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Spray Application	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.0E−02	0.11
Female of Reproductive Age – Spray Application	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.6E−02	9.8E−02
ONU – Spray Application	Dose Rate (APDR, mg/day)	6.2	6.2
	Acute (AD, mg/kg-day)	7.8E−02	7.8E−02
	Intermediate (IADD, mg/kg-day)	5.7E−02	5.7E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	5.0E−02	5.3E−02
Average Adult Worker – Non-spray Application	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.0E−02	0.11
Female of Reproductive Age – Non-spray Application	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.6E−02	9.8E−02

3.10.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-53. Summary of Estimated Worker Aggregate Exposures for Spray and Non-spray Application of Adhesives and Sealants

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker – Spray Application	Acute (AD, mg/kg-day)	0.25	2.4
	Intermediate (IADD, mg/kg-day)	0.18	1.7
	Chronic, Non-cancer (ADD, mg/kg-day)	0.16	1.6
Female of Reproductive Age – Spray Application	Acute (AD, mg/kg-day)	0.26	2.6
	Intermediate (IADD, mg/kg-day)	0.19	1.9
	Chronic, Non-cancer (ADD, mg/kg-day)	0.16	1.8
ONU – Spray Application	Acute (AD, mg/kg-day)	0.25	0.25
	Intermediate (IADD, mg/kg-day)	0.18	0.18
	Chronic, Non-cancer (ADD, mg/kg-day)	0.16	0.17
Average Adult Worker – Non-spray Application	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.0E−02	0.11
Female of Reproductive Age – Non-spray Application	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.6E−02	9.8E−02
ONU – Non-spray Application	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.5E−05	5.4E−05

3.11 Application of Paints and Coatings

3.11.1 Process Description

DINP is a plasticizer in paint and coating products for commercial used including paints, pigments, and inks for screen printing (ACC, 2020). EPA assessed container sizes and product concentrations using relevant SDSs and the 2011 Emission Scenario Document on Radiation Curable Coatings, Inks and Adhesives (OECD, 2011b), the 2011 Emission Scenario Document on Coating Application via Spray-Painting in the Automotive Finishing Industry (OECD, 2011a), the 2004 Generic Scenario on Spray Coatings in the Furniture Industry (U.S. EPA, 2004b), and the European Council of the Paint, Printing Ink, and Artist's Colours Industry (CEPE) *SpERC Factsheet for Industrial Application of Coatings and Inks by Spraying* (ESIG, 2020a). EPA assessed the application of inks and pigments as a part of the application of paints and coatings due to the similarities in physical properties of paints, coatings, and screen-printing inks. EPA expects screen printing inks to behave more similarly to paints than to inks found in pens or printing inks (see Appendix F for EPA identified DINP-containing products for this OES).

Paint and coating products containing DINP may arrive at end use sites in containers ranging from spray cans of a few ounces to 5- and 20-gallon pails with DINP concentrations of 0.01 to 20 percent (OECD, 2011a, b; U.S. EPA, 2004b) (see Appendix F for EPA identified DINP-containing products for this OES). Application sites transfer the paint/coating product from the shipping container to the application equipment (if used) and apply the coating to the substrate (U.S. EPA, 2014b; OECD, 2009c; U.S. EPA, 2004c). The majority of the 11 DINP-containing paint and coating products identified by EPA are spray-applied. The remainder are applied via brush, roller, or uncertain application methods. However, the product search is not exhaustive, and the OECD application methods for paints and coatings include spray, curtain, brush, roll, and trowel coating (OECD, 2011b). EPA did not identify information on the prevalence of these various application methods. 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 during spray applications (OECD, 2011a). DINP will remain in the dried/cured coating as an additive following application. Applications may occur over the course of an 8-hour workday for 1 or 2 days at a given site, accounting for multiple coats and typical drying or curing times (ACC, 2020). Figure 3-12 provides an illustration of the spray application of paints and coatings (U.S. EPA, 2014b; OECD, 2011b, 2009c; U.S. EPA, 2004c).

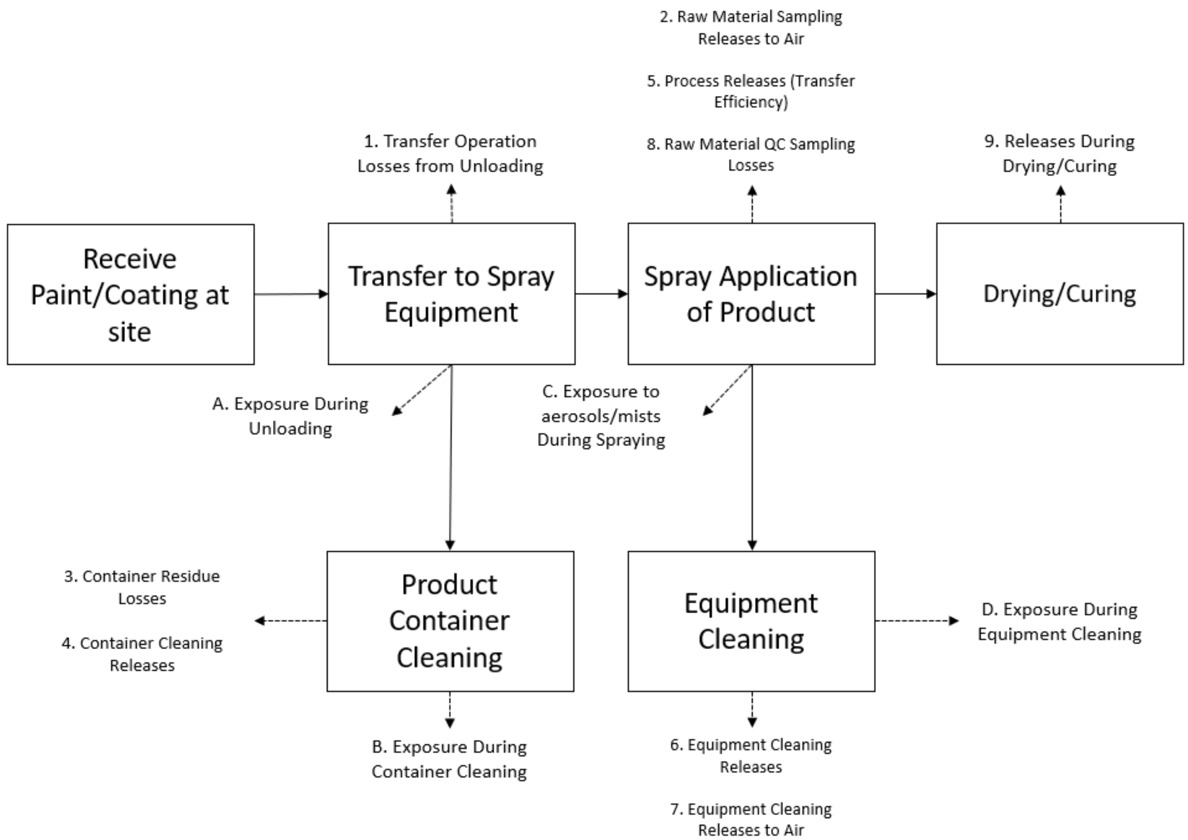

Figure 3-12. Application of Paints and Coatings Flow Diagram

3.11.2 Facility Estimates

Since application of paints and coatings occurs immediately downstream of incorporation into paints and coatings, EPA expects these OES to have the same production volume. The production volume for paint and coating use under both CASRN was 589,670 to 4,340,879 kg/year (see Section 3.4.2 for details).

EPA did not identify site- or chemical-specific paint and coating operating data (*e.g.*, facility use rates, operating days). EPA based the facility use rate on the 2011 Emission Scenario Document on Radiation Curable Coatings, Inks and Adhesives (OECD, 2011b), the 2011 Emission Scenario Document on Coating Application via Spray-Painting in the Automotive Finishing Industry (OECD, 2011a), the 2004 Generic Scenario on Spray Coatings in the Furniture Industry (U.S. EPA, 2004b), and the European Council of the Paint, Printing Ink, and Artist's Colours Industry (CEPE) *SpERC Factsheet for Industrial Application of Coatings and Inks by Spraying* (ESIG, 2020a).The ESDs, GSs, and SpERC provided coating use rates of 2,694 to 446,600 kg/site-year. Based on a DINP concentration in the paints and coatings of 0.01 to 20 percent, EPA estimated a DINP use rate of 2.7 to 89,320 kg/site-year. Additionally, the ESDs, GSs, and SpERC estimated the number of operating days as 225 to 300 days/year with 8 hour/day operations. EPA did not identify estimates of the number of sites that may apply paint and coating products that contain DINP. Therefore, EPA estimated the total number of application sites that use DINP-containing paints and coatings using a Monte Carlo model (see Appendix E.10 for details). The modeled 50th to 95th percentile range of the number of sites was 145 to 795.

3.11.3 Release Assessment

3.11.3.1 Environmental Release Points

EPA assigned release points based on the 2011 Emission Scenario Document on Radiation Curable Coatings, Inks and Adhesives (OECD, 2011b). EPA assigned default models to quantify releases from each release point and suspected fugitive air release point. The Agency expects fugitive air releases from unloading, sampling, container cleaning, and equipment cleaning. EPA also expects wastewater, incineration, or landfill releases from container residue losses, equipment cleaning, and sampling. 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. Furthermore, EPA expects the site to release the remaining 90 percent of its operational losses to wastewater, landfill, or incineration. If the site does not use control technology, the Agency expects the site to release all process related operational losses to fugitive air, wastewater, incineration, or landfill in unknown percentages.

3.11.3.2 Environmental Release Assessment Results

Table 3-54. Summary of Modeled Environmental Releases for Application of Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
1,300,000–9,570,000 lb production volume Control Technology	Fugitive Air	2.72E−06	7.01E−06	257	287	1.06E−08	2.71E−08
	Stack Air	6.82E02	2.12E03			2.64	8.25
	Wastewater, Incineration, or Landfill	6.59E03	2.01E04			2.55E01	7.84E01
1,300,000–9,570,000 lb production volume No Control Technology	Fugitive Air	2.72E−06	7.01E−06	257	287	1.06E−08	2.71E−08
	Wastewater, Incineration, or Landfill	4.31E02	1.15E03			1.66	4.47
	Unknown	6.84E03	2.11E04			2.65E01	8.22E01

3.11.4 Occupational Exposure Assessment

3.11.4.1 Worker Activities

During the use of DINP-containing paints and coatings, workers are potentially exposed to DINP mist during spray application. Vapor inhalation exposures to DINP for workers and ONUs may also occur from DINP that volatilizes during product unloading, raw material sampling, application, and container and equipment cleaning. Workers may be exposed via dermal contact to liquids containing DINP during product unloading into application equipment, brush and trowel applications, raw material sampling, and container and equipment cleaning (OECD, 2011b). EPA did not find information on the extent to which engineering controls and worker PPE are used at facilities that apply DINP-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 through the inhalation route while in the application area. For spray application, dermal exposures from contact with surfaces where mist has been deposited were assessed for ONUs.

3.11.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during the application of paints and coatings. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides further details regarding the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 332431, 334416, 335931, 337124, 337214, 337127, 337215, 337122, 337211, 337212, 337110, and 811120 for this OES based on the Emission Scenario Documents for the Coating Industry and Automotive Refinishing as well as the Generic Scenario on Spray Coatings in the Furniture Industry (OECD, 2011a, 2009c; U.S. EPA, 2004c). Table 3-55 summarizes the per site estimates for this OES. As described in Section 3.11.2, EPA did not identify site-specific data for the number of facilities in the United States that apply DINP-containing paints and coatings.

Table 3-55. Estimated Number of Workers Potentially Exposed to DINP During Application of Paints and Coatings

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
332431 – Metal Can Manufacturing	N/A	31	N/A	11	N/A
334416 – Capacitor, Resistor, Coil, Transformer, and Other Inductor Manufacturing		22		20	
335931 – Arrestors and Coils, Lighting, Manufacturing		25		9	
337124 – Metal Household Furniture Manufacturing		8		6	
337214 – Office Furniture (except wood) Manufacturing		22		9	
337127 – Institutional Furniture Manufacturing		9		7	
337215 – Showcase, Partition, Shelving, and Locker Manufacturing		8		4	
337122 – Nonupholstered Wood Household Furniture Manufacturing		3		2	
337211 – Wood Office Furniture Manufacturing		9		4	
337212 – Custom Architectural Woodwork and Millwork Manufacturing		5		2	
337110 – Wood Kitchen Cabinet and Countertop Manufacturing		3		2	
811120 – Automotive Body, Paint, Interior, and Glass Repair		3		0.31	
Total/Average	145–795	12	1,790–9,817	6	915–5,016

[a] The result is expressed as a range between the central tendency and the high-end value. Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.11.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data specific to DINP for the use of paints and coatings during systematic review of literature sources. To account for the variety in application methods, EPA assessed two application scenarios: spray application and non-spray application. For the spray application scenario, EPA assessed using the Automotive Refinishing Spray Coating Mist Inhalation Model from the Emission Scenario Document on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a) to estimate inhalation exposure to overspray mist. For the non-spray application scenario, EPA assessed worker inhalation exposure from volatilization of DINP in the paint or coating during application via brush or other non-spray methods.

EPA assessed exposures from spray application using 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 concentrations along with the concentration of DINP in the paint to estimate the central tendency and high-end inhalation exposures, respectively.

EPA estimated vapor inhalation exposures from non-spray application using monitoring data for DINP during PVC plastics compounding and converting from a study conducted by Irwin et al. (2022) at a PVC roofing manufacturing site. EPA expects that vapor inhalation exposures during plastics converting will represent a bounding range of exposures for other processing operations, such as non-spray application of paints and coatings, because of the elevated temperature of converting operations and relatively high concentration of DINP present in PVC plastics.

The Irwin et al. (2022) study collected oil mist samples using NIOSH method 5026 to estimate the concentration of DINP in the air at breathing zone level and at three select stationary points near the process line. The three 10-hour TWA PBZ airborne oil mist samples—two workers and one ONU—were below the LOD, whereas the three stationary samples ranged from the LOD to an order of magnitude higher than the LOD (0.0052 mg/m^3). The stationary samples were located above each process unit (*i.e.*, not in the personal breathing zone) and are therefore not representative of worker exposures. As a result, EPA did not use these samples to assess worker exposures; however, the concentrations of DINP in the stationary samples were similar to the concentrations in the PBZ samples. Since the PBZ oil mist samples were all below the LOD, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. As a result, EPA used the LOD reported in the study to estimate high-end exposures, and EPA used half of the LOD to estimate central tendency exposures.

Table 3-56 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during the use of paints and coatings. The central tendency and high-end exposures use 250 days per year as the exposure frequency since the 50th and 95th percentiles of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of working days. Appendix B describes the approach for estimating AD, IADD, and ADD.

Table 3-56. Summary of Estimated Worker Inhalation Exposures for Spray and Non-spray Application of Paints and Coatings

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Spray Application	8-hour TWA Exposure Concentration (mg/m^3)	0.68	8.8
	Acute Dose (AD) (mg/kg/day)	8.4E−02	1.1
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	6.2E−02	0.81
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	5.8E−02	0.76
Female of Reproductive Age – Spray Application	8-hour TWA Exposure Concentration (mg/m^3)	0.68	8.8
	Acute Dose (AD) (mg/kg/day)	9.3E−02	1.2
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	6.8E−02	0.90
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	6.4E−02	0.84
ONU – Spray Application	8-hour TWA Exposure Concentration (mg/m^3)	0.68	0.68
	Acute Dose (AD) (mg/kg/day)	8.4E−02	8.4E−02
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	6.2E−02	6.2E−02
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	5.8E−02	5.8E−02
Average Adult Worker – Non-spray Application	8-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute Dose (AD) (mg/kg/day)	3.9E−05	7.8E−05
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	2.9E−05	5.7E−05
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	2.7E−05	5.4E−05
Female of Reproductive Age – Non-spray Application	8-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute Dose (AD) (mg/kg/day)	4.3E−05	8.6E−05
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	3.2E−05	6.3E−05
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	3.0E−05	5.9E−05
ONU – Non-spray Application	8-hour TWA Exposure Concentration (mg/m^3)	2.5E−04	5.0E−04
	Acute Dose (AD) (mg/kg/day)	3.9E−05	7.8E−05
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	2.9E−05	5.7E−05
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	2.7E−05	5.4E−05

3.11.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-57 are explained in Appendix B. Because dermal exposures of DINP to workers may occur in a concentrated liquid form during the application of paints or coatings, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). The dermal exposure potential for average adult workers and female workers of reproductive age are estimated similarly across both spray and non-spray application methods. However, EPA only assessed ONU exposures from spray application since mist may be deposited on surfaces during spray application. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with liquids containing DINP were assumed representative of ONU dermal exposure for spray application.

Table 3-57 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-57. Summary of Estimated Worker Dermal Exposures for Application of Paints and Coatings

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Spray Application	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age – Spray Application	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02
ONU – Spray Application	Dose Rate (APDR, mg/day)	6.2	6.2
	Acute (AD, mg/kg-day)	7.8E−02	7.8E−02
	Intermediate (IADD, mg/kg-day)	5.7E−02	5.7E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	5.3E−02
Average Adult Worker – Non-spray Application	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age – Non-spray Application	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02

3.11.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-58 Summary of Estimated Worker Aggregate Exposures for Spray and Non-spray Application of Paints and Coatings

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker – Spray Application	Acute (AD, mg/kg-day)	0.16	1.3
	Intermediate (IADD, mg/kg-day)	0.12	0.92
	Chronic, Non-cancer (ADD, mg/kg-day)	0.11	0.86
Female of Reproductive Age – Spray Application	Acute (AD, mg/kg-day)	0.16	1.4
	Intermediate (IADD, mg/kg-day)	0.12	1.0
	Chronic, Non-cancer (ADD, mg/kg-day)	0.11	0.93
ONU – Spray Application	Acute (AD, mg/kg-day)	0.16	0.16
	Intermediate (IADD, mg/kg-day)	0.12	0.12
	Chronic, Non-cancer (ADD, mg/kg-day)	0.11	0.11
Average Adult Worker – Non-spray Application	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age – Non-spray Application	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	9.8E−02
ONU – Non-spray Application	Acute (AD, mg/kg-day)	3.9E−05	7.8E−05
	Intermediate (IADD, mg/kg-day)	2.9E−05	5.7E−05
	Chronic, Non-cancer (ADD, mg/kg-day)	2.7E−05	5.4E−05

3.12 Use of Laboratory Chemicals

3.12.1 Process Description

DINP is a laboratory chemical used at commercial laboratory sites (ACC, 2020). EPA identified relevant SDS that indicate laboratory chemicals containing DINP arrive at end use sites in containers ranging in size from 0.5 to 1 gallon or 0.5 to 1 kg, depending on the chemical form (see Appendix F for EPA identified DINP-containing products for this OES). The end use site transfers the chemical to labware and/or other laboratory equipment for analyses. After analysis, laboratory sites clean containers, labware, and laboratory equipment and dispose of laboratory waste and unreacted DINP-containing laboratory chemicals. Figure 3-13 provides an illustration of the use of laboratory chemicals (U.S. EPA, 2023c).

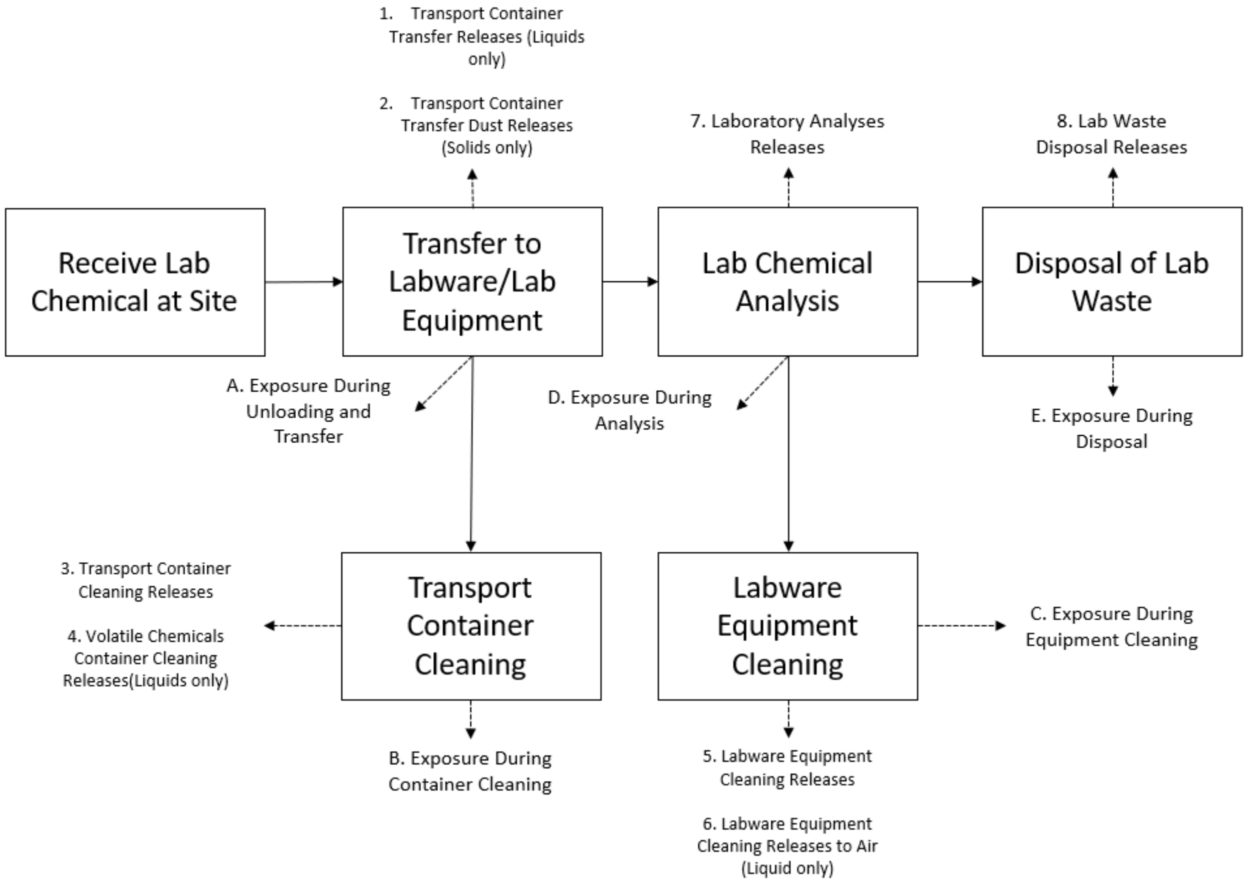

Figure 3-13. Use of Laboratory Chemicals Flow Diagram

3.12.1 Facility Estimates

No sites reported the use of DINP-containing laboratory chemicals in the 2020 CDR (U.S. EPA, 2020a) and it was not referenced as a use in the 2003 *DINP Risk Assessment* published by the European Union (ECJRC, 2003b). Based on estimates from the 2023 GS on the Use of Laboratory Chemicals (U.S. EPA, 2023c), EPA anticipated that the minimum PV described in the *EU Risk Assessment*, 0.87 percent, was too large for this OES. Instead, EPA estimated the total production volume of DINP in laboratory chemicals using the CDR reporting threshold limits of either 25,000 pounds (11,340 kg) or 5 percent of a site's reported production volume, whichever value was smaller. EPA considered every site that reported using DINP to CDR, regardless of assigned OES. EPA assumed that sites that claimed their production volume as CBI used 25,000 pounds of DINP-containing laboratory chemicals annually. Table 3-59 lists the sites and associated production volumes that EPA considered in calculating the total production volume for this OES (U.S. EPA, 2020a). The total production volume for this OES was 263,843 kg/year.

Table 3-59. CDR Reported Site Information for Use in Calculation of Laboratory Chemicals Production Volume

CASRN	Site Name	Site Location	Reported Production Volume (kg/year)	Threshold Limit Used	Production Volume Added to Total[a] (kg/year)
28553-12-0	Alac International Inc.	New York, NY	11,349,540	11,340 kg	11,340
28553-12-0	BASF Imports	Florham Park, NJ	CBI	11,340 kg	11,340
28553-12-0	Belt Concepts of America Inc.	Spring Hope, NC	299,752	11,340 kg	11,340
28553-12-0	Bostik Inc.	Wauwatosa, WI	CBI	11,340 kg	11,340
68515-48-0	Cascade Columbia Distribution	Sherwood, OR	674,115	11,340 kg	11,340
68515-48-0	CBI	CBI	CBI	11,340 kg	11,340
28553-12-0	CBI	CBI	97,514	5%	4,876
28553-12-0	CBI	CBI	CBI	11,340 kg	11,340
28553-12-0	Chemspec Ltd.	Uniontown, OH	50,431	5%	2,522
28553-12-0	Evonik Corp.	Parsippany, NJ	CBI	11,340 kg	11,340
68515-48-0	ExxonMobil	Baton Rouge, LA	CBI	11,340 kg	11,340
68515-48-0	ExxonMobil	Spring, TX	CBI	11,340 kg	11,340
28553-12-0	Formosa Global Solutions	Livingston, NJ	17,100	5%	855
28553-12-0	Gehring Montgomery	Warminster, PA	40,191	5%	2,010
28553-12-0	Geon Performance Solutions	Louisville, KY	380,745	11,340	11,340
28553-12-0	Greenchem	West Palm Beach, FL	CBI	11,340	11,340
28553-12-0	Harwick Standard Distribution Corp.	Akron, OH	59,923	5%	2,996
28553-12-0	Henkel	Louisville, KY	11,189	5%	559
28553-12-0	ICC Chemical Corp.	New York, NY	CBI	11,340 kg	11,340
28553-12-0	Mercedes-Benz	Vance, AL	140,614	5%	7,031
28553-12-0	Showa Denko Materials	San Jose, CA	CBI	11,340 kg	11,340
28553-12-0	Silver Fern Chemical	Seattle, WA	97,184	5%	4,859
28553-12-0	Superior Oil Company Inc.	Indianapolis, IN	CBI	11,340 kg	11,340
68515-48-0	Teknor Apex	Brownsville, TN	CBI	11,340 kg	11,340
28553-12-0	The Chemical Company	Jamestown, RI	CBI	11,340 kg	11,340
28553-12-0	The DOW Chemical Co.	Midland, MI	CBI	11,340 kg	11,340

CASRN	Site Name	Site Location	Reported Production Volume (kg/year)	Threshold Limit Used	Production Volume Added to Total[a] (kg/year)
28553-12-0	Tribute Energy Inc.	Houston, TX	380,000	11,340 kg	11,340
28553-12-0	Univar Solutions Inc.	Redmond, WA	239,157	11,340 kg	11,340
68515-48-0	Westlake Compounds LLC.	Houston, TX	CBI	11,340 kg	11,340
[a] Values reported are rounded to the nearest whole number value, the sum of the column exceeds the reported production volume by 5 kg due to rounding effects.					

EPA did not identify site- or chemical-specific operating data for laboratory use of DINP (*i.e.*, facility throughput, operating days, number of sites). For solid products, the 2023 Generic Scenario on The Use of Laboratory Chemicals provides an estimated throughput of 0.92 kg/site-day for solid laboratory chemicals (U.S. EPA, 2023c). Based on the mass fraction of DINP in the laboratory chemical of 0.03 kg/kg, EPA estimated a daily facility DINP use rate of 0.03 kg/site-day. For liquid products, the 2023 Generic Scenario on the Use of Laboratory Chemicals provided an estimated throughput of 0.042 to 4 L/site-day for liquid laboratory chemicals. Based on the concentration of DINP in liquid laboratory chemicals of 99.5 percent or 0.1 percent, and the DINP density of 0.9758 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 1.96 to 3.69 kg/site-day. Additionally, the GS estimated the number of operating days as 174 to 260 days/year, with 8 hour/day operations (U.S. EPA, 2023c). EPA did not identify estimates of the number of sites that use laboratory chemicals containing DINP. Therefore, EPA estimated the total number of sites that use DINP-containing laboratory chemicals using a Monte Carlo model (see Appendix E.11 for details). The 50th to 95th percentile range of the number of sites was 586 to 4,912 for the high-concentration liquid use case. The maximum bounding estimate of 36,873 sites for the low-concentration liquid use case. Based on the use rate, modeling results for number of sites exceeded the maximum in the GS. Therefore, EPA assessed the maximum number of sites of 36,873 as a bounding estimate. (U.S. EPA, 2023c).

3.12.2 Release Assessment

3.12.2.1 Environmental Release Points

EPA assigned release points based on the 2023 Generic Scenario on the Use of Laboratory Chemicals (U.S. EPA, 2023c). 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 the release estimate EPA assumed each site used either the liquid or the solid form of the DINP-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 laboratory analysis. In the solid laboratory chemical use case, EPA expects sites to release dust from unloading to stack air, incineration, or landfill. In both use cases, EPA expects wastewater, incineration, or landfill releases from container cleaning wastes, labware equipment cleaning wastes, and laboratory wastes.

3.12.2.2 Environmental Release Assessment Results

Table 3-60. Summary of Modeled Environmental Releases for Use of Laboratory Chemicals

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
581,675 lb production volume Liquid, High Concentration Laboratory Chemicals	Fugitive or Stack Air	4.55E−07	7.91E−07	235	258	1.98E−09	3.35E−09
	Wastewater, Incineration, or Landfill	4.48E02	8.72E02			1.96	3.68
581,675 lb production volume Solid Laboratory Chemicals	Stack Air	4.04E−02	1.13E−01	260		1.55E−04	4.34E−04
	Wastewater, Incineration, or Landfill	7.11	7.14			2.74E−02	2.75E−02
581,675 lb production volume Liquid, Low Concentration Laboratory Chemicals	Fugitive or Stack Air	6.20E−10	9.92E−10	260		2.38E−12	3.82E−12
	Wastewater, Incineration, or Landfill	7.13	7.15			2.74E−02	2.75E−02

3.12.3 Occupational Exposure Assessment

3.12.3.1 Worker Activities

Worker exposures to DINP may occur through the inhalation of solid powders while unloading and transferring laboratory chemicals and during laboratory analysis. Inhalation exposures to DINP vapor and dermal exposure to liquid and solid chemicals 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, 2023c). EPA did not find information on the extent to which laboratories that use DINP-containing chemicals also use engineering controls and/or worker PPE.

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

3.12.3.2 Number of Workers and Occupational Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during the use of laboratory chemicals. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides further details regarding the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 541380, 541713, 541714, 541715, and 621511 for this OES based on the Generic Scenario on the Use of

Laboratory Chemicals (U.S. EPA, 2023c). Table 3-61 summarizes the per site estimates for this OES. NAICS codes 541715 and 621511 were all excluded from the table as they lacked worker data. As described in Section 3.12.1, EPA did not identify site-specific data for the number of facilities in the United States that use DINP-containing laboratory chemicals.

Table 3-61. Estimated Number of Workers Potentially Exposed to DINP During Use of Laboratory Chemicals

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
541380 – Testing Laboratories	N/A	1	N/A	9	N/A
541715 – Research and Development in the Physical, Engineering, and Life Sciences (except nanotechnology and biotechnology)	N/A	N/A	N/A	N/A	N/A
Total/Average (Liquid)	586−4,912	1	564-4,724	9	5,070–42,499
Total/Average (Solid)	36,873	1	35,463	9	319,026

[a] The result is expressed as a range between the central tendency and the high-end value. Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.12.3.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the use of laboratory chemicals during systematic review of literature sources. However, EPA estimated inhalation exposures for this OES using monitoring data for DINP vapor exposures during manufacturing (ExxonMobil, 2022b) and dust 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). EPA expects that vapor inhalation exposures during manufacturing to be greater than inhalation exposures during use of laboratory chemicals and serve as a reasonable bounding estimate.

For exposure to liquid laboratory chemicals, EPA used surrogate monitoring data provided in an exposure study conducted by ExxonMobil at their DINP manufacturing site to estimate inhalation exposures for this OES. ExxonMobil collected PBZ samples using an AIHA validated method involving PTFE Teflon filters, extraction with acetonitrile, and HPLC analysis with UV detection. ExxonMobil sampled plasticizer assistant operators, laboratory technicians, and maintenance operators (ExxonMobil, 2022a). EPA used the samples taken during filter change-out from maintenance operators to represent this OES, as this activity was determined to best represent the activities that occur during manufacturing. EPA also used these samples to evaluate laboratory worker exposures. The study included 12 PBZ data points for DINP. All data points were below the LOD. Therefore, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. To estimate high-end exposures to workers, EPA used the LOD reported in the study. To estimate central tendency worker exposures, EPA used half of the LOD.

DINP is also present in solid laboratory chemicals (see Appendix F for DINP-containing product data), so EPA expects worker inhalation exposures to DINP via exposure to particulates of laboratory chemicals. Therefore, EPA estimated worker inhalation exposures during the use of laboratory chemicals 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). Model approaches and parameters are described in Appendix E.14. To estimate particulate concentrations in the air, EPA used a subset of the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) data that came from facilities with NAICS codes starting with 54 (Professional, Scientific, and Technical Services). This dataset consisted of 33 measurements. EPA then used the highest expected concentration of DINP in laboratory chemicals to estimate the concentration of DINP in particulates. For this OES, EPA selected 3 percent by mass as the highest expected DINP concentration based on identified DINP-containing products applicable to this OES. EPA assumed that DINP is present in particulates of solid laboratory chemicals at this fixed concentration throughout the working shift. The Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) uses an 8-hour TWA for particulate concentrations, by assuming exposures outside the sample duration are zero. This model does not determine exposures during individual worker activities. EPA estimated bounding exposures for ONUs using the worker central tendency of the PNOR model results.

Table 3-62 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during the use of laboratory chemicals. The high-end and central tendency exposures to solid laboratory chemicals use 250 days per year as the exposure frequency, since the 50th and 95th percentile of operating days in the release assessment exceeded 250 days per year, which is the expected maximum number of working days. For liquid laboratory chemicals, 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 B describes the approach for estimating AD, IADD, and ADD.

Table 3-62. Summary of Estimated Worker Inhalation Exposures for Use of Laboratory Chemicals

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Liquids	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute (AD, mg/kg-day)	4.3E−03	8.6E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	6.3E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.8E−03	5.9E−03
Female of Reproductive Age – Liquids	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute (AD, mg/kg-day)	4.8E−03	9.5E−03
	Intermediate (IADD, mg/kg-day)	3.5E−03	7.0E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	3.1E−03	6.5E−03
ONU – Liquids	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	3.5E−02
	Acute (AD, mg/kg-day)	4.3E−03	4.3E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	3.2E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.8E−03	3.0E−03
Average Adult Worker – Solids	8-hour TWA Exposure Concentration to Dust (mg/m^3)	5.7E−03	8.1E−02
	Acute (AD, mg/kg-day)	7.1E−04	1.0E−02
	Intermediate (IADD, mg/kg-day)	5.2E−04	7.4E−03

Worker Population	Exposure Concentration Type	Central Tendency	High-End
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−04	6.9E−03
Female of Reproductive Age – Solids	8-hour TWA Exposure Concentration to Dust (mg/m^3)	5.7E−03	8.1E−02
	Acute (AD, mg/kg-day)	7.9E−04	1.1E−02
	Intermediate (IADD, mg/kg-day)	5.8E−04	8.2E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	5.4E−04	7.7E−03
ONU – Solids	8-hour TWA Exposure Concentration to Dust (mg/m^3)	5.7E−03	5.7E−03
	Acute (AD, mg/kg-day)	7.1E−04	7.1E−04
	Intermediate (IADD, mg/kg-day)	5.2E−04	5.2E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−04	4.9E−04

3.12.3.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-63 are explained in Appendix B. Because dermal exposures to workers may occur in the neat liquid form or solid form during the use of DINP in laboratory settings, EPA assessed the absorptive flux of DINP according to both dermal absorption data of neat DINP (Appendix D.2.1.1) and dermal modeling results for solid materials (Appendix D.2.1.2). Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-63 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-63. Summary of Estimated Worker Dermal Exposures for Use of Laboratory Chemicals

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Liquids	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.7E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	5.0E−02	0.11
Female of Reproductive Age – Liquids	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	5.3E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.6E−02	9.8E−02
Average Adult Worker – Solids	Dose Rate (APDR, mg/day)	2.5E−02	4.9E−02
	Acute (AD, mg/kg-day)	3.1E−04	6.2E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	4.5E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	2.1E−04	4.2E−04
Female of Reproductive Age – Solids	Dose Rate (APDR, mg/day)	2.0E−02	4.1E−02
	Acute (AD, mg/kg-day)	2.8E−04	5.7E−04
	Intermediate (IADD, mg/kg-day)	2.1E−04	4.1E−04

Worker Population	Exposure Concentration Type	Central Tendency	High-End
	Chronic, Non-cancer (ADD, mg/kg-day)	1.9E−04	3.9E−04
ONU – Solids	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	2.1E−04	2.1E−04

3.12.3.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-64. Summary of Estimated Worker Aggregate Exposures for Use of Laboratory Chemicals

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker – Liquids	Acute (AD, mg/kg-day)	8.2E−02	0.16
	Intermediate (IADD, mg/kg-day)	6.0E−02	0.12
	Chronic, Non-cancer (ADD, mg/kg-day)	5.3E−02	0.11
Female of Reproductive Age – Liquids	Acute (AD, mg/kg-day)	7.6E−02	0.15
	Intermediate (IADD, mg/kg-day)	5.6E−02	0.11
	Chronic, Non-cancer (ADD, mg/kg-day)	4.9E−02	0.10
ONU – Liquids	Acute (AD, mg/kg-day)	4.3E−03	4.3E−03
	Intermediate (IADD, mg/kg-day)	3.2E−03	3.2E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	2.8E−03	3.0E−03
Average Adult Worker – Solids	Acute (AD, mg/kg-day)	1.0E−03	1.1E−02
	Intermediate (IADD, mg/kg-day)	7.5E−04	7.9E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.0E−04	7.4E−03
Female of Reproductive Age – Solids	Acute (AD, mg/kg-day)	1.1E−03	1.2E−02
	Intermediate (IADD, mg/kg-day)	7.8E−04	8.6E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.3E−04	8.0E−03
ONU – Solids	Acute (AD, mg/kg-day)	1.0E−03	1.0E−03
	Intermediate (IADD, mg/kg-day)	7.5E−04	7.5E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	7.0E−04	7.0E−04

3.13 Use of Lubricants and Functional Fluids

3.13.1 Process Description

DINP is incorporated into lubricants and functional fluids (see Appendix F for EPA identified DINP-containing products for this OES) (ACC, 2020). A typical end use site unloads the lubricant/functional fluid when ready for changeout (OECD, 2004b). Sites incorporate the product into the system with a frequency ranging from once every 3 months to once every 5 years. After changeout, sites clean the transport containers and equipment, and dispose of used fluid. Figure 3-14 provides an illustration of the expected use of lubricants and functional fluids process (OECD, 2004b).

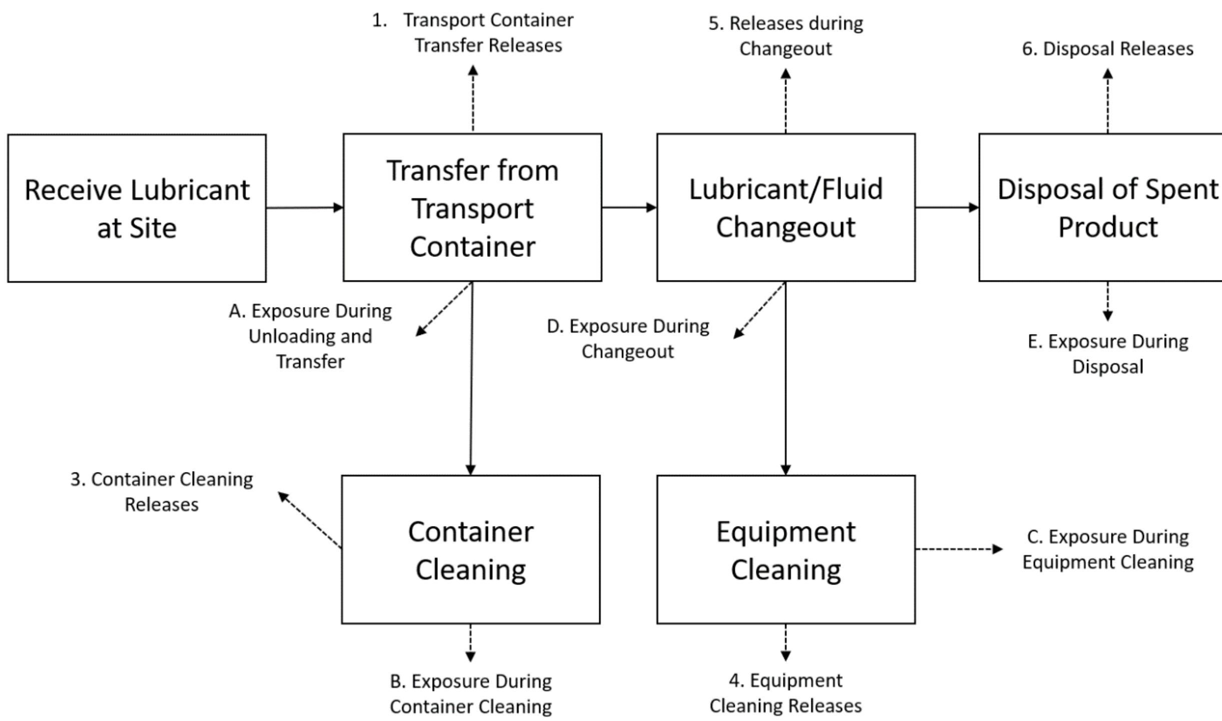

Figure 3-14. Use of Lubricants and Functional Fluids Flow Diagram

3.13.2 Facility Estimates

No sites reported the use of DINP-containing lubricants or functional fluids to the 2020 CDR (U.S. EPA, 2020a). ACC indicated that the use rate of DINP in the EU is similar to the use rate in the United States (ACC, 2020), however, the 2003 *DINP Risk Assessment* published by the European Union (ECJRC, 2003b) did not estimate a production volume for lubricants and functional fluids. The smallest PV breakdown the EU risk assessment provided was 2.6 percent for inks, adhesives/sealants, and paints. Based on minimal data for the "lubricants and functional fluids" breakdown, EPA uses one-third of the 2.6 percent as a conservative estimate for lubricants and functional fluid. Therefore, the Agency estimated all OESs that are not accounted for in the EU Risk Assessment as being less than or equal to 0.87 percent. As a result, EPA calculated the production volume of DINP in other formulations, mixtures, and reaction products as 0.87 percent of the yearly production volume of DINP for both CASRN reported to CDR. The 2020 CDR reported a national production volume range for DINP; therefore, EPA also provided the lubricant and functional fluid production volume as a range. The resulting total production volume was 589,670 to 4,340,879 kg/year.

EPA did not identify site- or DINP-specific lubricant and functional fluid operating data (*e.g.*, facility use rates, operating days). However, based on the 2004 *Emission Scenario Document on Lubricants and Lubricant Additives*, EPA assumed a product throughput equivalent to one container per lubricant/functional fluid changeout (OECD, 2004b).

The ESD provides an estimate of 1 to 4 changeouts per year for different types of hydraulic fluids, and EPA assumed each changeout occurs over the course of 1 day. Based on this relationship, EPA assessed 1 to 4 operating days per year. Based on this operating day distribution, the 50th to 95th percentile range of the resulting product use rate was 921 to 2,908 kg/site-year. EPA did not identify any estimates of the number of sites that may use lubricants/functional fluids containing DINP. Therefore, EPA estimated the total number of sites that use DINP-containing lubricants/functional fluids using a Monte Carlo model (see Appendix E.12 for details). The 50th to 95th percentile range of the number of sites was 7,033 to 48,659 sites.

3.13.3 Release Assessment

3.13.3.1 Environmental Release Points

EPA assigned release points based on the 2004 *Emission Scenario Document on Lubricants and Lubricant Additives* (OECD, 2004b). EPA assigned default models to quantify releases from each release point and suspected fugitive air release. EPA expects releases to wastewater, landfill, or incineration from the use of equipment. Releases to wastewater, landfill, and incineration from fuel blending activities are expected from fluid changeouts.

3.13.3.2 Environmental Release Assessment Results

Table 3-65. Summary of Modeled Environmental Releases for Use of Lubricants and Functional Fluids

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
1,300,000–9,570,000 lb production volume	Wastewater	1.61E02	7.56E02	2	4	7.27E01	2.69E02
	Landfill	7.04E01	3.61E02			3.19E01	1.30E02
	Recycling	2.54	1.70E01			1.18	6.27
	Fuel Blending (Incineration)	5.65E01	3.78E02			2.64E01	1.39E02

3.13.4 Occupational Exposure Assessment

3.13.4.1 Worker Activities

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

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

3.13.4.2 Number of Workers and Occupational Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during the use of lubricants and functional fluids. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides further details regarding the methodology that EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 336100, 336200, 336300, 336400, 336500, 336600, 336900, and 811100 for this OES based on the *Emission Scenario Document on Lubricants and Lubricant Additives* (OECD, 2004b). Table 3-66 summarizes the per site estimates for this OES. As described in Section 3.13.2, EPA did not identify site-specific data for the number of facilities in the United States that use DINP-containing lubricants and functional fluids.

Table 3-66. Estimated Number of Workers Potentially Exposed to DINP During Use of Lubricants and Functional Fluids

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed Occupation Non-users per Site[b]	Total Number of Exposed ONUs[a]
336100 – Motor Vehicle Manufacturing	N/A	447	N/A	59	N/A
336200 – Motor Vehicle Body and Trailer Manufacturing		40		5	
336300 – Motor Vehicle Parts Manufacturing		51		15	
336400 – Aerospace Product and Parts Manufacturing		75		64	
336500 – Railroad Rolling Stock Manufacturing		35		15	
336600 – Ship and Boat Building		36		11	
336900 – Other Transportation Equipment Manufacturing		16		4	
811100 – Automotive Repair and Maintenance		3		0.27	
Total/Average	7,033-48,659	88	617,370-4,271,378	22	151,950-1,051,294

[a] The result is expressed as a range between the central tendency and the high-end value. Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.13.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the use of lubricants and functional fluids during systematic review of literature sources. However, EPA estimated inhalation exposures for this OES using monitoring data for DINP exposures during manufacturing (ExxonMobil, 2022b). EPA expects that inhalation exposures during manufacturing to be greater than inhalation exposures during the use of lubricants and functional fluids and serve as a reasonable bounding estimate.

EPA used surrogate monitoring data provided in an exposure study conducted by ExxonMobil at their DINP manufacturing site to estimate inhalation exposure for this OES. ExxonMobil collected PBZ samples using an AIHA validated method involving PTFE Teflon filters, extraction with acetonitrile, and HPLC analysis with UV detection. ExxonMobil took PBZ samples from plasticizer assistant operators, laboratory technicians, and maintenance operators (ExxonMobil, 2022a). EPA used the samples taken during filter change-out from maintenance operators to represent this OES, as this activity was determined to best represent the activities that occur during manufacturing. The study included 12 PBZ data points for DINP. All data points were below the LOD. Therefore, EPA could not create a full distribution of monitoring results to estimate central tendency and high-end exposures. To estimate high-end worker exposures, EPA used the LOD reported in the study. To estimate central tendency worker exposures, EPA used half of the LOD.

Table 3-67 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during use of lubricants and functional fluids. The high-end exposures use 4 days per year as the exposure frequency, based on the 50th percentile of operating days from the release assessment. The central tendency exposures use 2 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix B describes the approach for estimating AD, IADD, and ADD.

Table 3-67. Summary of Estimated Worker Inhalation Exposures for Use of Lubricants and Functional Fluids

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute Dose (AD) (mg/kg/day)	4.3E−03	8.6E−03
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	2.9E−04	1.2E−03
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	2.4E−05	9.5E−05
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	6.9E−02
	Acute Dose (AD) (mg/kg/day)	4.8E−03	9.5E−03
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	3.2E−04	1.3E−03
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	2.6E−05	1.0E−04
ONU	8-hour TWA Exposure Concentration (mg/m^3)	3.5E−02	3.5E−02
	Acute Dose (AD) (mg/kg/day)	4.3E−03	4.3E−03
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	2.9E−04	5.8E−04
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	2.4E−05	4.7E−05

3.13.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-68 are explained in Appendix B. Because dermal exposures to workers may occur in a concentrated liquid form during the use of lubricants and functional fluids, EPA assessed the absorptive flux of DINP according to dermal absorption data of neat DINP (see Appendix D.2.1.1 for details). Table 3-68 summarizes the APDR, AD, IADD, and ADD for both average adult workers and female workers of reproductive age. Because there are no dust or mist expected to be deposited on surfaces from this OES, dermal exposures to ONUs from contact with surfaces were not assessed. Dermal exposure parameters are described in Appendix D.

Table 3-68. Summary of Estimated Worker Dermal Exposures for Use of Lubricants and Functional Fluids

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	6.2	12
	Acute (AD, mg/kg-day)	7.8E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.2E−03	2.1E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	4.3E−04	1.7E−03
Female of Reproductive Age	Dose Rate (APDR, mg/day)	5.2	10
	Acute (AD, mg/kg-day)	7.2E−02	0.14
	Intermediate (IADD, mg/kg-day)	4.8E−03	1.9E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	3.9E−04	1.6E−03

3.13.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-69. Summary of Estimated Worker Aggregate Exposures for Use of Lubricants and Functional Fluids

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	8.2E−02	0.16
	Intermediate (IADD, mg/kg-day)	5.5E−03	2.2E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	4.5E−04	1.8E−03
Female of Reproductive Age	Acute (AD, mg/kg-day)	7.6E−02	0.15
	Intermediate (IADD, mg/kg-day)	5.1E−03	2.0E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	4.2E−04	1.7E−03
ONU	Acute (AD, mg/kg-day)	4.3E−03	4.3E−03
	Intermediate (IADD, mg/kg-day)	2.9E−04	5.8E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	2.4E−05	4.7E−05

3.14 Fabrication and Final Use of Products or Articles

3.14.1 Process Description

EPA expects DINP to be present in a wide array of final articles that are used both commercially and industrially, based on identified product SDSs, including wall coverings, erasers, floor mattings, and glass filaments (see Appendix F for EPA identified DINP-containing products for this OES)(U.S. CPSC, 2015).

3.14.2 Facility Estimates

EPA identified multiple products for the fabrication and final use of products or articles OES. The concentration of DINP in these products varied depending on the type of product and the necessary characteristics of that product. Therefore, EPA could not identify a production concentration range from any combination of products, due to varied uses and product functions. 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 DINP-containing article use occurs at many disparate industrial and commercial sites, with different operating conditions. Use cases are expected to include welding or melting articles containing DINP; drilling, cutting, grinding, or otherwise shaping articles containing DINP; and the general use of DINP-containing abrasives. 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 DINP. EPA assumed the number of operating days was 250 days/year, with 5 day/week operations and two full weeks of downtime each operating year.

3.14.3 Release Assessment

3.14.3.1 Environmental Release Points

EPA did not quantitatively assess environmental releases for this OES due to the lack of available process-specific and DINP-specific data; however, EPA expects releases from this OES to be small and disperse in comparison to other upstream uses, as DINP is present in smaller amounts and predominantly remains in the final article, limiting the potential for release. Table 3-70 describes the fabrication and use activities that may generate releases. All releases are non-quantifiable due to a lack of identified process- and product- specific data.

Table 3-70. Release Activities for Fabrication/Use of Final Articles Containing DINP

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

3.14.4 Occupational Exposure Assessment

3.14.4.1 Worker Activities

During fabrication and final use of products or articles, worker exposures to DINP may occur via dermal contact while handling and shaping articles containing DINP 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, DINP vapor inhalation exposure may occur during heating or plastic welding. 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 DINP 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 DINP-containing materials or articles. ONUs are potentially exposed through the inhalation route while in the working area. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.14.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during the fabrication and final use of products or articles. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides further details regarding the methodology EPA used to estimating the number of workers and ONUs per site. EPA assigned the

NAICS codes 236100, 236200, 237100, 237200, 237300, 237900, 337100, and 337200 for this OES based on NAICS codes that matched the relevant COUs for this scenario. Table 3-71 summarizes the per site estimates for this OES. As discussed in Section 3.14.2, EPA did not identify site-specific data for the number of facilities in the United States that fabricate or use final products or articles that contain DINP.

Table 3-71. Estimated Number of Workers Potentially Exposed to DINP During the Fabrication and Final Use of Products or Articles

NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
236100 – Residential Building Construction	2	1
236200 – Nonresidential Building Construction	9	4
237100 – Utility System Construction	12	3
237200 – Land Subdivision	1	1
237300 – Highway, Street, and Bridge Construction	20	4
237900 – Other Heavy and Civil Engineering Construction	13	3
337100 – Household and Institutional Furniture Manufacturing	5	4
337200 – Office Furniture (including Fixtures) Manufacturing	7	3
Total/Average	9	3

[a] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or occupational non-users by the total number of sites for a given NAICS code. The number of workers and occupational non-users are rounded to the nearest integer. Values which would otherwise be displayed as "0" are left unrounded.

3.14.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data to assess exposures to DINP during fabrication and final use of products or articles containing DINP. Based on the presence of DINP as an additive in products (U.S. CPSC, 2015), EPA assessed worker inhalation exposures to DINP as an exposure to particulates of final products. Therefore, the Agency estimated worker inhalation exposures during fabrication and final use of products 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). Model approaches and parameters are described in Appendix E.14.

To estimate final product DINP particulate concentrations in the air, EPA used a subset of the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021c) data from facilities with NAICS codes starting with 337 (Furniture and Related Product Manufacturing). Particulate exposures across end-use industries may include trimming, cutting, and/or abrasive actions on the DINP-containing product, and EPA expects similar actions during furniture and related products manufacturing. This dataset consisted of 272 measurements. EPA used the highest expected concentration of DINP in final products to estimate the concentration of DINP in the particulates. For this OES, EPA selected 45 percent by mass as the highest expected DINP concentration based on the estimated plasticizer concentrations in relevant products given by the Use of Additives in Plastic Compounding Generic Scenario (U.S. EPA, 2021d). The estimated exposures assume that DINP is present in particulates at this fixed concentration throughout the working shift.

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 an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. EPA estimated bounding exposures for ONUs using the worker central tendency of the PNOR model results.

Table 3-72 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during fabrication and final use of products or articles. 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 B describes the approach for estimating AD, IADD, and ADD. The estimated exposures assume that the worker is exposed to DINP in the form of product particulates and does not account for other potential inhalation exposure routes, such as from vapors.

Table 3-72. Summary of Estimated Worker Inhalation Exposures for Fabrication and Final Use of Products or Articles

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration to Dust (mg/m^3)	9.0E−02	0.81
	Acute Dose (AD) (mg/kg/day)	1.1E−02	0.10
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	8.3E−03	7.4E−02
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	7.7E−03	6.9E−02
Female of Reproductive Age	8-hour TWA Exposure Concentration to Dust (mg/m^3)	9.0E−02	0.81
	Acute Dose (AD) (mg/kg/day)	1.2E−02	0.11
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	9.1E−03	8.2E−02
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	8.5E−03	7.7E−02
ONU	8-hour TWA Exposure Concentration to Dust (mg/m^3)	9.0E−02	9.0E−02
	Acute Dose (AD) (mg/kg/day)	1.1E−02	1.1E−02
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	8.3E−03	8.3E−03
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	7.7E−03	7.7E−03

3.14.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various “Exposure Concentration Types” from Table 3-73 are explained in Appendix B. Because dermal exposures of DINP to workers is expected to occur through contact with solids or articles for this OES, EPA assessed the absorptive flux of DINP according to dermal absorption modeling approach for solids outlined in Appendix D.2.1.2. Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-73 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-73. Summary of Estimated Worker Dermal Exposures for Fabrication and Final Use of Products or Articles

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5E−02	4.9E−02
	Acute (AD, mg/kg-day)	3.1E−04	6.2E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	4.5E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	2.1E−04	4.2E−04
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.0E−02	4.1E−02
	Acute (AD, mg/kg-day)	2.8E−04	5.7E−04
	Intermediate (IADD, mg/kg-day)	2.1E−04	4.1E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.9E−04	3.9E−04
ONU	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	2.1E−04	2.1E−04

3.14.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in Table 3-74 below.

Table 3-74. Summary of Estimated Worker Aggregate Exposures for Fabrication and Final Use of Products or Articles

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.2E−02	0.10
	Intermediate (IADD, mg/kg-day)	8.5E−03	7.5E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	7.9E−03	7.0E−02
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.3E−02	0.11
	Intermediate (IADD, mg/kg-day)	9.3E−03	8.2E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	8.7E−03	7.7E−02
ONU	Acute (AD, mg/kg-day)	1.2E−02	1.2E−02
	Intermediate (IADD, mg/kg-day)	8.5E−03	8.5E−03
	Chronic, Non-cancer (ADD, mg/kg-day)	7.9E−03	7.9E−03

3.15 Recycling

3.15.1 Process Description

DINP is primarily recycled industrially as DINP-containing PVC, including roofing membranes and carpet squares. Based on Irwin Engineer's report about the usage of DINP by the Sika Corporation, all roofing membrane recycling is completed using mechanical recycling technology, in the form of scrap regrinding and recycling (Irwin, 2022). Although chemical/feedstock recycling is possible, EPA did not identify any market share data indicating chemical/feedstock recycling processes for DINP-containing waste streams.

The Association of Plastic Recyclers reported that recycled PVC 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 DINP-containing waste and separate the PVC and non-PVC fractions using electrostatic separation, washing/floatation, or air/jet separation. Following cooling of grinded PVC, the site transfers the product to feedstock storage for use in the plastics compounding or converting line or loads the products into containers for shipment to downstream use sites. Table 3-17 provides an illustration of the PVC recycling process (U.S. EPA, 2021d).

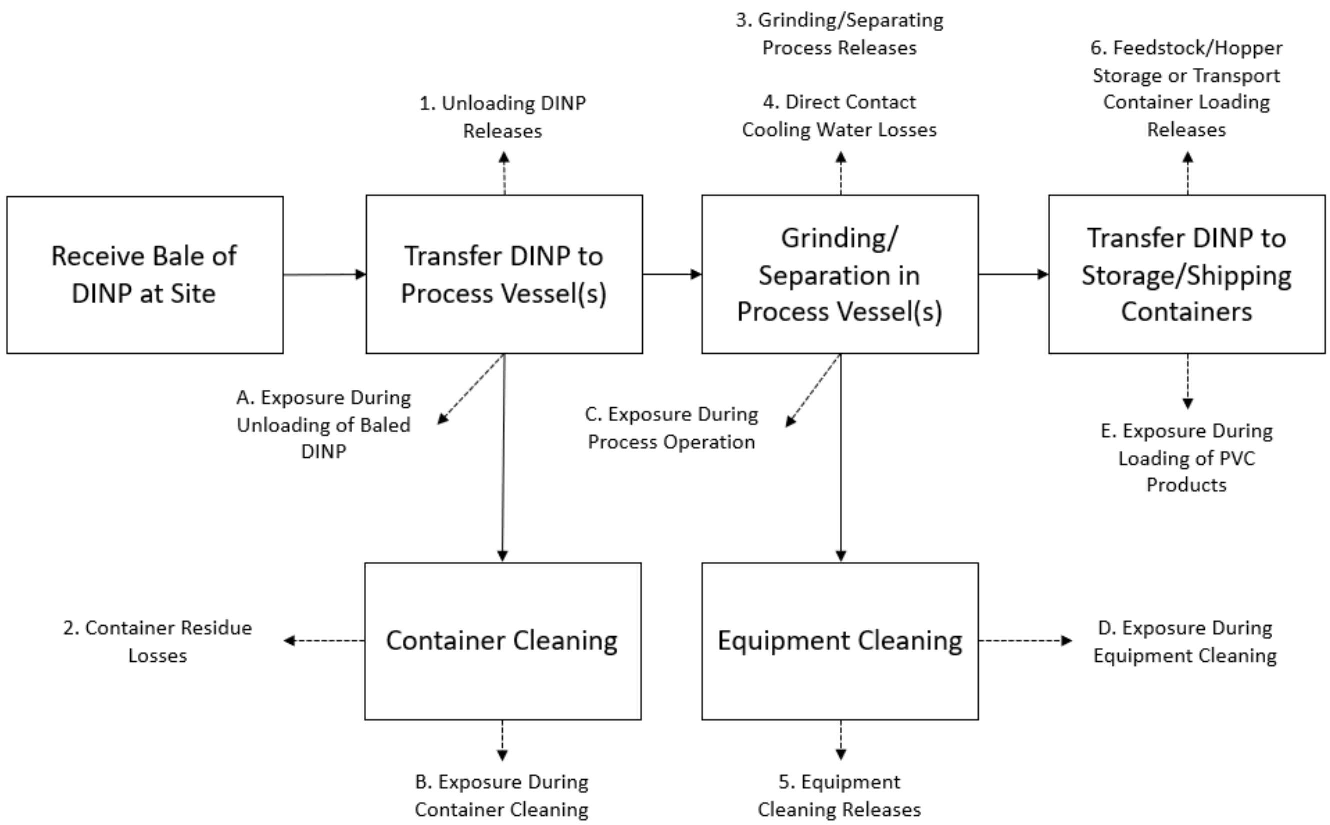

Figure 3-15. DINP-Containing PVC Recycling Flow Diagram

3.15.2 Facility Estimates

EPA evaluated releases to disposal waste sites in the individual release assessments for each OES. EPA expects that post consumer disposal of DINP consumer goods occurs via incineration or landfill; however, the disperse nature of general disposal makes it difficult to quantify. Recycling facilities, especially those for PVC, are much more consolidated.

ENF Recycling estimated that there are a total of 228 plastics recyclers operating in the United States 58 of which accept PVC wastes for recycling (ENF Plastic, 2024). It is unclear if the total number of sites includes some or all circular recycling sites, which are facilities that manufacture new PVC from both recycled and virgin materials. A Sika Corporation notice indicated that the company uses sites with in-house, post-consumer roofing membrane grinding capabilities (Irwin, 2022). EPA could potentially identify these sites based on the manufactured product; however, EPA selected compounding site parameters and developed release estimates using generic values specified in the Generic Scenario on Plastics Compounding. Thus, the compounding estimates incorporate all PVC material streams, including recycled and virgin PVC (U.S. EPA, 2021d).

The Quantification and Evaluation of Plastic Waste in the United States estimated that of the 699 kilotons of PVC waste in 2019, 3 percent was recycled or 20,970,000 kg PVC (Milbrandt et al., 2022). The 2010 technical report on the *Evaluation of New Scientific Evidence Concerning DINP and DIDP* estimated the fraction of DINP-containing PVC used in the overall PVC market as 18.33 percent (ECHA, 2010). As a result, EPA calculated the use rate of recycled PVC plastics containing DINP as 18.33 percent of the yearly recycled production volume of PVC or 3,846,801 kg/year. This is comparable to the estimated production volume of DINP-containing PVC of 64,568,873 to 473,505,075 kg/year. Plastics compounding sites may engage in the reformulation of plastics from recycled plastic products. EPA expects the 2021 Generic Scenario on Plastics Compounding to be representative of PVC recycling activities and their associated releases, which estimated the mass fraction of DINP used as a plasticizer in PVC as 10 to 45 percent (U.S. EPA, 2021d). EPA estimated the production volume of DINP in recycled PVC plastic as 384,450 to 1,730,025 kg based on the use rate of DINP-containing PVC in the overall market and the mass fraction of DINP used as plasticizer in PVC. The GS estimated the total number of operating days as 148 to 264 days/year, with 24 hours/day, 7 days/week (*i.e.*, multiple shifts) operations for the given site throughput scenario (U.S. EPA, 2021d).

3.15.3 Release Assessment

3.15.3.1 Environmental Release Points

EPA assigned release points based on the 2021 Generic Scenario on Plastics Compounding (U.S. EPA, 2021d). EPA assigned default models to quantify releases from each release point and suspected fugitive air release. EPA does not expect recycling sites to utilize air pollution capture and control technologies. EPA expects fugitive air, wastewater, incineration, or landfill releases from unloading and loading, general recycling processing, container residue losses, and equipment cleaning. EPA expects wastewater releases from direct contact cooling and storage and/or loading of recycled plastic. EPA expects stack air releases from storage and/or loading of recycled plastic.

3.15.3.2 Environmental Release Assessment Results

Table 3-75. Summary of Modeled Environmental Releases for Recycling

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
847,567–3,814,052 lb production volume	Stack Air	9.36	1.88E02	223	254	4.33E−02	8.67E−01
	Fugitive Air, Wastewater, Incineration, or Landfill	7.30E02	1.30E03			3.46	6.30
	Wastewater	3.21E02	6.74E02			1.46	3.19

3.15.4 Occupational Exposure Assessment

3.15.4.1 Worker Activities

At PVC recycling sites, worker exposures from dermal contact with solids and inhalation may occur during the unloading of bailed PVC, loading of processed DINP-containing PVC onto compounding or converting lines or into transport containers, processing of recycled PVC, and equipment cleaning (U.S. EPA, 2021d). 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 DINP-containing PVC or the recycled compounded product. ONUs are potentially exposed through the inhalation route while in the working area. Also, dermal exposures from contact with surfaces where dust has been deposited were assessed for ONUs.

3.15.4.2 Number of Workers and Occupational Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during recycling and disposal. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides further details regarding the methodology EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 562212, 562213, and 562219 for this OES based on the NAICS codes that related to the process description in Section 3.15.1. Table 3-76 summarizes the per site estimates for this OES. As described in Section 3.15.2, EPA did not identify site-specific data for the number of facilities in the United States that recycle and dispose of DINP-containing materials.

Table 3-76. Estimated Number of Workers Potentially Exposed to DINP During Recycling and Disposal

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUOccupational Non-users per Site[b]	Total Number of Exposed ONUs[a]
562212 – Solid Waste Landfill	N/A	3	N/A	2	N/A
562213 – Solid Waste Combustors and Incinerators		13		8	
562219 – Other Nonhazardous Waste Treatment and Disposal		3		2	
Total/Average	58	6	377	4	216

[a] Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.15.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the recycling OES during systematic review. Based on the presence of DINP as an additive in plastics (U.S. CPSC, 2015), EPA assessed worker inhalation exposures to DINP as an exposure to particulates of recycled plastic materials. Therefore, EPA estimated worker inhalation exposures during recycling 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). Model approaches and parameters are described in Appendix E.14.

To estimate plastic particulate concentrations in the air, EPA used a subset of the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021c) data that came from facilities with the NAICS code starting with

56 (Administrative and Support and Waste Management and Remediation Services). This dataset consisted of 130 measurements. EPA used the highest expected concentration of DINP in recyclable plastic products to estimate the concentration of DINP present in particulates. For this OES, EPA selected 45 percent by mass as the highest expected DINP concentration based on the estimated plasticizer concentrations in flexible PVC given by the Use of Additives in Plastic Compounding Generic Scenario (U.S. EPA, 2021d). The estimated exposures assume that DINP is present in particulates of the plastic at this fixed concentration throughout the working shift.

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 an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. EPA estimated bounding exposures for ONUs using the worker central tendency of the PNOR model results.

Table 3-77 summarizes the estimated 8-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during recycling operations. 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 used 223 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. Appendix B describes the approach for estimating AD, IADD, and ADD. The estimated exposures assume that the worker is exposed to DINP in the form of plastic particulates and does not account for other potential inhalation exposure routes, such as from the inhalation of vapors.

Table 3-77. Summary of Estimated Worker Inhalation Exposures for Recycling

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m^3)	0.11	1.6
	Acute Dose (AD) (mg/kg/day)	1.4E−02	0.2
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	9.9E−03	0.14
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	8.2E−03	0.13
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m^3)	0.11	1.6
	Acute Dose (AD) (mg/kg/day)	1.5E−02	0.22
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	1.1E−02	0.16
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	9.1E−03	0.15
ONU	8-hour TWA Exposure Concentration (mg/m^3)	0.11	0.11
	Acute Dose (AD) (mg/kg/day)	1.4E−02	1.4E−02
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	9.9E−03	9.9E−03
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	8.2E−03	9.2E−03

3.15.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-78 are explained in Appendix B. Because dermal exposures of DINP to workers is expected to occur through contact with solids or articles for this OES, EPA assessed the absorptive flux of DINP according to dermal absorption modeling approach for solids outlined in Appendix D.2.1.2. Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-78 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-78. Summary of Estimated Worker Dermal Exposures for Recycling

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5E−02	4.9E−02
	Acute (AD, mg/kg-day)	3.1E−04	6.2E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	4.5E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.9E−04	4.2E−04
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.0E−02	4.1E−02
	Acute (AD, mg/kg-day)	2.8E−04	5.7E−04
	Intermediate (IADD, mg/kg-day)	2.1E−04	4.1E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.7E−04	3.9E−04
ONU	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.9E−04	2.1E−04

3.15.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-79. Summary of Estimated Worker Aggregate Exposures for Recycling

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.4E−02	0.20
	Intermediate (IADD, mg/kg-day)	1.0E−02	0.14
	Chronic, Non-cancer (ADD, mg/kg-day)	8.4E−03	0.14
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.5E−02	0.22
	Intermediate (IADD, mg/kg-day)	1.1E−02	0.16
	Chronic, Non-cancer (ADD, mg/kg-day)	9.3E−03	0.15
ONU	Acute (AD, mg/kg-day)	1.4E−02	1.4E−02
	Intermediate (IADD, mg/kg-day)	1.0E−02	1.0E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	8.4E−03	9.5E−03

3.16 Disposal

3.16.1 Process Description

Each of the conditions of use of DINP may generate waste streams that are collected and transported to third-party sites for disposal, treatment, or recycling. Wastes of DINP that are generated during a condition of use and sent to a third-party site for treatment, disposal, or recycling may include the following:

Wastewater: DINP may be contained in wastewater discharged to POTW or other, non-public treatment works for treatment. Industrial wastewater containing DINP and discharged to a POTW may be subject to EPA or authorized NPDES state pretreatment programs. EPA included an assessment of DINP-containing wastewater discharges to POTWs and non-public treatment works in each of the OESs assessments in Sections 3.1 through 3.15.

Solid Wastes: Solid wastes are defined under RCRA as any material that is discarded by being abandoned, is 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 in 40 CFR sections 261.30 to 261.35 or by meeting waste-like characteristics as defined in 40 CFR sections 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. DINP is not listed as a toxic chemical as specified in Subtitle C of RCRA and is not subject to hazardous waste regulation. However, solid wastes containing DINP may require regulation if the waste leaches certain constituents, specified in the toxicity characteristic leaching procedure (TLCP), in excess of regulatory limits. The regulation includes toxins such as lead and cadmium, which are used as stabilizers in PVC. EPA assessed solid waste discharges of DINP in each of the condition of use assessments in Sections 3.1 to 3.15.

EPA expects off-site transfers of DINP and DINP-containing substances for land disposal, wastewater treatment, incineration, and recycling, or transfer to an unknown off-site disposal/treatment facility, based on industry supplied data and published EPA and OECD emission documentation (*e.g.*, GS, ESD). See Figure 3-16.

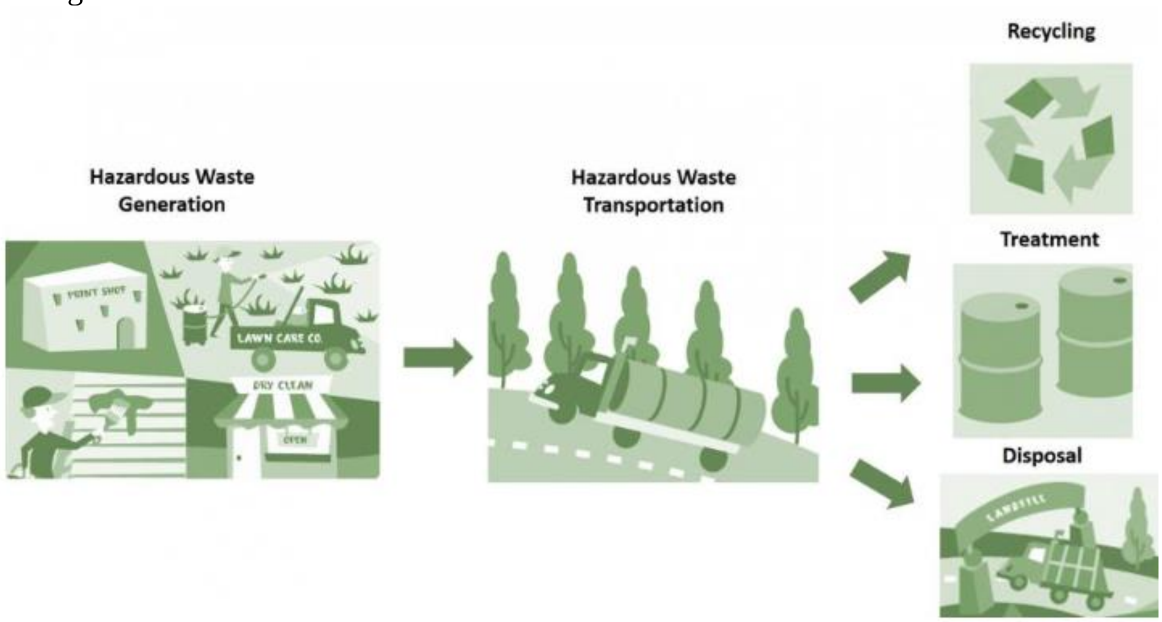

Figure 3-16. Typical Waste Disposal Process (U.S. EPA, 2017)

Municipal Waste Incineration

Municipal waste combustors (MWCs) that recover energy are generally located at large facilities and include 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, workers do not generally handle waste materials directly. Trucks may dump the waste directly into the pit or tip the waste to the floor, where it is later pushed into the pit by a worker-operated front-end loader. A large grapple from an overhead crane grabs the waste from the pit and drops it into a hopper, where hydraulic rams continuously feed the material into the combustion unit at a controlled rate. The crane operator also uses the grapple to mix the waste within the pit, to provide a fuel with consistent 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, facilities transfer the waste material to a storage pit or convey it directly to the hopper for combustion.

Tipping floor operations may generate dust. However, one or more forced air fans typically draw air from the enclosed tipping floor into the combustion unit to provide combustion air and minimize odors. Filters or other cleaning devices typically capture dust and lint present in the air to prevent clogging of the steam coils, which 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, consisting of a rotary kiln followed by an afterburner, which accept both solid and liquid wastes. Waste incineration facilities typically pump liquid wastes into the unit through pipes with nozzles that atomize the liquid for optimal combustion. These facilities may gravity feed loose solids though a hooper or convey solids to the kiln in drums or containers (ETC, 2018; Heritage, 2018).

Facilities typically receive incoming hazardous waste by truck or rail and require inspection of all incoming waste. Receiving areas for liquid waste generally consist of a docking area, a pumphouse, and some kind of storage facility. Facilities typically use conveyor devices to transport incoming solid waste (ETC, 2018; Heritage, 2018).

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 Figure 3-17 for a typical incineration process.

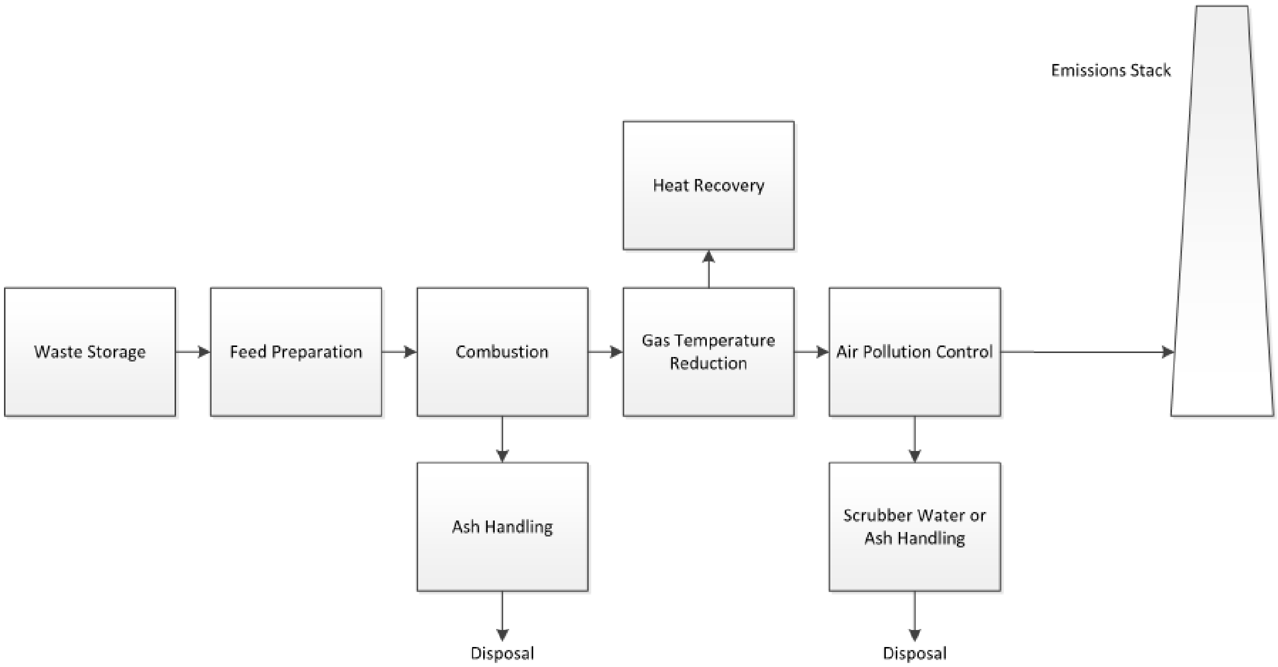

Figure 3-17. Typical Industrial Incineration Process

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 systems, 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 states may impose more stringent requirements.

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

Hazardous Waste Landfill

Hazardous waste landfills are excavated or engineered sites that are specifically designed for the final disposal of non-liquid hazardous wastes. Design standards for these landfills require double liners; double leachate collection and removal systems; leak detection systems; run-on, runoff and wind dispersal controls; and construction quality assurance programs (U.S. EPA, 2018). There are also requirements for closure and post-closure, such as the addition of a final cover over the landfill and continued monitoring and maintenance. These standards and requirements prevent potential contamination of groundwater and nearby surface water resources. Hazardous waste landfills are regulated under 40 CFR part 264/265, subpart N.

3.16.2 Facility Estimates

EPA assumes that facilities will dispose of all DINP-containing products in some fashion. The concentration of DINP 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 the disposal OES (*i.e.*, facility throughput, number of sites, total production volume, operating days, product concentration), as DINP-containing wastes occur at all levels of the DINP life cycle. EPA expects disposal routes to include POTW and non-publicly owned treatment works; municipal and hazardous waste incineration; and municipal and hazardous waste landfill. Due to a lack of readily available information for this OES, the number of industrial or commercial use sites is unquantifiable and unknown. 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 DINP. EPA assumed the number of operating days was 250 days/year with 5 day/week operations and two full weeks of downtime each operating year.

3.16.3 Release Assessment

3.16.3.1 Environmental Release Points

EPA did not quantitatively assess environmental releases for this OES due to the lack of readily available, process-specific and DINP-specific data; however, EPA expects releases from this OES to be small and disperse in comparison to other upstream OES, as EPA expects DINP 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.

3.16.4 Occupational Exposure Assessment

3.16.4.1 Worker Activities

At waste disposal sites, workers are potentially exposed via dermal contact with waste containing DINP or via inhalation of DINP vapor or dust. Depending on the concentration of DINP in the waste stream, the route and level of exposure may be similar to that associated with container unloading activities. See Section 3.2.4.1 for the assessment of worker exposure from chemical unloading activities.

Municipal Waste Incineration

At municipal waste incineration facilities, there may be one or more technicians present on the tipping floor to oversee operations, direct trucks, inspect incoming waste, or perform other tasks as warranted by individual facility practices. These workers may wear protective gear such as gloves, safety glasses, or dust masks. Specific worker protocols are largely up to individual companies, although state or local regulations may require certain worker safety standards be met. Federal operator training requirements pertain more to the operation of the regulated combustion unit rather than operator health and safety. Workers are potentially exposed via inhalation to vapors 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 (CalRecycle, 2018).

3.16.4.2 Number of Workers and Occupation Non-users

EPA used data from the BLS and the U.S. Census' SUSB (U.S. BLS, 2016; U.S. Census Bureau, 2015) to estimate the number of workers and ONUs per site that are potentially exposed to DINP during recycling and disposal. This approach involved the identification of relevant SOC codes within the BLS data for select NAICS codes. Section 2.4.2 provides further details regarding the methodology EPA used to estimate the number of workers and ONUs per site. EPA assigned the NAICS codes 562212, 562213, and 562219 for this OES based on the NAICS codes that related to the process description in Section 3.16.1. Table 3-80 summarizes the per site estimates for this OES. As described in Section 3.16.2, EPA did not identify site-specific data for the number of facilities in the United States that dispose of DINP-containing materials.

Table 3-80. Estimated Number of Workers Potentially Exposed to DINP During Recycling and Disposal

NAICS Code	Number of Sites[a]	Exposed Workers per Site[b]	Total Number of Exposed Workers[a]	Exposed ONUs per Site[b]	Total Number of Exposed ONUs[a]
562212 – Solid Waste Landfill	N/A	3	N/A	2	N/A
562213 – Solid Waste Combustors and Incinerators		13		8	
562219 – Other Nonhazardous Waste Treatment and Disposal		3		2	
Total/Average	58	6	377	4	216

[a] Results were not assessed by NAICS code for this scenario.
[b] Number of workers and ONUs per site are calculated by dividing the total number of exposed workers or ONUs by the total number of sites for a given NAICS code. The number of workers and ONUs are rounded to the nearest integer. Values that would otherwise be displayed as "0" are left unrounded.

3.16.4.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data for the Disposal OES during systematic review. Based on the presence of DINP as an additive in plastics (U.S. CPSC, 2015), the Agency assessed worker inhalation exposures to DINP as an exposure to particulates of discarded plastic materials. Therefore, EPA estimated worker inhalation exposures during disposal 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). Model approaches and parameters are described in Appendix E.14.

To estimate plastic particulate concentrations in the air, EPA used a subset of the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021c) data that came from facilities with the NAICS code starting with 56 (Administrative and Support and Waste Management and Remediation Services). This dataset consisted of 130 measurements. EPA used the highest expected concentration of DINP in plastic products to estimate the concentration of DINP present in particulates. For this OES, EPA selected 45 percent by mass as the highest expected DINP concentration based on the estimated plasticizer concentrations in flexible PVC given by the Use of Additives in Plastic Compounding Generic Scenario (U.S. EPA, 2021d). The estimated exposures assume that DINP is present in particulates of the plastic at this fixed concentration throughout the working shift.

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 an 8-hour TWA for particulate concentrations by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities.

Table 3-81 summarizes the estimated 10-hour TWA concentration, AD, IADD, and ADD for worker exposures to DINP during disposal operations. 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 recycling release assessment, which EPA assumed to be equivalent. Appendix B describes the approach for estimating AD, IADD, and ADD. The estimated exposures assume that the worker is exposed to DINP in the form of plastic particulates and does not account for other potential inhalation exposure routes, such as the inhalation of vapors.

Table 3-81. Summary of Estimated Worker Inhalation Exposures for Disposal

Modeled Scenario	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	8-hour TWA Exposure Concentration (mg/m^3)	0.11	1.6
	Acute Dose (AD) (mg/kg/day)	1.4E−02	0.2
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	9.9E−03	0.14
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	8.2E−03	0.13
Female of Reproductive Age	8-hour TWA Exposure Concentration (mg/m^3)	0.11	1.6
	Acute Dose (AD) (mg/kg/day)	1.5E−02	0.22
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	1.1E−02	0.16
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	9.1E−03	0.15
ONU	8-hour TWA Exposure Concentration (mg/m^3)	0.11	0.11
	Acute Dose (AD) (mg/kg/day)	1.4E−02	1.4E−02
	Intermediate Average Daily Dose, Non-cancer Exposures (IADD) (mg/m^3)	9.9E−03	9.9E−03
	Chronic Average Daily Dose, Non-cancer Exposures (ADD) (mg/kg/day)	8.2E−03	9.2E−03

3.16.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Appendix D. The various "Exposure Concentration Types" from Table 3-82 are explained in Appendix B. Because dermal exposures of DINP to workers is expected to occur through contact with solids or articles for this OES, EPA assessed the absorptive flux of DINP according to dermal absorption modeling approach for solids outlined in Appendix D.2.1.2. Also, since there may be dust deposited on surfaces from this OES, dermal exposures to ONUs from contact with dust on surfaces were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure is representative of ONU exposure. Therefore, worker central tendency exposure values for dermal contact with solids containing DINP were assumed representative of ONU dermal exposure.

Table 3-82 summarizes the APDR, AD, IADD, and ADD for average adult workers, female workers of reproductive age, and ONUs. Dermal exposure parameters are described in Appendix D.

Table 3-82. Summary of Estimated Worker Dermal Exposures for Recycling

Worker Population	Exposure Concentration Type	Central Tendency	High-End
Average Adult Worker	Dose Rate (APDR, mg/day)	2.5E−02	4.9E−02
	Acute (AD, mg/kg-day)	3.1E−04	6.2E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	4.5E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.9E−04	4.2E−04
Female of Reproductive Age	Dose Rate (APDR, mg/day)	2.0E−02	4.1E−02
	Acute (AD, mg/kg-day)	2.8E−04	5.7E−04
	Intermediate (IADD, mg/kg-day)	2.1E−04	4.1E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.7E−04	3.9E−04
ONU	Dose Rate (APDR, mg/day)	2.5E−02	2.5E−02
	Acute (AD, mg/kg-day)	3.1E−04	3.1E−04
	Intermediate (IADD, mg/kg-day)	2.3E−04	2.3E−04
	Chronic, Non-cancer (ADD, mg/kg-day)	1.9E−04	2.1E−04

3.16.4.5 Occupational Aggregate Exposure Results

Inhalation and dermal exposure estimates were aggregated based on the approach described in Appendix B to arrive at the aggregate worker and ONU exposure estimates in the table below.

Table 3-83. Summary of Estimated Worker Aggregate Exposures for Disposal

Modeled Scenario	Exposure Concentration Type (mg/kg/day)	Central Tendency	High-End
Average Adult Worker	Acute (AD, mg/kg-day)	1.4E−02	0.20
	Intermediate (IADD, mg/kg-day)	1.0E−02	0.14
	Chronic, Non-cancer (ADD, mg/kg-day)	8.4E−03	0.14
Female of Reproductive Age	Acute (AD, mg/kg-day)	1.5E−02	0.22
	Intermediate (IADD, mg/kg-day)	1.1E−02	0.16
	Chronic, Non-cancer (ADD, mg/kg-day)	9.3E−03	0.15
ONU	Acute (AD, mg/kg-day)	1.4E−02	1.4E−02
	Intermediate (IADD, mg/kg-day)	1.0E−02	1.0E−02
	Chronic, Non-cancer (ADD, mg/kg-day)	8.4E−03	9.5E−03

3.17 Distribution in Commerce

3.17.1 Process Description

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

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

4 CONCLUSIONS ON WEIGHT OF SCIENTIFIC EVIDENCE

4.1 Environmental Releases

For each OES, EPA considered the assessment approach; the quality of the data and models; and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine a weight of scientific evidence rating. EPA considered factors that increase or decrease the (1) strength of the evidence supporting the release estimate (*e.g.*, quality of the data/information), (2) applicability of the release or exposure data to the OES (*e.g.*, temporal relevance, locational relevance), and (3) representativeness of the estimate for the whole industry. The Agency used the descriptors of robust, moderate, slight, or indeterminant to categorize the available scientific evidence using its best professional judgment, according to EPA's Draft Systematic Review Protocol (U.S. EPA, 2021a). For example, EPA used moderate to categorize measured release data from a limited number of sources, such that there is a limited number of data points that may not cover most or all the sites within the OES. The Agency used slight to describe limited information that does not sufficiently cover all sites within the OES, and for which the assumptions and uncertainties are not fully known or documented. See the Draft Systematic Review Protocol (U.S. EPA, 2021a) for additional information on weight of scientific evidence conclusions.

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

Table 4-1 Summary of Assumptions, Uncertainty, and Overall Confidence in Release Estimates by OES

OES	Weight of Scientific Evidence Conclusion in Release Estimates
Manufacturing	EPA found limited chemical specific data for the manufacturing OES and assessed environmental releases using models and model parameters derived from CDR, the *2023 Methodology for Estimating Environmental Releases from Sampling Wastes* (U.S. EPA, 2023b), and sources identified through systematic review (including industry supplied data). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, with media of release assessed using assumptions from EPA/OPPT models and industry supplied data. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than a discrete value. Additionally, Monte Carlo modeling uses a large number of data points (simulation runs) and considers the full distributions of input parameters. EPA used facility-specific DINP manufacturing volumes for all facilities that reported this information to CDR and DINP-specific operating parameters derived using data with a high data quality ranking from a current U.S. manufacturing site to provide more accurate estimates than the generic values provided by the EPA/OPPT models. The primary limitation of EPA's approach is the uncertainty in the representativeness of release estimates toward the true distribution of potential releases. In addition, EPA lacks DINP facility production volume data for some DINP manufacturing sites that claim this information as CBI for the purposes of CDR reporting; therefore, throughput estimates for these sites are based on the CDR reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. Additional limitations include uncertainties in the representativeness of the industry-provided operating parameters and the generic EPA/OPPT models for all DINP manufacturing sites. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases considering the strengths and limitations of the reasonably available data.
Import and repackaging	EPA found limited chemical specific data for the import and repackaging OES and assessed releases to the environment using the assumptions and values from the Chemical Repackaging GS, which the systematic review process rated high for data quality (U.S. EPA, 2022a). EPA also referenced the *2023 Methodology for Estimating Environmental Releases from Sampling Wastes* (U.S. EPA, 2023b) and used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment. EPA assessed the media of release using assumptions from the ESD and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases at sites than discrete value. Additionally, Monte Carlo modeling uses a high number of data points (simulation runs) and the full distributions of input parameters. EPA used facility specific DINP import volumes for all facilities that reported this information to CDR. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, because the default values in the ESD are generic, there is uncertainty in the representativeness of these generic site estimates in characterizing actual releases from real-world sites that import and repackage DINP. In addition, EPA lacks DINP facility import volume data for some CDR-reporting import and repackaging sites that claim this information as CBI; therefore, throughput estimates for these sites are based on the CDR reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
Incorporation into adhesives and sealants	EPA found limited chemical specific data for the incorporation into adhesives and sealants OES and assessed releases to the environment using the ESD on the Formulation of Adhesives, which has a high data quality rating based on the systematic review process (OECD, 2009a). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using assumptions from the ESD and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases at sites than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-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. EPA based the production volume for the OES on use rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the default values in the ESD may not be representative of actual releases from real-world sites that incorporate DINP into adhesives and sealants. In addition, EPA lacks data on DINP-specific facility production volume and number of formulation sites; therefore, EPA based throughput estimates on CDR which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. The respective share of DINP use for each OES (as presented in the *EU Risk Assessment Report*) may differ from actual conditions adding additional uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
Incorporation into paints and coatings	EPA found limited chemical specific data for the incorporation into paints and coatings OES and assessed releases to the environment using the Draft GS for the Formulation of Waterborne Coatings, which has a medium data quality rating based on systematic review (U.S. EPA, 2014a). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using assumptions from the GS and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentrations in paint and coating products to provide more accurate estimates of DINP concentrations than the generic values provided by the GS. EPA based the production volume for the OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS are specific to waterborne coatings and may not be representative of releases from real-world sites that incorporate DINP into paints and coatings, particularly for sites formulating other coating types (*e.g.*, solvent-borne coatings). In addition, EPA lacks data on DINP-specific facility production volume and number of formulation sites; therefore, EPA based throughput estimates on CDR which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. The share of

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
Incorporation into other formulations, mixtures, and reaction products	EPA found limited chemical specific data for the incorporation into other formulations, mixtures, and reaction products not covered elsewhere OES and assessed releases to the environment using the Draft GS for the Formulation of Waterborne Coatings, which has a medium data quality rating based on systematic review process (U.S. EPA, 2014a). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentrations in other formulation, mixture, and reaction products in the analysis to provide more accurate estimates than the generic values provided by the GS. The safety and product data sheets that EPA obtained these values from have high data quality ratings based on the systematic review process. EPA based the production volume for the OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD are based on the formulation of paints and coatings and may not represent releases from real-world sites that incorporate DINP into other formulations, mixtures, or reaction products. In addition, EPA lacks data on DINP-specific facility production volume and number of formulation sites; therefore, EPA based the throughput estimates on CDR which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. Finally, the share of DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
PVC plastics compounding	EPA found limited chemical specific data for the PVC plastics compounding OES and assessed releases to the environment using the Revised Draft GS for the Use of Additives in Plastic Compounding, which has a medium data quality rating based on systematic review (U.S. EPA, 2021d). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentrations in different DINP-containing PVC plastic products and PVC-specific additive throughputs in the analysis. These data provide are more accurate than the generic values provided by the GS. The safety and product data sheets that EPA obtained these values from have high data quality ratings based on systematic review. EPA based production volumes for the OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD consider all types of plastic compounding and may not represent releases from real-world sites that compound DINP into PVC plastic raw material. In addition, EPA lacks data on DINP-specific facility production volume and number of compounding sites; therefore, EPA estimated throughput based on CDR which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. The respective share of DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
PVC plastics converting	EPA found limited chemical specific data for the PVC plastics converting OES and assessed releases to the environment using the *Revised* Draft GS on the Use of Additives in the Thermoplastics Converting Industry, which has a medium data quality rating based on systematic review (U.S. EPA, 2021e). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values is more likely to capture actual releases than discrete values. Monte Carlo also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentrations in different DINP-containing PVC plastic products and PVC-specific additive throughputs in the analysis. These data provide more accurate estimates than the generic values provided by the GS. The safety and product data sheets that EPA used to obtain these values have high data quality ratings based on systematic review. EPA based the production volume for the OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD are based on all types of thermoplastics converting sites and processes and may not represent actual releases from real-world sites that convert DINP-containing PVC raw material into PVC articles using a variety of methods, such as extrusion or calendaring. In addition, EPA lacks data on DINP-specific facility production volume and number of converting sites; therefore, EPA estimated throughput based on CDR which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. The respective share of DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
Non-PVC material compounding	EPA found limited chemical specific data for the non-PVC material compounding OES and assessed releases to the environment using the Revised Draft GS for the Use of Additives in Plastic Compounding and the ESD on Additives in the Rubber Industry. Both sources have a medium data quality rating based on the systematic review process (U.S. EPA, 2021d; OECD, 2004a). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS, ESD, and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific concentration data for different DINP-containing rubber products in the analysis. These data provide more accurate estimates than the generic values provided by the GS and ESD. The safety and product data sheets that EPA obtained these values from have high data quality ratings based on systematic review. EPA based the production volume for the OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS and ESD are based on all types of plastic compounding and rubber manufacturing, and the DINP-specific concentration data only consider rubber products. As a result, these values may not be representative of actual releases from real-world sites that compound DINP into non-PVC material. In addition, EPA lacks data on DINP-specific facility production volume and number of compounding sites; therefore, EPA estimated throughput based on CDR which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented) and an annual DINP production volume range that spans an order of magnitude. The respective share of DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
Non-PVC material converting	EPA found limited chemical specific data for the non-PVC material converting OES and assessed releases to the environment using the Revised Draft GS on the Use of Additives in the Thermoplastics Converting Industry and the ESD on Additives in the Rubber Industry. Both documents have a medium data quality rating based on systematic review (U.S. EPA, 2021e; OECD, 2004a). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS, ESD, and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentrations in different DINP-containing rubber products in the analysis. These data provide more accurate estimates than the generic values provided by the GS and ESD. The safety and product data sheets that EPA obtained these values from have high data quality ratings based on the systematic review process. EPA based the production volume for the OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS and ESD consider all types of plastic converting and rubber manufacturing sites, and the DINP-specific concentration data only considers rubber products. As a result, these generic site estimates may not represent actual releases from real-world sites that convert DINP containing non-PVC material into finished articles. In addition, EPA lacks data on DINP-specific facility production volume and number of converting sites; therefore, EPA based throughput estimates on values from industry SpERC documents, CDR data (which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented), and an annual DINP production volume range that spans an order of magnitude. The share of DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate and the assessment provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.
Application of adhesives and sealants	EPA found limited chemical specific data for the application of adhesives and sealants OES and assessed releases to the environment using the ESD on the Use of Adhesives, which has a medium data quality rating based on systematic review (OECD, 2015a). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the ESD and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentration and application methods for different DINP-containing adhesives and sealant products in the analysis. These data 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. EPA based OES PV on rates cited by the ACC (2020), which references the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD may not represent releases from real-world sites that incorporate DINP into adhesives and sealants. In addition, EPA lacks data on DINP-specific facility use volume and number of use sites; therefore, EPA based throughput estimates on values from industry SpERC documents, CDR data (which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented), and an annual DINP production volume range that spans an order of magnitude. The respective share of DINP use for each OES as presented in the EU Risk Assessment Report may differ from actual conditions adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate and the assessment provides a plausible estimate of releases, considering the strengths and limitations of reasonably available data.
Application of paints and coatings	EPA found limited chemical specific data for the application of paints and coatings OES and assessed releases to the environment using the ESD on the Application of Radiation Curable Coatings, Inks and Adhesives, the GS on Coating Application via Spray Painting in the Automotive Refinishing Industry, the GS on Spray Coatings in the Furniture Industry. These documents have a medium data quality rating based on the systematic review process (U.S. EPA, 2014b; OECD, 2011b; U.S. EPA, 2004c). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment. EPA assessed media of release using assumptions from the ESD, GS, and EPA/OPPT models and a default assumption that all paints and coatings are applied via spray application. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentration and application methods for different DINP-containing paints and coatings in the analysis. These data provide more accurate estimates than the generic values provided by the GS and ESDs. The safety and product data sheets that EPA obtained these values from have high data quality ratings based on the systematic review process. EPA based production volumes for these OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS and ESDs may not represent releases from real-world sites that incorporate DINP into paints and coatings. Additionally, EPA assumes spray applications of the coatings, which may not be representative of other coating application methods. In addition, EPA lacks data on DINP-specific facility use volume and number of use sites; therefore, EPA based throughput estimates on values from industry SpERC documents, CDR data (which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented), and an annual DINP production volume range that spans an order of magnitude. The share of DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate and the assessment provides a plausible estimate of releases, considering the strengths and limitations of reasonably available data.
Use of laboratory chemicals	EPA found limited chemical specific data for the use of laboratory chemicals OES and assessed releases to the environment using the Draft GS on the Use of Laboratory Chemicals, which has a high data quality rating based on systematic review (U.S. EPA, 2023c). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models for solid and liquid DINP materials. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. EPA used SDSs from identified laboratory DINP products to inform product concentration and material states. EPA believes the primary limitation to be the uncertainty in the representativeness of values toward the true distribution of potential releases. In addition, EPA lacks data on DINP laboratory chemical throughput and number of laboratories; therefore, EPA based the number of laboratories and throughput estimates on stock solution throughputs from the Draft GS on the Use of Laboratory Chemicals and on CDR reporting thresholds. Additionally, because no entries in CDR indicate a laboratory use case and there were no other sources to estimate the volume of DINP used in this OES, EPA developed a high-end bounding estimate based on the CDR reporting threshold, which by definition is expected to over-estimate the average release case. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate and the assessment provides a plausible estimate of releases, considering the strengths and limitations of reasonably available data.
Use of lubricants and functional fluids	EPA found limited chemical specific data for the use of lubricants and functional fluids OES and assessed releases to the environment using the ESD on the Lubricant and Lubricant Additives, which has a medium data quality rating based on systematic review (OECD, 2004b). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the ESD and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. EPA only identified one DINP-containing functional fluid for use in Monte Carlo analysis. Therefore, EPA used products containing DIDP as surrogate for concentration and use data in the analysis. This data provides more accurate estimates than the generic values provided by the ESD. The safety and product data sheets that EPA used to obtain these values have high data quality ratings based on systematic review. EPA based production volumes for the OES on rates cited by the ACC (2020) and referenced the *2003 EU Risk Assessment Report* (ECJRC, 2003b) for the expected U.S. DINP use rates per use scenario.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD may not represent releases from real-world sites using DINP-containing lubricants and functional fluids. In addition, EPA lacks information on the specific facility use rate of DINP-containing products and number of use sites; therefore, EPA estimated the number of sites and throughputs based on CDR, which has a reporting threshold of 25,000 lb (*i.e.*, not all potential sites represented), and an annual DINP production volume range that spans an order of magnitude. The respective share of DINP use for each OES presented in the *EU Risk Assessment Report* may differ from actual conditions adding some uncertainty to estimated releases. Furthermore, EPA lacks chemical-specific information on concentrations of DINP in lubricants and functional fluids and primarily relied on surrogate data. Actual concentrations may differ adding some uncertainty to estimated releases. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate and the assessment provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Fabrication and final use of products or articles	No data were available to estimate releases for this OES and there were no suitable surrogate release data or models. This release is described qualitatively.
Recycling and disposal	EPA found limited chemical specific data for the recycling and disposal OES. EPA assessed releases to the environment from recycling activities using the Revised Draft GS for the Use of Additives in Plastic Compounding as surrogate for the recycling process. The GS has a medium data quality rating based on systematic review (U.S. EPA, 2021d). EPA used EPA/OPPT models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using assumptions from the GS and EPA/OPPT models. EPA believes the strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential release values are more likely to capture actual releases than discrete values. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used DINP-specific data on concentrations in different DINP-containing PVC plastic products in the analysis to provide more accurate estimates than the generic values provided by the GS. The safety and product data sheets that EPA used to obtain these values have high data quality ratings based on systematic review. EPA referenced the Quantification and evaluation of plastic waste in the United States, which has a medium quality rating based on systematic review (Milbrandt et al., 2022), to estimate the rate of PVC recycling in the United States, and applied it to DINP PVC market share to define an approximate recycling volume of PVC containing DINP. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS represent all types of plastic compounding sites and may not represent sites that recycle PVC products containing DINP. In addition, EPA lacks DINP-specific PVC recycling rates and facility production volume data; therefore, EPA based throughput estimates on PVC plastics compounding data and U.S. PVC recycling rates, which are not specific to DINP, and may not accurately reflect current U.S. recycling volume. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, yet the assessment still provides a plausible estimate of releases, considering the strengths and limitations of the reasonably available data.

4.2 Occupational Exposures

For each OES, EPA considered the assessment approach, the quality of the data and models, and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine a weight of scientific evidence rating. EPA considered factors that increase or decrease the strength of the evidence supporting the release estimate—including quality of the data/information, applicability of the release or exposure data to the OES (including considerations of temporal relevance, locational relevance), and the representativeness of the estimate for the whole industry. As described in 4.1, the best professional judgment is summarized using the descriptors of robust, moderate, slight, or indeterminant. See EPA's Draft Systematic Review Protocol (U.S. EPA, 2021a) for additional information on weight of scientific evidence conclusions.

Table 4-2 provides a summary of EPA's overall confidence in its occupational exposure estimates for each of the OESs assessed.

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

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
Manufacturing	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the full-shift TWA inhalation exposure estimates for the Manufacturing OES. The primary strength is the use of directly applicable monitoring data, which are preferrable to other assessment approaches such as modeling or the use of OELs. EPA used PBZ air concentration data to assess inhalation exposures, with the data source having a high data quality rating from the systematic review process (ExxonMobil, 2022a). Data from these sources were DINP-specific from a DINP manufacturing facility, though it is uncertain whether the measured concentrations accurately represent the entire industry. A further strength of the data is that it was compared against an EPA developed Monte Carlo model and the data points from ExxonMobil were found to be more protective. The primary limitations of these data include the uncertainty of the representativeness of these data toward the true distribution of inhalation concentrations in this scenario, that the data come from one industry-source, and that 100% of the data for both workers and ONUs from the source were reported as below the LOD. EPA also assumed 8 exposure hours per day and 180 exposure days per year based on a manufacturing site reporting half-year DINP campaign runs (ExxonMobil, 2022b); it is uncertain whether this captures actual worker schedules and exposures at that and other manufacturing sites. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of exposures.
Import and repackaging	EPA used surrogate monitoring data from a DINP manufacturing facility to estimate worker inhalation exposures due to limited data available for import and repackaging inhalation exposures. The primary strength is the use of monitoring data, which are preferrable to other assessment approaches such as modeling or the use of OELs. EPA used PBZ air concentration data to assess inhalation exposures, with the data source having a high data quality rating from the systematic review process (ExxonMobil, 2022a). Data from these sources were DINP-specific from a DINP manufacturing facility, though it is uncertain whether the measured concentrations accurately represent the entire industry. The primary limitations of these data include the uncertainty of the representativeness of these data toward this OES and the true distribution of inhalation concentrations in this scenario; that the data come from one industry-source; and that 100% of the data for both workers and ONUs from the source were reported as below the LOD. EPA also assumed 8 exposure hours per day and 250 exposure days per year based on continuous DINP exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Incorporation into adhesives and sealants	EPA used surrogate monitoring data from a PVC converting facility to estimate worker inhalation exposures due to limited data. The primary strength is the use of monitoring data, which are preferrable to other assessment approaches such as modeling or the use of OELs. EPA used compiled PBZ concentration data from one study to assess inhalation exposures. Worker and ONU PBZ data are for oil mist exposures to DINP at a PVC roofing manufacturing site (Irwin, 2022). The data source has a high data quality rating from the systematic review process.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	The primary limitation of this data include the uncertainty of the representativeness of the monitoring data, as the data are specific to a PVC plastic converting facility, and it is uncertain whether the measured concentrations accurately represent the incorporation into adhesives and sealants. Another limitation is that the data comes from a singular source, and that the data for both workers and ONUs were reported as below the LOD. Monitoring data points were based on a 10-hour TWA with annual exposure of 200 days/year (Irwin, 2022); it is uncertain whether this captures actual worker schedules and exposures for the entire industry. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Incorporation into paints and coatings	EPA used surrogate monitoring data from a PVC converting facility to estimate worker inhalation exposures due to limited data. The primary strength is the use of monitoring data, which are preferrable to other assessment approaches such as modeling or the use of OELs. EPA used compiled PBZ concentration data from one study to assess inhalation exposures. Worker and ONU PBZ data are for oil mist exposures to DINP at a PVC roofing manufacturing site (Irwin, 2022). The data source has a high data quality rating from the systematic review process. The primary limitation of this data include the uncertainty of the representativeness of the monitoring data, as the data are specific to a PVC plastic converting facility, and it is uncertain whether the measured concentrations accurately represent the incorporation into paints and coatings. Another limitation is that the data comes from a singular source and that the majority of the data for both workers and ONUs were reported as below the LOD. Monitoring data points were based on a 10-hour TWA with annual exposure of 200 days/year (Irwin, 2022); it is uncertain whether this captures actual worker schedules and exposures for the entire industry. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Incorporation into other formulations, mixtures, and reaction products not covered elsewhere	EPA used surrogate monitoring data from a PVC converting facility to estimate worker inhalation exposures due to limited data. The primary strength is the use of monitoring data, which are preferrable to other assessment approaches such as modeling or the use of OELs. EPA used compiled PBZ concentration data from one study to assess inhalation exposures. Worker and ONU PBZ data are for oil mist exposures to DINP at a PVC roofing manufacturing site (Irwin, 2022). The data source has a high data quality rating from the systematic review process. The primary limitation of this data include the uncertainty of the representativeness of the monitoring data, as the data are specific to a PVC plastic converting facility, and it is uncertain whether the measured concentrations accurately represent the incorporation into other formulations, mixtures, and reaction products not covered elsewhere. Another limitation is that the data comes from a singular source and that the majority of the data for both workers and ONUs were reported as below the LOD. Monitoring data points were based on a 10-hour TWA with annual exposure of 200 days/year (Irwin, 2022); it is uncertain whether this captures actual worker schedules and exposures for the entire industry. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
PVC plastics compounding	EPA considered the assessment approach, the quality of the data, and the uncertainties in the assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates for PVC plastics compounding. EPA used monitoring data from a single combined plastics compounding and converting site to estimate worker inhalation exposures to vapor. This source provided both worker and ONU exposures (Irwin, 2022). The primary strength of this approach is that it uses monitoring data specific to this OES, which is preferrable to other assessment approaches, such as modeling or the use of OELs. Additionally, the data is also well characterized and the study sampled a variety of work areas and has a high data quality rating from the systematic review process. EPA also expects compounding activities to generate dust from solid PVC plastic products; therefore, EPA incorporated the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021c) into the assessment to estimate worker inhalation exposures to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the plastics industry and the resulting dataset contains 237 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of DINP in plastic using industry provided data on DINP concentration in PVC plastic. These data were also rated high for data quality in the systematic review process. The primary limitations of these data include uncertainty in the representativeness of the vapor monitoring data and the PNOR model in capturing the true distribution of inhalation concentrations for this OES. Additionally, the vapor monitoring dataset consisted of just two datapoints for workers and one for ONUs and 100% of the datapoints were reported as below the LOD. The OSHA CEHD dataset used in the PNOR model is not specific to DINP. Finally, EPA also assumed 8 exposure hours per day and 223-250 exposure days per year based on continuous DINP exposure during each working day for a typical worker schedule with the exposure day representing the 50th-95th percentile. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
PVC plastics converting	EPA considered the assessment approach, the quality of the data, and the uncertainties in the assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates for PVC plastics converting. EPA used monitoring data from a single combined plastics compounding and converting site to estimate worker inhalation exposures to vapor. This source provided both worker and ONU exposures (Irwin, 2022). The primary strength is this approach is that it uses monitoring data specific to this OES, which is preferrable to other assessment approaches such as modeling or the use of OELs. Additionally, the study data is well characterized, sampled from a variety of work areas, and has a high data quality rating from the systematic review process. EPA also expects converting activities to generate dust from solid PVC plastic products; therefore, EPA incorporated the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021c) into the assessment to estimate worker inhalation exposures to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the plastics industry and the resulting dataset contains 237 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of DINP in plastic using industry provided data on DINP concentration in PVC plastic. These data were also rated high for data quality in the systematic review process. The primary limitations of these data include uncertainty in the representativeness of the vapor monitoring data and the PNOR model in capturing the true distribution of inhalation concentrations for this OES. Additionally, the vapor monitoring dataset consisted of just two

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	datapoints for workers and one for ONUs and 100% of the datapoints were reported as below the LOD. The OSHA CEHD dataset used in the PNOR model is not specific to DINP. Finally, EPA also assumed 8 exposure hours per day and 219 to 250 exposure days per year based on continuous DINP exposure during each working day for a typical worker schedule with the exposure days representing the 50th-95th percentile. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Non-PVC material compounding	EPA used surrogate monitoring data from a PVC converting facility to estimate worker inhalation exposures to vapor, 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 estimate worker inhalation exposures to particulates. Non-PVC material compounding vapor inhalation exposures were estimated using study data from a single combined plastics compounding and converting site. The source provided worker and ONU exposures to vapor/mist and only worker exposures to dust (Irwin, 2022). The primary strength is the use of monitoring data for a similar OES, which are preferrable to other assessment approaches such as modeling or the use of OELs. Additionally, the data is also well characterized and the study sampled a variety of work areas and has a high data quality rating from the systematic review process. EPA also expects compounding activities to generate dust from solid PVC plastic products; therefore, EPA incorporated the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) into the assessment to estimate worker inhalation exposures to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the plastics industry and the resulting dataset contains 237 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of DINP in plastic using industry provided data on DINP concentration in PVC plastic. These data were also rated high for data quality in the systematic review process. The primary limitations of these data include uncertainty in the representativeness of the vapor monitoring data and the PNOR model in capturing the true distribution of inhalation concentrations for this OES. Additionally, the vapor monitoring dataset consisted of just two datapoints for workers and one for ONUs and 100% of the datapoints were reported as below the LOD. The OSHA CEHD dataset used in the PNOR model is not specific to DINP. Finally, EPA also assumed 8 exposure hours per day and 234 to 250 exposure days per year based on continuous DINP exposure during each working day for a typical worker schedule with the exposure days representing the 50th-95th percentile of exposure. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Non-PVC material converting	EPA used surrogate monitoring data from a PVC converting facility to estimate worker inhalation exposures to vapor, 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 estimate worker inhalation exposures to particulates. Non-PVC material converting vapor inhalation exposures were estimated using study data from a single combined plastics compounding and converting site. The source provided worker and ONU exposures to vapor/mist and only worker exposures to dust (Irwin, 2022). The primary strength is the use of monitoring data for a similar OES, which are preferrable to other assessment approaches such as modeling or the use of OELs. Additionally, the data is also well characterized and the study sampled a variety of work areas and has a high data quality rating from the systematic review process. EPA also expects compounding activities to generate dust from solid PVC plastic products; therefore, EPA incorporated the Generic Model for

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) into the assessment to estimate worker inhalation exposures to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the plastics industry and the resulting dataset contains 237 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of DINP in plastic using industry provided data on DINP concentration in PVC plastic. These data were also rated high for data quality in the systematic review process. The primary limitations of these data include uncertainty in the representativeness of the vapor monitoring data and the PNOR model in capturing the true distribution of inhalation concentrations for this OES. Additionally, the vapor monitoring dataset consisted of just two datapoints for workers and one for ONUs and 100% of the datapoints were reported as below the LOD. The OSHA CEHD dataset used in the PNOR model is not specific to DINP. Finally, EPA also assumed 8 exposure hours per day and 219-250 exposure days per year based on continuous DINP exposure during each working day for a typical worker schedule with the exposure days representing the 50th-95th percentile of exposure. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Application of adhesives and sealants	For inhalation exposure from spray application, EPA used surrogate monitoring data from the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a), which the systematic review process rated high for data quality. For inhalation exposure from non-spray application, EPA estimated vapor inhalation exposures using DINP monitoring data from PVC compounding and converting (Irwin, 2022), which the systematic review process rated high for data quality. EPA used SDSs and product data sheets from identified DINP-containing adhesives and sealant products to identify product concentrations. The primary limitation is the lack of DINP-specific monitoring data for the application of adhesives and sealants. For the spray application scenario, data outlined in the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry is representative of the level of mist exposure that could be expected at a typical work site for the given spray application method, but the data are not specific to DINP. For the non-spray application scenario, vapor exposure from volatilization is estimated using DINP-specific data, but for a different scenario which imposes uncertainty. EPA only assessed mist exposures to DINP over a full 8-hour work shift to estimate the level of exposure, though other activities may result in vapor exposures other than mist and application duration may be variable depending on the job site. EPA assessed a high end of 232-250 days of exposure per year based on workers applying coatings on every working day, however, application sites may use DINP-containing coatings at much lower or variable frequencies. The exposure days represent the 50th to 95th percentile range of exposure days per year. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Application of paints and coatings	For inhalation exposure from spray application, EPA used surrogate monitoring data from the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a), which the systematic review process rated high for data quality. For inhalation exposure from non-spray application, EPA estimated vapor inhalation exposures using DINP monitoring data from PVC compounding and converting (Irwin, 2022), which the systematic review process rated high for data quality. EPA used SDSs and product data sheets from identified DINP-containing products to identify product concentrations.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	The primary limitation is the lack of DINP-specific monitoring data for the application of paints and coatings. For the spray application scenario, data outlined in the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry is representative of the level of mist exposure that could be expected at a typical work site for the given spray application method, but the data are not specific to DINP. For the non-spray application scenario, vapor exposure from volatilization is estimated using DINP-specific data, but for a different scenario which imposes uncertainty. EPA only assessed mist exposures to DINP over a full 8-hour work shift to estimate the level of exposure, though other activities may result in vapor exposures other than mist and application duration may be variable depending on the job site. EPA assessed 250 days of exposure per year based on workers applying coatings on every working day, however, application sites may use DINP-containing coatings at much lower or variable frequencies. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Use of laboratory chemicals	EPA used surrogate monitoring data from a DINP manufacturing facility to estimate worker vapor inhalation exposures, 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) was used to characterize worker particulate inhalation exposures. The primary strength is the use of monitoring data, which are preferrable to other assessment approaches such as modeling or the use of OELs. EPA used PBZ air concentration data to assess inhalation exposures, with the data source having a high data quality rating from the systematic review process (ExxonMobil, 2022a). EPA incorporated the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) into the assessment to estimate worker inhalation exposures to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the plastics industry and the resulting dataset contains 33 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of DINP in identified DINP-containing products applicable to this OES. These data were also rated high for data quality in the systematic review process. The primary limitations of these data include uncertainty in the representativeness of the vapor monitoring data and the PNOR model in capturing the true distribution of inhalation concentrations for this OES; that the vapor monitoring data come from one industry-source; and that 100% of the data for both workers and ONUs from the source were reported as below the LOD; and that the OSHA CEHD dataset used in the PNOR model is not specific to DINP. EPA also assumed 8 exposure hours per day and 235-250 exposure days per year based on continuous DINP exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. The exposure days represent the 50th-95th percentile range of exposure days per year. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Use of lubricants and functional fluids	EPA used surrogate monitoring data from a DINP manufacturing facility to estimate worker inhalation exposures due to limited data. The primary strength is the use of monitoring data, which are preferrable to other assessment approaches such as modeling or the use of OELs. EPA used PBZ air concentration data to assess inhalation exposures, with the data source having a high data quality rating from the systematic review process (ExxonMobil, 2022a). Data from this source are DINP-specific and from a DINP manufacturing facility.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	The primary limitations of these data include the uncertainty of the representativeness of these data toward this OES and the true distribution of inhalation concentrations in this scenario; that the data come from one industry-source; and that 100% of the data for both workers and ONUs from the source were reported as below the LOD. EPA also assumed 8 exposure hours per day and 2 to 4 exposure days per year based on a typical equipment maintenance schedule; it is uncertain whether this captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures
Fabrication and final use of products or articles	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. EPA utilized the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021c) to estimate worker inhalation exposure to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the plastics industry and the resulting dataset contains 272 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of DINP in plastic using industry provided data on DINP concentration in PVC plastic. These data were also rated high for data quality in the systematic review process. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Additionally, the representativeness of the CEHD dataset and the identified DINP concentrations in plastics for this specific fabrication and final use of products or articles is uncertain. EPA lacks facility and DINP-containing product fabrication and use rates, methods, and operating times and EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous DINP exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Recycling and disposal	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. EPA utilized the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable Particulates Not Otherwise Regulated (PNOR) (U.S. EPA, 2021c) to estimate worker inhalation exposure to solid particulate. A strength of the model is that the respirable PNOR range was refined using OSHA CEHD datasets, which EPA tailored to the plastics industry and the resulting dataset contains 130 discrete sample data points. The systematic review process rated the source high for data quality (OSHA, 2020). EPA estimated the highest expected concentration of DINP in plastic using industry provided data on DINP concentration in PVC plastic. These data were also rated high for data quality in the systematic review process. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Additionally, the representativeness of the CEHD dataset and the identified DINP concentrations in plastics for this specific fabrication and final use of products or articles is uncertain. EPA lacks facility and DINP-containing product fabrication and use rates, methods, and operating times and EPA assumed 8 exposure hours per day and 223-250 exposure days per year based on continuous DINP exposure

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. The exposure days represent the 50th-95th percentile range of exposure days per year. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of exposures.
Dermal – liquids	EPA used *in vivo* rat absorption data for neat DINP (Midwest Research Institute, 1983) to estimate occupational dermal exposures to workers since exposures to the neat material or concentrated formulations are possible for occupational scenarios. Because rat skin generally has greater permeability than human skin (Scott et al., 1987), the use of *in vivo* rat absorption data is considered to be a conservative assumption. Also, it is acknowledged that variations in chemical concentration and co-formulant components affect the rate of dermal absorption. However, it is assumed that absorption of the neat chemical serves as a reasonable upper bound across chemical compositions and the data received a medium rating through EPA's systematic review process. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and that the chemical is contacted at least once per day. Because DINP has low volatility and low absorption, it is possible that the chemical remains on the surface of the skin after a dermal contact until the skin is washed. Therefore, absorption of DINP from occupational dermal contact with materials containing DINP may extend up to 8 hours per day (U.S. EPA, 1991a). For average adult workers, the surface area of contact was assumed equal to the area of one hand (*i.e.*, 535 cm^2), or two hands (*i.e.*, 1,070cm^2), for central tendency exposures, or high-end exposures, respectively (U.S. EPA, 2011). The standard sources for exposure duration and area of contact received high ratings through EPA's systematic review process. The occupational dermal exposure assessment for contact with liquid materials containing DINP was based on dermal absorption data for the neat material, as well as standard occupational inputs for exposure duration and area of contact, as described above. Based on the strengths and limitations of these inputs, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of occupational dermal exposures.
Dermal – solids	EPA used dermal modeling of aqueous materials (U.S. EPA, 2023a, 2004a) to estimate occupational dermal exposures of workers and ONUs to solid materials as described in Appendix D.2.1.2. The modeling approach for determining the aqueous permeability coefficient was used outside the range of applicability given the p-chem parameters of DINP. Also, it is acknowledged that variations in chemical concentration and co-formulant components affect the rate of dermal absorption. However, it is assumed that the aqueous absorption of a saturated solution of DINP serves as a reasonable upper bound for the potential dermal absorption of DINP from solid matrices, and the modeling approach received a medium rating through EPA's systematic review process. For modeling potential dermal exposure levels from solids containing DINP, EPA used the maximum value of water solubility from available data (NLM, 2015; Howard et al., 1985). These data sources for water solubility all received high ratings through EPA's systematic review process. By using the maximum value of water solubility from available data, rather than a water solubility value near the low-end of available data, EPA is providing a protective assessment for human health. For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and that the chemical is contacted at least once per day. Because DINP has low volatility and low absorption, it is possible that the chemical remains on the surface of the skin after a dermal contact until the skin is washed. Therefore, absorption of DINP from occupational dermal contact with materials containing DINP may extend up to 8 hours per day (U.S. EPA, 1991a). For average adult workers, the surface area of contact was assumed equal to the area

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	of one hand (*i.e.*, 535 cm^2), or two hands (*i.e.*, 1,070cm^2), for central tendency exposures, or high-end exposures, respectively (U.S. EPA, 2011). The standard sources for exposure duration and area of contact received high ratings through EPA's systematic review process. The occupational dermal exposure assessment for contact with solid materials containing DINP was based on dermal absorption modeling of aqueous DINP with the maximum value for aqueous solubility identified through systematic review, as well as standard occupational inputs for exposure duration and area of contact, as described above. Based on the strengths and limitations of these inputs, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a protective but plausible estimate of occupational dermal exposures.

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APPENDICES

Appendix A EXAMPLE OF ESTIMATING NUMBER OF WORKERS AND OCCUPATIONAL NON-USERS

This appendix summarizes the methods that EPA used to estimate the number of workers who are potentially exposed to DINP in each of its COUs. The method comprises the following steps:

1. Check relevant emission scenario documents (ESDs) and Generic Scenarios (GSs) for estimates on the number of workers potentially exposed.
2. Identify the NAICS codes for the industry sectors associated with each condition of use.
3. Estimate total employment by industry/occupation combination using the Bureau of Labor Statistics' Occupational Employment Statistics (OES) data (U.S. BLS, 2016).
4. Refine the OES estimates where they are not sufficiently granular by using the U.S. BLS (2016)Statistics of U.S. Businesses (SUSB) data on total employment by 6-digit NAICS.
5. Estimate the percentage of employees likely to be using DINP instead of other chemicals (*i.e.*, the market penetration of DINP in the condition of use).
6. Estimate the number of sites and number of potentially exposed employees per site.
7. Estimate the number of potentially exposed employees within the condition of use.

Step 1: Identifying Affected NAICS Codes

As a first step, EPA identified NAICS industry codes associated with each condition of use. EPA generally identified NAICS industry codes for a condition of use by:

- Querying the U.S. Census Bureau's *NAICS Search* tool using keywords associated with each condition of use to identify NAICS codes with descriptions that match the condition of use.
- Referencing EPA Generic Scenarios (GS's) and Organisation for Economic Co-operation and Development (OECD) Emission Scenario Documents (ESDs) for a condition of use to identify NAICS codes cited by the GS or ESD.
- Reviewing CDR data for the chemical, identifying the industrial sector codes reported for downstream industrial uses, and matching those industrial sector codes to NAICS codes using Table D-2 provided in the CDR reporting instructions (U.S. EPA, 2019).

Each condition of use section in the main body of this report identifies the NAICS codes EPA identified for the respective condition of use.

Step 2: Estimating Total Employment by Industry and Occupation

U.S. BLS (2016) OES data provide employment data for workers in specific industries and occupations. The industries are classified by NAICS codes (identified previously), and occupations are classified by Standard Occupational Classification (SOC) codes.

Among the relevant NAICS codes (identified previously), EPA reviewed the occupation description and identified those occupations (SOC codes) where workers are potentially exposed to DINP.

Table_Apx A-1 shows the SOC codes EPA classified as occupations potentially exposed to DINP. These occupations are classified as workers (W) and occupational non-users (O). All other SOC codes are assumed to represent occupations where exposure is unlikely.

Table_Apx A-1. SOCs With Worker and ONU Designation for All COUs Except Dry Cleaning

SOC	Occupation	Designation
11-9020	Construction Managers	O
17-2000	Engineers	O
17-3000	Drafters, Engineering Technicians, and Mapping Technicians	O
19-2031	Chemists	O
19-4000	Life, Physical, and Social Science Technicians	O
47-1000	Supervisors of Construction and Extraction Workers	O
47-2000	Construction Trades Workers	W
49-1000	Supervisors of Installation, Maintenance, and Repair Workers	O
49-2000	Electrical and Electronic Equipment Mechanics, Installers, and Repairers	W
49-3000	Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	W
49-9010	Control and Valve Installers and Repairers	W
49-9020	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	W
49-9040	Industrial Machinery Installation, Repair, and Maintenance Workers	W
49-9060	Precision Instrument and Equipment Repairers	W
49-9070	Maintenance and Repair Workers, General	W
49-9090	Miscellaneous Installation, Maintenance, and Repair Workers	W
51-1000	Supervisors of Production Workers	O
51-2000	Assemblers and Fabricators	W
51-4020	Forming Machine Setters, Operators, and Tenders, Metal and Plastic	W
51-6010	Laundry and Dry-Cleaning Workers	W
51-6020	Pressers, Textile, Garment, and Related Materials	W
51-6030	Sewing Machine Operators	O
51-6040	Shoe and Leather Workers	O
51-6050	Tailors, Dressmakers, and Sewers	O
51-6090	Miscellaneous Textile, Apparel, and Furnishings Workers	O
51-8020	Stationary Engineers and Boiler Operators	W
51-8090	Miscellaneous Plant and System Operators	W
51-9000	Other Production Occupations	W
W = worker designation; O = ONU designation		

For dry cleaning facilities, due to the unique nature of work expected at these facilities and that different workers may be expected to share among activities with higher exposure potential (*e.g.*, unloading the dry-cleaning machine, pressing/finishing a dry-cleaned load), EPA made different SOC code worker and ONU assignments for this condition of use. Table_Apx A-2 summarizes the SOC codes with worker and ONU designations used for dry cleaning facilities.

Table_Apx A-2. SOCs with Worker and ONU Designations for Dry Cleaning Facilities

SOC	Occupation	Designation
41-2000	Retail Sales Workers	O
49-9040	Industrial Machinery Installation, Repair, and Maintenance Workers	W
49-9070	Maintenance and Repair Workers, General	W
49-9090	Miscellaneous Installation, Maintenance, and Repair Workers	W
51-6010	Laundry and Dry-Cleaning Workers	W
51-6020	Pressers, Textile, Garment, and Related Materials	W
51-6030	Sewing Machine Operators	O
51-6040	Shoe and Leather Workers	O
51-6050	Tailors, Dressmakers, and Sewers	O
51-6090	Miscellaneous Textile, Apparel, and Furnishings Workers	O
W = worker designation; O = ONU designation		

After identifying relevant NAICS and SOC codes, EPA used BLS data to determine total employment by industry and by occupation based on the NAICS and SOC combinations. For example, there are 110,640 employees associated with 4-digit NAICS 8123 (*Drycleaning and Laundry Services*) and SOC 51-6010 (*Laundry and Dry-Cleaning Workers*).

Using a combination of NAICS and SOC codes to estimate total employment provides more accurate estimates for the number of workers than using NAICS codes alone. Using only NAICS codes to estimate number of workers typically result in an overestimate, because not all workers employed in that industry sector will be exposed. However, in some cases, BLS only provide employment data at the 4-digit or 5-digit NAICS level; therefore, further refinement of this approach may be needed (see next step).

Step 3: Refining Employment Estimates to Account for Lack of NAICS Granularity

The third step in EPA's methodology was to further refine the employment estimates by using total employment data in the U.S. Census Bureau (2015) SUSB. In some cases, BLS OES's occupation-specific data are only available at the 4- or 5-digit NAICS level, whereas the SUSB data are available at the 6-digit level (but are not occupation-specific). Identifying specific 6-digit NAICS will ensure that only industries with potential DINP exposure are included. As an example, OES data are available for the 4-digit NAICS 8123 *Drycleaning and Laundry Services*, which includes the following 6-digit NAICS:

- NAICS 812310 Coin-Operated Laundries and Drycleaners;
- NAICS 812320 Drycleaning and Laundry Services (except coin-operated);
- NAICS 812331 Linen Supply; and
- NAICS 812332 Industrial Launderers.

In this example, only NAICS 812320 may be of interest. The Census data allow EPA to calculate employment in the specific 6-digit NAICS of interest as a percentage of employment in the BLS 4-digit NAICS.

The 6-digit NAICS 812320 comprises 46 percent of total employment under the 4-digit NAICS 8123. This percentage can be multiplied by the occupation-specific employment estimates given in the BLS

OES data to further refine our estimates of the number of employees with potential exposure. Table_Apx A-3 illustrates this granularity adjustment for NAICS 812320.

Table_Apx A-3. Estimated Number of Potentially Exposed Workers and ONUs under NAICS 812320

NAICS	SOC CODE	SOC Description	Occupation Designation	Employment by SOC at 4-digit NAICS level	% of Total Employment	Estimated Employment by SOC at 6-digit NAICS level
8123	41-2000	Retail Sales Workers	O	44,500	46.0%	20,459
8123	49-9040	Industrial Machinery Installation, Repair, and Maintenance Workers	W	1,790	46.0%	823
8123	49-9070	Maintenance and Repair Workers, General	W	3,260	46.0%	1,499
8123	49-9090	Miscellaneous Installation, Maintenance, and Repair Workers	W	1,080	46.0%	497
8123	51-6010	Laundry and Dry-Cleaning Workers	W	110,640	46.0%	50,867
8123	51-6020	Pressers, Textile, Garment, and Related Materials	W	40,250	46.0%	18,505
8123	51-6030	Sewing Machine Operators	O	1,660	46.0%	763
8123	51-6040	Shoe and Leather Workers	O	Not Reported for this NAICS Code		
8123	51-6050	Tailors, Dressmakers, and Sewers	O	2,890	46.0%	1,329
8123	51-6090	Miscellaneous Textile, Apparel, and Furnishings Workers	O	0	46.0%	0
Total Potentially Exposed Employees				**206,070**		**94,740**
Total Workers						**72,190**
Total Occupation Non-users						**22,551**
W = worker; O = occupational non-user Note: numbers may not sum exactly due to rounding Source: (U.S. BLS, 2016; U.S. Census Bureau, 2015)						

Step 4: Estimating the Percentage of Workers Using DINP Instead of Other Chemicals
In the final step, EPA accounted for the market share by applying a factor to the number of workers determined in Step 3. This accounts for the fact that DINP may be only one of multiple chemicals used for the applications of interest. EPA did not identify market penetration data for any conditions of use. In the absence of market penetration data for a given condition of use, EPA assumed DINP may be used at up to all sites and by up to all workers calculated in this method as a bounding estimate. This assumes a market penetration of 100 percent. Market penetration is discussed for each condition of use in the main body of this report.

Step 5: Estimating the Number of Workers per Site
EPA calculated the number of workers and occupational non-users in each industry/occupation combination using the formula below (granularity adjustment is only applicable where SOC data are not available at the 6-digit NAICS level):

Number of Workers or ONUs in NAICS/SOC (Step 2) ´ Granularity Adjustment Percentage (Step 3) = Number of Workers or ONUs in the Industry/Occupation Combination

EPA then estimated the total number of establishments by obtaining the number of establishments reported in the U.S. Census Bureau's SUSB (U.S. Census Bureau, 2015) data at the 6-digit NAICS level.

EPA then summed the number of workers and occupational non-users over all occupations within a NAICS code and divided these sums by the number of establishments in the NAICS code to calculate the average number of workers and occupational non-users per site.

Step 6: Estimating the Number of Workers and Sites for a Condition of Use
EPA estimated the number of workers and occupational non-users potentially exposed to DINP and the number of sites that use DINP in a given condition of use through the following steps:

1. Obtaining the total number of establishments by:
    a. Obtaining the number of establishments from SUSB (U.S. Census Bureau, 2015) at the 6-digit NAICS level (Step 5) for each NAICS code in the condition of use and summing these values; or
    b. Obtaining the number of establishments from the TRI, DMR, NEI, or literature for the condition of use.
2. Estimating the number of establishments that use DINP by taking the total number of establishments from 1a and multiplying it by the market penetration factor from Step 4.
3. Estimating the number of workers and occupational non-users potentially exposed to DINP by taking the number of establishments calculated in 1b and multiplying it by the average number of workers and ONUs per site from Step 5.

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

This report assesses DINP inhalation exposures to workers in occupational settings, presented as 8-hour time weighted average (TWA). The full-shift TWA exposures are then used to calculate acute doses (AD), intermediate average daily doses (IADD), and average daily doses (ADD) for chronic non-cancer risks. This report also assesses DINP 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.

B.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 B-1.

Equation B-1.

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

Where:

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

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

Equation B-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 B-3.

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

Where:

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

WY = Working years per lifetime (yr)

B.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 B-4.

Equation B-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 B-5.

Equation B-5.

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

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 B-6.

Equation B-6.

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

Where:

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

B.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 B-7

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

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 does (mg/kg-day).

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

B.4 Acute, Intermediate, and Chronic (Non-cancer) Equation Inputs

EPA used the input parameter values in Table_Apx B-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 Appendix B.1 and B.2 and summarized in Table_Apx B-1.

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

Parameter Name	Symbol	Value	Unit
Exposure Duration	ED	8	h/day
Breathing Rate	BR	1.25	m^3/h
Exposure Frequency	EF	2–250[a]	days/yr
Exposure Frequency, Intermediate	EF_{int}	22	days
Days for Duration, Intermediate	ID	30	days
Working years	WY	31 (50th percentile) 40 (95th percentile)	years
Lifetime Years	LT	78	years
Body Weight	BW	80 (average adult worker) 72.4 (female of reproductive age)	kg
[a] Depending on OES			

B.4.1 Exposure Duration (ED)

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

B.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 m^3 of air in 8 hours or 1.25 m^3/hour (U.S. EPA, 1991b).

B.4.3 Exposure Frequency (EF)

EPA generally used 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 B-8.

$$EF = AWD \times f$$

Where:

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

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

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

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

For DINP, 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 B-9.

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

B.4.5 Intermediate Duration (ID)

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

B.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 and LADC calculations, respectively.

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

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

SIPP data include fields for the industry in which each surveyed, employed individual works (TJBIND1); worker age (TAGE); and years of work experience *with all employers* over the surveyed individual's lifetime[3] 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 years and older, (2) workers aged 60 and older, and (3) workers of all ages employed at time of survey. EPA used tenure data for age group "50 and older" to determine the high-end lifetime working years, because the sample size in this age group is often substantially higher than the sample size for age group "60 and older." For some industries, the number of workers surveyed, or the *sample size*, was too small to provide a reliable representation of the worker tenure in that industry. Therefore, EPA excluded data where the sample size is less than five from the analysis.

Table_Apx B-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.

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

Industry Sectors	Working Years			
	Average	50th Percentile	95th Percentile	Maximum
Manufacturing sectors (NAICS 31–33)	35.7	36	39	40
Non-manufacturing sectors (NAICS 42–81)	36.1	36	39	44

Source: (U.S. BLS, 2016)
Note: Industries where sample size is <5 were excluded from this analysis.

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

BLS CPS data provide the median years of tenure that wage and salary workers had been with their current employer. Table B3 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 B-3. Median Years of Tenure with Current Employer by Age Group

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

B.4.7 Lifetime Years (LT)

EPA assumed a lifetime of 78 years for all worker demographics.

B.4.8 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 C SAMPLE CALCULATIONS FOR CALCULATING ACUTE AND CHRONIC (NON-CANCER) INHALATION EXPOSURES

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

C.1 Inhalation Exposures

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

Calculating AD_{HE}:

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

$$AD_{HE} = \frac{\left(\left(5 \times 10^{-4}\ \frac{mg}{m^3} \times 10\,\frac{hr}{day}\right) + \left(2.1\,\frac{mg}{m^3} \times 8\,\frac{hr}{day}\right)\right) \times 1.25\,\frac{m^3}{hr}}{80\ kg} = 0.26\ \frac{\frac{mg}{kg}}{day}$$

Note: In this example, the first concentration (0.0005 mg/m^3) is the estimated vapor exposure over a 10-hour TWA and the second concentration value (2.1 mg/m^3) is the estimated dust exposure over an 8-hour TWA and thus they are split in the equation as shown. Most scenarios only have vapor or dust, typically not both.

Calculating $IADD_{HE}$:

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

$$IADD_{HE} = \frac{\left(\left(5 \times 10^{-4}\ \frac{mg}{m^3} \times 10\,\frac{hr}{day}\right) + \left(2.1\,\frac{mg}{m^3} \times 8\,\frac{hr}{day}\right)\right) \times 1.25\,\frac{m^3}{hr} \times 22\,\frac{days}{year}}{80\ kg \times 30\,\frac{days}{year}} = 0.19\ \frac{\frac{mg}{kg}}{day}$$

Calculating ADD_{HE}:

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

$$ADD_{HE} = \frac{\left(\left(5 \times 10^{-4}\ \frac{mg}{m^3} \times 10\,\frac{hr}{day}\right) + \left(2.1\,\frac{mg}{m^3} \times 8\,\frac{hr}{day}\right)\right) \times 1.25\,\frac{m^3}{hr} \times 250\,\frac{days}{year} \times 40\ years}{80\ kg \times 365\,\frac{days}{year} \times 40\ years}$$

$$= 0.18\,\frac{\frac{mg}{kg}}{day}$$

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

Calculating AD_{CT}:

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

$$AD_{CT} = \frac{\left(\left(2.5 \times 10^{-4}\ \frac{mg}{m^3} \times 10\,\frac{hr}{day}\right) + \left(0.10\,\frac{mg}{m^3} \times 8\,\frac{hr}{day}\right)\right) \times 1.25\,\frac{m^3}{hr}}{80\ kg} = 1.3 \times 10^{-2}\ \frac{\frac{mg}{kg}}{day}$$

Calculating $IADD_{CT}$:

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

$$IADD_{CT} = \frac{\left(\left(2.5 \times 10^{-4}\ \frac{mg}{m^3} \times 10\,\frac{hr}{day}\right) + \left(0.10\,\frac{mg}{m^3} \times 8\,\frac{hr}{day}\right)\right) \times 1.25\,\frac{m^3}{hr} \times 22\,\frac{days}{year}}{80\ kg \times 30\,\frac{days}{year}}$$

$$= 9.5 \times 10^{-3}\ \frac{\frac{mg}{kg}}{day}$$

Calculating ADD_{CT}:

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

$$ADD_{CT} = \frac{\left(\left(2.5 \times 10^{-4}\ \frac{mg}{m^3} \times 10\,\frac{hr}{day}\right) + \left(0.10\,\frac{mg}{m^3} \times 8\,\frac{hr}{day}\right)\right) \times 1.25\,\frac{m^3}{hr} \times 223\,\frac{days}{year} \times 31\ years}{80\ kg \times 365\,\frac{days}{year} \times 31\ years}$$

$$= 7.9 \times 10^{-3}\,\frac{\frac{mg}{kg}}{day}$$

C.2 Dermal Exposures

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

Calculating AD_{HE}:

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

$$AD_{HE} = \frac{12\,\frac{mg}{day}}{80\ kg} = 0.16\,\frac{mg}{kg\text{-}day}$$

Calculate $IADD_{HE}$:

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

$$IADD_{HE} = \frac{12\,\frac{mg}{day} \times 22\,\frac{day}{yr}}{80\ kg \times 30\,\frac{day}{yr}} = 0.11\,\frac{mg}{kg\text{-}day}$$

Calculate ADD_{HE} (non-cancer):

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

$$ADD_{HE} = \frac{12\,\frac{mg}{day} \times 250\,\frac{day}{yr} \times 40\ years}{80\ kg \times 365\,\frac{day}{yr} \times 40\ years} = 0.11\,\frac{mg}{kg\text{-}day}$$

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

Calculating AD_{CT}:

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

$$AD_{CT} = \frac{6.2\,\frac{mg}{day}}{80\ kg} = 7.8 \times 10^{-2}\,\frac{mg}{kg\text{-}day}$$

Calculating $IADD_{CT}$:

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

$$IADD_{CT} = \frac{6.2\,\frac{mg}{day} \times 22\,\frac{days}{yr}}{80\ kg \times 30\,\frac{days}{yr}} = 5.7 \times 10^{-2}\,\frac{mg}{kg\text{-}day}$$

Calculate ADD_{CT} (non-cancer):

$$ADD_{CT} = \frac{APDR \times EF \times WY}{BW \times 365\,\frac{day}{yr} \times WY}$$

$$ADD_{CT} = \frac{6.2\,\frac{mg}{day} \times 223\,\frac{days}{yr} \times 31\ yrs}{80\ kg \times 365\,\frac{day}{yr} \times 31\ yrs} = 4.8 \times 10^{-2}\,\frac{mg}{kg\text{-}day}$$

Appendix D DERMAL EXPOSURE ASSESSMENT METHOD

D.1 Dermal Dose Equation

As described in Section 2.4.4, occupational dermal exposures to DINP are characterized using a flux-based approach to dermal exposure estimation. Therefore, EPA used Equation D-1 to estimate the acute potential dose rate (APDR) from occupational dermal exposures. The APDR (units of mg/day) characterizes the quantity of chemical that is potentially absorbed by a worker on a given workday.

Equation D-1.

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

Where:

J = Average absorptive flux through and into skin (mg/cm²/h);
S = Surface area of skin in contact with the chemical formulation (cm²);
t_{abs} = Duration of absorption (h/day)
PF = Glove protection factor (unitless, $PF \geq 1$)

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

D.2 Parameters of the Dermal Dose Equation

Table_Apx D-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 D-1. Summary of Dermal Dose Equation Values

Input Parameter	Symbol	Value	Unit	Rationale
Absorptive Flux	J	Dermal Contact with Liquids: 1.46E−03 Dermal Contact with Solids: 5.75E−06	mg/cm²/h	See Appendix D.2.1
Surface Area	S	Workers: 535 (central tendency) 1,070 (high-end) Females of reproductive age: 445 (central tendency) 890 (high-end)	cm²	See Appendix D.2.2
Absorption time	t_{abs}	8	hr	See Appendix D.2.3
Glove Protection Factor	PF	1; 5; 10; or 20	unitless	See Appendix D.2.4

D.2.1 Absorptive Flux

D.2.1.1 Dermal Contact with Liquids or Formulations Containing DINP

As described in Section 2.4.4.1, the work of the Midwest Research Institute (1983) showed that the highest expected steady-state absorptive flux of neat DINP from a finite dose application (*i.e.*, approximately 8 mg/cm^2) was estimated as 1.46 $\times 10^{-3}$ mg/cm^2/h. Because the data comes from a finite dose scenario of the neat material similar to occupational exposures, EPA considers the dermal absorption data from the Midwest Research Institute (1983) to be representative of occupational dermal exposures to liquids or formulations containing DINP. Though it is possible that lower concentration materials exhibit higher fluxes than the neat material due to the properties of the vehicle of absorption, the flux of the neat material serves as a reasonable upper bound of potential flux across concentrations. Using flowchart presented in Figure 3 in OECD 156 (OECD, 2011d), it is suggested that an exposure assessor should use dermal absorption data from a realistic surrogate formulation or material if there are no data on absorption of the exact material under investigation. Because there were only acceptable dermal absorption data for neat DINP, and workers are reasonably exposed to the neat material or concentrated formulations, EPA considered the dermal absorption of neat DINP to be representative across chemical concentrations.

Using the work of Kissel (2011) to interpret the absorption data from the Midwest Research Institute (1983), it was determined that dermal absorption of DINP may be flux-limited, even for finite doses (*i.e.*, <10 µL/cm^2 for liquids (OECD, 2004c)). Therefore, the steady-state flux (*i.e.*, 1.46 $\times 10^{-3}$ mg/cm^2/h) reported by the Midwest Research Institute was assumed for the duration of chemical retention on the skin, which is expected to last up to 8 hours in occupational settings. However, it is also important to consider the magnitude of dermal loading of DINP in occupational settings to ensure there is enough material present on the skin to support the assumption of the steady-state flux for an 8-hour shift. For contact with liquids in occupational settings, EPA assumes a range of dermal loading of 0.7 to 2.1 mg/cm^2 (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/cm^2 and a high-end (95th percentile) dermal loading value of 2.1 mg/cm^2 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/cm^2 (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/cm^2 and a high-end (95th percentile) value of 10.3 mg/cm^2 for scenarios aligned with dermal immersion in liquids.

The absorptive flux of DINP reported by the Midwest Research Institute (1983) would result in maximum absorption of 1.2 $\times 10^{-2}$ mg/cm^2 over an 8-hour period. Therefore, the high-end dermal exposure estimate for liquids containing DINP is quite reasonable with respect to the amount of material that may be available for absorption in an occupational setting.

D.2.1.2 Dermal Contact with Solids or Articles Containing DINP

As described in Section 2.4.4.2, the average absorptive flux of DINP from solid matrices is expected to vary between 3.0$\times 10^{-6}$ and 1.6 $\times 10^{-5}$ mg/cm^2/hour for durations between 1-hour and 1-day based on aqueous absorption modeling from U.S. EPA (2004a). Using Equation 2-2 from Section 2.4.4.2, the average absorptive flux of DINP over an 8-hour exposure period is calculated as 5.75 $\times 10^{-6}$ mg/cm^2/h. Because exposures to solids containing DINP may extend up to 8 hours in occupational settings, the 8-hr time weighted average (TWA) aqueous flux value of 5.75 $\times 10^{-6}$ mg/cm^2/h was chosen as a representative value for dermal exposures to solids or articles containing DINP. However, the aqueous dermal exposure model assumes that DINP absorbs as a saturated aqueous solution (*i.e.*, concentration of absorption is equal to water solubility), which would be the maximum concentration of absorption of DINP expected from a solid material. Also, EPA used the maximum value of water solubility from available data, as shown in Section 2.4.4.2, rather than a value near the low-end of the range of available data. Therefore, the estimates of dermal exposure to DINP from solid materials are considered realistic but on the conservative end of expected dermal exposures.

Using the work of Kissel (2011) to interpret the dermal modeling results for aqueous DINP, it was determined that dermal absorption of DINP may be flux-limited, even for finite doses (*i.e.*, typically 1 to 5 mg/cm^2 for solids (OECD, 2004c)). Therefore, the 8-hour TWA flux (*i.e.*, 5.75 $\times 10^{-6}$ mg/cm^2/h) of aqueous DINP was assumed for the duration of chemical retention on the skin, which is expected to last up to 8 hours in occupational settings. However, it is also important to consider the magnitude of dermal loading of DINP in occupational settings to ensure there is enough material present on the skin to support the assumption of the steady-state flux for an 8-hour shift. 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 to 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 to 95th percentile from Lansink et al. (1996)) as shown in the ChemSTEER Manual (U.S. EPA, 2015).

The average absorptive flux of DINP for an 8-hour absorption period, as determined through modeling efforts (U.S. EPA, 2022b, 2004a), would result in maximum absorption of 4.6×10^{-5} mg/cm^2 over an 8-hour period. Therefore, the high-end dermal exposure estimate for solids containing DINP is quite reasonable with respect to the amount of material that may be available for absorption in an occupational setting.

D.2.2 Surface Area

Regarding surface area of occupational dermal exposure, EPA assumed a high-end value of 1,070 cm^2 for male workers and 890 cm^2 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 cm^2 for male workers and 445 cm^2 for female workers).

It should be noted that while the surface area of exposed skin is derived from data for hand surface area, EPA did not assume that only the workers hands may be exposed to the chemical. Nor did EPA assume that the entirety of the hands is exposed for all activities. Rather, EPA assumed that dermal exposures occur to some portion of the hands plus some portion of other body parts (*e.g.*, arms) such that the total exposed surface area is approximately equal to the surface area of one or two hands for the central tendency and high-end exposure scenario, respectively.

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

D.2.4 Glove Protection Factors

Gloves may mitigate dermal exposures, if used correctly and consistently. However, data about the frequency of effective glove use (*i.e.*, the proper use of effective gloves) – is very limited in industrial settings. Initial literature review suggests that there is unlikely to be sufficient data to justify a specific probability distribution for effective glove use for a chemical or industry. Instead, the impact of effective glove use should be explored by considering different percentages of effectiveness (*e.g.*, 25 vs. 50% 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 though 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). Whereas, 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 D-2 presents the PF values from ECETOC TRA model (Version 3). In the exposure data used to evaluate the ECETOC TRA model, Marquart (2017) reported that the observed glove protection factor was 34, compared to PF values of 5 or 10 used in the model.

Table_Apx D-2. 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.e.*, as b above) with "basic" employee training		90	10
d. Chemically resistant gloves in combination with specific activity training (*e.g.*, procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur	Industrial users only	95	20

Appendix E ENVIRONMENTAL RELEASES AND OCCUPATIONAL EXPOSURE ASSESSMENT

E.1 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/OPPT models, ESDs, and/or GSs. An individual model input parameter could either have a discrete value or a distribution of values. EPA assigned statistical distributions based on reasonably available literature data. 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.

E.1.1 EPA/OPPT Standard Models

This appendix section discusses the standard models used by EPA to estimate environmental releases of chemicals and occupational inhalation exposures. All the models presented in this section are models that were previously developed by EPA and are not the result of any new model development work for this risk evaluation. Therefore, this appendix does not provide the details of the derivation of the model equations which have been provided in other documents such as the *ChemSTEER User Guide* (U.S. EPA, 2015), *Chemical Engineering Branch Manual for the Preparation of Engineering Assessments, Volume 1* (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 (Associates, 1988). The models include loss fraction models as well as models for estimating chemical vapor generation rates used in subsequent model equations to estimate the volatile releases to air and occupational inhalation exposure concentrations. The parameters in the equations of this appendix section are specific to calculating environmental releases and occupational inhalation exposures to DINP.

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

Equation E-1.

$$G_{activity} = \frac{(8.24 \times 10^{-8}) * (MW_{DINP}^{0.835}) * F_{correction\_factor} * VP * \sqrt{Rate_{air\_speed}} * (0.25\pi D_{opening}^{2}) \sqrt[4]{\frac{1}{29} + \frac{1}{MW_{DINP}}}}{T^{0.05} * \sqrt{D_{opening}} * \sqrt{P}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
MW_{DINP}	=	DINP molecular weight (g/mol)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	DINP vapor pressure (torr)
$Rate_{air\_speed}$	=	Air speed (cm/s)
$D_{opening}$	=	Diameter of opening (cm)
T	=	Temperature (K)
P	=	Pressure (torr)

The EPA/OPPT Mass Transfer Coefficient Model estimates releases to air from the evaporation of a chemical from an open, exposed liquid surface. This model is appropriate for determining this type of volatile release from activities that are performed outdoors or when air velocities are expected to be greater than 100 feet per minute. The EPA/OPPT Mass Transfer Coefficient Model calculates the average vapor generation rate of the chemical from the exposed liquid surface using the following equation:

Equation E-2.

$$G_{activity} = \frac{(1.93 \times 10^{-7}) * \left(MW_{DINP}{}^{0.78}\right) * F_{correction\_factor} * VP * Rate_{air\_speed}^{0.78} * (0.25\pi D_{opening}^{2})\sqrt[3]{\frac{1}{29} + \frac{1}{MW_{DINP}}}}{T^{0.4} D_{opening}^{0.11} (\sqrt{T} - 5.87)^{2/3}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
MW_{DINP}	=	DINP molecular weight (g/mol)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	DINP 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 model calculates the average vapor generation rate from loading or unloading using the following equation:

Equation E-3.

$$G_{activity} = \frac{F_{saturation\_factor} * MW_{DINP} * V_{container} * 3785.4\frac{cm^3}{gal} * F_{correction\_factor} * VP * \frac{RATE_{fill}}{3600\frac{s}{hr}}}{R * T}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
$F_{saturation\_factor}$	=	Saturation factor (unitless)
MW_{DINP}	=	DINP molecular weight (g/mol)
$V_{container}$	=	Volume of container (gal/container)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)

VP	=	DINP vapor pressure (torr)
$RATE_{fill}$	=	Fill rate of container (containers/h)
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 DINP 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 DINP in the liquid of interest. Using the mass fraction of DINP 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 DINP, 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 DINP, the mass fraction of DINP will be an overestimate of the mole fraction. If other components in the liquid of interest have much higher molecular weights than DINP, the mass fraction of DINP will underestimate the mole fraction.

If calculating an environmental release, the vapor generation rate calculated from one of the above models (Equation E-1, Equation E-2, and Equation E-3) is then used along with an operating time to calculate the release amount:

Equation E-4.

$$Release\_Year_{activity} = Time_{activity} * G_{activity} * 3600\,\frac{s}{hr} * 0.001\,\frac{kg}{g}$$

Where:

$Release\_Year_{activity}$	=	DINP released for activity per site-year (kg/site-yr)
$Time_{activity}$	=	Operating time for activity (h/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/OPPT Small Container Residual Model
- EPA/OPPT Drum Residual Model
- EPA/OPPT Bulk Transport Residual Model
- EPA/OPPT Multiple Process Vessel Residual Model
- EPA/OPPT Single Process Vessel Residual Model
- EPA/OPPT Solid Residuals in Transport Containers Model
- March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

The loss fraction models apply a given loss fraction to the overall throughput of DINP for the given process. The loss fraction value or distribution of values differs for each model; however, the models each follow the same general equation based on the approaches described for each OES:

Equation E-5.

$$Release\_Year_{activity} = PV * F_{activity\_loss}$$

Where:

$Release\_Year_{activity}$	=	DINP released for activity per site-year (kg/site-yr)

PV	=	Production volume throughput of DINP (kg/site-yr)
$F_{activity\_loss}$	=	Loss fraction for activity (unitless)

The EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Dust Release Model) 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 Dust Release Model 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 E-6.

$$Elocal_{dust\_not\_captured} = Elocal_{dust\_generation} * \left(1 - F_{dust\_capture}\right)$$

Where:

$Elocal_{dust\_not\_captured}$	=	Daily amount emitted from transfers/unloading that is not captured (kg not captured/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg generated/site-day)
$F_{dust\_capture}$	=	Capture technology efficiency (kg captured/kg generated)

Equation E-7.

$$Elocal_{dust\_cap\_uncontrol} = Elocal_{dust\_generation} * F_{dust\_capture} * \left(1 - F_{dust\_control}\right)$$

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 E-8.

$$Elocal_{dust\_cap\_control} = Elocal_{dust\_generation} * F_{dust\_capture} * F_{dust\_control}$$

Where:

$Elocal_{dust\_cap\_control}$	=	Daily amount captured and removed by control technology from transfers/unloading (kg controlled/site-day)
$Elocal_{dust\_generation}$	=	Daily release of dust from transfers/unloading (kg generated/site-day)
$F_{dust\_capture}$	=	Capture technology efficiency (kg captured/kg generated)
$F_{dust\_control}$	=	Control technology removal efficiency (kg controlled/kg captured)

EPA uses the above equations in the DINP environmental release models, and EPA references the model equations by model name and/or equation number within Appendix E.

E.2 Manufacturing Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases and occupational exposures for DINP during the manufacturing OES. This approach utilizes the *Virtual Tour of the Exxon Mobil Baton Rouge Chemical Plant DIDP/DINP Production Facility* (ExxonMobil virtual tour) (ExxonMobil, 2022b) and CDR data (U.S. EPA, 2020a) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on ExxonMobil's virtual tour (ExxonMobil, 2022b), 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: Crude and Final Filtrations.
- Release source 4: Product Sampling Wastes.
- Release source 5: Open Surface Losses to Air During Product Sampling.
- Release source 6: Equipment Cleaning Wastes.
- Release source 7: Open Surface Losses to Air During Equipment Cleaning.
- Release source 8: Transfer Operation Losses to Air from Packaging Manufactured DINP into Transport Containers.
- Release source 9: Container Cleaning Wastes.

Environmental releases for DINP during manufacturing are a function of DINP'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, DINP 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.

E.2.1 Model Equations

Table_Apx E-1 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the manufacturing OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix E.2.2. The Monte Carlo simulation calculated the total DINP 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 E-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 E-9	Q_{DINP_day}; F_{DINP_SPERC}
Release source 2: Process Waste from Reaction/Separations/Other Process Operations	See Equation E-10	Q_{DINP_day}; WS_{DINP}
Release source 3: Crude and Final Filtrations	See Equation E-11	Q_{DINP_day}; $LF_{filtration}$
Release source 4: Product Sampling Wastes	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix E.1)	Q_{DINP_day}; $LF_{sampling}$
Release source 5: Open Surface Losses to Air During Product Sampling	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; MW; VP; $RATE_{air\_speed}$; $D_{sampling}$; T; P Operating Time: $OH_{sampling}$
Release source 6: Equipment Cleaning Wastes	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{equip_clean}
Release source 7: Open Surface Losses to Air During Equipment Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; MW; VP; $RATE_{air\_speed}$; D_{equip_clean}; T; P Operating Time: OH_{equip_clean}
Release source 8: Transfer Operation Losses to Air from Packaging Manufactured DINP into Transport Containers	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{DINP}; VP; f_{sat}; MW; R; T; $RATE_{fill\_drum}$ Operating Time: $N_{prodcont\_yr}$; $RATE_{fill\_cont}$; $RATE_{fill\_drum}$; OD
Release source 9: Container Cleaning Wastes	EPA/OPPT Bulk Transport Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{bulk}

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

Equation E-9.

$$Release\_perDay_{RP1} = Q_{DINP\_day} * F_{DINP\_SPERC}$$

Where:

$Release\_perDay_{RP1}$ = DINP released for release source 1 (kg/site-day)
Q_{DINP_day} = Facility throughput of DINP (kg/site-day)
F_{DINP_SPERC} = Loss fraction for unit operations (unitless)

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

Equation E-10.

$$Release\_perDay_{RP2} = Q_{DINP_{day}} * \frac{WS_{DINP}}{1000}$$

Where:

$Release\_perDay_{RP2}$	=	DINP released for release source 2 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
WS_{DINP}	=	Water solubility for DINP (g/L)

Release source 3 daily release (Crude and Final Filtrations) is calculated using the following equation. Note that this release point is calculated differently for the site with a non-CBI production volume, and for the other three sites that claimed their production volumes (PVs) as CBI:

Equation E-11.

$$Release\_perDay_{RP3} = Q_{DINP_{day}} * LF_{filtration} \text{ (1 site with non-CBI PV)}$$

or

$$Release\_perDay_{RP3} = Q_{filtration\_release} \text{ (5 sites with CBI PVs)}$$

Where:

$Release\_perDay_{RP3}$	=	DINP released for release source 3 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
$LF_{filtration}$	=	Loss fraction for filtration (unitless)
$Q_{filtration\_release}$	=	Estimated daily filtration releases from ExxonMobil virtual tour (kg/site-day)

E.2.2 Model Input Parameters

Table_Apx E-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 E-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	
Facility Production Rate – Site with Non-CBI PVs	PV	kg/site-yr	40,191	–	–	–	–	See Section E.2.4
Assessed Production Rate for Facilities with PVs claimed as CBI (CASRN 28553-12-0)	PV	kg/site-yr	3,219,635	951,673	3,219,635	–	Uniform	See Section E.2.4
Assessed Production Rate for Facilities with PVs claimed as CBI (CASRN 68515-48-0)	PV	kg/site-yr	90,535,821	8,889,194	90,535,821	–	Uniform	See Section E.2.4
Manufactured DINP Concentration – Sites with Non-CBI Concentrations	F_{DINP}	kg/kg	1	0.9	1	–	Uniform	See Section E.2.7
Manufactured DINP Concentration – Sites with Concentrations Claimed as CBI	F_{DINP}	kg/kg	0.995	0.9	1	0.995	Triangular	See Section E.2.7
Air Speed	$RATE_{air\_speed}$	ft/min	19.7	2.56	398	–	Lognormal	See Section E.2.8
Diameter of Sampling Opening	$D_{sampling}$	cm	2.5	2.5	10	2.5	Triangular	See Section E.2.9
Diameter of Equipment Opening	D_{equip_clean}	cm	92	–	–	–	–	See Section E.2.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.2.10
Drum Size	V_{drum}	gal	55	20	100	55	Triangular	See Section E.2.11
Bulk Container Size	V_{cont}	gal	20,000	5,000	20,000	20,000	Triangular	See Section E.2.11
Bulk Container Loss Fraction	LF_{bulk}	kg/kg	0.0007	0.0002	0.002	0.0007	Triangular	See Section E.2.12
Loss Fraction for Filtration Releases (PV1 and CASRN 28553-12-0)	$LF_{filtration}$	kg/kg	0.0176	0.00173	0.0176	–	Uniform	See Section E.2.13

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Fraction of DINP Lost During Sampling – 1 (Q_{DINP_day} <50 kg/site-day)	$F_{sampling\_1}$	kg/kg	0.02	0.002	0.02	0.02	Triangular	See Section E.2.14
Fraction of DINP Lost During Sampling – 2 (Q_{DINP_day} 50–200 kg/site-day)	$F_{sampling\_2}$	kg/kg	0.005	0.0006	0.005	0.005	Triangular	See Section E.2.14
Fraction of DINP Lost During Sampling – 3 (Q_{DINP_day} 200–5,000 kg/site-day)	$F_{sampling\_3}$	kg/kg	0.004	0.0005	0.004	0.004	Triangular	See Section E.2.14
Fraction of DINP Lost During Sampling – 4 (Q_{DINP_day} >5,000 kg/site-day)	$F_{sampling\_4}$	kg/kg	0.0004	0.00008	0.0004	0.0004	Triangular	See Section E.2.14
Number of Sites	Ns	sites	6	–	–	–	–	See Section E.2.3
Operating Days	OD	days/yr	180	–	–	–	–	See Section E.2.15
Vapor Pressure at 25C	VP	mmHg	5.40E−07	–	–	–	–	Physical property
Vapor Pressure at 140F	VP_{140}	mmHg	5.21E−05	–	–	–	–	Physical property, surrogated from DIDP
Vapor Pressure at 250F	VP_{250}	mmHg	6.16E−03	–	–	–	–	Physical property, surrogated from DIDP
Vapor Pressure at 375F	VP_{375}	mmHg	0.283	–	–	–	–	Physical property, surrogated from DIDP
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Process Operation Emission Factor	F_{DINP_SPERC}	kg/kg	0.001	–	–	–	–	See Section E.2.16

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Water Solubility of DINP	WS_{DINP}	g/L	0.00020	–	–	–	–	Physical property
Exxon Filtration Release Amount	$Q_{filtration\_release}$	kg/day	869	–	–	–	–	See Section E.2.13
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Equipment cleaning loss fraction	LF_{equip_clean}	kg/kg	0.02	–	–	–	–	See Section E.2.17
Drum Fill Rate	$RATE_{fill\_drum}$	drums/h	20	–	–	–	–	See Section E.2.18
Bulk Container Fill Rate	$RATE_{fill\_cont}$	containers/h	1	–	–	–	–	See Section E.2.18
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property
Mixing Factor	F_{mixing}	dimensionless	0.5	0.1	1	0.5	Triangular	See Section E.2.19

E.2.3 Number of Sites

EPA used 2020 CDR data (U.S. EPA, 2020a) to identify the number of sites that manufacture DINP. In CDR, six sites reported domestic manufacturing of DINP. Table_Apx E-3 presents the names and locations of these sites.

The production volume data associated with each site is discussed in Section E.2.4.

Table_Apx E-3. Sites Reporting to CDR for Domestic Manufacture of DINP

Facility Name	Facility Location
Gehring-Montgomery	Warminster, PA
ExxonMobil	Baton Rouge, LA
ExxonMobil	Spring, TX
Teknor Apex	Brownsville, TN
Bostik Inc.	Wauwatosa, WI
CBI Site	Unknown

E.2.4 Throughput Parameters

EPA ran the Monte Carlo model once to estimate releases and exposures from the single site with a non-CBI production volume, once to estimate releases and exposures from the three sites that reported under CASRN 28553-12-0 with production volumes (PV) as CBI, and once to estimate releases and exposures from two sites that reported under CASRN 68515-48-0 with PVs as CBI. EPA used 2020 CDR data (U.S. EPA, 2020a) to identify annual facility PV for each site. Out of the six sites that reported domestic manufacturing of DINP in CDR, only one site provided a non-CBI production volume. Gehring-Montgomery reported 88,607 pounds (40,191 kg) of DINP manufactured.

For the other five sites, EPA used a uniform distribution set within the national PV range for each CASRN (DINP encompasses two CASRNs). EPA calculated the bounds of the range by taking the total PV range in CDR and subtracting out the PVs that belonged to sites with non-CBI PVs (both MFG and import). Then, for each bound of the PV range for the remaining sites, EPA divided the value by the number of sites with CBI PVs for each CASRN. CDR estimates a total national DINP PV of 50,000,000 to 100,000,000 lb for CASRN 28533-12-0 and 100,000,000 to 1,000,000,000 lb for CASRN 68515-48-0. Based on the non-CBI PVs from importers and manufacturers, the total PV associated with the three sites with CBI PVs for CASRN 28533-12-0 is 2,098,080 to 7,098,080 lb/site-yr, and the total PV associated with the two sites with CBI PVs for CASRN 68515-48-0 is 19,597,318 to 199,597,318 lb/site-yr. Based on this (and converting pounds to kilograms), EPA set a uniform distribution of 951,673 kg/site-yr, and an upper bound of 3,219,635 kg/site-yr for CASRN 28533-12-0 and a uniform distribution of 8,889,194 kg/site-yr, and an upper bound of 90,535,821 kg/site-yr for CASRN 68515-48-0.

The daily throughput of DINP is calculated using Equation E-12 by dividing the annual production volume per site by the number of operating days. The number of operating days is determined according to Section E.2.15.

Equation E-12.

$$Q_{DINP\_day} = \frac{PV}{OD}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
PV	=	Annual production volume (kg/site-yr)
OD	=	Operating days (see Section E.2.15) (days/yr)

E.2.5 Number of Containers per Year

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

Equation E-13.

$$N_{prodcont\_yr} = \frac{PV}{RHO * \left(3.79 \frac{L}{gal}\right) * V_{drum/cont}}$$

Where:

$N_{prodcont\_yr}$	=	Annual number of product containers (container/site-year)
$V_{drum/cont}$	=	Product container volume (see Section E.2.11) (gal/container)
PV	=	Facility production rate (see Section E.2.4) (kg/site-year)
RHO	=	DINP density (kg/L)

E.2.6 Operating Hours

EPA estimated operating hours using ExxonMobil's virtual tour (ExxonMobil, 2022b), and through calculation from other parameters. Worker activities with operating hours provided from ExxonMobil's virtual tour include product sampling, equipment cleaning, and loading.

For product sampling (release point 5), ExxonMobil stated via their virtual tour that one h/day is spent on product sampling (ExxonMobil, 2022b). This is consistent with the default value provided in the *ChemSTEER User Guide* (U.S. EPA, 2015).

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).

The operating hours for loading of DINP into transport containers (release point 8) is calculated based on the number of product containers filled at the site and the fill rate using the following equation:

Equation E-14.

$$Time_{RP8} = \frac{N_{prodcont\_yr}}{RATE_{fill\_drum/cont} * OD}$$

Where:

$Time_{RP8}$	=	Operating time for release point 8 (h/site-day)
$RATE_{fill\_drum/cont}$	=	Fill rate of container, dependent on volume (see Section E.2.18) (containers/h)
$N_{prodcont\_yr}$	=	Annual number of product containers (see Section E.2.5) (containers/site-year)
OD	=	Operating days (see Section E.2.15) (days/site-year)

E.2.7 Manufactured DINP Concentration

For the site that provided details in CDR (Gehring-Montgomery), EPA used the manufactured concentration range reported in CDR (U.S. EPA, 2020a) to make a uniform distribution of 90-100 percent DINP.

CDR Data from the remaining five sites indicated a concentration range of 90-100 percent DINP (U.S. EPA, 2020a). According to the Australian Assessment Report, DINP is manufactured at or above 99.5 percent. In addition, during ExxonMobil's virtual tour of the DIDP/DINP production facility, the company indicates a concentration of 99.6 percent DINP. Based on this information, EPA modeled the manufactured DINP concentration for the other three sites using a triangular distribution with a lower bound of 90 percent, upper bound of 100 percent, and mode of 99.5 percent.

E.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 dataset 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.

E.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).

E.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).

E.2.11 Container Size

For the site with a non-CBI PV, (Gehring-Montgomery), EPA assumed that manufactured DINP was packaged into drums, based on the reported PV of 40,191 kg/site-yr. According to the *ChemSTEER User Guide*, drums are defined as containing between 20 and 100 gallons of liquid, and the default drum size is 55 gallons (U.S. EPA, 2015). Therefore, EPA modeled drum size using a triangular distribution with a lower bound of 20 gallons, an upper bound of 100 gallons, and a mode of 55 gallons.

For the other five sites, EPA assumed that DINP was packaged into bulk containers, based on the larger PV ranges of 951,673 to 3,219,635 kg/site-yr for CASRN 28533-12-0 and 8,889,194 kg/site-yr, to 90,535,821 kg/site-yr for CASRN 68515-48-0. According to ExxonMobil's virtual tour (ExxonMobil, 2022b), DINP is transported via marine vessels (58.5%), rail cars (28.5%), and trucks (13%) at the facility. According to the *ChemSTEER User Guide* (U.S. EPA, 2015), the default tank truck size is 5,000 gallons, and the default rail car size is 20,000 gallons. Therefore, EPA modeled bulk container size using a triangular distribution with a lower bound of 5,000 gallons, an upper bound of 20,000 gallons, and a mode of 20,000 gallons. The mode was set at 20,000 gallons since ExxonMobil listed that the majority of transport methods were rail cars or marine vessels (ExxonMobil, 2022b).

E.2.12 Bulk Container Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying tanks by gravity-draining was aligned with the default central tendency and high-end values from the EPA/OPPT Bulk Transport Residual Model. For unloading tanks by gravity-draining in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.02 percent to 0.19 percent and an average of 0.06 percent (Associates, 1988). The EPA/OPPT Bulk Transport Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 0.07 percent and a high-end loss fraction of 0.2 percent.

The underlying distribution of the loss fraction parameter for bulk containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Bulk Transport Residual Model in the *ChemSTEER User Guide* (U.S.

EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study for emptying tanks by gravity-draining (Associates, 1988).

E.2.13 Filtration Loss Fraction

For the two sites with CBI PVs for CASRN 68515-48-0, EPA used estimates from ExxonMobil's virtual tour (ExxonMobil, 2022b) to estimate environmental releases from filtration losses. In the virtual tour, ExxonMobil stated that during DINP/DIDP production, crude filtration losses are 397 kg/day, and final filtration losses are 472 kg/day, for a total of 869 kg/day for filtration losses. As the PV of ExxonMobil is expected to be on the same scale as the PV estimate for the two sites with CBI PVs for CASRN 68515-48-0, this release estimate of 869 kg/day is used directly.

For the site with a non-CBI PV (Gehring-Montgomery) and the three sites with CBI PVs for CASRN 28533-12-0, EPA did not expect the ExxonMobil filtration loss estimates to be accurate due to the smaller PV of DINP. Therefore, EPA developed a uniform distribution of loss fractions from ExxonMobil's filtration loss estimates. EPA divided 869 kg/day by the range of daily production volumes for the three sites with CBI PVs. This resulted in a uniform distribution of filtration loss fractions with a lower bound of 1.7E−03 kg/kg and an upper bound of 1.76E−02 kg/kg.

E.2.14 Sampling Loss Fraction

Sampling loss fractions were estimated using the *March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes* (U.S. EPA, 2023b). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and Low Volume Exemptions (LVEs). Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites (~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 E-4 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx E-4. 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 E.2.4.

E.2.15 Operating Days

According to ExxonMobil's virtual tour (ExxonMobil, 2022b), DINP production occurs continuously for half a year (180 days). The other half year is dedicated to DIDP production. EPA used this value as a constant for the number of operating days for DINP production.

E.2.16 Process Operations Emission Factor

In order to estimate releases from reactions, separations, and other process operations, EPA used an emission factor from the European Solvents Industry Group (ESIG). According to the ESD on Plastic Additives, the processing temperature during manufacture of plasticizers is 375 °F (OECD, 2009b). As EPA did not identify DINP vapor pressures at varying temperatures, the vapor pressures of DIDP were used as surrogates for those of DINP. At 375 °F, DIDP has a vapor pressure of 37.8 Pa. ESIG's Specific Environmental Release Category for Industrial Substance Manufacturing (solvent-borne) states that a chemical with a vapor pressure between 10 to 100 Pa will have an emission factor of 0.001 (ESIG, 2012). Therefore, EPA used this emission factor as a constant value for process operation releases.

E.2.17 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015), provides an overall loss fraction of 2 percent from equipment cleaning.

E.2.18 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 one container per hour for containers with over 10,000 gallons of liquid.

E.2.19 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 in the CEB Manual; therefore, EPA assigned a mode value of 0.5 based on the typical value provided in the *ChemSTEER User Guide* for the EPA/OPPT Mass Balance Inhalation Model (U.S. EPA, 2015).

E.3 Import and Repackaging Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the import and repackaging OES. This approach utilizes the Generic Scenario for Chemical Repackaging (U.S. EPA, 2022a) and CDR data (U.S. EPA, 2020a) combined with Monte Carlo simulation (a type of stochastic simulation).

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

- Release source 1: Transfer Operation Losses to Air from Unloading DINP.
- Release source 2: Product Sampling Wastes.
- Release source 3: Container Cleaning Wastes.
- 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 DINP.

Environmental releases for DINP during import and repackaging are a function of DINP's physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production rate, operating days, DINP concentration, air speed, saturation factor, container size, and loss fractions. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

E.3.1 Model Equations

Table_Apx E-5 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the import and repackaging OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix E.3.2. The Monte Carlo simulation calculated the total DINP 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 E-5. Models and Variables Applied for Release Sources in the Import and Repackaging OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Transfer Operation Losses to Air from Unloading DINP	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{DINP}; VP; f_{sat}; MW; R; T ; V_{tote}; $RATE_{fill\_tote}$; V_{rail}; $RATE_{fill\_rail}$ Operating Time: $N_{tote/rail\_unload\_yr}$; $RATE_{fill\_tote}$; $RATE_{fill\_rail}$; OD
Release source 2: Product Sampling Wastes	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix E.1)	Q_{DINP_day}; $LF_{sampling}$
Release source 3: Container Cleaning Wastes	EPA/OPPT Bulk Transport Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{bulk}
Release source 4: Open Surface Losses to Air During Container Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; MW; VP; $RATE_{air\_speed}$; $D_{cont\_clean\_tote}$; $D_{cont\_clean\_rail}$; T; P Operating Time: $N_{tote/rail\_unload\_yr}$; $RATE_{fill\_tote}$; $RATE_{fill\_rail}$; OD
Release source 5: Equipment Cleaning Wastes	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{equip_clean}
Release source 6: Open Surface Losses to Air During Equipment Cleaning	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; 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 DINP.	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{DINP}; VP; f_{sat}; MW; R; T; V_{drum}; $RATE_{fill\_drum}$; V_{tote}; $RATE_{fill\_tote}$; V_{truck}; $RATE_{fill\_truck}$ V_{rail}; $RATE_{fill\_rail}$ Operating Time: $N_{drum/tote/truck/rail\_load\_yr}$; $RATE_{fill\_drum}$; $RATE_{fill\_tote}$ $RATE_{fill\_truck}RATE_{fill\_rail}$; OD

E.3.2 Model Input Parameters

Table_Apx E-6 summarizes the model parameters and their values for the Import and Repackaging Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx E-6. Summary of Parameter Values and Distributions Used in the Import and Repackaging Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Facility Production Rate	PV	kg/site-yr	Multiple distributions based on CDR data			–	Uniform	See Section E.3.4
Operating Days	OD	days/yr	208	174	260	–	Discrete	See Section E.3.7
Manufactured DINP Concentration	F_{DINP}	kg/kg	Multiple distributions based on CDR data.				Triangular	See Section E.3.8
Air Speed	$RATE_{air\_speed}$	ft/min	19.7	2.56	398	–	Lognormal	See Section E.3.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.3.10
Drum Size	V_{drum}	gal	55	20	100	55	Triangular	See Section E.3.11
Tote Size	V_{tote}	gal	550	100	1,000	550	Triangular	See Section E.3.11
Truck Size	V_{truck}	gal	5,000	1,000	10,000	5,000	Triangular	See Section E.3.11
Rail Car Size	V_{rail}	gal	20,000	10,000	20,000	20,000	Triangular	See Section E.3.11
Bulk Container Loss Fraction	LF_{bulk}	kg/kg	0.0007	0.0002	0.002	0.0007	Triangular	See Section E.3.12
Fraction of DINP Lost During Sampling – 1 (Q_{DINP_day} < 50 kg/site-day)	$F_{sampling\_1}$	kg/kg	0.02	0.002	0.02	0.02	Triangular	See Section E.3.13
Fraction of DINP Lost During Sampling – 2 (Q_{DINP_day} 50-200 kg/site-day)	$F_{sampling\_2}$	kg/kg	0.005	0.0006	0.005	0.005	Triangular	See Section E.3.13
Fraction of DINP Lost During Sampling – 3 (Q_{DINP_day} 200-5000 kg/site-day)	$F_{sampling\_3}$	kg/kg	0.004	0.0005	0.004	0.004	Triangular	See Section E.3.13
Fraction of DINP Lost During Sampling – 4 (Q_{DINP_day} > 5000 kg/site-day)	$F_{sampling\_4}$	kg/kg	0.0004	0.00008	0.0004	0.0004	Triangular	See Section E.3.13
Number of Sites	Ns	sites	28	–	–	–	–	See Section E.3.3
Diameter of Tote Opening	$D_{cont\_clean\_tote}$	cm	5.08	–	–	–	–	See Section E.3.14
Diameter of Rail Car Opening	$D_{cont\_clean\_rail}$	cm	7.6	–	–	–	–	See Section E.3.14

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Diameter of Opening for Equipment Cleaning	D_{equip_clean}	cm	92	–	–	–	–	See Section E.3.14
Vapor Pressure at 25 °C	VP	mmHg	5.40E−07	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Equipment cleaning loss fraction	LF_{equip_clean}	kg/kg	0.02	–	–	–	–	See Section E.3.15
Drum Fill Rate	$RATE_{fill\_drum}$	drums/h	20	–	–	–	–	See Section E.3.16
Tote Fill Rate	$RATE_{fill\_tote}$	totes/h	20	–	–	–	–	See Section E.3.16
Truck Fill Rate	$RATE_{fill\_truck}$	trucks/h	2	–	–	–	–	See Section E.3.16
Rail Car Fill Rate	$RATE_{fill\_cont}$	rail car/h	1	–	–	–	–	See Section E.3.16
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property

E.3.3 Number of Sites

EPA used 2020 CDR data (U.S. EPA, 2020a) to identify the number of sites that import DINP. In CDR, 28 sites reported importing DINP. Table_Apx E-7 presents the names and locations of these sites.

Table_Apx E-7. Sites Reporting to CDR for Import of DINP

Facility Name	Facility Location
Alac International, Inc.	New York, NY
BASF Imports Part 1	Florham Park, NJ
Belt Concepts of America, Inc.	Spring Hope, NC
Cascade Columbia Distribution	Sherwood, OH
Chemspec, Ltd.	Uniontown, OH
Colonial Chemical Solutions, Inc.	Savannah, GA
Connell Bros. Co. LLC	San Francisco, CA
Evonik Corporation	Parsippany, NJ
Formosa Global Solutions, Inc.	Savannah, GA
Geon Performance Solutions LLC	Louisville, KY
Greenchem	West Palm Beach, FL
Harwick Standard Distribution Corp.	Akron, OH
Henkel Louisville	Louisville, KY
ICC Chemical Corp.	New York, NY
Industrial Chemicals, Inc.	Vestavia Hills, AL
M.A. Global Resources, Inc.	Apex, NC
MAK Chemicals, Inc.	Passaic, NJ
Mercedes-Benz US International, Inc.	Vance, AL
Showa Denko Materials America, Inc.	San Jose, CA
Silver Fern Chemical	Seattle, WA
Soyventis North America LLC	Fairfield, NJ
Superior Oil Company, Inc.	Indianapolis, IN
The Chemical Company	Jamestown, RI
The Dow Chemical Co.	Midland, MI
Tribute Energy, Inc.	Houston, TX
Univar Solutions USA Inc.	Redmond, WA
Westlake Compounds LLC	Houston, TX
1 CBI Site	Unknown

E.3.4 Throughput Parameters

EPA ran 15 unique scenarios for the import and repackaging OES: 1 unique scenario for each of the sites with non-CBI PVs, 1 scenario to estimate releases from 10 sites with CBI PVs for CASRN 28553-12-0, and 1 scenario to estimate releases from 5 sites with CBI PVs for CASRN 68515-48-0. EPA used 2020 CDR data (U.S. EPA, 2020a) to identify annual facility PVs for each site. Out of the 28 sites that reported importing DINP in CDR, 13 sites provided a non-CBI production volume. Table_Apx E-8 presents the non-CBI facilities and their DINP production volumes.

Table_Apx E-8. Sites with Non-CBI Production Volumes in 2020 CDR

Facility Name	Facility Location	Reported 2019 Production Volume (lb)
Henkel Louisville	Louisville, KY	24,668
Formosa Global Solutions, Inc.	Livingston, NJ	37,699
Chemspec, Ltd.	Uniontown, OH	111,182
Harwick Standard Distribution Corp.	Akron, OH	132,107
Silver Fern Chemical	Seattle, WA	214,255
MAK Chemicals, Inc.	Passaic, NJ	214,982
Mercedes-Benz US International, Inc	Vance, AL	310,000
Univar Solutions USA Inc.	Redmond, WA	527,252
Belt Concepts of America, Inc.	Spring Hope, NC	660,840
Tribute Energy, Inc.	Houston, TX	837,756
Geon Performance Solutions LLC	Louisville, KY	839,400
Cascade Columbia Distribution	Sherwood, OR	1,486,170
Alac International, Inc.	New York, NY	25,021,453

For the other 15 sites, EPA used a uniform distribution set within the national PV range for each CASRN (DINP encompasses 2 CASRNs). EPA calculated the bounds of the uniform distribution by taking the total PV range in CDR and subtracting out the non-CBI PVs (both MFG and import). Then, for each adjusted bound of the CDR range, EPA divided this value by the number of sites with CBI PVs for each CASRN.

For CASRN 28533-12-0, CDR estimates a total national DINP PV of 50,000,000 to 100,000,000 lb. Based on the non-CBI PVs from importers and manufacturers, the total PV associated with the remaining three sites with CBI PVs is 20,980,799 to 70,980,799 lb. When divided equally among the ten sites, this resulted in an estimated PV of 2,098,080 to 7,098,080 lb/site-yr. EPA used a uniform distribution using this range as the upper and lower bounds.

For CASRN 68515-48-0, CDR estimates a total national DINP PV of 100,000,000 to 1,000,000,000 lb. Based on the non-CBI PVs from importers and manufacturers, the total PV associated with the five sites with CBI PVs is 97,986,578 to 997,986,578 lb/site-yr. When divided equally among the five sites, this resulted in an estimated PV of 19,598,318 to 199,597,318 lb/site-yr. EPA used a uniform distribution using this range as the upper and lower bounds.

The daily throughput of DINP is calculated using Equation E-15 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section E.3.7.

Equation E-15.

$$Q_{DINP\_day} = \frac{PV}{OD}$$

Where:

Q_{DINP_day} = Facility throughput of DINP (kg/site-day)

PV	=	Annual production volume (kg/site-yr)
OD	=	Operating days (see Section E.3.7) (days/yr)

E.3.5 Number of Containers per Year

The number of imported DINP containers unloaded by a site per year is calculated using the following equation:

Equation E-16.

$$N_{cont\_unload\_yr} = \frac{PV}{RHO * \left(3.79\ \frac{L}{gal}\right) * V_{cont}}$$

Where:

V_{cont}	=	Product container volume (rail or tote; see Section E.3.11) (gal/container)
PV	=	Facility production rate (see Section E.3.4) (kg/site-year)
RHO	=	DINP density (kg/L)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (containers/site-year)

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

Equation E-17.

$$N_{cont\_load\_yr} = \frac{PV}{RHO * \left(3.79\ \frac{L}{gal}\right) * V_{cont}}$$

Where:

V_{cont}	=	Product container volume (rail, tote, drum, or truck; see Section E.3.11) (gal/container)
PV	=	Facility production rate (see Section E.3.4) (kg/site-year)
RHO	=	DINP density (kg/L)
$N_{cont\_load\_yr}$	=	Annual number of containers loaded (containers/site-year)

E.3.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the *ChemSTEER User Guide* (U.S. EPA, 2015) and/or through calculation from other parameters. Release points with operating hours provided from the *ChemSTEER User Guide* include unloading, container cleaning, 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 imported containers unloaded at the site and the unloading rate using the following equation:

Equation E-18.

$$OH_{RP1/RP4} = \frac{N_{cont\_unload\_yr}}{RATE_{fill\_cont} * OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 (hrs/site-day)
$RATE_{fill\_cont}$	=	Fill rate of container, dependent on volume (see Section E.3.16) (containers/h)
$N_{cont\_unload\_yr}$	=	Annual number of containers (see Section E.3.5) (containers/site-year)
OD	=	Operating days (see Section E.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 number of product containers filled per year, or on remaining time after accounting for container unloading. The operating hours are calculated using the following equation:

Equation E-19.

$$OH_{RP7} = \frac{N_{cont\_load\_yr}}{RATE_{fill\_cont} * OD}$$

Where:

OH_{RP7}	=	Operating time for release point 7 (hours/site-day)
$RATE_{fill\_cont}$	=	Fill rate of container, dependent on volume (see Section E.3.16) (containers/h)
$N_{cont\_load\_yr}$	=	Annual number of containers (see Section E.3.5) (containers/site-year)
OD	=	Operating days (see Section E.3.7) (days/site-year)

E.3.7 Operating Days

EPA assessed the number of operating days associated with import and repackaging using employment data obtained through the U.S. BLS Occupational Employment Statistics (U.S. BLS, 2023). 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, 2023). Therefore, dividing this time by an assumed working duration of 8 to 12 hours/day yields a number of operating days between 174-260 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-, 10-, and 12-hour shifts. These shift durations correspond to 260, 208, and 174 operating days per year, respectively. Therefore, EPA used a discrete distribution with equal probability for each shift length/operating days combination to model this parameter.

E.3.8 Imported DINP Concentration

For the 13 sites that had non-CBI production volumes in CDR, 12 sites provided DINP concentrations as well. For each site, EPA used a uniform distribution with the upper and lower bounds as presented in Table_Apx E-9.

Table_Apx E-9. Sites with Non-CBI DINP Concentrations in CDR

Facility Name	Facility Location	DINP Concentration (%)
Henkel Louisville	Louisville, KY	1–30
Formosa Global Solutions, Inc.	Savannah, GA	90–100
Chemspec, Ltd.	Uniontown, OH	90–100
Harwick Standard Distribution Corp.	Akron, OH	90–100
MAK Chemicals, Inc.	Passaic, NJ	90–100
Mercedes-Benz US International, Inc.	Vance, AL	30–60
Univar Solutions USA Inc.	Redmond, WA	30–60
Belt Concepts of America, Inc.	Spring Hope, NC	90–100
Tribute Energy, Inc.	Houston, TX	90–100
Geon Performance Solutions LLC	Louisville, KY	30–60
Cascade Columbia Distribution	Sherwood, OH	90–100
Alac International, Inc.	New York, NY	30–60

CDR Data from the remaining 16 sites indicated a concentration range of 1 to 100 percent DINP (U.S. EPA, 2020a). According to the Australian Assessment Report and the European Risk Report for DINP (NICNAS, 2015; ECJRC, 2003a), neat DINP is typically handled at 99 percent or higher. Based on this information, EPA modeled the manufactured DINP concentration for the other 16 sites using a triangular distribution with a lower bound of 1 percent, upper bound of 100 percent, and mode of 99 percent.

E.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 dataset 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). Because 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.

E.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).

E.3.11 Container Size

EPA assessed container size based on the PV of each model run. For example, a site with a PV of over 100 million kg would likely use rail cars for transportation, as the volume would require an unreasonable number of smaller drums. Drums, totes, tank trucks and rail cars were all used in this model. 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. 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. Tank trucks are defined as containing between 1,000 and 10,000 gallons, with a default of 5,000 gallons. Therefore, EPA modeled tote size using a triangular distribution with a lower bound of 1,000 gallons, an upper bound of 10,000 gallons, and a mode of 5,000 gallons. Rail cars are defined as containing 10,000 or more gallons. The default rail car size is 20,000 gallons (U.S. EPA, 2015). Therefore, EPA modeled rail car size using a triangular distribution with a lower bound of 10,000 gallons and an upper bound and mode of 20,000 gallons.

E.3.12 Bulk Container Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying tanks by gravity-draining was aligned with the default central tendency and high-end values from the EPA/OPPT Bulk Transport Residual Model. For unloading tanks by gravity-draining in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.02 percent to 0.19 percent and an average of 0.06 percent (Associates, 1988). The EPA/OPPT Bulk Transport Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 0.07 percent and a high-end loss fraction of 0.2 percent.

The underlying distribution of the loss fraction parameter for bulk containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Bulk Transport Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study for emptying tanks by gravity-draining (Associates, 1988).

E.3.13 Sampling Loss Fraction

Sampling loss fractions were estimated using the *March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes* (U.S. EPA, 2023b). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and LVEs. Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites (~75% 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 E-10 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx E-10. 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 E.3.4

E.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, and 7.6 cm for containers greater than or equal to 5,000 gallons (U.S. EPA, 2015).

E.3.15 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015), provides an overall loss fraction of 2 percent from equipment cleaning.

E.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, 2 containers per hour for containers with 1,000 to 10,000 gallons of liquid, and a typical fill rate of one container per hour for containers with over 10,000 gallons of liquid.

E.4 Incorporation into Adhesives and Sealants Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the incorporation into adhesives and sealants OES. This approach utilizes the *Emission Scenario Document on Adhesive Formulation* (OECD, 2009a) and CDR data (U.S. EPA, 2020a) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD, EPA identified the following release sources from 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: Container Cleaning Wastes.
- Release source 4: Open Surface Losses to Air During Container Cleaning.
- Release source 5: Vented Losses to Air During Dispersion and Blending.
- 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 Operation Losses to Air from Packaging Adhesive/Sealant into Transport Containers.
- Release source 11: Off-Spec and Other Waste Adhesive.

Environmental releases for DINP during incorporation into adhesives and sealants are a function of DINP'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, DINP 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.

E.4.1 Model Equations

Table_Apx E-11 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 Appendix E.4.2. The Monte Carlo simulation calculated the total DINP 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 E-11. 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 Adhesive Component.	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{DINP_import}; VP; f_{sat}; MW; R; T; $RATE_{fill\_drum\_tote}$ Operating Time: Q_{DINP_year}; V_{cont}; $RATE_{fill\_drum\_tote}$; RHO; OD
Release source 2: Dust Generation from Transfer Operations.	Not Assessed for liquid DINP.	N/A
Release source 3: Container Cleaning Wastes.	EPA/OPPT Drum Residual Model (Appendix E.1)	Q_{DINP_year}; LF_{drum}; V_{cont}; RHO; OD
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_import}; MW; VP; $RATE_{air\_speed}$; D_{cont_clean}; T; P Operating Time: Q_{DINP_year}; V_{cont}; $RATE_{fill\_drum\_tote}$; RHO; OD
Release source 5: Vented Losses to Air During Dispersion and Blending.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; MW; VP; $RATE_{air\_speed}$; D_{blend}; T; P Operating Time: Q_{DINP_year}; Q_{batch}; OD
Release source 6: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix E.1)	Q_{DINP_day}; $LF_{sampling}$
Release source 7: Open Surface Losses to Air During Product Sampling.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; MW; VP; $RATE_{air\_speed}$; $D_{sampling}$; T; P Operating Time: $OH_{sampling}$
Release source 8: Equipment Cleaning Wastes.	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{equip_clean}
Release source 9: Open Surface Losses to Air During Equipment Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_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 (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; VP; f_{sat}; MW; R; T; $V_{cont\_packaged}$; $RATE_{fill\_cont}$; $RATE_{fill\_drum\_tote}$; OD; Operating Time: PV; $V_{cont\_packaged}$; $RATE_{fill\_cont}$; RHO; OD; Q_{DINP_year}; V_{cont}; $RATE_{fill\_drum\_tote}$; $RATE_{fill\_adjusted}$

Release Source	Model(s) Applied	Variables Used
Release source 11: Off-Spec and Other Waste Adhesive.	See Equation E-20	$Q_{DIDP\_day}; LF_{offspec}$

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

Equation E-20.

$$Release\_perDay_{RP11} = Q_{DINP\_day} * LF_{offspec}$$

Where:

$Release\_perDay_{RP11}$	=	DINP released for release source 11 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
$LF_{offspec}$	=	Loss fraction for off-spec and waste adhesive (unitless)

E.4.2 Model Input Parameters

Table_Apx E-12 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 E-12. 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 DINP at All Sites	PV_{total}	kg/yr	4,340,879	589,670	4,340,879	–	Uniform	See Section E.4.3
Initial DINP Concentration	F_{DINP_import}	kg/kg	0.6	0.3	0.6	–	Uniform	See Section E.4.7
Final DINP Concentration	F_{DINP_final}	kg/kg	0.01	0.001	0.4	0.1	Triangular	See Section E.4.8
Air Speed	$RATE_{air\_speed}$	ft/min	19.7	2.56	398	–	Lognormal	See Section E.4.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.4.10
Import Container Size	V_{cont}	gal	55	20	100	55	Triangular	See Section E.4.11
Drum Residual Loss Fraction	LF_{drum}	kg/kg	0.025	0.017	0.03	0.025	Triangular	See Section E.4.12
Fraction of DINP Lost During Sampling – 1 (Q_{DINP_day} <50 kg/site-day)	$F_{sampling\_1}$	kg/kg	0.02	0.002	0.02	0.02	Triangular	See Section E.4.13
Fraction of DINP Lost During Sampling – 2 (Q_{DINP_day} 50–200 kg/site-day)	$F_{sampling\_2}$	kg/kg	0.005	0.0006	0.005	0.005	Triangular	See Section E.4.13
Fraction of DINP Lost During Sampling – 3 (Q_{DINP_day} 200–5,000 kg/site-day)	$F_{sampling\_3}$	kg/kg	0.004	0.0005	0.004	0.004	Triangular	See Section E.4.13
Fraction of DINP Lost During Sampling – 4 (Q_{DINP_day} > 5,000 kg/site-day)	$F_{sampling\_4}$	kg/kg	0.0004	0.00008	0.0004	0.0004	Triangular	See Section E.4.13
Diameter of Opening – Blending	D_{blend}	cm	10	10	168.92	–	Uniform	See Section E.4.14
Diameter of Opening – Sampling	$D_{sampling}$	cm	2.5	2.5	10	–	Uniform	See Section E.4.14
Hours per Batch for Equipment Cleaning	$OH_{batch\_equip\_clean}$	hours/batch	4	1	4	4	Triangular	See Section E.4.15
Packaged Container Size	$V_{cont\_packaged}$	gal	55	0.10	100	55	Triangular	See Section E.4.11
Vapor Pressure at 25C	VP	mmHg	5.40E−07	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Operating Days	OD	days/yr	250	–	–	–	–	See Section E.4.16
Batch Size	Q_{batch}	kg/batch	4,000	–	–	–	–	See Section E.4.17
Drum and Tote Fill Rate	$RATE_{fill\_drum\_tote}$	containers/h	20	–	–	–	–	See Section E.4.18
Small Container Fill Rate	$RATE_{fill\_cont}$	containers/h	60	–	–	–	–	See Section E.4.18
Diameter of Opening – Container Cleaning	D_{cont_clean}	cm	5.08	–	–	–	–	See Section E.4.14
Diameter of Opening – Equipment Cleaning	D_{equip_clean}	cm	92	–	–	–	–	See Section E.4.14
Sampling Duration	$OH_{sampling}$	h/day	1	–	–	–	–	See Section E.4.6
Equipment Cleaning Loss Fraction	LF_{equip_clean}	kg/kg	0.02	–	–	–	–	See Section E.4.19
Off-Spec and Waste Loss Fraction	$LF_{offspec}$	kg/kg	0.01	–	–	–	–	See Section E.4.20

E.4.3 Number of Sites

Per 2020 U.S. Census Bureau data for NAICS code 32552 (Adhesives Manufacturing), there are 540 adhesive/sealant formulation 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 E-21.

$$N_s = \frac{PV}{Q_{DINP\_year}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume (see Section E.4.4) (kg/year)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.4.4) (kg/site-yr)

E.4.4 Throughput Parameters

EPA estimated the total production volume for all sites using a uniform distribution with a lower bound of 589,670 kg/yr and an upper bound of 4,340,879 kg/yr.

Both bounds are based on CDR data (U.S. EPA, 2020a) and the 2003 European Union Risk Assessment on DINP (ECJRC, 2003b). The EU Risk Assessment found that only 2.6 percent of the DINP produced goes to non-PVC, non-polymer end use categories. As this Risk Evaluation includes three OESs that fall under this category, EPA assumes that each category accounts for an equal amount to this percentage (*i.e.*, 0.87 percent each). CDR states that the total U.S. national production volume of DINP is 150,000,000 to 1,100,000,000 lb/yr. Multiplying this range by 0.87 percent results in 1,305,000 to 9,570,000 lb/yr (589,670 to 4,340,879 kg/yr).

The annual throughput of DINP is calculated using Equation E-22 by multiplying batch size by the concentration of DINP in the final adhesive product and by operating days. Batch size is determined according to Section E.4.17 and operating days is determined according to Section E.4.16. EPA assumes the number of batches is equal to the number of operating days.

Equation E-22.

$$Q_{DINP\_year} = Q_{batch} * OD * F_{DINP_{final}} * N_{batch\_day}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
Q_{batch}	=	Adhesive/Sealant batch size (see Section E.4.17) (kg/bt)
OD	=	Operating days (see Section E.4.16) (days/yr)
F_{DINP_final}	=	Concentration of DINP in final adhesive/sealant (see Section E.4.8) (kg/kg)
N_{batch_day}	=	Number of batches per day of adhesive/sealant (default of 1) (bt/day)

The daily throughput of DINP is calculated using Equation E-23 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section E.4.16.

Equation E-23.

$$Q_{DINP\_day} = \frac{Q_{DINP\_year}}{OD}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
OD	=	Operating days (see Section E.4.16) (days/yr)

E.4.5 Number of Containers per Year

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

Equation E-24.

$$N_{cont\_unload\_yr} = \frac{Q_{DINP\_year}}{RHO * \left(3.79 \frac{L}{gal}\right) * V_{cont}}$$

Where:

V_{cont}	=	Import container volume (see Section E.4.11) (gal/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.4.3) (kg/site-yr)
RHO	=	DINP density (kg/L)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (container/site-year)

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

Equation E-25.

$$N_{cont\_load\_yr} = \frac{Q_{DINP\_year}}{RHO * \left(3.79 \frac{L}{gal}\right) * V_{cont\_packaged}}$$

Where:

$V_{cont\_packaged}$	=	Product container volume (see Section E.4.11) (gal/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.4.3) (kg/site-yr)
RHO	=	DINP density (kg/L)
$N_{cont\_load\_yr}$	=	Annual number of containers loaded (container/site-year)

E.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 E-26.

$$OH_{RP1/RP4} = \frac{N_{cont\_unload\_yr}}{RATE_{fill\_drum\_tote} * OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 (hours/site-day)
$RATE_{fill\_drum\_tote}$	=	Fill rate of drums and totes (see Section E.4.18) (containers/h)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (see Section E.4.5) (container/site-year)
OD	=	Operating days (see Section E.4.16) (days/site-year)

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

Equation E-27.

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

Where:

OH_{RP5}	=	Operating time for release point 5 (hours/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.4.3) (kg/site-yr)
Q_{batch}	=	Average batch size (see Section E.4.17) (kg/batch)
OD	=	Operating days (see Section E.4.16) (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 1 and 3 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 4 hours based on the ESD for Adhesive Formulation (OECD, 2009a). EPA calculated the equipment cleaning operating hours using the following equation:

Equation E-28.

$$OH_{RP9} = \left(\frac{Q_{DINP\_year}}{Q_{batch} * OD}\right) * OH_{batch\_equip\_clean}$$

Where:

OH_{RP9}	=	Operating time for release point 9 (hours/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.4.3) (kg/site-yr)
Q_{batch}	=	Average batch size (see Section E.4.17) (kg/batch)
OD	=	Operating days (see Section E.4.16) (days/site-year)

$OH_{batch\_equip\_clean}$	=	Duration for batch equipment cleaning (see Section E.4.6) (hours/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 E-29.

$$OH_{RP10} = \begin{cases} \frac{N_{cont\_load\_yr}}{RATE_{fill\_cont} * OD}, & \frac{N_{cont\_load\_yr}}{RATE_{fill\_cont} * OD} \leq [24 - OH_{RP1/RP4}] \\ 24 - OH_{\frac{RP1}{RP4}}, & \frac{N_{cont\_load\_yr}}{RATE_{fill\_cont} * OD} > [24 - OH_{RP1/RP4}] \end{cases}$$

Where:

OH_{RP10}	=	Operating time for release point 10 (hours/site-day)
$RATE_{fill\_cont}$	=	Fill rate of containers (see Section E.4.18) (containers/h)
$N_{cont\_load\_yr}$	=	Annual number of containers loaded (see Section E.4.5) (container/site-year)
OD	=	Operating days (see Section E.4.16) (days/site-year)
$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 (hours/site-day)

E.4.7 Initial DINP Concentration

EPA modeled the initial DINP concentration using a uniform distribution with a lower bound of 30 percent and upper bound of 60 percent based on information reported in the 2020 CDR by sites indicating DINP use in adhesives and sealants (U.S. EPA, 2020a).

E.4.8 Final DINP Concentration

EPA modeled final DINP concentration in adhesives and sealants using a triangular distribution with a lower bound of 0.1 percent, upper bound of 40 percent, and mode of 10 percent. The upper bound, lower bound, and mode are based on compiled SDS information for adhesives and sealant products containing DINP. 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 concentration was 40 percent, and the mode of low-end product concentrations was 10 percent. The mode of low-end concentrations was selected as 10 percent was also the median of all concentration data. Table provides the DINP-containing adhesive and sealant products compiled from SDS along with their concentrations of DINP.

Table_Apx E-13. Product DINP Concentrations for Incorporation into Adhesives and Sealants

Product	DINP Concentration (%)	Source Reference(s)
Duro-Last® Pitch-Pan Filler	0.1–1	(Duro-Last Inc., 2017)
SIDE Winder Advanced Polymer Sealant – All Colors	1–2.5	(DAP Products Inc., 2015)
3M™ Polyurethane Sealant 540 (Various Colors)	0–4.99	(3M, 2019)
HVAC – Acrylic Duct Sealant	0–4.99	(Hodgson Sealants, 2015c)

Product	DINP Concentration (%)	Source Reference(s)
Fireseal 6	0–5	(Macsim Fastenings, 2017)
SB 150HV – Natural	1–5	(Seal Bond, 2018)
HS20	0–9.99	(Hodgson Sealants, 2015a)
Aquacaulk	5–9.99	(Hodgson Sealants, 2014)
Brewers Premium Decorators' Caulk	5–9.99	(C.Brewer & Sons Ltd., 2016)
PF 225 Urethane Windshield Adhesive Black	1–10	(Pro Form Products Ltd., 2016)
CP 606 Flexible Firestop Sealant	10–15	(Hilti (Canada) Corporation, 2012)
DuoSil® Ultra	10–15	(Siroflex Incorporated, 2016)
Tremco JS443 A, B	10–19.99	(Tremco Illbruck Production, 2017a, b)
Illbruck SP523	10–19.99	(Tremco Illbruck Production, 2016)
wedi Joint Sealant	5–20	(Wedi Corporation, 2018)
U–Pol Tiger Seal – Grey	5–23	(U-Pol Australia Pty Limited, 2019)
Everbuild EB25 Crystal Clear	20–24.99	(Sika, 2019)
HS20 Clear	10–25	(Hodgson Sealants, 2015b)
SRW Vertical Instant Lock Adhesive	10–25	(SRW Products Technical Services, 2019)
CT1 Colours (Excluding Silver)	10–29.99	(C-Tec N.I Limited, 2017)
Illbruck SP036	20–29.99	(Tremco Illbruck Produktion GmbH, 2015)
FUSOR 800DTM	25–30	(LORD Corporation, 2018)
EPDM Solvent-Free Bonding Adhesive	30–31	(Firestone Building Products Company, 2018)
ClearSeal Glasklar	25–39.99	(Sika Danmark A/S, 2018)
Coat & Seal	20–40	(Selena USA Inc., 2015)
A-A_529 Adhesive and Sealing Compound	3–100	(Mach-Dynamics, 2014)
BETASEAL™ Xpress 30 BP Urethane Adhesive	15–25	(The Dow Chemical Company, 2018)
Quick-Cure Primerless HV Urethane U418HV	15–25	(Nova Scotia Company, 2018)
SRP 180 HV	10–30	(Shat-R-Proof Corp., 2014)
Gardner Flex 'n Fill Premium Patching Paste	2	(Home Depot, 2018)
HawkFlash LiquiCap – Component A	0–5	(Ergon Asphalt & Emulsions Inc., 2019)

E.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 dataset 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.

E.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).

E.4.11 Container Size

EPA assumed that adhesive and sealant manufacturing sites would receive DINP 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 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 adhesives and sealants after production, EPA identified products in bottles as small as 0.1 gallons, in small containers, and in drums. According to the ESD for Adhesive Formulation (OECD, 2009a), 55-gallon drums are expected to be the default container size for finished adhesives and sealants. Therefore, EPA modeled finished adhesive container size using a triangular distribution with a lower bound of 0.1 gallons, an upper bound of 100 gallons, and a mode of 55 gallons.

E.4.12 Drum Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pumping in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 1.7 percent to 4.7 percent and an average of 2.6 percent. The EPA/OPPT Drum Residual Model from the *ChemSTEER User Guide* recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent (U.S. EPA, 2015).

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study (Associates, 1988) for emptying drums by pumping.

E.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, 2023b). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and LVEs. Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites (~75% 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 E-14 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx E-14. Sampling Loss Fraction Data from the March 2023 Methodology for Estimating Environmental Releases from Sampling Waste

Chemical Daily Throughput (kg/site-day) ($Q_{chem\_site\_day}$)	Number of Data Points	Sampled Quantity (kg chemical/day)		Sampling Loss Fraction ($LF_{sampling}$)	
		50th Percentile	95th Percentile	50th Percentile	95th Percentile
<50	13	0.03	0.20	0.002	0.02
50 to <200	10	0.10	0.64	0.0006	0.005
200 to <5,000	25	0.37	3.80	0.0005	0.004
≥5,000	10	1.36	6.00	0.00008	0.0004
All	58	0.20	5.15	0.0005	0.008

For each range of daily throughputs, EPA estimated sampling loss fractions using a triangular distribution of the 50th percentile value as the lower bound, and the 95th percentile value as the upper bound and mode. The sampling loss fraction distribution was chosen based on the calculation of daily throughput, as shown in Section E.4.3.

E.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 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 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 the Guide (U.S. EPA, 2015).

For blending operations, the ESD for Adhesive Formulation (OECD, 2009a)and GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a) assumes a closed vessel with a 4-inch diameter process vent, corresponding to 10 cm in diameter. In addition, EPA considered the potential for open process vessels used for blending as mentioned in both the ESD for Adhesive Formulation (OECD, 2009a) and GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a), with diameters of the open vessel calculated based on the batch volume for the simulation iteration and the assumption in the ESD and GS of a one-to-one height to diameter ratio for the process vessel. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution defined by an estimated lower bound, upper bound, and mode of the parameter. EPA assigned the value of 10 cm for both the lower bound and mode of the triangular distribution as the recommended value by the ESD for Adhesive Formulation (OECD, 2009a) and GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a). For the upper bound value of the triangular distribution, EPA assigned an equation calculating the diameter of an open process vessel with a one-to-one height to diameter ratio and fixed batch volume of approximately 1,000 gallons based on the batch size discussed in Section E.4.17:

Equation E-30.

$$D_{blending\_max} = \left[\frac{4 * V_{batch} * 3785.41\,\frac{cm^3}{gal}}{\pi}\right]^{1/3}$$

E.4.15 Hours per Batch for Equipment Cleaning

The ESD for Adhesive Formulation (OECD, 2009a) cites a cleaning time per batch of one to four hours and suggests that a value of four hours per cleaning be used for model defaults. Therefore, EPA modeled this parameter via a triangular distribution with a lower bound of one hour/batch, upper bound of four hours/batch, and mode of four hours/batch.

E.4.16 Operating Days

EPA was unable to identify DINP-specific information for operating days in the production of adhesives and sealants. Therefore, EPA assumes a constant value of 250 days/yr, which assumes the production sites operate 5 days per week and 50 weeks per year, with 2 weeks down for turnaround.

E.4.17 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.

E.4.18 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 E-31.

$$if\ 24 < (OH_{RP1/RP4} + OH_{RP10}), \qquad RATE_{fill\_adjusted} = \frac{N_{cont\_load\_yr}}{(24 - OH_{RP1/RP4}) * OD}$$

Where:

$RATE_{fill\_adjusted}$	=	Corrected fill rate for product containers (containers/hour)
$N_{cont\_load\_yr}$	=	Annual number of product containers (containers/site-year)
OH_n	=	Operating time for release point “n” (hours/site-day)
OD	=	Operating days (days/site-year)

E.4.19 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015) provides an overall loss fraction of 2 percent from equipment cleaning.

E.4.20 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).

E.5 Incorporation into Paints and Coatings Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the incorporation into paints and coatings OES. This approach utilizes the Generic Scenario for Formulation of Waterborne Coatings (U.S. EPA, 2014a) and CDR data (U.S. EPA, 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 Cleaning 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 DINP during incorporation into paints and coatings are a function of DINP'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, DINP 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.

E.5.1 Model Equations

Table_Apx E-15 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 Appendix E.5.2. The Monte Carlo simulation calculated the total DINP 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 E-15. 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 (Appendix E.1)	Vapor Generation Rate: F_{DINP_import}; VP; f_{sat}; MW; R; T; V_{cont}; $RATE_{fill\_drum\_tote}$ Operating Time: Q_{DINP_year}; V_{cont}; $RATE_{fill\_drum\_tote}$; RHO; OD
Release source 2: Dust Generation from Transfer Operations.	Not Assessed for liquid DINP.	N/A
Release source 3: Container Cleaning Wastes.	EPA/OPPT Drum Residual Model (Appendix E.1)	LF_{drum}; V_{cont}; Q_{DINP_year}; V_{cont}; RHO; OD
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_import}; MW; VP; $RATE_{air\_speed}$; D_{cont_clean}; T; P Operating Time: Q_{DINP_year}; V_{cont}; $RATE_{fill\_drum\_tote}$; RHO; OD

Release Source	Model(s) Applied	Variables Used
Release source 5: Vented Losses to Air During Blending/Process Operations.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; MW; VP; $RATE_{air\_speed}$; D_{blend}; T; P Operating Time: Q_{DINP_year}; Q_{DINP_batch}; OD
Release source 6: Product Sampling Wastes.	March 2023 Methodology for Estimating Environmental Releases from Sampling Waste (Appendix E.1)	Q_{DINP_day}; $LF_{sampling}$
Release source 7: Open Surface Losses to Air During Product Sampling.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; MW; VP; $RATE_{air\_speed}$; $D_{sampling}$; T; P Operating Time: $OH_{sampling}$
Release source 8: Equipment Cleaning Wastes.	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{equip_clean}
Release source 9: Open Surface Losses to Air During Equipment Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; MW; VP; $RATE_{air\_speed}$; D_{equip_clean}; T; P Operating Time: $OH_{batch\_equip\_clean}$; Q_{DINP_year}; Q_{DINP_batch}; OD
Release source 10: Filter Waste Losses.	No available data or models for estimation. Estimate on a case-by-case basis.	N/A
Release source 11: Open Surface Losses to Air During Filter Media Replacement	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; MW; VP; $RATE_{air\_speed}$; D_{filter}; T; P Operating Time: OH_{filter}
Release source 12: Transfer Operation Losses to Air from Packaging Paint/Coating into Transport Containers.	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{DINP_final}; VP; f_{sat}; MW; R; T; $V_{cont\_packaged}$ Operating Time: Q_{DINP_year}; $V_{cont\_packaged}$; $RATE_{fill\_cont}$; RHO; OD; $RATE_{fill\_adjusted}$
Release source 13: Off-Spec and Other Waste Paint/Coating.	See Equation E-32	Q_{DINP_day}; $LF_{offspec}$

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

Equation E-32.

$$Release\_perDay_{RP13} = Q_{DINP\_day} * LF_{offspec}$$

Where:

$Release\_perDay_{RP13}$ = DINP released for release source 13 (kg/site-day)
Q_{DINP_day} = Facility throughput of DINP (see Section E.5.3) (kg/site-day)

$LF_{offspec}$ = Loss fraction for off-spec and waste adhesive (see Section E.5.21) (unitless)

E.5.2 Model Input Parameters

Table_Apx E-16 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 E-16. 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 DINP at All Sites	PV_{total}	kg/yr	4,340,879	589,670	4,340,879	–	Uniform	See Section E.5.3
Initial DINP Concentration	F_{DINP_import}	kg/kg	0.9	0.3	0.9	–	Uniform	See Section E.5.7
Final DINP Concentration	F_{DINP_final}	kg/kg	0.05	0.0001	0.2	0.05	Triangular	See Section E.5.8
Air Speed	$RATE_{air\_speed}$	ft/min	19.7	2.56	398	–	Lognormal	See Section E.5.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.5.10
Drum Size	V_{drum}	gal	55	20	100	55	Triangular	See Section E.5.11
Tote Size	V_{tote}	gal	550	100	1000	550	Triangular	See Section E.5.11
Drum Residual Loss Fraction	LF_{drum}	kg/kg	0.025	0.017	0.03	0.025	Triangular	See Section E.5.12
Bulk Container Residual Loss Fraction	LF_{bulk}	kg/kg	0.07	0.02	0.2	0.07	Triangular	See Section E.5.13
Fraction of DINP Lost During Sampling – 1 (Q_{DINP_day} < 50 kg/site-day)	$F_{sampling\_1}$	kg/kg	0.02	0.002	0.02	0.02	Triangular	See Section E.5.14
Fraction of DINP Lost During Sampling – 2 (Q_{DINP_day} 50–200 kg/site-day)	$F_{sampling\_2}$	kg/kg	0.005	0.0006	0.005	0.005	Triangular	See Section E.5.14
Fraction of DINP Lost During Sampling – 3 (Q_{DINP_day} 200–5,000 kg/site-day)	$F_{sampling\_3}$	kg/kg	0.004	0.0005	0.004	0.004	Triangular	See Section E.5.14
Fraction of DINP Lost During Sampling – 4 (Q_{DINP_day} > 5,000 kg/site-day)	$F_{sampling\_4}$	kg/kg	0.0004	0.00008	0.0004	0.0004	Triangular	See Section E.5.14
Diameter of Opening-Blending	D_{blend}	cm	10	10	168.92	–	Uniform	See Section E.5.15
Diameter of Opening – Sampling	$D_{sampling}$	cm	2.5	2.5	10	–	Uniform	See Section E.5.15

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Hours per Batch for Equipment Cleaning	$OH_{batch\_equip\_clean}$	hours/batch	4	1	4	4	Triangular	See Section E.5.6
Packaged Container Size	$V_{cont\_packaged}$	gal	1	0.10	20	1	Triangular	See Section E.5.11
Overall Paint/Coating Production Rate	Q_{paint}	kg/site-yr	16,000,000	1,600,000	16,000,000	—	Uniform	See Section E.5.16
Vapor Pressure at 25C	VP	mmHg	5.40E−07	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Operating Days	OD	days/yr	250	–	–	–	–	See Section E.5.17
Batch Size	Q_{batch}	kg/batch	5,030	–	–	–	–	See Section E.5.18
Drum and Tote Fill Rate	$RATE_{fill\_drum\_tote}$	containers/h	20	–	–	–	–	See Section E.5.19
Small Container Fill Rate	$RATE_{fill\_cont}$	containers/h	60	–	–	–	–	See Section E.5.19
Diameter of Opening – Container Cleaning	D_{cont_clean}	cm	5.08	–	–	–	–	See Section E.5.15
Diameter of Opening – Equipment Cleaning	D_{equip_clean}	cm	92	–	–	–	–	See Section E.5.15
Diameter of Opening – Filter Media Replacement	D_{filter}	cm	182.4	–	–	–	–	See Section E.5.15
Sampling Duration	$OH_{sampling}$	h/day	1	–	–	–	–	See Section E.5.6
Filter Media Replacement Duration	OH_{filter}	h/day	1	–	–	–	–	See Section E.5.6

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	0.02	–	–	–	–	See Section E.5.20
Off-Spec and Waste Loss Fraction	$LF_{offspec}$	kg/kg	0.012	–	–	–	–	See Section E.5.21

E.5.3 Number of Sites

Per 2020 U.S. Census Bureau data for NAICS code 32551 (Paint and Coating Manufacturing), there are 1,131 paint/coating formulation 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 E-33.

$$N_s = \frac{PV}{Q_{DINP\_year}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume (see Section E.4.4) (kg/year)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.4.4) (kg/site-yr)

E.5.4 Throughput Parameters

EPA estimated the total production volume for all sites using a uniform distribution with a lower bound of 589,670 kg/yr and an upper bound of 4,340,879 kg/yr.

Both bounds are based on CDR data (U.S. EPA, 2020a) and the 2003 European Union Risk Assessment on DINP (ECJRC, 2003b). The EU Risk Assessment found that only 2.6 percent of the DINP produced goes to non-PVC, non-polymer end use categories. As this Risk Evaluation includes three OESs that fall under this category, EPA assumes that each category accounts for an equal amount to this percentage (*i.e.*, 0.87% each). CDR states that the total U.S. national production volume of DINP is 150,000,000 to 1,100,000,000 lb/yr. Multiplying this range by 0.87 percent results in 1,305,000 to 9,570,000 lb/yr (589,670 to 4,340,879 kg/yr).

The annual throughput of DINP is calculated using Equation E-34 by multiplying overall paint and coating production rate by the concentration of DINP in the final paint or coating product. Overall paint and coating production rate is determined according to Section E.5.16 and concentration of DINP in the final article is determined according to Section E.5.8.

Equation E-34.

$$Q_{DINP\_year} = Q_{paint} * F_{DINP_{final}}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
Q_{paint}	=	Overall paint/coating production rate (see Section E.5.16) (kg/site-yr)
$F_{DINP_{final}}$	=	Concentration of DINP in final paint/coating (see Section E.5.8) (kg/kg)

The daily throughput of DINP is calculated using Equation E-35 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section E.5.17.

Equation E-35.

$$Q_{DINP\_day} = \frac{Q_{DINP\_year}}{OD}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
OD	=	Operating days (see Section E.5.17) (days/yr)

E.5.5 Number of Containers per Year

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

Equation E-36.

$$N_{cont\_unload\_yr} = \frac{Q_{DINP\_year}}{RHO * \left(3.79\ \frac{L}{gal}\right) * V_{cont}}$$

Where:

V_{cont}	=	Import container volume (drum or tote; see Section E.5.11) (gal/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.5.3) (kg/site-yr)
RHO	=	DINP density (kg/L)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (container/site-year)

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

Equation E-37.

$$N_{cont\_load\_yr} = \frac{Q_{DINP\_year}}{RHO * \left(3.79\ \frac{L}{gal}\right) * V_{cont\_packaged}}$$

Where:

$V_{cont\_packaged}$	=	Product container volume (see Section E.5.11) (gal/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.5.3) (kg/site-yr)
RHO	=	DINP density (kg/L)
$N_{cont\_load\_yr}$	=	Annual number of containers loaded (container/site-year)

E.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 E-38.

$$OH_{RP1/RP4} = \frac{N_{cont\_unload\_yr}}{RATE_{fill\_drum\_tote} * OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 (h/site-day)
$RATE_{fill\_drum\_tote}$	=	Fill rate of drums and totes (see Section E.5.19) (containers/h)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (see Section E.5.5) (container/site-year)
OD	=	Operating days (see Section E.5.17) (days/site-year)

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

Equation E-39.

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

Where:

OH_{RP5}	=	Operating time for release point 5 (h/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.5.3) (kg/site-yr)
Q_{batch}	=	Average batch size (see Section E.5.18) (kg/batch)
OD	=	Operating days (see Section E.5.17) (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 1 and 3 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 1 hour based on the lower end cleaning time observed in the case study (OECD, 2009a) and the upper bound as 4 hours based on the *ChemSTEER User Guide* default value for this worker activity. For the mode, EPA assigned 4 hours based on the ESD for Adhesive Formulation (OECD, 2009a). EPA calculated the equipment cleaning operating hours using the following equation:

Equation E-40.

$$OH_{RP9} = \left(\frac{Q_{DINP\_year}}{Q_{batch} * OD}\right) * OH_{batch\_equip\_clean}$$

Where:

OH_{RP9}	=	Operating time for release point 9 (h/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.5.3) (kg/site-yr)
Q_{batch}	=	Average batch size (see Section E.5.18) (kg/batch)
OD	=	Operating days (see Section E.5.17) (days/site-year)
$OH_{batch\_equip\_clean}$	=	Batch duration for equipment cleaning (see Section E.5.6) (h/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 E-41.

$$OH_{RP12} = \begin{cases} \frac{N_{cont\_load\_yr}}{RATE_{fill\_cont} * OD}, & \frac{N_{cont\_load\_yr}}{RATE_{fill\_cont} * OD} \leq [24 - OH_{RP1/RP4}] \\ 24 - OH_{RP1/RP4}, & \frac{N_{cont\_load\_yr}}{RATE_{fill\_cont} * OD} > [24 - OH_{RP1/RP4}] \end{cases}$$

Where:

OH_n	=	Operating time for release point "n" (h/site-day)
$RATE_{fill\_cont}$	=	Fill rate of containers, dependent on volume (see Section E.5.19) (containers/h)
$N_{cont\_load\_yr}$	=	Annual number of containers loaded (see Section E.5.5) (container/site-year)
OD	=	Operating days (see Section E.5.17) (days/site-year)

E.5.7 Initial DINP Concentration

EPA modeled the initial DINP concentration using a uniform distribution with a lower bound of 30 percent and upper bound of 90 percent based on information reported in the 2020 CDR by sites indicating DINP use in paints and coatings (U.S. EPA, 2020a).

E.5.8 Final DINP Concentration

EPA modeled final DINP concentration in paints and coatings using a triangular distribution with a lower bound of 0.01 percent, upper bound of 20 percent, and mode of 5 percent. This is based on compiled SDS information for paint and coating products containing DINP. The lower and upper bounds represent the minimum and maximum reported concentrations in the SDSs. The mode of high-end product concentrations was 5 percent. Table_Apx E-17 provides the DINP-containing paint and coating products compiled from SDSs along with their concentrations of DINP.

Table_Apx E-17. Product DINP Concentrations for Incorporation into Paints and Coatings

Product	DINP Concentration (%)	Source Reference(s)
PHENOLINE 380 PART A	0.1–1	(Carboline Company, 2015)
RAL 9010 White Aerosol	0.1–1	(Premier Aerosol Packaging Inc., 2017)
Freeman 90-1 Burnt Orange Pattern Coating	1–5	(Freeman Manufacturing and Supply Company, 2018)
Castle® Cast Iron Gray Paint™	1–5	(Castle Products Inc., 2016)
"KEM AQUA® 600T Water Reducible Enamel – White"	0–5	(Sherwin Williams, 2020)
Brush On Electrical Tape Black 4 Fl.Oz	1–10	(Chemical and Company, 2016)
B610-01006 Flattener	1–10	(RPM Wood Finishes Group, 2004c)
GlasGrid	0–20	(Saint-Gobain ADFOR, 2017)
B101-G804 B104-G202 White Gloss Jet Spray, B101- G826 Black Gloss Jet Spray	1–10	(RPM Wood Finishes Group, 2004a, b)
Skudo Glass Advanced	10–20	(Skudo LLC, 2013)

E.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 dataset 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.

E.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).

E.5.11 Container Size

EPA assumed that paint and coating manufacturing sites would receive DINP 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). Totes are defined as containing between 100 and 1,000 gallons, and the default tote size is 550 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, 1-gallon containers are the default packaged container size. 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 1 gallon.

E.5.12 Drum Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pumping in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 1.7 percent to 4.7 percent and an average of 2.6 percent. The EPA/OPPT Drum Residual Model from the *ChemSTEER User Guide* recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent (U.S. EPA, 2015).

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study (Associates, 1988) for emptying drums by pumping.

E.5.13 Bulk Container Loss Fraction

EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying tanks by gravity-draining was aligned with the default central tendency and high-end values from the EPA/OPPT Bulk Transport Residual Model. For unloading tanks by gravity-draining in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.02 percent to 0.19 percent and an average of 0.06 percent (Associates, 1988). The EPA/OPPT Bulk Transport Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 0.07 percent and a high-end loss fraction of 0.2 percent.

The underlying distribution of the loss fraction parameter for bulk containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Bulk Transport Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study for emptying tanks by gravity-draining (Associates, 1988).

E.5.14 Sampling Loss Fraction

Sampling loss fractions were estimated using the *March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes* (U.S. EPA, 2023b). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and LVEs. Of the searched IRERs, 60 data points for sampling release loss fractions, primarily for sampling releases from submitter-controlled sites (~75% 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 E-18 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx E-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
≥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 E.4.3

E.5.15 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 guide indicates a single default value of 92 cm (U.S. EPA, 2015). For container cleaning activities, the guide indicates a single default value of 5.08 cm for containers less than 5,000 gallons (U.S. EPA, 2015). 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). The Agency also assigned 2.5 cm as the mode diameter value for sampling liquids based on the typical value described in *ChemSTEER User Guide* (U.S. EPA, 2015).

For blending operations, the ESD for Adhesive Formulation (OECD, 2009a)and GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a) assumes a closed vessel with a 4-inch diameter process vent, corresponding to 10 cm in diameter. In addition, EPA considered the potential for open process vessels used for blending as mentioned in both the ESD for Adhesive Formulation (OECD, 2009a) and GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a), with diameters of the open vessel calculated based on the batch volume for the simulation iteration and the assumption in the ESD and GS of a one-to-one height to diameter ratio for the process vessel. The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution defined by an estimated lower bound, upper bound, and mode of the parameter. EPA assigned the value of 10 cm for both the lower bound and mode of the triangular distribution as the recommended value by the ESD for Adhesive Formulation (OECD, 2009a) and GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a). For the upper bound value of the triangular distribution, EPA assigned an equation calculating the diameter of an open process vessel with a one-to-one height to diameter ratio and fixed batch volume of approximately 1,000 gallons based on the batch size discussed in Section E.5.18:

Equation E-42.

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

E.5.16 Overall Paint/Coating Production Rate

The GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a) provides two estimates for overall paint/coating production rates. For architectural coatings, the GS estimates 16 million kg of coatings/site-yr. For special purpose coatings, the GS estimates 1.6 million kg of coatings/site-yr. Therefore, EPA modeled this parameter with a uniform distribution with a lower bound of 1.6 million kg/site-yr and an upper bound of 16 million kg/site-yr.

E.5.17 Operating Days

EPA was unable to identify DINP-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/yr, which assumes the production sites operate five days per week and 50 weeks per year, with 2 weeks down for turnaround.

E.5.18 Batch Size

The GS for Formulation of Waterborne Coatings (U.S. EPA, 2014a) cites a default batch size of 5,030 kg coatings per batch with an approximate batch volume of 1,000 gallons.

E.5.19 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 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 E-43.

$$if\ 24 < (OH_{RP1/RP4} + OH_{RP12}), \qquad RATE_{fill\_adjusted} = \frac{N_{cont\_load\_yr}}{(24 - OH_{RP1/RP4}) * OD}$$

Where:

$RATE_{fill\_adjusted}$	=	Corrected fill rate for product containers (containers/h)
$N_{cont\_load\_yr}$	=	Annual number of product containers (containers/site-year)
OH_n	=	Operating time for release point "n" (hours/site-day)
OD	=	Operating days (days/site-year)

E.5.20 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015) provides an overall loss fraction of two percent from equipment cleaning.

E.5.21 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).

E.6 Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the incorporation into other formulations, mixtures, and reaction products not covered elsewhere OES. This approach utilizes the same equations and assumptions presented for Incorporation into Paints and Coatings in Appendix E.5. Therefore, only the parameters that differ between approaches, which includes concentration of DINP in the raw material and final product DINP concentrations, will be presented in this section for brevity.

E.6.1 Initial DINP Concentration

EPA modeled the imported DINP concentration using a uniform distribution with a lower bound of 30 percent and upper bound of 90 percent based on information reported in the 2020 CDR by sites indicating DINP use in other formulations, mixtures, and reaction products (U.S. EPA, 2020a).

E.6.2 Final DINP Concentration

EPA modeled final DINP concentration in other articles using a triangular distribution with a lower bound of 0.5 percent, upper bound of 50 percent, and mode of 20 percent. This is based on compiled SDS information for adhesives and sealant products containing DINP. From the compiled data, the minimum concentration was 0.5 percent, the maximum concentration was 50 percent, and the mode was 20 percent. The mode of 20 percent also represents the median of the high-end concentration range endpoints. Table_Apx E-19 provides the DINP-containing products compiled from SDSs along with their concentrations of DINP.

Table_Apx E-19. Product DINP Concentrations for Incorporation into Other Formulations, Mixtures, and Reaction Products Not Covered Elsewhere

Product	DINP Concentration (%)	Source(s)
Gans Deep Klene	40–50	(Gans Ink and Supply Co Inc., 2018)
Spotcheck ® SKL-SP2	10–20	(ITW Ltd., 2018)
Avery Dennison 4930 Series Screen Ink	0–0.5	(Nazdar Company, 2015)
Porelon Red SP Premix	15–20	(Porelon, 2007)

E.7 Non-PVC Plastics Materials Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the Non-PVC Plastics Material Compounding and Non-PVC Plastics Material Converting OESs. This approach utilizes the Generic Scenario for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d), the 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e), Emission Scenario Document on Additives in Rubber Industry (OECD, 2004a), and CDR data (U.S. EPA, 2020a) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the GS, EPA identified the following release sources from non-PVC plastics materials compounding:

- Release source 1: Transfer Operation Losses to Air from Unloading Plastics Additives.
- Release source 2: Container Cleaning Wastes.
- Release source 3: Open Surface Losses to Air During 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, EPA identified the following release sources from non-PVC plastics materials 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 DINP during non-PVC plastics materials production are a function of DINP'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, DINP 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.

E.7.1 Model Equations

Table_Apx E-20 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the non-PVC plastics materials OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix E.7.2. The Monte Carlo simulation calculated the total DINP 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 E-20. Models and Variables Applied for Release Sources in the Non-PVC Plastics Materials OES

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 (Appendix E.1)	Vapor Generation Rate: F_{DINP}; VP; f_{sat}; MW; R; T; V_{drum}; V_{tote}; $RATE_{fill\_drum\_tote}$ Operating Time: Q_{DINP_year}; V_{drum}; $RATE_{fill\_drum\_tote}$; V_{tote}; RHO; OD_{comp}
Release source 2: Container Cleaning Wastes.	EPA/OPPT Drum Residual Model or EPA/OPPT Bulk Transport Residual Model, based on container size (Appendix E.1)	Q_{DINP_year}; LF_{drum}; V_{cont}; LF_{bulk}; V_{bulk} RHO; OD_{comp}
Release source 3: Open Surface Losses to Air During Compounding.	See Equation E-44	Q_{DINP_day}; $F_{vapor\_emissions}$
Release source 4: Equipment Cleaning Wastes.	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{equip_clean}
Release source 5: Direct Contact Cooling Water Losses.	See Equation E-46	Q_{DINP_day}; $F_{cooling\_water}$
Release source 6: Transfer Operations Losses to Air from Loading Compounded Plastic.	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix E.1)	Q_{DINP_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/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix E.1)	Q_{DINP_day}; $F_{dust\_generation}$; $F_{dust\_capture}$; $F_{dust\_control}$
Release source 2: Container Cleaning Wastes.	EPA/OPPT Solid Residuals in Transport Containers Model (Appendix E.1)	Q_{DINP_year}; LF_{cont}; V_{cont}; RHO; $N_{cont\_unload\_day}$; OD_{conv}

Release Source	Model(s) Applied	Variables Used
Release source 3: Vapor Emissions from Converting.	See Equation E-44	Q_{DINP_day}; $F_{vapor\_emissions}$
Release source 4: Particulate Emissions from Converting.	See Equation E-45	Q_{DINP_day}; $F_{particulate\_emissions}$
Release source 5: Equipment Cleaning Wastes.	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{equip_clean}
Release source 6: Direct Contact Cooling Water Losses.	See Equation E-46	Q_{DINP_day}; $F_{cooling\_water}$
Release source 7: Solid Wastes from Trimming Operations.	See Equation E-47	Q_{DINP_day}; $F_{trimming}$

Compounding and converting release source 3 daily release (Open Surface Losses to Air During Compounding/Converting) is calculated using the following equation:

Equation E-44.

$$Release\_perDay_{RP3} = Q_{DINP\_day} * F_{vapor\_emissions}$$

Where:

$Release\_perDay_{RP3}$ = DINP released for release source 3 (kg/site-day)
Q_{DINP_day} = Facility throughput of DINP (see Section E.7.3) (kg/site-day)
$F_{vapor\_emissions}$ = Fraction of DINP lost from volatilization during compounding/converting operations (see Section E.7.21) (kg/kg)

Converting release source 4 daily release (Particulate Emissions from Converting) is calculated using the following equation:

Equation E-45.

$$Release\_perDay_{RP4} = Q_{DINP\_day} * F_{particulate\_emissions}$$

Where:

$Release\_perDay_{RP4}$ = DINP released for release source 4 (kg/site-day)
Q_{DINP_day} = Facility throughput of DINP (see Section E.7.3) (kg/site-day)
$F_{particulate\_emissions}$ = Fraction of DINP lost as particulates during converting operations (see Section E.7.16) (kg/kg)

Compounding and converting release source 5 daily release (Direct Contact Cooling Water Losses) is calculated using the following equation:

Equation E-46.

$$Release\_perDay_{RP5} = Q_{DINP\_day} * F_{cooling\_water}$$

Where:

$Release\_perDay_{RP5}$ = DINP released for release source 5 (kg/site-day)
Q_{DINP_day} = Facility throughput of DINP (see Section E.7.3) (kg/site-day)
$F_{cooling\_water}$ = Cooling water loss fraction (see Section E.7.19) (kg/kg)

Converting release source 7 daily release (Solid Wastes from Trimming Operations) is calculated using the following equation:

Equation E-47.

$$Release\_perDay_{RP7} = Q_{DINP\_day} * F_{trimming}$$

Where:

$Release\_perDay_{RP7}$	=	DINP released for release source 7 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (see Section E.7.3) (kg/site-day)
$F_{trimming}$	=	Trimming loss fraction (see Section E.7.23) (kg/kg)

E.7.2 Model Input Parameters

Table_Apx E-21 and summarizes the model parameters and their values for the Non-PVC Plastics Materials Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx E-21. Summary of Parameter Values and Distributions Used in the Non-PVC Plastics Materials Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Total PV of DINP at all Sites	PV_{total}	kg/yr	12,972,742	1,769,010	12,972,742	–	Uniform	See Section E.7.3
Initial DINP Concentration	F_{DINP_import}	kg/kg	1	0.3	1	1	Triangular	See Section E.7.9
Plastic DINP Concentration	F_{DINP}	kg/kg	0.2	0.01	0.4	0.2	Triangular	See Section E.7.10
Operating Days – Compounding	OD_{comp}	days/yr	246	147	301	246	Triangular	See Section E.7.11
Operating Days – Converting	OD_{conv}	days/yr	253	136	255	253	Triangular	See Section E.7.11
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.7.12
Drum Container Size	V_{drum}	gal	55	20	100	55	Triangular	See Section E.7.13
Tote Container Size	V_{tote}	gal	550	100	1,000	550	Triangular	See Section E.7.13
Solid Container Size	V_{cont}	gal	7	7	132	7	Triangular	See Section E.7.13
Drum Residual Loss Fraction	LF_{drum}	kg/kg	0.025	0.017	0.03	0.025	Triangular	See Section E.7.14
Bulk Container Loss Fraction	LF_{bulk}	kg/kg	0.07	0.02	0.2	0.07	Triangular	See Section E.7.14
Fraction of chemical lost during transfer of solid powders	$F_{dust\_generation}$	kg/kg	0.0050	0.000006	0.045	0.005	Triangular	See Section E.7.15
Capture efficiency for dust capture methods	$F_{dust\_capture}$	kg/kg	0.9630	0.931	1	0.963	Triangular	See Section E.7.15
Control efficiency for dust control methods	$F_{dust\_control}$	kg/kg	Multiple distributions depending on control type				Triangular	See Section E.7.15
Fraction of DINP lost as particulates during converting processes	$F_{particulate\_emissions}$	kg/kg	0.00006	0.00002	0.0001	0.00006	Triangular	See Section E.7.16
Mass fraction of all additives in the compounded plastic resin	$F_{additives\_resin}$	kg/kg	0.49	0.49	0.87	–	Uniform	See Section E.7.5
Annual use rate of all plastic additives	$Q_{additives\_yr}$	kg/site-yr	198,773	–	–	–	–	See Section E.7.6
Vapor Pressure at 25C	VP	mmHg	5.40E−07	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Drum and Tote Fill Rate	$RATE_{fill\_drum\_tote}$	containers/h	20	–	–	–	–	See Section E.7.17
Small Container Fill Rate	$RATE_{fill\_cont}$	containers/h	60	–	–	–	–	See Section E.7.17
Tank Truck Fill Rate	$RATE_{fill\_truck}$	containers/h	2	–	–	–	–	See Section E.7.17
Rail Car Fill Rate	$RATE_{fill\_rail}$	containers/h	1	–	–	–	–	See Section E.7.17
Equipment Cleaning Loss Fraction	LF_{equip_clean}	kg/kg	0.02	–	–	–	–	See Section E.7.18
Cooling Water Loss Fraction	$F_{cooling\_water}$	kg/kg	0.01	–	–	–	–	See Section E.7.19
Rubber Production Rate	Q_{rubber}	kg/day	55,000	–	–	–	–	See Section E.7.20
Fraction of the chemical of interest lost from volatilization during forming and molding processes (open process)	$F_{vapor\_emissions\_open}$	kg/kg	0.00010	–	–	–	–	See Section E.7.21
Fraction of the chemical of interest lost from volatilization during forming and molding processes (closed process)	$F_{vapor\_emissions\_closed}$	kg/kg	0.00002	–	–	–	–	See Section E.7.21
Solid container loss fraction	LF_{cont}	kg/kg	0.01	–	–	–	–	See Section E.7.22
Trimming loss fraction	$F_{trimming}$	kg/kg	0.025	–	–	–	–	See Section E.7.23

E.7.3 Number of Sites

Number of sites is calculated using the following equation.:

Equation E-48.

$$N_s = \frac{PV}{Q_{DINP_{year}}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume (see Section E.7.4) (kg/year)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.7.4) (kg/site-yr)

E.7.4 Throughput Parameters

EPA estimated the total production volume for all sites using a uniform distribution with a lower bound of 1,769,010 kg/yr and an upper bound of 12,972,742 kg/yr. This is based on CDR data (U.S. EPA, 2020a) and the *2003 European Union Risk Assessment on DINP* (ECJRC, 2003b).

The upper and lower bounds are based on CDR data (U.S. EPA, 2020a) and the 2003 European Union Risk Assessment on DINP (ECJRC, 2003b). The 2003 EU Risk Assessment found that 2.6 percent of the DINP produced is used in non-PVC polymers. CDR states that the total U.S. national PV of DINP is in the range of 150,000,000 lb/yr to 1,100,000,000 lb/yr. Multiplying these figures by 2.6 percent results in 3,900,000 lb/yr (1,769,010 kg/yr) to 28,600,000 lb/yr (12,972,742 kg/yr). This production range is used for both non-PVC plastic compounding and converting, since EPA assumes 100 percent of the compounded plastic goes to the converting process.

For compounding, the annual throughput of DINP is calculated using Equation E-49 by multiplying daily rubber production rate by operating days and the concentration of DINP in the final article. Daily rubber production rate is determined according to Section E.7.20, operating days is determined according to Section E.7.11, and concentration of DINP in the final article is determined according to Section E.7.10.

Equation E-49.

$$Q_{DINP\_year} = Q_{rubber} * F_{DINP} * OD_{comp}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
Q_{rubber}	=	Overall non-PVC plastic material production rate (see Section E.7.20) (kg/site-day)
F_{DINP}	=	Concentration of DINP in final plastic/rubber (see Section E.7.10) (kg/kg)
OD_{comp}	=	Operating days for compounding (see Section E.7.11) (days/yr)

For converting, the annual throughput of DINP is calculated using Equation E-50 by multiplying the annual use rate of all plastics additives by the concentration of DINP in the final article and dividing by the mass fraction of all additives in the compounded plastic resin. Annual use rate of all plastics additives is determined according to Section E.7.6, concentration of DINP in the final article is determined according to Section E.7.10, and mass fraction of all additives in compounded resin is determined according to Section E.7.5.

Equation E-50.

$$Q_{DINP\_year} = \frac{Q_{additives\_yr} * F_{DINP}}{F_{additives\_resin}}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
$Q_{additives\_yr}$	=	Annual use rate of all plastic additives (see Section E.7.6) (kg/site-yr)
F_{DINP}	=	Concentration of DINP in final plastic/rubber (see Section E.7.10) (kg/kg)
$F_{additives\_resin}$	=	Mass fraction of all additives in the compounded plastic resin (see Section E.7.5) (kg/kg)

For both compounding and converting, the daily throughput of DINP is calculated using Equation E-51 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section E.7.11

Equation E-51.

$$Q_{DINP\_day} = \frac{Q_{DINP\_year}}{OD_{comp/conv}}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
$OD_{comp/conv}$	=	Operating days for either compounding or converting (based on the specific OES assessed) (see Section E.7.11) (days/yr)

E.7.5 Mass Fraction of All Additives in Compounded Plastic Resin

EPA modeled the mass fraction of additives in compounded plastic resin using a uniform distribution with a lower bound of 0.49 and an upper bound of 0.87. This is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e). The GS provides a range of 0.49 to 0.87 for the fraction of additives in flexible PVC. While this OES is for non-PVC products, EPA used these values as a surrogate for non-PVC plastics.

E.7.6 Annual Use Rate of All Plastic Additives During Converting

The 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e) estimates that the annual facility use rate of all plastic additives is 198,773 kg additives/site-yr. This was calculated by dividing the annual U.S. demand for plastics additives by the number of sites estimated in the GS.

E.7.7 Number of Containers per Year

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

Equation E-52.

$$N_{cont\_unload\_yr} = \frac{Q_{DINP\_year}}{RHO * \left(3.79\ \frac{L}{gal}\right) * V_{drum/tote}}$$

Where:

$V_{drum/tote}$	=	Import container volume (drum or tote; see Section E.7.13) (gal/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.7.10) (kg/site-yr)
RHO	=	DINP density (kg/L)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (container/site-year)

E.7.8 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the 2021 Use of Additives in Plastic Compounding Draft Generic Scenario (U.S. EPA, 2021d), 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e), *ChemSTEER User Guide* (U.S. EPA, 2015), and/or through calculation from other parameters. Release points with operating hours provided from these sources include unloading, compounding, converting, and loading into transport containers.

For unloading during compounding and converting, (release point 1), the operating hours are calculated based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation E-53.

$$OH_{RP1} = \frac{N_{cont\_unload\_yr}}{RATE_{fill\_drum\_tote} * OD}$$

Where:

OH_{RP1}	=	Operating time for release point 1 (hours/site-day)
$RATE_{fill\_drum\_tote}$	=	Fill rate of drums and totes (see Section E.7.17) (containers/h)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (see Section E.7.7) (container/site-year)
OD	=	Operating days (see Section E.7.11) (days/yr)

For compounding and converting operations (release point 3 for compounding, 3 and 4 for converting), EPA assumes compounding and converting occurs for the entirety of a work-shift and assigns a duration of 8 hours/day.

E.7.9 Initial DINP Concentration

EPA modeled the initial DINP concentration using a triangular distribution with a lower bound of 30 percent, upper bound of 100 percent, and mode of 100 percent based on information reported in the 2020 CDR by sites indicating DINP use in non-PVC plastics (U.S. EPA, 2020a).

E.7.10 Final DINP Concentration

EPA modeled final DINP concentration in non-PVC plastic materials using a triangular distribution with a lower bound of 1 percent, upper bound of 40 percent, and mode of 20 percent. This is based on compiled SDS information for non-PVC plastic materials containing DINP. From the compiled data, the minimum concentration was 0 percent and the maximum concentration was 40 percent. EPA used 1 percent as the lower bound as a concentration of 0 percent indicates no DINP in the product and thus not be relevant to the scenario being assessed. The mode represents the median of the high-end concentration range endpoints found in SDSs, as there was no mode of the data. Table_Apx E-22 provides the DINP-containing products compiled from SDS along with their concentrations of DINP.

Table_Apx E-22. Product DINP Concentrations for Incorporation into Non-PVC Plastic Materials

Product	DINP Concentration (%)	Source(s)
Urethane 2718 Part A	0–10	(Smooth-On Inc., 2018b)
Part A: PMC-790	10–20	(Smooth-On Inc., 2018a)
TC-890 PART A	10–30	(BJB Enterprises Inc., 2019b)
TC-889 PART B	15–40	(BJB Enterprises Inc., 2019a)
SoftSand™	4	(Soft Point Industries Inc., 2018)

E.7.11 Operating Days

For compounding, EPA modeled the operating days per year using a triangular distribution with a lower bound of 148 days/yr, an upper bound of 300 days/yr, and a mode of 246 days/yr. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 148-300 days/yr. The lower bound is based on the 2014 Plastics Compounding Draft Generic Scenario (U.S. EPA, 2014c). The report states that a typical range of 148-264 days/yr are assumed. The upper bound is based on ESIG's Specific Environmental Release Category for Rubber Production and Processing (ESIG, 2020b). The SpERC indicates a default of 300 days/yr for rubber manufacturing. The mode is based on the 2021 Generic Scenario for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d), which states that 246 days/yr 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/yr, an upper bound of 254 days/yr, and a mode of 253 days/yr. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 137 to 254 days/yr. 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/yr should be assumed. The mode is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e), which states that an average value of 253 days/yr should be used as a default.

E.7.12 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).

E.7.13 Container Size

EPA assumed that non-PVC plastic manufacturing sites would receive DINP 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). Totes are defined as containing between 100 and 1,000 gallons, and the default tote size is 550 gallons. EPA modeled triangular distributions for each container type using these values, with the lower and upper bounds corresponding to the range of volumes for each container type, and the mode corresponding to the default container size for each container type.

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 2021 Use of Additives in Plastics Converting Draft Generic Scenario (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 7 gallons, and an upper bound of 132 gallons.

E.7.14 Container Residue Loss Fractions

For drums, EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pumping in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 1.7 percent to 4.7 percent and an average of 2.6 percent. The EPA/OPPT Drum Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent (U.S. EPA, 2015).

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Drum Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study (Associates, 1988) for emptying drums by pumping.

For bulk containers, EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying tanks by gravity-draining was aligned with the default central tendency and high-end values from the EPA/OPPT Bulk Transport Residual Model. For unloading tanks by gravity-draining in the PEI Associates Inc. study, EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.02 percent to 0.19 percent and an average of 0.06 percent (Associates, 1988). The EPA/OPPT Bulk Transport Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 0.07 percent and a high-end loss fraction of 0.2 percent.

The underlying distribution of the loss fraction parameter for bulk containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Bulk Transport Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study for emptying tanks by gravity-draining (Associates, 1988).

E.7.15 Dust Generation Loss Fraction, Dust Capture Efficiency, and Dust Control Efficiency

The EPA/OPPT 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 6.0×10^{-6} to 0.045 with a mode of 0.005 by mass. EPA assigned the mode based on the recommended default value for the parameter in the Dust Release Model. The range of initial loss fraction values comes from the range of values compiled from various sources and considered in the development of the Dust Release Model (U.S. EPA, 2021c).

For the fraction captured, EPA assigned a range of 0.931 to 1.0 with a mode of 0.963 by mass. EPA assigned the range for the fraction captured based on the minimum and maximum estimated capture efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction captured based on the average of all lower bound estimated capture efficiency values for all capture technologies presented in the model (U.S. EPA, 2021c).

For the fraction removed/controlled, the 2021 Generic Scenario for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d) and 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e) state that many facilities collect fugitive dust emissions in filters or utilize wet scrubbers. Therefore, EPA used two triangular distributions: a distribution for filter efficiency, and a distribution for wet scrubber efficiency. Each control technology distribution has an equal probability of being selected during each iteration of the simulation. The triangular distribution for filter efficiency has a lower bound of 0.97, upper bound of 0.99999, and mode of 0.99. The triangular distribution for wet scrubber efficiency has a lower bound of 0.20, upper bound of 0.995, and mode of 0.55. These distributions are based on the minimum, maximum, and default values presented for each control technology in the Dust Release Model (U.S. EPA, 2021c).

E.7.16 Fraction of DINP Lost as Particulates During Converting Processes

EPA modeled the loss fraction of particulate DINP during converting using a triangular distribution with a lower bound of 2.0×10^{-5} kg/kg, upper bound of 1.0×10^{-4} kg/kg, and mode of 6.0×10^{-5} kg/kg. This is based on the 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e). The GS presents loss fractions for three types of converting: open process (1.0×10^{-4} kg/kg), partially open process (6.0×10^{-5} kg/kg), or closed process (2.0×10^{-5} kg/kg). EPA used these loss fractions to build the triangular distribution based on magnitude of the values, with the loss fraction for a partially open process being the central value. The distribution does not reflect prevalence of each type of process in the industry.

E.7.17 Container Fill Rates

The *ChemSTEER User Guide* (U.S. EPA, 2015) provides typical fill rates of one container per hour for containers over 10,000 gallons of liquid; two containers per hour for containers with 1,000 to 10,000 gallons of liquid; 20 containers per hour for containers with 20 to 100 gallons of liquid; and 60 containers per hour for containers with less than 20 gallons of liquid.

E.7.18 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015), provides an overall loss fraction of two percent from equipment cleaning.

E.7.19 Cooling Water Loss Fraction

The 2021 Generic Scenario for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d) and 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e) state that the if direct contact cooling water is used for compounding/converting, that the EPA/OPPT Single Vessel Residual Model should be used to estimate releases. The 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).

E.7.20 Rubber Production Rate

The Emission Scenario Document on Additives in Rubber Industry (OECD, 2004a) provides a point source estimate for all rubber manufacturing, with a default production rate of 55,000 kg/day, which is based on a 1999 German Rubber Industry study.

E.7.21 Fraction of DINP Lost from Volatilization During Forming and Molding Processes

The 2021 Use of Additives in Plastics Converting Draft Generic Scenario (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. DINP 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.

E.7.22 Solid Container Loss Fraction

EPA used the EPA/OPPT Solid Residuals in Transport Containers Model to estimate residual releases from solid container cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015), provides an overall loss fraction of one percent from container cleaning.

E.7.23 Trimming Loss Fraction

The 2021 Use of Additives in Plastics Converting Draft Generic Scenario (U.S. EPA, 2021e) recommends a default trimming loss fraction of 0.025 kg/kg.

E.8 PVC Plastics Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the PVC plastics compounding and PVC plastics converting OESs. This approach utilizes the same equations and assumptions presented for non-PVC plastics materials in Appendix E.7. Therefore, only the parameters that differ between approaches, including throughput parameters, DINP concentrations, and dust control efficiency, will be presented in this section for brevity.

E.8.1 Throughput Parameters

EPA estimated the total production volume for all sites using a uniform distribution with a lower bound of 64,568,873 kg/yr and an upper bound of 473,505,075 kg/yr. This is based on CDR data (U.S. EPA, 2020a) and the *2003 European Union Risk Assessment on DINP* (ECJRC, 2003b). The EU Risk Assessment found that 94.9 percent of the DINP produced is used in PVC polymers. CDR states that the total U.S. national PV of DINP is in the range of 150,000,000 lb/yr to 1,100,000,000 lb/yr. Multiplying these figures by 94.9 percent results in 142,350,000 lb/yr (64,568,873 kg/yr) to 1,044,000,000 lb/yr (473,505,075 kg/yr). This production range is used for both PVC 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 DINP is calculated using Equation E-54 by multiplying annual use rate of all plastic additives by mass fraction of DINP in the compounded plastic resin and dividing by the mass fraction of all additives in the compounded plastic resin. Annual use rate of all plastic additives is determined according to Section E.8.5 for compounding and Section E.7.6 for converting. Mass fraction of DINP in the compounded plastic resin is determined according to Section E.8.3, and mass fraction of all additives in the compounded plastic resin is determined according to Section E.7.5.

Equation E-54.

$$Q_{DINP\_year} = \frac{Q_{additives\_yr} * F_{chem\_resin}}{F_{additives\_resin}}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
$Q_{additives\_yr}$	=	Annual use rate of all plastic additives (see Section E.8.5) (kg/site-yr)
F_{chem_resin}	=	Mass fraction of DINP in the compounded plastic resin (see Section E.8.3) (kg/kg)
$F_{additives\_resin}$	=	Mass fraction of all additives in the compounded plastic resin (see Section E.7.5) (kg/kg)

E.8.2 Plastic DINP Concentration

EPA modeled final DINP concentration in PVC plastics using a uniform distribution with a lower bound of 10 percent and upper bound of 45 percent. This is based on a presentation by ACC on DINP and DINP Product Life cycles (ACC, 2020). ACC indicated that DINP is present in PVC wire and cable at 25 percent, in PVC film and sheets at 20 to 45 percent, and in other PVC products at 10 to 40 percent. Therefore, EPA used the lower bound and upper bound of the provided ranges to create a uniform distribution.

E.8.3 Fraction of DINP in Compounded Plastic Resin

EPA modeled the mass fraction of DINP in compounded plastic resin using a uniform distribution with a lower bound of 0.3 and an upper bound of 0.45. This is based on the Generic Scenario for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d). The GS provides a range of 0.3 to 0.45 for the typical weight fraction of plasticizers in rigid PVC.

E.8.4 Dust Capture and Control Efficiency

The EPA/OPPT 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. Section E.7.15 provides the distribution for the initial loss fraction.

For the fraction captured, EPA assigned a range of 0 to 1.0 with a mode of 0.321 by mass. The Agency assigned the range for the fraction captured based on the minimum and maximum estimated capture efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction captured based on the average of all lower bound estimated capture efficiency values for all capture technologies presented in the model with a safety factor of three applied according to the model.

For the fraction removed/controlled, EPA assigned a range of 0 to 1.0 with a mode of 0.26 by mass. EPA assigned the range for the fraction controlled based on the minimum and maximum estimated control efficiencies listed in the data compiled for the Dust Release Model. EPA assigned the mode for the fraction controlled based on the average of all lower bound estimated control efficiency values for all control technologies presented in the model with a safety factor of three applied according to the model.

E.8.5 Annual Use Rate of All Plastic Additives During Compounding

The Generic Scenario for the Use of Additives in Plastic Compounding (U.S. EPA, 2021d) estimates that the annual facility use rate of all plastic additives at compounding sites is 4,319,048 kg additives/site-yr. This was calculated by dividing the annual U.S. demand for plastics additives by the number of sites estimated in the GS.

E.9 Application of Adhesives and Sealants Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the application of adhesives and sealants OES. This approach utilizes the Emission Scenario Document 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 DINP during use of adhesives and sealants are a function of DINP's physical properties, container size, mass fractions, and other model parameters. Although physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production volume, product throughput, DINP 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.

E.9.1 Model Equations

Table_Apx E-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 use of adhesives and sealants OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix E.9.2. The Monte Carlo simulation calculated the total

DINP 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 E-23. 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/OAQPS AP-42 Small Container Residual Model (Appendix E.1)	Q_{DINP_year}; $F_{residue}$; V_{cont}; RHO; OD; F_{DINP}
Release source 2: Open Surface Losses to Air During Container Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; MW; VP; $RATE_{air\_speed}$; D_{cont_clean}; T; P Operating Time: $RATE_{fill\_cont}$; RHO; V_{cont}; Q_{DINP_year}
Release source 3: Transfer Operation Losses from Unloading Adhesive Formulation.	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{DINP}; VP; f_{sat}; MW; R; T ; $RATE_{fill\_cont}$; V_{cont} Operating Time: $RATE_{fill\_cont}$; RHO; V_{cont}; Q_{DINP_year}
Release source 4: Equipment Cleaning Wastes.	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; $F_{equipment\_cleaning}$
Release source 5: Open Surface Losses to Air During Equipment Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; 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 E-55.	Q_{DINP_day}; $F_{trimming}$

Release source 8 daily release (Trimming Wastes) is calculated using the following equation:

Equation E-55.

$$Release\_perDay_{RP8} = Q_{DINP\_day} * F_{trimming}$$

Where:

$Release\_perDay_{RP8}$ = DINP released for release source 8 (kg/site-day)
Q_{DINP_day} = Facility throughput of DINP (see Section E.9.3) (kg/site-day)
$F_{trimming}$ = Fraction of DINP released as trimming waste (see Section E.9.13) (kg/kg)

E.9.2 Model Input Parameters

Table_Apx E-24 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 E-24. 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	$Q_{product\_yr}$	kg/yr	13,500	2,300	141,498	13,500	Triangular	See Section E.9.3
Adhesive/Sealant DINP Concentration	F_{DINP}	kg/kg	0.1	0.001	0.4	0.1	Triangular	See Section E.9.7
Operating Days	OD	days/yr	250	50	365	260	Triangular	See Section E.9.8
Air Speed	$RATE_{air\_speed}$	ft/min	19.7	2.56	398	–	Lognormal	See Section E.9.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.9.10
Small Container Volume	V_{cont}	gal	1	1	5	1	Triangular	See Section E.9.11
Small Container Residual Loss Fraction	$F_{residue}$	kg/kg	0.003	0.0003	0.006	0.003	Triangular	See Section E.9.12
Fraction of DINP Released as Trimming Waste	$F_{trimming}$	kg/kg	0.04	0	0.04	0.04	Triangular	See Section E.9.13
Vapor Pressure at 25C	VP	mmHg	5.40E−07	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Small Container Fill Rate	$RATE_{fill\_cont}$	containers/h	60	–	–	–	–	See Section E.9.14
Diameter of Opening – Container Cleaning	D_{cont_clean}	cm	5.08	–	–	–	–	See Section E.9.15
Diameter of Opening – Equipment Cleaning	D_{equip_clean}	cm	92	–	–	–	–	See Section E.9.15
Operating Hours for Equipment Cleaning	OH_{equip_clean}	h/day	1	–	–	–	–	See Section E.9.6
Equipment Cleaning Loss Fraction	$F_{equipment\_cleaning}$	kg/kg	0.02	–	–	–	–	See Section E.9.16

E.9.3 Number of Sites

Per 2020 U.S. Census Bureau data for the NAICS codes identified in the *Emission Scenario Document on Use of Adhesives* (OECD, 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 E-56.

$$N_s = \frac{PV}{Q_{DINP_{year}}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume (see Section E.9.4) (kg/year)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.9.4) (kg/site-yr)

E.9.4 Throughput Parameters

The annual throughput of adhesive and sealant product is modeled using a triangular distribution with a lower bound of 2,300 kg/yr, an upper bound of 141,498 kg/yr, and mode of 13,500 kg/yr. This is based on the Emission Scenario Document 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), and computer/electronic and electrical product manufacturing. The lower and upper bound adhesive use rates for these categories was 2,300 to 141,498 kg/yr. The mode is based on the ESD default for unknown end-use markets.

The annual throughput of DINP in adhesives/sealants is calculated using Equation E-57 by multiplying the annual throughput of all adhesives and sealants by the concentration of DINP in the adhesives/sealants.

Equation E-57.

$$Q_{DINP\_year} = Q_{product\_yr} * F_{DINP}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
$Q_{product\_yr}$	=	Facility annual throughput of all adhesive/sealant (kg/bt)
F_{DINP}	=	Concentration of DINP in adhesive/sealant (see Section E.9.8) (kg/kg)

The daily throughput of DINP is calculated using Equation E-58 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section E.9.8.

Equation E-58.

$$Q_{DINP\_day} = \frac{Q_{DINP\_year}}{OD}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
OD	=	Operating days (see Section E.9.8) (days/yr)

E.9.5 Number of Containers per Year

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

Equation E-59.

$$N_{cont\_unload\_yr} = \frac{Q_{DINP\_year}}{RHO * \left(3.79\ \frac{L}{gal}\right) * V_{cont}}$$

Where:

V_{cont}	=	Import container volume (see Section E.9.11) (gal/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.9.3) (kg/site-yr)
RHO	=	DINP density (kg/L)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (container/site-year)

E.9.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the Emission Scenario Document 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 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 E-60.

$$OH_{RP2/RP3} = \frac{N_{cont\_unload\_yr}}{RATE_{fill\_cont} * OD}$$

Where:

$OH_{RP2/RP3}$	=	Operating time for release points 2 and 3 (hours/site-day)
$RATE_{fill\_cont}$	=	Container fill rate (see Section E.9.14) (containers/h)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (see Section E.9.5) (container/site-year)
OD	=	Operating days (see Section E.9.8) (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 one hour/batch multiplied by the number of batches per day. Per the Emission Scenario Document on Use of Adhesives (OECD, 2015b), the default number of batches per day is one. Therefore, EPA assumes that equipment cleaning occurs for one hour/day.

E.9.7 Adhesive/Sealant DINP Concentration

EPA modeled DINP concentration in adhesives and sealants using a triangular distribution with a lower bound of 0.1 percent, upper bound of 40 percent, and mode of 10 percent. The upper bound, lower bound, and mode are based on compiled SDS information for adhesives and sealant products containing DINP. 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 concentration was 40 percent, and the mode of low-end product concentrations was 10 percent. The mode of low-end concentrations was selected since 10 percent was also the median of all concentration data. Table_Apx E-25 provides the DINP-containing adhesive and sealant products compiled from SDS along with their concentrations of DINP.

Table_Apx E-25. Product DINP Concentrations for Use of Adhesives and Sealants

Product	DINP Concentration (%)	Source(s)/Reference(s)
Duro-Last® Pitch-Pan Filler	0.1–1	(Duro-Last Inc., 2017)
SIDE Winder Advanced Polymer Sealant – All Colors	1–2.5	(DAP Products Inc., 2015)
3M™ Polyurethane Sealant 540 (Various Colors)	0–4.99	(3M, 2019)
HVAC – Acrylic Duct Sealant	0–4.99	(Hodgson Sealants, 2015c)
Fireseal 6	0–5	(Macsim Fastenings, 2017)
SB 150HV – Natural	1–5	(Seal Bond, 2018)
HS20	0–9.99	(Hodgson Sealants, 2015a)
Aquacaulk	5–9.99	(Hodgson Sealants, 2014)
Brewers Premium Decorators' Caulk	5–9.99	(C.Brewer & Sons Ltd., 2016)
PF 225 Urethane Windshield Adhesive Black	1–10	(Pro Form Products Ltd., 2016)
CP 606 Flexible Firestop Sealant	10–15	(Hilti (Canada) Corporation, 2012)
DuoSil® Ultra	10–15	(Siroflex Incorporated, 2016)
Tremco JS443 A, B	10–19.99	(Tremco Illbruck Production, 2017a, b)
Illbruck SP523	10–19.99	(Tremco Illbruck Production, 2016)
wedi Joint Sealant	5–20	(Wedi Corporation, 2018)
U-Pol Tiger Seal – Grey	5–23	(U-Pol Australia Pty Limited, 2019)
Everbuild EB25 Crystal Clear	20–24.99	(Sika, 2019)
HS20 Clear	10–25	(Hodgson Sealants, 2015b)
SRW Vertical Instant Lock Adhesive	10–25	(SRW Products Technical Services, 2019)
CT1 Colours (Excluding Silver)	10–29.99	(C-Tec N.I Limited, 2017)
Illbruck SP036	20–29.99	(Tremco Illbruck Produktion GmbH, 2015)
FUSOR 800DTM	25–30	(LORD Corporation, 2018)
EPDM Solvent-Free Bonding Adhesive	30–31	(Firestone Building Products Company, 2018)
ClearSeal Glasklar	25–39.99	(Sika Danmark A/S, 2018)
Coat & Seal	20–40	(Selena USA Inc., 2015)
A-A_529 Adhesive and Sealing Compound	3–100	(Mach-Dynamics, 2014)

Product	DINP Concentration (%)	Source(s)/Reference(s)
BETASEAL™ Xpress 30 BP Urethane Adhesive	15–25	(The Dow Chemical Company, 2018)
Quick-Cure Primerless HV Urethane U418HV	15–25	(Nova Scotia Company, 2018)
SRP 180 HV	10–30	(Shat-R-Proof Corp., 2014)
Gardner Flex 'n Fill Premium Patching Paste	2	(Home Depot, 2018)
HawkFlash LiquiCap – Component A	0–5	(Ergon Asphalt & Emulsions Inc., 2019)

E.9.8 Operating Days

EPA modeled the operating days per year using a triangular distribution with a lower bound of 50 days/yr, an upper bound of 365 days/yr, and a mode of 260 days/yr. 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 to 365 days/yr. This is based on the Emission Scenario Document on Use of Adhesives (OECD, 2015b). The ESD provides operating days for several end-use categories, as listed in Section E.9.3. The range of operating days for the end-use categories is 50 to 365 days/yr. The mode of the distribution is based on the ESD's default of 260 days/yr for unknown or general use cases.

E.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 dataset 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.

E.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). It 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).

E.9.11 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 1 and 5 gallons of liquid, and the default bottle size is 1 gallon (U.S. EPA, 2015). Therefore, EPA modeled container size using a triangular distribution with a lower bound and mode of 1 gallon, an upper bound of 5 gallons.

E.9.12 Small Container Residue Loss Fraction

EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying drums by pouring was aligned with the default central tendency and high-end values from the EPA/OPPT Small Container Residual Model. For unloading drums by pouring in the PEI Associates Inc. study (Associates, 1988), EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.03 percent to 0.79 percent and an average of 0.32 percent. The EPA/OPPT Small Container Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent.

The underlying distribution of the loss fraction parameter for small containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Small Container Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study (Associates, 1988) for emptying drums by pouring.

E.9.13 Fraction of DINP Released as Trimming Waste

EPA modeled the fraction of DINP released as trimming waste using a uniform distribution with a lower bound of 0 and upper bound of 0.04. This is based on the Emission Scenario Document 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.

E.9.14 Container Unloading 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.

E.9.15 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 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).

E.9.16 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015) provides an overall loss fraction of 2 percent from equipment cleaning.

E.10 Application of Paints and Coatings Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the application of paints and coatings OES. This approach utilizes the Emission Scenario Document on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a), Emission Scenario Document on the Coating Industry (Paints, Lacquers, and Varnishes) (OECD, 2009c), and Emission Scenario Document 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 DINP during the application of paints and coatings are a function of DINP's physical properties, container size, mass fractions, and other model parameters. Although physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production volume, throughput, DINP 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.

E.10.1 Model Equations

Table_Apx E-26 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Application of paints and coatings OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix E.10.2. The Monte Carlo simulation calculated the total DINP 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 E-26. 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 (Appendix E.1)	Vapor Generation Rate: F_{DINP}; VP; f_{sat}; MW; R; T; V_{cont}; $RATE_{fill\_cont}$ Operating Time: Q_{DINP_year}; $RATE_{fill\_cont}$; V_{cont}; RHO; F_{DINP}; OD
Release source 2: Open Surface Losses to Air During Raw Material Sampling.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; MW; VP; $RATE_{air\_speed}$; $D_{sampling}$; T; P Operating Time: $OH_{sampling}$
Release source 3: Container Cleaning Wastes.	EPA/OAQPS AP-42 Small Container Residual Model (Appendix E.1)	Q_{DINP_day}; $F_{residue}$
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; MW; VP; $RATE_{air\_speed}$; D_{cont_clean}; T; P Operating Time: Q_{DINP_year}; $RATE_{fill\_cont}$; V_{cont}; RHO; F_{DINP}; OD
Release source 5: Process Releases During Operations.	See Equation E-61 through Equation E-65	Q_{DINP_day}; $F_{transfer\_eff}$; $F_{capture\_eff}$; $F_{solidrem\_eff}$; OD
Release source 6: Equipment Cleaning Wastes.	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	Q_{DINP_day}; LF_{equip_clean}
Release source 7: Open Surface Losses to Air During Equipment Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP}; 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 (Appendix E.1)	Q_{DINP_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 E-61.

$$Release\_perDay_{RP5\_total} = Q_{DINP\_day} * (1 - F_{transfer\_eff})$$

Where:

$Release\_perDay_{RP5\_total}$ = DINP released for release source 5 to all release media (kg/site-day)

Q_{DINP_day}	=	Facility throughput of DINP (see Section E.10.3) (kg/site-day)
$F_{transfer\_eff}$	=	Paint/coating transfer efficiency fraction (see Section E.10.15) (unitless)

Transfer efficiency is determined according to Section E.10.15. The percent of release 5 that is released to water is calculated using the following equation:

Equation E-62.

$$\%_{water} = F_{capture\_eff} * \left(1 - F_{solidrem\_eff}\right)$$

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 E.10.18) (kg/kg)
$F_{solidrem\_eff}$	=	Fraction of solid removed in the spray mist of sprayed paints/coatings (see Section E.10.19) (kg/kg)

Booth capture efficiency is determined according to Section E.10.18 and solid removal efficiency is determined according to Section E.10.19. The percent of release 5 that is released to air is calculated using the following equation:

Equation E-63.

$$\%_{air} = \left(1 - F_{capture\_eff}\right)$$

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 E.10.18) (kg/kg)

The percent of release 5 that is released to land is calculated using the following equation:

Equation E-64.

$$\%_{land} = F_{capture\_eff} * F_{solidrem\_eff}$$

Where:

$\%_{land}$	=	Percent of release 5 that is released to land (unitless)
$F_{capture\_eff}$	=	Booth capture efficiency for spray-applied paints/coatings (see Section E.10.18) (kg/kg)
$F_{solidrem\_eff}$	=	Fraction of solid removed in the spray mist of sprayed paints/coatings (see Section E.10.19) (kg/kg)

Finally, the release amounts to each media are calculated using the following equation:

Equation E-65.

$$Release\_perDay_{RP5\_media} = Release\_perDay_{RP5\_total} * \%_{media}$$

Where:

$Release\_perDay_{RP5\_media}$	=	Amount of release 5 that is released to water, air, or land (kg/site-day)
$Release\_perDay_{RP5\_total}$	=	DINP 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)

E.10.2 Model Input Parameters

Table_Apx E-27 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 E-27. 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	225,000	2,694	446,600	225,000	Triangular	See Section E.10.3
Paint/Coating DINP Concentration	F_{DINP}	kg/kg	0.05	0.001	0.2	0.05	Triangular	See Section E.10.7
Operating Days	OD	days/yr	250	225	300	250	Triangular	See Section E.10.8
Air Speed	$RATE_{air\_speed}$	ft/min	19.7	2.56	398	–	Lognormal	See Section E.10.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.10.10
Container Size	V_{cont}	gal	5	5	20	5	Triangular	See Section E.10.11
Small Container Loss Fraction	$F_{residue}$	kg/kg	0.003	0.003	0.006	0.003	Triangular	See Section E.10.12
Fraction of DINP Lost During Sampling – 1 (Q_{DINP_day} < 50 kg/site-day)	$F_{sampling\_1}$	kg/kg	0.02	0.002	0.02	0.02	Triangular	See Section E.10.13
Fraction of DINP Lost During Sampling – 2 (Q_{DINP_day} 50-200 kg/site-day)	$F_{sampling\_2}$	kg/kg	0.005	0.0006	0.005	0.005	Triangular	See Section E.10.13
Fraction of DINP Lost During Sampling – 3 (Q_{DINP_day} 200-5000 kg/site-day)	$F_{sampling\_3}$	kg/kg	0.004	0.0005	0.004	0.004	Triangular	See Section E.10.13
Fraction of DINP Lost During Sampling – 4 (Q_{DINP_day} > 5000 kg/site-day)	$F_{sampling\_4}$	kg/kg	0.0004	0.00008	0.0004	0.0004	Triangular	See Section E.10.13
Diameter of Opening – Sampling	$D_{sampling}$	cm	2.5	2.5	10	—	Uniform	See Section E.10.14
Transfer Efficiency Fraction	$F_{transfer\_eff}$	unitless	0.65	0.2	0.8	0.65	Triangular	See Section E.10.15

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	5.40E−07	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Small Container Fill Rate	$RATE_{fill\_cont}$	containers/h	60	–	–	–	–	See Section E.10.16
Diameter of Opening – Container Cleaning	D_{cont_clean}	cm	5.08	–	–	–	–	See Section E.10.14
Diameter of Opening – Equipment Cleaning	D_{equip_clean}	cm	92	–	–	–	–	See Section E.10.14
Sampling Duration	$OH_{sampling}$	h/day	1	–	–	–	–	See Section E.10.6
Equipment Cleaning Duration	OH_{equip_clean}	h/day	4	–	–	–	–	See Section E.10.6
Equipment Cleaning Loss Fraction	LF_{equip_clean}	kg/kg	0.02	–	–	–	–	See Section E.10.17
Capture Efficiency for Spray Booth	$F_{capture\_eff}$	kg/kg	0.9	–	–	–	–	See Section E.10.18
Fraction of Solid Removed in Spray Mist	$F_{solidrem\_eff}$	kg/kg	1	–	–	–	–	See Section E.10.19

E.10.3 Number of Sites

Per 2020 U.S. Census Bureau data for the NAICS codes identified in the Emission Scenario Document on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a), Emission Scenario Document on the Coating Industry (Paints, Lacquers, and Varnishes) (OECD, 2009c), and Emission Scenario Document 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 E-66.

$$N_s = \frac{PV}{Q_{DINP_{year}}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume (see Section E.9.4) (kg/year)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.9.4) (kg/site-yr)

E.10.4 Throughput Parameters

The annual throughput of paint and coating product is modeled using a triangular distribution with a lower bound of 2,694 kg/yr, an upper bound of 446,600 kg/yr, and mode of 225,000 kg/yr. The lower bound is based on the Emission Scenario Document 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 2,694-265,000 kg of radiation curable coatings produced per site, per year. The lower bound was taken from this range. The upper bound is based on the Generic Scenario for Spray Coatings in the Furniture Industry (U.S. EPA, 2004c). The GS provides a range of 5,000 to 446,000 L of furniture coatings used per year based on plant size, with an assumption of 1 kg/L as the density of the coating. The upper bound was taken from this range and using the assumed coating density. The mode is based on CEPE's *SpERC Industrial Application of Coatings by Spraying* (ESIG, 2020a). The factsheet provides a production rate of 1,000 kg/day for 225 days/yr, for a total of 225,000 kg/yr.

The annual throughput of DINP In paints/coatings is calculated using Equation E-67 by multiplying the annual throughput of all paints and coatings by the concentration of DINP in the paints/coatings.

Equation E-67.

$$Q_{DINP\_year} = Q_{coat\_yr} * F_{DINP}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
Q_{coat_yr}	=	Facility annual throughput of all paints/coatings (kg/bt)
F_{DINP}	=	Concentration of DINP in paints/coatings (see Section E.10.7) (kg/kg)

The daily throughput of DINP is calculated using Equation E-68 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section E.10.8.

Equation E-68.

$$Q_{DINP\_day} = \frac{Q_{DINP\_year}}{OD}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
OD	=	Operating days (see Section E.10.8) (days/yr)

E.10.5 Number of Containers per Year

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

Equation E-69.

$$N_{cont\_unload\_yr} = \frac{Q_{DINP\_year}}{F_{DINP} * RHO * \left(3.79\ \frac{L}{gal}\right) * V_{cont}}$$

Where:

V_{cont}	=	Container volume (see Section E.10.11) (gal/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.10.3) (kg/site-yr)
RHO	=	DINP density (kg/L)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (container/site-year)
F_{DINP}	=	Concentration of DINP in paints/coatings (see Section E.10.7) (kg/kg)

E.10.6 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 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 E-70.

$$OH_{RP1/RP4} = \frac{N_{cont\_unload\_yr}}{RATE_{fill\_cont} * OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 (hours/site-day)
$RATE_{fill\_cont}$	=	Container fill rate (see Section E.10.16) (containers/h)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (see Section E.10.5) (container/site-year)
OD	=	Operating days (see Section E.10.8) (days/site-year)

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).

E.10.7 Paint/Coating DINP Concentration

EPA modeled DINP concentration in paints and coatings using a triangular distribution with a lower bound of 0.01 percent, upper bound of 20 percent, and mode of 5 percent. This is based on compiled SDS information for paint and coating products containing DINP. The lower and upper bounds represent the minimum and maximum reported concentrations in the SDSs. The mode of high-end product concentrations was 5 percent. Table_Apx E-28 provides the DINP-containing paint and coating products compiled from SDS along with their concentrations of DINP.

Table_Apx E-28. Product DINP Concentrations for Use of Paints and Coatings

Product	DINP Concentration (%)	Source(s)
PHENOLINE 380 PART A	0.1–1	(Carboline Company, 2015)
RAL 9010 White Aerosol	0.1–1	(Premier Aerosol Packaging Inc., 2017)
Freeman 90-1 Burnt Orange Pattern Coating	1–5	(Freeman Manufacturing and Supply Company, 2018)
Castle® Cast Iron Gray Paint™	1–5	(Castle Products Inc., 2016)
"KEM AQUA® 600T Water Reducible Enamel – White"	0–5	(Sherwin Williams, 2020)
Brush On Electrical Tape Black 4 Fl.Oz	1–10	(Chemical and Company, 2016)
B610-01006 Flattener	1–10	(RPM Wood Finishes Group, 2004c)
GlasGrid	0–20	(Saint-Gobain ADFOR, 2017)
B101-G804 B104-G202 White Gloss Jet Spray, B101- G826 Black Gloss Jet Spray	1–10	(RPM Wood Finishes Group, 2004a, b)
Skudo Glass Advanced	10–20	(Skudo LLC, 2013)

E.10.8 Operating Days

EPA modeled the operating days per year using a triangular distribution with a lower bound of 225 days/yr, an upper bound of 300 days/yr, and a mode of 250 days/yr. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 225 to 300 days/yr. 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/yr as the number of emission days. The upper bound is based on the European Risk Report for DINP (ECJRC, 2003a) which provided a default of 300 days/yr. The mode is based on the Generic Scenario for Automobile Spray Coating (U.S. EPA, 1996) which estimates 250 days/yr, based on 5 days/week operation that takes place 50 weeks/yr.

E.10.9 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom (Baldwin and Maynard, 1998). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the dataset 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.

E.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 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).

E.10.11 Container Size

EPA assumed that paint and coating use sites would receive DINP in small containers. According to the *ChemSTEER User Guide*, small containers are defined as containing between 5 and 20 gallons of liquid, and the default drum size is 5 gallons (U.S. EPA, 2015). Therefore, EPA modeled import container size using a triangular distribution with a lower bound of 5 gallons, an upper bound of 20 gallons, and a mode of 5 gallons.

E.10.12 Small Container Loss Fraction

EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying drums by pouring was aligned with the default central tendency and high-end values from the EPA/OPPT Small Container Residual Model. For unloading drums by pouring in the PEI Associates Inc. study (Associates, 1988), EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.03 percent to 0.79 percent and an average of 0.32 percent. The EPA/OPPT Small Container Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent.

The underlying distribution of the loss fraction parameter for small containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Small Container Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study (Associates, 1988) for emptying drums by pouring.

E.10.13 Sampling Loss Fraction

Sampling loss fractions were estimated using the *March 2023 Methodology for Estimating Environmental Releases from Sampling Wastes* (U.S. EPA, 2023b). In this methodology, EPA completed a search of over 300 IRERs completed in the years 2021 and 2022 for sampling release data, including a similar proportion of both PMNs and 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 E-29 presents a summary of the chemical daily throughputs and corresponding loss fractions.

Table_Apx E-29. 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 E.10.3.

E.10.14 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 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 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 guide (U.S. EPA, 2015).

E.10.15 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/OPPT Automobile OEM Overspray Loss Model. Per the model, the transfer efficiency varies based on the type of spray gun used. For high volume, low pressure (HVLP) spray guns, the default transfer efficiency is 0.65. For conventional spray guns, the default transfer efficiency is 0.2 by mass. Across all spray technologies, the ESD on Coating Industry (OECD, 2009c) estimates a transfer efficiency of 30 to 80 percent. Therefore, EPA used 0.8 as the upper bound.

E.10.16 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.

E.10.17 Equipment Cleaning Loss Fraction

EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015), provides an overall loss fraction of 2 percent from equipment cleaning.

E.10.18 Capture Efficiency for Spray Booth

The Emission Scenario Document on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating (OECD, 2011b) uses the EPA/OPPT Automobile Refinish Coating Overspray Loss Model to estimate releases from spray coating. This model assumes a spray booth capture efficiency of 90 percent.

E.10.19 Fraction of Solid Removed in Spray Mist

The Emission Scenario Document on the Application of Radiation Curable Coatings, Inks, and Adhesives via Spray, Vacuum, Roll, and Curtain Coating (OECD, 2011b) uses the EPA/OPPT Automobile Refinish Coating Overspray Loss Model to estimate releases from spray coating. This model assumes a solid removal efficiency of 100 percent.

E.11 Use of Laboratory Chemicals Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the use of laboratory chemicals OES. This approach utilizes the Generic Scenario on Use of Laboratory Chemicals (U.S. EPA, 2023c) and CDR data (U.S. EPA, 2020a) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the GS, EPA identified the following release sources from use of laboratory chemicals:

- Release source 1: Transfer Operation Losses to Air from Unloading Laboratory Chemicals.
- Release source 2: Dust Emissions from Transferring Powders.
- Release source 3: Container Cleaning Wastes.
- 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: Releases During Laboratory Analysis.
- Release source 8: Laboratory Waste Disposal.

Environmental releases for DINP during the use of laboratory chemicals are a function of DINP'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, DINP 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.

E.11.1 Model Equations

Table_Apx E-30 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 values for these variables are provided in Appendix E.11.2. The Monte Carlo simulation calculated the total DINP 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 E-30. 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.	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{DINP-L}; VP; f_{sat}; MW; R; T; V_{cont}; $RATE_{fill}$ Operating Time: Q_{DINP_day}; V_{cont}; $RATE_{fill}$; RHO; OD; F_{DINP-L}
Release source 2: Dust Emissions from Transferring Powders.	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading/Loading Operations of Solid Powders (Appendix E.1)	Q_{DINP_day}; $F_{dust\_generation}$
Release source 3: Container Cleaning Wastes.	EPA/OAQPS AP-42 Small Container Residual Model or EPA/OPPT Solid Residuals in Transport Containers Model, based on physical form (Appendix E.1)	Q_{DINP_day}; $F_{residue}$; V_{cont}; RHO; F_{DINP-S}; F_{DINP-L}; LF_{cont}; OD; Q_{cont_solid}
Release source 4: Open Surface Losses to Air During Container Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP-L}; MW; VP; $RATE_{air\_speed}$; $D_{cleaning}$; T; P Operating Time: Q_{DINP_day}; V_{cont}; $RATE_{fill}$; RHO; OD; F_{DINP-L}
Release source 5: Equipment Cleaning Wastes.	EPA/OPPT Multiple Process Vessel Residual Model or EPA/OPPT Solids Residuals in	Q_{DINP_day}; $F_{lab\_residue\_L}$; $F_{lab\_residue\_S}$

Release Source	Model(s) Applied	Variables Used
	Transport Container Model, based on physical form (Appendix E.1)	
Release source 6: Open Surface Losses to Air During Equipment Cleaning.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP-L}; MW; VP; $RATE_{air\_speed}$; $D_{cleaning}$; T; P Operating Time: $OH_{cleaning}$
Release source 7: Releases During Laboratory Analysis.	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{DINP-L}; MW; VP; $RATE_{air\_speed}$; $D_{testing}$; T; P Operating Time: $OH_{testing}$
Release source 8: Laboratory Waste Disposal.	See Equation E-71 and Equation E-72	Q_{DINP_day}; $F_{residue}$; LF_{cont}; $F_{lab\_residue\_L}$; $F_{lab\_residue\_S}$; $F_{dust\_generation}$; Release Points 1,3,6,and 7

For liquid DINP, release source 8 (Laboratory Waste Disposal) is calculated via a mass-balance, via the following equation:

Equation E-71.

$$Release\_perDay_{RP8-L} = \left(Q_{DINP\_day} - Release_{perDay_{RP1}} - Release_{perDay_{RP3}} - Release_{perDay_{RP6}} - Release\_perDay_{RP7}\right) * \left(1 - F_{residue} - F_{lab\_residue\_L}\right)$$

Where:

$Release\_perDay_{RP8-L}$	=	Liquid DINP released for release source 8 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (see Section E.11.3) (kg/site-day)
$Release\_perDay_{RP1}$	=	Liquid DINP released for release source 1 (kg/site-day)
$Release\_perDay_{RP3}$	=	Liquid DINP released for release source 3 (kg/site-day)
$Release\_perDay_{RP6}$	=	Liquid DINP released for release source 6 (kg/site-day)
$Release\_perDay_{RP7}$	=	Liquid DINP released for release source 7 (kg/site-day)
$F_{residue}$	=	Fraction of DINP remaining in transport containers (see Section E.11.12) (kg/kg)
$F_{lab\_residue\_L}$	=	Fraction of DINP remaining in lab equipment (see Section E.11.16) (kg/kg)

For solids containing DINP, release source 8 (Laboratory Waste Disposal) is calculated via a mass-balance, via the following equation:

Equation E-72

$$Release\_perDay_{RP8-S} = Q_{DINP\_day} * \left(1 - F_{dust\_generation} - LF_{cont} - F_{lab\_residue\_S}\right)$$

Where:

$Release\_perDay_{RP8-S}$	=	Solid DINP released for release source 8 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (see Section E.11.3) (kg/site-day)
$F_{dust\_generation}$	=	Fraction of DINP lost during unloading of solid powder (see Section E.11.13) (kg/kg)
LF_{cont}	=	Fraction of DINP remaining in transport containers (see Section

		E.11.12) (kg/kg)
$F_{lab\_residue\_S}$	=	Fraction of DINP remaining in lab equipment (see Section E.11.16) (kg/kg)

E.11.2 Model Input Parameters

Table_Apx E-31 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 E-31. 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	
Total Production Volume of DINP	PV	kg/yr	263,843	–	–	–	–	See Section E.11.3
Annual Facility Throughput of Solid DINP	$Q_{stock\_site\_day\_S}$	g/site-day	917.4	–	–	–	–	See Section E.11.3
Annual Facility Throughput of Liquid DINP (High Concentration)	$Q_{stock\_site\_day\_L}$	mL/site-day	2,000	42.4	4000	2000	Triangular	See Section E.11.3
Annual Facility Throughput of Liquid DINP (Low Concentration)	$Q_{stock\_site\_day\_C}$	mL/site-day	34,829	–	–	–	–	See Section E.11.3
Liquid DINP Concentration (High Concentration)	$F_{DINP\text{-}L}$	kg/kg	0.995	–	–	–	–	See Section E.11.7
Liquid DINP Concentration (Low Concentration)	$F_{DINP\text{-}C}$	kg/kg	0.001	–	–	–	–	See Section E.11.7
Solid DINP Concentration	$F_{DINP\text{-}S}$	kg/kg	0.03	–	–	–	–	See Section E.11.7
Operating Days	OD	days/yr	260	174	260	—	Discrete	See Section E.11.8
Air Speed	$RATE_{air\_speed}$	ft/min	19.7	2.56	398	—	Lognormal	See Section E.11.9
Saturation Factor	f_{sat}	dimensionless	0.5	0.5	1.45	0.5	Triangular	See Section E.11.10
Liquid Container Size	V_{cont}	gal	1	0.5	1	1	Triangular	See Section E.11.11
Solid Container Mass	Q_{cont_solid}	kg	1	0.5	1	1	Triangular	See Section E.11.11
Small Container Loss Fraction	$F_{residue}$	kg/kg	0.003	0.003	0.006	0.003	Triangular	See Section E.11.12
Solid Container Loss Fraction	LF_{cont}	kg/kg	0.01	–	–	–	–	See Section E.11.12
Fraction of chemical lost during transfer of solid powders	$F_{dust\_generation}$	kg/kg	0.005	0.001	0.03	0.005	Triangular	See Section E.11.13

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	5.40E−07	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	418.62	–	–	–	–	Physical property
Gas Constant	R	atm-cm3/gmol-L	82.05	–	–	–	–	Universal constant
Density of DINP	RHO	kg/L	0.9758	–	–	–	–	Physical property
Density of Low-Concentration DINP	RHO_C	kg/L	0.79018	–	–	–	–	Physical property
Temperature	T	K	298	–	–	–	–	Process parameter
Pressure	P	atm	1	–	–	–	–	Process parameter
Small Container Fill Rate	$RATE_{fill}$	containers/h	60	–	–	–	–	See Section E.11.14
Diameter of Opening – Container Cleaning	$D_{cleaning}$	cm	5.08	–	–	–	–	See Section E.11.15
Lab Testing Duration	$OH_{testing}$	h/day	1	–	–	–	–	See Section E.11.6
Equipment Cleaning Duration	$OH_{cleaning}$	h/day	4	–	–	–	–	See Section E.11.6
Equipment Cleaning Loss Fraction – Liquid	$F_{lab\_residue\_L}$	kg/kg	0.02	–	–	–	–	See Section E.11.16
Equipment Cleaning Loss Fraction – Solid	$F_{lab\_residue\_S}$	kg/kg	0.01	–	–	–	–	See Section E.11.16

E.11.3 Throughput Parameters

The Use of Laboratory Chemicals – Generic Scenario for Estimating Occupational Exposures and Environmental Releases (U.S. EPA, 2023c) provides daily throughput of DINP 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. Midpoints of these ranges are 2 L/day for liquids and 255 g/day for solids. Laboratory stock solutions are used for multiple analyses and eventually need to be replaced. The expiration or replacement times range from daily to six months (U.S. EPA, 2023c). For this scenario, EPA assumes stock solutions are prepared daily. Therefore, EPA initially assigned a triangular distribution for the daily throughput of laboratory stock solutions with upper and lower bounds corresponding to the high and low use rates, and the midpoints as the modes.

However, the proposed distribution for low concentration (0.1% DINP) liquid stock solutions and solids would exceed the maximum number of 36,873 sites. Therefore, EPA used a deterministic value of 917.4 g/site-day for solids and 34,829 mL/site-day for low concentration liquid stock solutions. These deterministic values were calculated using the maximum operating days of 260 days/yr and the highest known concentrations (0.03 kg/kg for solids and 0.001 kg/kg for low concentration liquids). For high concentration liquids (99.5% DINP), EPA kept the mode and upper bounds from the initial distribution but adjusted the lower bound to prevent the number of sites from exceeding the maximum. This lower bound ended up as 42.4 mL/site-day.

The daily throughput of DINP in liquid laboratory chemicals is calculated using Equation E-73 by multiplying the daily throughput of all laboratory solutions by the concentration of DINP in the solutions and converting volume to mass.

Equation E-73.

$$Q_{DINP\_day} = Q_{stock\_site\_day\_L} * F_{DINP-L} * RHO * \frac{0.001L}{mL}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
$Q_{stock\_site\_day\_L}$	=	Facility annual throughput of liquid laboratory chemicals (mL/site-day)
F_{DINP-L}	=	Concentration of DINP in liquid laboratory chemicals (see Section E.11.7) (kg/kg)
RHO	=	Density of DINP (kg/L)

The daily throughput of DINP in solid laboratory chemicals is calculated using Equation E-74 by multiplying the daily throughput of all laboratory solids by the concentration of DINP in the solids.

Equation E-74.

$$Q_{DINP\_day} = Q_{stock\_site\_day\_S} * F_{DINP-S} * \frac{0.001kg}{g}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
$Q_{stock\_site\_day\_S}$	=	Facility annual throughput of solid laboratory chemicals (g/site-day)

F_{DINP-S} = Concentration of DINP in solid laboratory chemicals (see Section E.11.7) (kg/kg)

The annual throughput of DINP is calculated using Equation E-75 by multiplying the daily throughput by the number of operating days. The number of operating days is determined according to Section E.11.8.

Equation E-75.

$$Q_{DINP\_year} = Q_{DINP\_day} * OD$$

Where:

Q_{DINP_year} = Facility annual throughput of DINP (kg/site-yr)
Q_{DINP_day} = Facility throughput of DINP (see Section E.11.3) (kg/site-day)
OD = Operating days (see Section E.11.8) (days/yr)

E.11.4 Number of Sites

Per 2020 U.S. Census Bureau data for the NAICS codes identified in the Use of Laboratory Chemicals – Generic Scenario for Estimating Occupational Exposures and Environmental Releases (U.S. EPA, 2023c) 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. Number of sites is calculated using the following equation:

Equation E-76.

$$N_s = \frac{PV}{Q_{DINP_{year}}}$$

Where:

N_s = Number of sites (sites)
PV = Production volume (see Section E.11.3) (kg/year)
Q_{DINP_year} = Facility annual throughput of DINP (see Section E.11.3) (kg/site-yr)

E.11.5 Number of Containers per Year

The number of liquid DINP laboratory containers unloaded by a site per year is calculated using the following equation:

Equation E-77.

$$N_{cont\_unload\_yr} = \frac{Q_{DINP\_year}}{F_{DINP-L} * RHO * \left(3.79 \frac{L}{gal}\right) * V_{cont}}$$

Where:

V_{cont} = Container volume (see Section E.11.11) (gal/container)
Q_{DINP_year} = Facility annual throughput of DINP (see Section E.11.3) (kg/site-yr)
RHO = DINP density (kg/L)
F_{DINP-L} = Mass fraction of DINP in liquid (see Section E.11.7) (kg/kg)
$N_{cont\_unload\_yr}$ = Annual number of containers unloaded (container/site-year)

The number of laboratory containers containing solids with DINP unloaded by a site per year is calculated using the following equation:

Equation E-78.

$$N_{cont\_unload\_yr} = \frac{Q_{DINP\_year}}{F_{DINP-S} * Q_{cont\_solid}}$$

Where:

Q_{cont_solid}	=	Mass in container of solids (see Section E.11.11) (kg/container)
Q_{DINP_year}	=	Facility annual throughput of DINP (see Section E.11.3) (kg/site-yr)
F_{DINP-S}	=	Mass fraction of DINP in solid (see Section E.11.7) (kg/kg)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (container/site-year)

E.11.6 Operating Hours

EPA estimated operating hours or hours of duration using data provided from the Use of Laboratory Chemicals – Generic Scenario for Estimating Occupational Exposures and Environmental Releases (U.S. EPA, 2023c), *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 E-79.

$$OH_{RP1/RP4} = \frac{N_{cont\_unload\_yr}}{RATE_{fill} * OD}$$

Where:

$OH_{RP1/RP4}$	=	Operating time for release points 1 and 4 (hours/site-day)
$RATE_{fill}$	=	Container fill rate (see Section E.11.14) (containers/h)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (see Section E.11.5) (container/site-year)
OD	=	Operating days (see Section E.11.8) (days/site-year)

For equipment cleaning (release point 6), the *ChemSTEER User Guide* provides an estimate of 4 hours per day for cleaning multiple vessels (U.S. EPA, 2015).

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

E.11.7 DINP Concentration in Laboratory Chemicals

For high-concentration liquid laboratory chemicals, EPA used the maximum weight fraction out of six identified SDSs (99.5% DINP by mass) as a deterministic value. For solid laboratory chemicals, EPA used the maximum weight fraction out of six identified SDSs (3% DINP by mass) as a deterministic value. For low-concentration liquid laboratory chemicals, EPA used the minimum weight fraction out of six identified SDSs (0.1% by mass) as a deterministic value. Table_Apx E-32 provides the DINP-containing laboratory chemicals compiled from SDS along with their concentrations of DINP.

Table_Apx E-32. Product DINP Concentrations for Use of Laboratory Chemicals

Product	DINP Concentration (%)	Source(s)
Diisononyl phthalate in PE	0.1	(Spex CertiPrep LLC, 2017a)
Phthalates in Poly(vinyl chloride)	3	(Spex CertiPrep LLC, 2017c)
Phthalates in Polyethylene Standard w/BPA	3	(Spex CertiPrep LLC, 2017d)
Phthalate Standard	0.1	(Spex CertiPrep LLC, 2017b)
Diisononyl Phthalate	99.5	(Veritas House, 2015)

E.11.8 Operating Days

EPA modeled the operating days per year using a discrete distribution with a low end of 174 days/yr and a high end of 260 days/yr based on the Use of Laboratory Chemicals – Generic Scenario for Estimating Occupational Exposures and Environmental Releases (U.S. EPA, 2023c). The generic scenario also assumes a working duration of eight or 12 hours/day. EPA assumed an equal probability that the number of operating days would be either 174 or 260 days/year.

E.11.9 Air Speed

Baldwin and Maynard measured indoor air speeds across a variety of occupational settings in the United Kingdom (Baldwin and Maynard, 1998). Fifty-five work areas were surveyed across a variety of workplaces. EPA analyzed the air speed data from Baldwin and Maynard and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. The Agency fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the dataset 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.

E.11.10 Saturation Factor

The *CEB Manual* indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 (U.S. EPA, 1991b). The 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).

E.11.11 Container Size

EPA identified laboratory chemicals packaged in small containers no larger than 1 gallon in size (liquids) or one kg in quantity (solids). The Use of Laboratory Chemicals – Generic Scenario for Estimating Occupational Exposures and Environmental Releases (U.S. EPA, 2023c) states that, in the absence of site-specific information, a default liquid volume of one gal and a default solid quantity of one kg may be used. Laboratory products containing DINP showed container sizes less than 1 gallon or one kg. Based on model assumptions of site daily throughput, EPA decided to allow for a lower bound of 0.5 gallons or 0.5 kg to account for smaller container sizes while maintaining the daily number of containers unloaded per site at a reasonable value. Therefore, EPA built a triangular distribution for liquid volumes with a lower bound of 0.5 gallons, and an upper bound and mode of 1 gallon. EPA similarly built a triangular distribution for solid quantities with a lower bound of 0.5 kg, and an upper bound and mode of one kg.

E.11.12 Container Loss Fractions

For small liquid containers, EPA paired the data from the PEI Associates Inc. study (Associates, 1988) such that the residuals data for emptying drums by pouring was aligned with the default central tendency and high-end values from the EPA/OPPT Small Container Residual Model. For unloading drums by pouring in the PEI Associates Inc. study (Associates, 1988), EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.03 percent to 0.79 percent and an average of 0.32 percent. The EPA/OPPT Small Container Residual Model from the *ChemSTEER User Guide* (U.S. EPA, 2015) recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent.

The underlying distribution of the loss fraction parameter for small containers is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. EPA assigned the mode and maximum values for the loss fraction probability distribution using the central tendency and high-end values, respectively, prescribed by the EPA/OPPT Small Container Residual Model in the *ChemSTEER User Guide* (U.S. EPA, 2015). EPA assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study (Associates, 1988) for emptying drums by pouring.

For solid containers, EPA used the EPA/OPPT Solid Residuals in Transport Containers Model to estimate residual releases from solid container cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015) provides an overall loss fraction of 1 percent from container cleaning.

E.11.13 Dust Generation Loss Fraction

The EPA/OPPT Dust Release Model was used to estimate loss fractions of solids from releases of dust to the environment (U.S. EPA, 2021c). EPA assumed that dust was not captured or controlled, so EPA assigned a value of 0.005 as the loss fraction with releases to wastewater according to Use of Laboratory Chemicals – Generic Scenario for Estimating Occupational Exposures and Environmental Releases (U.S. EPA, 2023c).

E.11.14 Small Container Fill Rate

The *ChemSTEER User Guide* (U.S. EPA, 2015) provides a typical fill rate of 60 containers per hour for containers with less than 20 gallons of liquid.

E.11.15 Diameters of Opening

For container cleaning activities, the *ChemSTEER User Guide* indicates a single default value of 5.08 cm for containers less than 5,000 gallons (U.S. EPA, 2015).

E.11.16 Equipment Cleaning Loss Fraction

For liquids, EPA used the EPA/OPPT Multiple Process Residual Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015) provides an overall loss fraction of 2 percent from equipment cleaning.

For solids, used the EPA/OPPT Solid Residuals in Transport Containers Model to estimate the releases from equipment cleaning. The model, as detailed in the *ChemSTEER User Guide* (U.S. EPA, 2015) provides an overall loss fraction of 1 percent from equipment cleaning.

E.12 Use of Lubricants and Functional Fluids Model Approaches and Parameters

This appendix presents the modeling approach and equations used to estimate environmental releases for DINP during the use of lubricants and functional fluids OES. This approach utilizes the Emission Scenario Document on Lubricants and Lubricant Additives (OECD, 2004b) combined with Monte Carlo simulation (a type of stochastic simulation).

Based on the ESD, EPA identified the following release sources from the use of lubricants and functional fluids:

- Release source 1: Release During the Use of Equipment.
- Release source 2: Release During Changeout.

Environmental releases for DINP during the use of lubricants and fluids are a function of DINP's physical properties, container size, mass fractions, and other model parameters. Although physical properties are fixed, some model parameters are expected to vary. EPA used a Monte Carlo simulation to capture variability in the following model input parameters: production volume, DINP concentrations, product density, container size, loss fractions, and operating days. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts for this OES.

E.12.1 Model Equations

Table_Apx E-33 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the use of lubricants and fluids OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix E.12.2. The Monte Carlo simulation calculated the total DINP 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 E-33. Models and Variables Applied for Release Sources in the Use of Lubricants and Functional Fluids OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Release During the Use of Equipment.	See Equation E-80 through Equation E-84	Q_{DINP_day}; LF_{land_use}; LF_{water_use}
Release source 2: Release During Changeout.		Q_{DINP_day}; $LF_{land\_disposal}$; $LF_{water\_disposal}$; $F_{waste\_recycle}$; $F_{waste\_incineration}$

Release source 1 (Release During the Use of Equipment) and 2 (Release During Changeout) are partitioned out by release media. Loss fractions are described in the model parameter sections below. For both water and land media, release 1 is then calculated using the following equation:

Equation E-80.

$$Release\_perDay_{RP1\_land/water} = Q_{DINP\_day} * (LF_{land\_use} + LF_{water\_use})$$

Where:

$Release\_perDay_{RP1\_land/water}$	=	DINP loss to land/water for release source 1 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (see Section E.12.3) (kg/site-day)
LF_{land_use}	=	Loss fraction to land during the use of equipment (see Section E.12.7) (unitless)
LF_{water_use}	=	Loss fraction to water during the use of equipment (see Section E.12.7) (unitless)

A similar equation is used to calculate release 2 to water and land:

Equation E-81.

$$Release\_perDay_{RP2\_land/water} = Q_{DINP\_day} * (LF_{land\_disposal} + LF_{water\_disposal})$$

Where:

$Release\_perDay_{RP2\_land/water}$	=	DINP loss to land/water for release source 2 (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (see Section E.12.3) (kg/site-day)
$LF_{land\_disposal}$	=	Loss fraction to land during lubricant disposal (see Section E.12.7) (unitless)
$LF_{water\_disposal}$	=	Loss fraction to water during lubricant disposal (see Section E.12.7) (unitless)

If the sum of LF_{land_use}, LF_{water_use}, $LF_{land\_disposal}$, and $LF_{water\_disposal}$ is over 100 percent, EPA creates adjusted loss fractions based on weighted contributions to equal exactly 100 percent release. The releases per day are then re-calculated using the adjusted loss fractions. For example, the adjusted land use loss fraction would be calculated using the following equation:

Equation E-82.

$$LF_{land\_use\_adjusted} = \frac{LF_{land\_use}}{(LF_{land\_use} + LF_{water\_use} + LF_{land\_disposal} + LF_{water\_disposal})}$$

Where:

$LF_{land\_use\_adjusted}$	=	Adjusted loss fraction to land during the use of equipment (unitless)
LF_{land_use}	=	Loss fraction to land during the use of equipment (see Section E.12.7) (unitless)
LF_{water_use}	=	Loss fraction to water during the use of equipment (see Section E.12.7) (unitless)
$LF_{land\_disposal}$	=	Loss fraction to land during lubricant disposal (see Section E.12.7) (unitless)
$LF_{water\_disposal}$	=	Loss fraction to water during lubricant disposal (see Section E.12.7) (unitless)

Finally, EPA will assess any DINP not released to the environment after accounting for release sources 1 and 2 as going to recycling and fuel blending (incineration). If all DINP is released during release sources 1 and 2, then the release to recycling and fuel blending will not be calculated. The following equations are used to calculate the amount of remaining DINP sent for recycling and fuel blending:

Equation E-83.

$$Release\_perDay_{RP2\_recycle} = \left(Q_{DINP\_day} - Release_{perDay}{}_{RP1\_land} - Release_{perDay}{}_{RP1\_water} - Release_{perDay}{}_{RP2\_land} - Release\_perDay_{RP2\_water}\right) * F_{waste\_recycle}$$

Equation E-84.

$$Release\_perDay_{RP2\_fuel\_blend} = \left(Q_{DINP\_day} - Release_{perDay}{}_{RP1\_land} - Release_{perDay}{}_{RP1\_water} - Release_{perDay}{}_{RP2\_land} - Release\_perDay_{RP2\_water}\right) * F_{waste\_incineration}$$

Where:

$Release\_perDay_{RP2\_recycle}$	=	DINP recycled (kg/site-day)
$Release\_perDay_{RP2\_fuel\_blend}$	=	DINP sent for fuel blending (kg/site-day)
Q_{DINP_day}	=	Facility throughput of DINP (see Section E.12.3) (kg/site-day)
$Release\_perDay_{RP1\_land}$	=	DINP released for release source 1 to land (kg/site-day)
$Release\_perDay_{RP1\_water}$	=	DINP released for release source 1 to water (kg/site-day)
$Release\_perDay_{RP2\_land}$	=	DINP released for release source 2 to land (kg/site-day)
$Release\_perDay_{RP2\_water}$	=	DINP released for release source 2 to water (kg/site-day)
$F_{waste\_recycle}$	=	Fraction of DINP that goes to recycling (see Section E.12.8) (kg/kg)
$F_{waste\_incineration}$	=	Fraction of DINP that goes to fuel blending (see Section E.12.9) (kg/kg)

E.12.2 Model Input Parameters

Table_Apx E-34 summarizes the model parameters and their values for the Use of Lubricants and Fluids Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

Table_Apx E-34. Summary of Parameter Values and Distributions Used in the Use of Lubricants and Functional Fluids Model

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale / Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Total Production Volume of DINP at All Sites	PV_{total}	kg/yr	4,340,879	589,670	4,340,879	–	Uniform	See Section E.12.3
Mass Fraction of DINP in Product	F_{DINP}	kg/kg	0.2	0.01	0.99	0.2	Triangular	See Section E.12.4
Density of DINP-based Products	$RHO_{product}$	kg/m3	900	840	1,000	900	Triangular	See Section E.12.4
Operating Days	OD	days/yr	4	1	4	–	Uniform	See Section E.12.5
Container Size	V_{cont}	gal	55	20	330	55	Triangular	See Section E.12.6
Loss Fraction to Land During Use	LF_{land_use}	kg/kg	0.16	0.014	0.16	–	Uniform	See Section E.12.7
Loss Fraction to Water During Use	LF_{water_use}	kg/kg	0.45	0.003	0.45	–	Uniform	See Section E.12.7
Loss Fraction to Land During Disposal	$LF_{land\_disposal}$	kg/kg	0.30	0.010	0.3	–	Uniform	See Section E.12.7
Loss Fraction to Water During Disposal	$LF_{water\_disposal}$	kg/kg	0.37	0.230	0.37	–	Uniform	See Section E.12.7
Percentage of Waste to Recycling	$F_{waste\_recycle}$	kg/kg	0.043	–	–	–	–	See Section E.12.8
Percentage of Waste to Fuel Blending	$F_{waste\_incineration}$	kg/kg	0.957	–	–	–	–	See Section E.12.9

E.12.3 Throughput Parameters

EPA estimated the total production volume for all sites using a uniform distribution with a lower bound of 589,670 kg/yr and an upper bound of 4,340,879 kg/yr.

Both bounds are based on CDR data (U.S. EPA, 2020a) and the 2003 *European Union Risk Assessment on DINP* (ECJRC, 2003b). The EU Risk Assessment found that only 2.6 percent of the DINP produced goes to non-PVC, non-polymer end use categories. As this risk evaluation includes three OESs that fall under this category, EPA assumes that each category accounts for an equal amount to this percentage (*i.e.*, 0.87% each). CDR states that the total U.S. national production volume of DINP is 150,000,000 to 1,100,000,000 lb/yr. Multiplying this range by 0.87 percent results in 1,305,000 to 9,570,000 lb/yr (589,670 to 4,340,879 kg/yr).

Product throughput is calculated by converting container volume to mass using the product density and multiplying by operating days. This equation assumes that each site uses one container of product each day. Container size is determined according to Section E.12.6. Product density is determined according to Section E.12.4. Operating days are determined according to Section E.12.5.

Equation E-85.

$$Q_{product\_year} = V_{cont} * 0.00379 \frac{m3}{gal} * RHO_{product} * OD$$

Where:

$Q_{product\_year}$	=	Facility annual throughput of lubricant/fluid (kg/site-yr)
V_{cont}	=	Container size (see Section E.12.6) (gal)
$RHO_{product}$	=	Product density (see Section E.12.4) (kg/m^3)
OD	=	Operating days (see Section E.12.5) (days/yr)

The annual throughput of DINP is calculated using Equation E-86 by multiplying product annual throughput by the concentration of DINP in the product. Concentration of DINP in the product is determined according to Section E.12.4.

Equation E-86.

$$Q_{DINP\_year} = Q_{product\_year} * F_{DINP}$$

Where:

Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
$Q_{product\_year}$	=	Facility annual throughput of lubricant/fluid (kg/site-yr)
F_{DINP}	=	Concentration of DINP in lubricant/fluid (see Section E.12.4) (kg/kg)

The daily throughput of DINP is calculated using Equation E-87 by dividing the annual production volume by the number of operating days. The number of operating days is determined according to Section E.12.5.

Equation E-87.

$$Q_{DINP\_day} = \frac{Q_{DINP\_year}}{OD}$$

Where:

Q_{DINP_day}	=	Facility throughput of DINP (kg/site-day)
Q_{DINP_year}	=	Facility annual throughput of DINP (kg/site-yr)
OD	=	Operating days (see Section E.12.5) (days/yr)

E.12.4 Mass Fraction of DINP in Lubricant/Fluid and Product Density

EPA identified a single DINP product that functioned as a pump flush fluid (see Mountain Grout in Appendix F); however, EPA did not determine it to be representative of the entirety of the OES as it was listed at a DINP concentration of 95 to 100 percent. Therefore, EPA used DIDP product data as surrogate data for this release assessment. EPA modeled DINP concentration in lubricants and fluids using a triangular distribution with a lower bound of 1 percent, upper bound of 99 percent, and mode of 20 percent. EPA modeled product density using a triangular distribution with a lower bound of 840 kg/m^3, an upper bound of 1,000 kg/m^3, and a mode of 900 kg/m^3. This is based on compiled surrogate SDS information for lubricants and fluids containing DIDP. The minimums and maximums represent the highest and lowest concentrations and densities identified in the products. The mode of product concentration represents the median of all range endpoints. For product densities, the median of all range endpoints was 897.5 kg/m^3, and the mean was 902 kg/m^3. Therefore, EPA selected 900 kg/m^3 as a midpoint between these two values. Table_Apx E-35 provides the DIDP-containing lubricants/fluids compiled from SDS along with their concentrations of DIDP and product densities.

Table_Apx E-35. Surrogate Product DIDP Concentrations for Lubricants and Functional Fluids

Product	DIDP Concentration (%)	Density (kg/m^3)	Source(s)
Anderol 3046	10–20	855–870	(Chemtura Corporation, 2015b)
Anderol 497	10–20	950	(Chemtura Corporation, 2015a)
DSL-125	10–30	951–960	(Klüber Lubrication NA LP, 2018a)
Ultima-68	10–30	920	(Klüber Lubrication NA LP, 2018c)
PS-200	5–10	870	(Klüber Lubrication NA LP, 2018b)
DACNIS SB 68	1–10	876	(Total USA, 2015)
SYNOLAN DE 100	10–40	1,000	(TOTAL Specialties USA Inc., 2015)
IR XL-700	10–40	920	(Ingersoll Rand, 2019)
BG ATC Plus	3–7	881.1	(BG Products Inc., 2016)
Quin Syn Flush Fluid	99	960	(Quincy Compressor, 2012)
Duratherm G	10–30	910–930	(Duratherm, 2019b)
Duratherm G-LV	10–30	880–900	(Duratherm, 2019c)
Duraclean	20–75	840–880	(Duratherm, 2018a)
Duraclean LSC	20–75	850–880	(Duratherm, 2018b)
U-Clean	10–75	840–950	(Duratherm, 2018c)
Duraclean Ultra	20–75	840–870	(Duratherm, 2019a)
DELF Clean	10–20	840–880	(Mokon, 2018b)
DELF Clean Ultra	20–75	850–950	(Mokon, 2018a)

E.12.5 Operating Days

EPA modeled operating days per year using a uniform distribution with a lower bound of 1 day/yr and an upper bound of 4 days/yr. To ensure that only integer values of this parameter were selected, EPA nested the uniform distribution probability formula within a discrete distribution that listed each integer between (and including) 1 to 4 days/yr. Both bounds are based on the Emission Scenario Document on Lubricants and Lubricant Additives (OECD, 2004b). The ESD states that changeout rates for hydraulic fluids range from 3 to 60 months. This corresponds to one to four changeouts per year, which EPA assumes is equal to operating days. Where changeout frequency occurs over 12 months, EPA used a value one container per 12 months as a representative value.

E.12.6 Container Size

EPA modeled container size using a triangular distribution with a lower bound of 20 gallons, an upper bound of 330 gallons, and a mode of 55 gallons. This was based on SDS and technical data sheets for DIDP-containing lubricants as a surrogate for DINP. In this data, EPA identified lubricants in containers from less than 1 gallon to 330 gallons. The mode of the reported container sizes was 55 gallons. However, when running the model, smaller use rates produced an unreasonable number of use sites. Therefore, EPA assumed this to be an indication that it is unlikely that sites only have one small piece of equipment. Based on this and the remaining technical data, EPA selected 20 gallons as the lower bound.

E.12.7 Loss Fractions

The loss fractions to each release media for the use and disposal of lubricants are based on the Emission Scenario Document on Lubricants and Lubricant Additives (OECD, 2004b). The ESD provides multiple values for loss fractions to land and water. EPA used these values to build the uniform distributions for each loss fraction. For the use of lubricants, the ESD provided a range of 0.014 to 0.16 for loss fractions to land, and 0.003 to 0.45 for loss fractions to water. For the disposal of lubricants, the ESD provided a range of 0.01 to 0.3 for loss fractions to land, and 0.23 to 0.37 for loss fractions to water.

E.12.8 Percentage of Waste to Recycling

The Emission Scenario Document on Lubricants and Lubricant Additives (OECD, 2004b) estimates that 4.3 percent of all hydraulic fluids are recycled.

E.12.9 Percentage of Waste to Fuel Blending

The Emission Scenario Document on Lubricants and Lubricant Additives (OECD, 2004b) estimates that 95.7 percent of all hydraulic fluids are reused for fuel oil or other general incineration releases.

E.13 Spray Exposure Model Approach and Parameters

This section presents the modeling approach and equations used to estimate occupational exposures for DINP during the use in paints and coatings and use in 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 DINP in the paint to estimate the central tendency and high-end inhalation exposures, respectively.

E.13.1 Model Design Equations

The Automotive Refinishing Spray Coating Mist Inhalation Model calculates the 8-hour TWA exposure to DINP present in mist and particulates using the following equation:

Equation E-88.

$$C_{DINP,8hr-TWA} = \frac{C_{mist} \times F_{INP\_solids} \times ED}{8\ hrs}$$

Where:

$C_{DINP,8hr-TWA}$	=	8-hour TWA inhalation exposure to DINP (mg/m^3)
C_{mist}	=	Over sprayed product mist concentration in the air within worker's breathing zone (mg/m^3)
F_{DINP_solids}	=	Mass fraction of DINP in the non-volatile portion of the spray ($mg_{DINP}/mg_{nonvolatile\ components}$)
ED	=	Exposure Duration (h)

E.13.2 Model Parameters

Table_Apx E-36 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 E-36. Summary of Parameter Values Used in the Spray Inhalation Model

Input Parameter	Symbol	Unit	OES	Parameter Value		Rationale / Basis
				Central Tendency	High-End	
Concentration of Mist	C_{mist}	mg/m^3	Use of paints and coatings	3.38	22.1	See Section 4.2E.13.2.1
			Use of adhesives and sealants			
DINP Concentration in Product	F_{DINP_prod}	kg/kg	Use of paints and coatings	0.05	0.20	See Section E.13.2.2
			Use of adhesives and sealants	0.10	0.32	
Concentration of Nonvolatile Solids in the Spray Product	F_{solids_prod}	kg/kg	Use of paints and coatings	0.25	0.5	See Section E.13.2.3
			Use of adhesives and sealants			
DINP Concentration of Nonvolatile Components	F_{DINP_solids}	mg/mg	Use of paints and coatings	0.20	0.40	See Section E.13.2.4
			Use of adhesives and sealants	0.40	0.64	
Exposure Duration	ED	hr	Use of paints and coatings	8		See Section E.13.2.5
			Use of adhesives and sealants			

E.13.2.1 Concentration of Mist

EPA utilized coating mist concentrations within spray booths obtained through a search of available OSHA In-Depth Surveys of the Automotive Refinishing Shop Industry and other relevant studies, as published in the ESD on Coating Application via Spray-Painting in the Automotive Refinishing Industry (OECD, 2011a). The data is divided into various combinations of spray booth types (*e.g.*, downdraft and crossdraft) and spray gun types (*e.g.*, conventional, high-volume low-pressure). EPA expects there to be a variety of facility types and substrates being coated such that a variety of spray booth and spray gun combinations may be used to apply the products. Due to this, EPA used mist concentrations from all scenarios for this parameter. Central tendency and high-end scenario parameters represent the 50th and 95th percentile mist concentrations, respectively. The central tendency mist concentration was 3.38 mg/m^3 and the high-end concentration was 22.1 mg/m^3.

E.13.2.2 DINP Product Concentration

EPA compiled DINP concentration information from the SDSs of various paint, coating, adhesive, and sealant products containing DINP (see Appendix F for a full list of products). EPA used material safety data sheets and technical data sheets to develop DINP concentration distributions in each of these product categories. These distributions were implemented in the modeled Monte Carlo release assessments for each scenario outlined in Appendix E.2 to E.12. For the exposure assessment, EPA used the 50th and 95th percentile results as the central tendency and high-end product concentration input parameters, respectively. For paints and coatings, the central tendency value was 0.05, and the high-end value was 0.20. For adhesives and sealants, the central tendency value was 0.10, and the high-end value was 0.32.

E.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 a spray paint or coating product can range from 0.15 to 0.50 mg/mg (OECD, 2011a; Kirk-Othmer, 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 central tendency and high-end parameters, respectively (OECD, 2011a).

E.13.2.4 DINP Concentration in Nonvolatile Components

The mass fraction of DINP in the nonvolatile portion of the sprayed product is calculated using the following equation:

Equation E-89.

$$F_{DINP\_solids} = \frac{F_{DINP\_prod}}{F_{solids\_prod}}$$

Where:

F_{DINP_solids}	=	Mass fraction of DINP in the nonvolatile portion of the sprayed product ($mg_{DINP}/mg_{nonvolatile\ components}$)
F_{DINP_prod}	=	Mass fraction of DINP in the paint, coating, adhesive, or sealant product, spray-applied ($mg_{DINP}/mg_{sprayed\ product}$)
F_{solids_prod}	=	Mass fraction of nonvolatile components within the sprayed product ($mg_{nonvolatile\ components}/mg_{sprayed\ product}$)

If this equation results in F_{DINP_solids} exceeding 1, then the value of F_{DINP_solids} is assessed at a value of 1. The results of this equation were a central tendency DINP concentration of 0.20 and a high-end concentration of 0.40 for paints and coatings, and a central tendency concentration of 0.40 and a high-end concentration of 0.64 for adhesives and sealants.

E.13.2.5 Exposure Duration

EPA did not identify DINP-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 8-hour duration for spraying is used and assumed to be protective of any contribution to exposures from vapors.

E.14 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.

EPA assumed DINP 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 DINP present in dust and particulates using the following equation:

Equation E-90.

$$C_{DINP,8hr-TWA} = C_{PNOR,8hr-TWA} \times F_{DINP}$$

Where:

$C_{DINP,8hr-TWA}$	=	8-hour TWA exposure to DINP (mg/m^3)
$C_{PNOR,8hr-TWA}$	=	8-hour TWA exposure to PNOR (mg/m^3)
F_{DINP}	=	Mass fraction of DINP in PNOR (mg/mg)

Table_Apx E-37 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, DINP mass fraction, and DINP 8-hour TWA exposures assessed for each OES.

Table_Apx E-37. Summary of DINP Exposure Estimates for OESs Using the Generic Model for Exposure to PNOR

Occupational Exposure Scenario	NAICS Code Assessed	Respirable PNOR 8-hour TWA from Model (mg/m^3)		DINP Mass Fraction Assessed	DINP 8-hour TWA (mg/m^3)	
		Central Tendency	High-End		Central Tendency	High-End
PVC plastics compounding	326 – Plastics and Rubber Manufacturing	0.23	4.7	0.45	0.1035	2.115
PVC plastics converting	326 – Plastics and Rubber Manufacturing	0.23	4.7	0.45	0.1035	2.115
Non-PVC materials compounding	326 – Plastics and Rubber Manufacturing	0.23	4.7	0.40	0.092	1.88
Non-PVC materials converting	326 – Plastics and Rubber Manufacturing	0.23	4.7	0.40	0.092	1.88
Use of laboratory chemicals	54 – Professional, Scientific, and Technical Services	0.19	2.7	0.03	0.0057	0.081
Fabrication and final use of products or articles	337 – Furniture and Related Product Manufacturing	0.20	1.8	0.45	0.108	1.575
Recycling and disposal	56 – Administrative and Support and Waste Management and Remediation Services	0.24	3.5	0.45	0.09	0.81

Appendix F Products Containing DINP

This section provides a sample of products containing DINP; it is not a comprehensive list of products containing DINP. In addition, some manufacturers may appear over-represented in this table. This may mean that they are more likely to disclose product ingredients online than other manufacturers but does not imply anything about the magnitude of use of the chemical compared to other manufacturers in this sector.

Table_Apx F-1. Products Containing DINP

OES	Product	Manufacturer	DINP Concentration	Source	HERO ID
Adhesive/sealant	PU1000 Multipurpose Adhesive	Chemtron International, Inc.	0.1–0.99, unspecified	Tremco U.S Sealants (2017)	11374517
Adhesive/sealant	Duro-Last® Pitch-Pan Filler	Duro-Last®, Inc.	0.1–1, unspecified	Duro-Last Inc. (2017)	6984722
Adhesive/sealant	SIDE Winder Advanced Polymer Sealant – All Colors	DAP Products Inc.	1–2.5, by weight	DAP Products Inc (2015)	6984718
Adhesive/sealant	3M™ Polyurethane Sealant 540 (Various Colors)	3M	0–4.99, by weight	3M Company (2019a)	6984702
Adhesive/sealant	HVAC – Acrylic Duct Sealant	Hodgson Sealants (Holdings)	0–4.99, by weight	Hodgson Sealant (2015c)	6984553
Adhesive/sealant	Fireseal 6	Macsim Fastenings	0–5, by weight	Macsim Fastenings (2017)	6984570
Adhesive/sealant	SB 150HV – Natural	Seal Bond	1–5, unspecified	Seal Bond (2018)	6984608
Adhesive/sealant	HS20	Hodgson Sealants (Holdings)	0–9.99, by weight	Hodgson Sealants (2015a)	6984547
Adhesive/sealant	Aquacaulk	Hodgson Sealants (Holdings)	5–9.99, by weight	Hodgson Sealants (2014)	6984544
Adhesive/sealant	Brewers Premium Decorators' Caulk	C.Brewer & Sons Ltd.	5–9.99, by weight	C.Brewer & Sons Ltd (2016)	6984709
Adhesive/sealant	PF 225 Urethane Windshield Adhesive Black	Pro Form Products Ltd.	1–10, by weight	Pro Form Products Ltd. (2016)	6984602

OES	Product	Manufacturer	DINP Concentration	Source	HERO ID
Adhesive/sealant	CP 606 Flexible Firestop Sealant	Hilti (Canada) Corporation	10–15, by weight	Hilti (Canada) Corp. (2012)	6984542
Adhesive/sealant	DuoSil® Ultra	Siroflex Incorporated	10 – 15, by weight	Siroflex Incorporated (2016)	6984614
Adhesive/sealant	Tremco JS443 A	Tremco Illbruck Production S.A.S.	10–19.99, unspecified	Tremco Illbruck Production S.A.S. (2017a;2017b)	6984638
Adhesive/sealant	Tremco JS443 B	Tremco Illbruck Production S.A.S.	30–49.99, unspecified	Tremco Illbruck Production S.A.S. (2017a;2017b)	6984642
Adhesive/sealant	Illbruck SP523	Tremco Illbruck Production GmBH	10–19.99, unspecified	Tremco Illbruck Production GmBH (2016)	6984653
Adhesive/sealant	Wedi Joint Sealant	Wedi Corporation	5–20, unspecified	Wedi Corporation (2018)	6984685
Adhesive/sealant	U-Pol Tiger Seal – Grey	U-Pol Australia Pty Limited	5–23, unspecified	U-Pol Australia Pty Limited (2019)	6984664
Adhesive/sealant	Everbuild EB25 Crystal Clear	Sika	20–24.99, unspecified	Sika Corporation (2019)	6984611
Adhesive/sealant	HS20 Clear	Hodgson Sealants (Holdings)	10–25, by weight	Hodgson Sealants (2015b)	6984549
Adhesive/sealant	SRW Vertical Instant Lock Adhesive	SRW Products Technical Services	10–25, unspecified	SRW Products Technical Services (2019)	6984561

OES	Product	Manufacturer	DINP Concentration	Source	HERO ID
Adhesive/sealant	CT1 Colours (Excluding Silver)	C-Tec N.I Limited	10–29.99, unspecified	C-Tec N.I Limited (2017)	6984708
Adhesive/sealant	Illbruck SP036	Tremco Illbruck Produktion GmBH	20–29.99, unspecified	Tremco Illbruck Produktion GmBH (2015)	6984652
Adhesive/sealant	FUSOR 800DTM	LORD Corporation	25–30, unspecified	LORD Corporation (2018)	6984568
Adhesive/sealant	EPDM Solvent-Free Bonding Adhesive	Firestone Building Products Company	30–31, unspecified	Firestone Building Products Company (2018)	6984725
Adhesive/sealant	ClearSeal Glasklar	Sika Danmark A/S	25–39.99, unspecified	Sika Danmark A/S (2018)	6984613
Adhesive/sealant	Coat & Seal	Selena USA, Inc.	20–40, by weight	Selena USA, Inc. (2015)	6984609
Adhesive/sealant	A-A_529 Adhesive and Sealing Compound	Mach-Dynamics	3–100, unspecified	Mach-Dynamics (2014)	6984569
Adhesive/sealant	BETASEAL™ Xpress 30 BP Urethane Adhesive	The DOW Chemical Company	15–25, unspecified	The Dow Chemical Company (2017)	6984571
Adhesive/sealant	Quick-Cure Primerless HV Urethane U418HV	Nova Scotia Company	15–25, unspecified	Nova Scotia Company (2018)	6984590
Adhesive/sealant	SRP 180 HV	Shat-R-Proof Corp.	10–30, by weight	Shat-R-Proof Corp. (2014)	6984612
Adhesive/sealant	Gardner Flex 'n Fill Premium Patching Paste	Gardner-Gibson	2, by weight	Home Depot (2018); Gardner-Gibson (2015)	6984556

OES	Product	Manufacturer	DINP Concentration	Source	HERO ID
Adhesive/sealant	Brush On Electrical Tape Black 4 Fl. OZ	Technical Chemical Company	1–10, unspecified	Technical Chemical Company (2016)	6984567
Other formulation, mixture, or reaction	Gans Deep Klene	Gans Ink and Supply Co, Inc.	40–50, by weight	Gans Ink and Supply (2018)	6836851
Other formulation, mixture, or reaction	Spotcheck® SKL-SP2	ITW Ltd.	10–20, unspecified	ITW Ltd. (2018)	6984562
Other formulation, mixture, or reaction	Avery Dennison 4930 Series Screen Ink	Nazdar Company	0–0.5, by weight	Nazdar Company (2015)	6984692
Other formulation, mixture, or reaction	Porelon Red SP Premix	Porelon	15–20, unspecified	Porelon (2007)	6836848
Paint/coating	Phenoline 380 Part A	Carboline Company	0.1–1, unspecified	Carboline Company (2015b)	6984711
Paint/coating	RAL 9010 White Aerosol	Premier Aerosol Packaging, Inc.	0.1–1, by weight	Premier0 Aerosol Packaging Inc. (2017	6984600
Paint/coating	Freeman 90-1 Burnt Orange Pattern Coating	Freeman Manufacturing and Supply Company	1–5, by weight	Freeman Manufacturing and Supply Company (2018)	6984728
Paint/coating	Castle® Cast Iron Gray Paint™	Castle Products, Inc.	1–5, unspecified	Castle Products Inc. (2016)	6984713
Paint/coating	KEM AQUA® 600T Water Reducible Enamel – White	The Sherwin-Williams Company	0–5, unspecified	Sherwin-Williams (2019)	6984610
Paint/coating	B610-01006 Flattener	RPM Wood Finishes Group	1–10, unspecified	RPM Wood Finishes Group (2004c)	6984606
Paint/coating	B101-G804 B104-G202 White Gloss Jet Spray	RPM Wood Finishes Group	1–10, unspecified	RPM Wood Finishes Group (2004b; 2004a)	6984604

OES	Product	Manufacturer	DINP Concentration	Source	HERO ID
Paint/coating	B101-G826 Black Gloss Jet Spray	RPM Wood Finishes Group	1–10, unspecified	RPM Wood Finishes Group (2004b; 2004a)	6984605
Paint/coating	Skudo Glass Advanced	Skudo LLC	10–20, by weight	Skudo LLC (2013)	6984615
Paint/coating	HawkFlash LiquiCap – Component A	Ergon Asphalt & Emulsions Inc.	0–5, unspecified	Ergon Asphalt & Emulsions Inc. (2019)	6984723
Non-PVC materials compounding	Biochek 8064	Lanxess Corporation	71 -77, unspecified	Lanxess Corporation (2016)	6984565
Non-PVC materials compounding	Diisononyl Phthalate	Megaloid Laboratories	100, unspecified	Megaloid Laboratories (2013)	6984587
Non-PVC materials compounding	Diisononyl Phthalate (DINP)	Redox Inc.	100, unspecified	Redox Inc. (2019)	6984603
Non-PVC materials compounding	DINP	Hanwha Chemical Co, Ltd.	100, unspecified	Hanwha Chemical Co Ltd. (2018)	6984537
Non-PVC materials compounding	PLASTHALL® DINP	The HallStar Company	100, unspecified	The Hallstar Company (2015)	6984572
Non-PVC materials compounding	DINP	HB Chemical	100, unspecified	HB Chemical (2014)	6984538
Non-PVC materials compounding	Urethane 2718 Part A	Smooth-On, Inc.	0–10, unspecified	Smooth-On Inc. (2018b)	6984548
Non-PVC materials compounding	Part A: PMC-790	Smooth-On, Inc.	10–20, by weight	Smooth-On, Inc. (2018a)	6984616
Non-PVC materials compounding	TC-890 Part A	BJB Enterprises Inc.	10–30, by weight	BJB Enterprises Inc. (2019b)	6984699
Non-PVC materials compounding	TC-889 Part B	BJB Enterprises Inc.	15–40, by weight	BJB Enterprises Inc. (2019a)	6984698
Non-PVC materials compounding	SoftSand™	Soft Point Industries, Inc.	4, unspecified	Soft Point Industries Inc. (2018)	6984557

OES	Product	Manufacturer	DINP Concentration	Source	HERO ID
Non-PVC materials compounding	Black 615	Era Polymers Pty. Ltd.	60–100, by weight	Era Polymers Pty Ltd. (2015)	6836850
PVC plastics compounding/converting	Vinyl Coated Fabrics and Films	Acoustical Surfaces Inc.	20–40, by weight	Acoustical Surfaces Inc. (1999)	6984704
PVC plastics compounding/converting	Alpha Style 3478-VS-2	Alpha Engineered Composites LLC	9.4–10.2, unspecified	Alpha Engineered Composites LLC (2018)	6984696
PVC plastics compounding/converting	Scotch® Vinyl Electrical Color-Coding Tape 35 (Multiple Colors)	3M	0–2.99, by weight	3M Company (2019b)	6984703
PVC plastics compounding/converting	VINI-TAPE	Denka Company Limited	25–30%, by weight	Denka Company Limited (2016)	6984721
PVC plastics compounding/converting	3M™ Nomad™ Scraper Matting 9100, Gypsy Red	3M	0.5–3, by weight	3M Company (2005)	6984695
PVC plastics compounding/converting	DVH 20/DVH 40	The Zippertubing Co.	10–20, by weight	The Zippertubing Co. (2018)	6984573
PVC plastics compounding/converting	PVC Laminated Polyester	BondCote Corporation	16, by weight	BondCote Corporation (2014)	6984707
PVC plastics compounding/converting	LG Premium PVC High Glossy Deco Sheet (G200)	LG Chemical Ltd.	0–2, by weight	LG Chemical Ltd. (2013)	6984566
PVC plastics compounding/converting	Serrated PVC Spline	Prime Line Products, Inc.	14, by weight	Prime Line Products, Inc. (2015)	6984601
PVC plastics compounding/converting	IL PVC Compact Sheet	O’Sullivan Films, Inc.	0–40, by weight	O’Sullivan Films Inc. (2016)	6847039
PVC plastics compounding/converting	186CGNSPL Pantone® 186 C Simulation	PolyOne Corporation	25–50, unspecified	PolyOne Corporation (2018)	6847117

OES	Product	Manufacturer	DINP Concentration	Source	HERO ID
Laboratory chemical	Diisononyl Phthalate	Veritas House	99.5, unspecified	Veritas House (2015)	6984684
Laboratory chemical	Diisononyl Phthalate in PE	SPEX CertiPrep LLC	0.1, unspecified	SPEX CertiPrep LLC (2017a)	6984559
Laboratory chemical	Phthalate Standard	SPEX CertiPrep LLC	0.1, unspecified	SPEX CertiPrep LLC (2017b)	6302569
Laboratory chemical	Phthalates in Poly(vinyl chloride)	SPEX CertiPrep LLC	3.0, unspecified	SPEX CertiPrep LLC (2017c)	6984560
Laboratory chemical	Phthalates in Polyethylene Standard w/BPA	SPEX CertiPrep LLC	3.0, unspecified	SPEX CertiPrep LLC (2017d)	6301542
Lubricants and functional fluids	Mountain Grout	Green Mountain International LLC	95–100, by weight	Green Mountain International LLC (2008)	6836844
Use of final products or articles containing DINP	Polyfoam SLV	Polygem	0–15, by weight	Polygem (2015)	6836845
Use of final products or articles containing DINP	GlasGrid	Saint-Gobain ADFOR	0–20, by weight	Saint-Gobain ADFOR (2017)	6984607
Use of final products or articles containing DINP	PM600-002	Polysol LLC	25–40, unspecified	PolySol LLC (2017)	6984596
Use of final products or articles containing DINP	PSI PolyClay Canes and PSI PolyClay Bricks	Penn State Industries	0–2.5, unspecified	Penn State Industries (2016)	6302544