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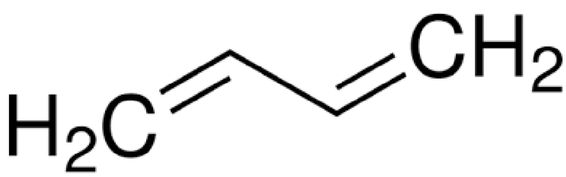
United States
Environmental Protection Agency

Environmental Release and Occupational Exposure Assessment for 1,3-Butadiene

Technical Support Document for the Risk Evaluation

CASRN 106-99-0



December 2025

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

KEY ABBREVIATIONS AND ACRONYMS

AC	Acute concentrations
ACC	American Chemistry Council
ADC	Average daily concentrations
$ADC_{intermediate}$	Intermediate average daily concentrations
AM	Arithmetic mean
APF	Assigned protection factor
APR	Air-purifying respirator
BLS	Bureau of Labor Statistics

BR	Butadiene rubber
CAA	Clean Air Act
CAP	Criteria Air Pollutant
CASRN	Chemical Abstracts Service Registry Number
CBI	Confidential business information
CDF	Cumulative distribution function
CDR	Chemical Data Reporting
CEHD	OSHA Chemical Exposure Health Database
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COU	Condition of use
CPS	Current Population Survey
DMR	Discharge Monitoring Report
DOD	U.S. Department of Defense
DOT	Department of Transportation
DRE	Destruction removal efficiency
ECHO	Enforcement and Compliance History Online
EIS	Emissions Inventory System
EPA	Environmental Protection Agency (U.S.)
EPCRA	Emergency Planning and Community Right-to-Know Act
ESBR	Emulsion styrene-butadiene rubber
ESD	Emission Scenario Document
FR	Federal Register
FRS	Facility Registry Services
GS	Generic scenario
HAP	Hazardous air pollutant
HHE	Health Hazard Evaluation
HSDB	NLM's Hazardous Substance Databank
ICR	Information Collection Request
IFC	Industrial Function Category
IISRP	International Institute of Synthetic Rubber Producers
LADC	Lifetime average daily concentrations
LCD	Life cycle diagram
LOD	Limit of detection
LPG	Liquified petroleum gas
MLE	Maximum likelihood estimation
MVUE	Minimum variance unbiased estimation
MWC	Municipal waste combustors
NAAQS	National Ambient Air Quality Standard
NAICS	North American Industry Classification System (codes)
NEI	National Emissions Inventory
NESHAP	National Emission Standard for Hazardous Air Pollutants
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NRC	National Response Center
OAQPS	Office of Air Quality Planning and Standards
OCPSF	Organic Chemicals, Plastics & Synthetic Fibers
OCSPP	Office of Chemical Safety and Pollution Prevention (EPA)
OECD	Organization for Economic Co-operation and Development

OEL	Occupational exposure limits
OES	Occupational exposure scenario
ONU	Occupational non-user
OPPT	Office of Pollution Prevention and Toxics (EPA)
OSHA	Occupational Safety and Health Administration (U.S.)
PBZ	Personal breathing zone
PEL	Permissible Exposure Limits
POTW	Publicly owned treatment works
PPE	Personal protective equipment
PV	Production volume
Q-Q	Quantile-quantile
RCRA	Resource Conservation and Recovery Act
SAR	Supplied-air respirator
SBR	Styrene-butadiene rubber
SCC	Source Classification Code
SDS	Safety data sheet
SEG	Similar exposure group
SHE	Safety, Health, and Environment
SIC	Standard Industrial Classification (codes)
SIPP	Survey of Income and Program Participation
SLT	State, local, and Tribal
SOC	Standard Occupational Classification (codes)
SPIN	Substances in Preparations in Nordic Countries
SSBR	Solution styrene-butadiene rubber
SUSB	U.S. Census' Statistics of US Businesses
TDR	Tiered Data Reporting rule
TLV	Threshold Limit Values
TRFID	TRI identification number
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TSD	Technical support document
TWA	Time-weighted average
U.S.	United States
VOC	Volatile organic compound
WWT	Wastewater treatment

SUMMARY

Environmental Release and Occupational Exposure: Key Points

The U.S. Environmental Protection Agency (EPA or the Agency) considered all reasonably available information identified by the Agency through its systematic review process under the Toxic Substances Control Act (TSCA) (U.S. EPA, 2025m) to characterize environmental releases of and occupational exposure to 1,3-butadiene, a colorless gas. The following points summarize the environmental release and occupational exposure from 1,3-butadiene:

- 1,3-Butadiene has a total production volume (PV) in the United States between 1 and 5 billion pounds (lb) from the 2020 Chemical Data Reporting (CDR) reporting period (U.S. EPA, 2020b).
- 1,3-Butadiene is primarily used as a monomer in the production of a wide range of polymers and copolymers. It is also used as an intermediate in the production of several chemicals.
- EPA evaluated environmental releases and occupational exposures for each occupational exposure scenario (OES).
    - OESs were developed based on a set of occupational activities and conditions such that similar occupational exposures and environmental releases are expected from the use(s) covered under each OES.
    - The Agency provided environmental release and occupational exposure results for each OES, which are expected to be representative of the population of 1,3-butadiene workers and sites for the given OES in the United States.
- EPA used release data from the databases Toxics Release Inventory (TRI) and the National Emissions Inventory (NEI) to assess releases to air, land, and water for a majority of 1,3-butadiene uses. One exception was the release from the use of adhesives and sealants, for which modeling approaches were used.
- A majority of releases of 1,3-butadiene were to air, with land and water releases occuring at far fewer sites.
- The OESs with the highest expected releases were manufacturing, plastic and rubber polymerization as well as application of adhesives and sealants.
- Uncertainty was introduced to the 1,3-butadiene release assessment due to both the lack of facility PV data and the use of generic models when site-specific data were not available.
- EPA used inhalation monitoring data to evaluate acute, intermediate, and chronic exposures to workers and occupational non-users (ONUs) for each OES. Where no monitoring data existed relevant to certain OESs, analogous monitoring data were used.
- Inhalation exposures to 1,3-butadiene are highest in the industrial settings of repackaging and plastics and rubber polymerization.
- Uncertainty was introduced to the exposure assessment due to lack of directly applicable monitoring data for certain OESs, thus leading to the use of analogous monitoring data. Uncertainty is also introduced inherently due to site-specific differences in use practices and engineering controls for 1,3-butadiene.

This technical support document (TSD) accompanies the *Risk Evaluation for 1,3-Butadiene* (also called the “1,3-butadiene risk evaluation” or “risk evaluation”) (U.S. EPA, 2025l). 1,3-Butadiene is (1) a TRI-reportable substance effective January 1, 1987 (40 CFR 372.65); (2), is included on EPA’s initial list of hazardous air pollutants (HAPs) under the Clean Air Act (CAA); and (3) is a hazardous substance under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This assessment describes the use of reasonably available information to estimate environmental releases of 1,3-butadiene and evaluate occupational exposure to workers and ONUs. The latter are those who may work in the vicinity of chemical-related activities but do not handle the chemicals themselves such as managers or inspectors. See Appendix C of the risk evaluation (U.S. EPA, 2025l) for a complete list of all the technical support documents (TSDs) for the 1,3-butadiene risk evaluation.

Focus of the Module on Environmental Release and Occupational Exposure Assessment

During scoping, EPA considered all known TSCA uses for 1,3-butadiene. 1,3-Butadiene is a colorless gas with a total production volume (PV) in the United States between 1 and 5 billion pounds (lb) from the 2020 CDR reporting period (U.S. EPA, 2020b). Review of preliminary 2024 CDR data shows that that total PV for the years 2020 to 2023 are similar to the previously reported range from 2020 CDR. It is primarily used as a monomer in the production of a wide range of polymers and copolymers but is also used as an intermediate in the production of several chemicals. The American Chemistry Council (ACC) reported in 2018 that roughly 63 to 69 percent of 1,3-butadiene PV goes toward the production of polymers and copolymers such as polybutadiene and styrene-butadiene rubber, while 26 to 32 percent goes toward the production of adiponitrile, chloroprene, and other intermediate chemicals (EPA-HQ-OPPT-2018-0451-0021). The remainder of the PV for 1,3-butadiene may go to either of these uses or support other uses such as use as a laboratory chemical (EPA-HQ-OPPT-2018-0451-0021).

Exposures to workers, consumers, the general population, and ecological species may occur from industrial, commercial, and consumer uses of 1,3-butadiene and 1,3-butadiene-containing articles, as well as from releases to air, water, or land. Workers and ONUs may be exposed to 1,3-butadiene during conditions of use (COUs) under TSCA, such as chemical manufacturing, processing as a reactant, and plastics and rubber polymerization. Exposure to the general population and ecological species may occur from industrial and commercial releases related to the manufacture, import, processing, distribution, and use of 1,3-butadiene. This TSD provides the details of the assessment of the environmental releases and occupational exposures from each TSCA COU of 1,3-butadiene and does not include releases or exposures resulting from consumer uses. Discussion of consumer uses can be found in Section 5.1.2 of the *Risk Evaluation for 1,3-Butadiene* (U.S. EPA, 2025l).

Approach for Assessing Environmental Releases and Occupational Exposures

EPA evaluated environmental releases of 1,3-butadiene to air, water, and land from the COUs assessed in this risk evaluation. The Agency used release data from TRI and NEI databases to assess releases for a majority of COUs. One exception was the release from the use of adhesives and sealants, for which modeling approaches were used.

EPA evaluated acute, intermediate, and chronic exposures to workers and ONUs associated with 1,3-butadiene COUs using inhalation monitoring data from public comments and literature sources. Where no 1,3-butadiene monitoring data existed relevant to certain COUs, the Agency used monitoring data from analogous uses.

Results for Environmental Releases and Occupational Exposures

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

The Agency evaluated environmental releases of 1,3-butadiene to air, water, and/or land for each OES assessed in the risk evaluation. A majority of releases of 1,3-butadiene were to air in the form of stack and fugitive releases; according to TRI between the years of 2016 and 2021 land releases contributed between 1 and 3 percent of 1,3-butadiene total releases, while discharges to surface water contributed 0.1 percent or less. The OESs with the highest expected releases were manufacturing, plastic and rubber polymerization, and application of adhesives and sealants.

EPA also evaluated inhalation exposures to worker populations, including ONUs, for each OES. The occupational exposure assessment has shown that inhalation exposures to 1,3-butadiene are highest in industrial settings for tasks such as repackaging and plastics and rubber polymerization. Detailed exposure results for each OES and exposure route can be found in Section 3.

Uncertainties

Uncertainties exist with the monitoring and modeling approaches used to assess 1,3-butadiene environmental releases and occupational exposures. For example, the lack of 1,3-butadiene facility PV data and use of throughput estimates based on CDR reporting thresholds may not be representative of the actual PV of 1,3-butadiene used in the United States. There was one case in the release assessment where EPA used generic models and default input parameter values when site-specific data were not available, and several cases in the occupational exposure assessment where analogous monitoring data were used when directly applicable data were not available. In addition, though EPA received information on the use of personal protective equipment (PPE) that is relevant to some uses of 1,3-butadiene, site-specific differences in use practices and engineering controls exist in these cases, whereas some uses have no information on PPE or engineering controls. This represents another source of variability that EPA could not quantify in the assessment.

Environmental and Exposure Pathways Considered

EPA used environmental releases to air, water, and land—primarily from TRI and NEI—to estimate exposures to the general population and ecological species for 1,3-butadiene COUs. The environmental release estimates developed by the Agency are used to estimate the presence of 1,3-butadiene in the environment and biota and evaluate the environmental hazards. The release estimates were used to model exposure to the general population and ecological species where environmental monitoring data were not available.

EPA assessed risks for acute, intermediate, and chronic exposure scenarios in workers (those directly handling 1,3-butadiene) and ONUs for 1,3-butadiene COUs. The Agency assumed that workers and ONUs would be individuals of both sexes (age 16+ years, including pregnant workers) based on occupational work permits. The monitored inhalation data were utilized to provide separate exposure level estimates for workers and ONUs.

1 INTRODUCTION

1.1 Overview

This document provides details on the environmental release and occupational exposure assessment and supports the risk evaluation for 1,3-butadiene under the Frank R. Lautenberg Chemical Safety for the 21st Century Act, which amended TSCA in 2016. TSCA section 6(b)(4) requires EPA to establish a risk evaluation process. In performing risk evaluations for existing chemicals, EPA is directed to "determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator under the conditions of use." In December 2019, EPA published a list of 20 chemical substances designated high priority substances for risk evaluations (84 FR 71924, December 30, 2019), as required by TSCA section 6(b)(2)(B), which initiated the risk evaluation process for those chemical substances. 1,3-Butadiene is one of the chemicals designated as a high-priority substance for risk evaluation.

1,3-Butadiene (CASRN 106-99-0) is a colorless gas with a total PV in the United States between 1 and 5 billion lb from the 2020 CDR reporting period (U.S. EPA, 2020b). It is a TRI-reportable substance effective January 1, 1987 (40 CFR 372.65), is included on EPA's initial list of HAPs under the CAA, and it is a hazardous substance under CERCLA. 1,3-Butadiene is primarily used as a monomer in the production of a wide range of polymers and copolymers. It is also used as an intermediate in the production of several chemicals. It was reported by the ACC in 2018 that roughly 63 to 69 percent of 1,3-butadiene PV goes toward the production of polymers and copolymers such as polybutadiene and styrene-butadiene rubber, while roughly 26 to 32 percent goes toward the production of intermediate chemicals such as adiponitrile and chloroprene. The remainder of the PV may go to either of these uses or other applications such as use as a laboratory chemical (EPA-HQ-OPPT-2018-0451-0021).

The life cycle diagram (LCD) is a graphical representation of the various life stages of the industrial, commercial, and consumer use categories included within the scope of this risk evaluation. The information in the LCD is grouped according to CDR processing codes and use categories (including functional use codes for industrial uses and product categories for industrial, commercial, and consumer uses). The CDR Rule under TSCA section 8(a) (40 CFR part 711) requires U.S. manufacturers (including importers) to provide EPA with information on the chemicals they manufacture or import into the United States. EPA collects CDR data every 4 years with the latest collections occurring in 2020. This document contains additional descriptions (*e.g.*, process descriptions, worker activities, process flow diagrams) for each manufacturing, processing, use, and disposal category.

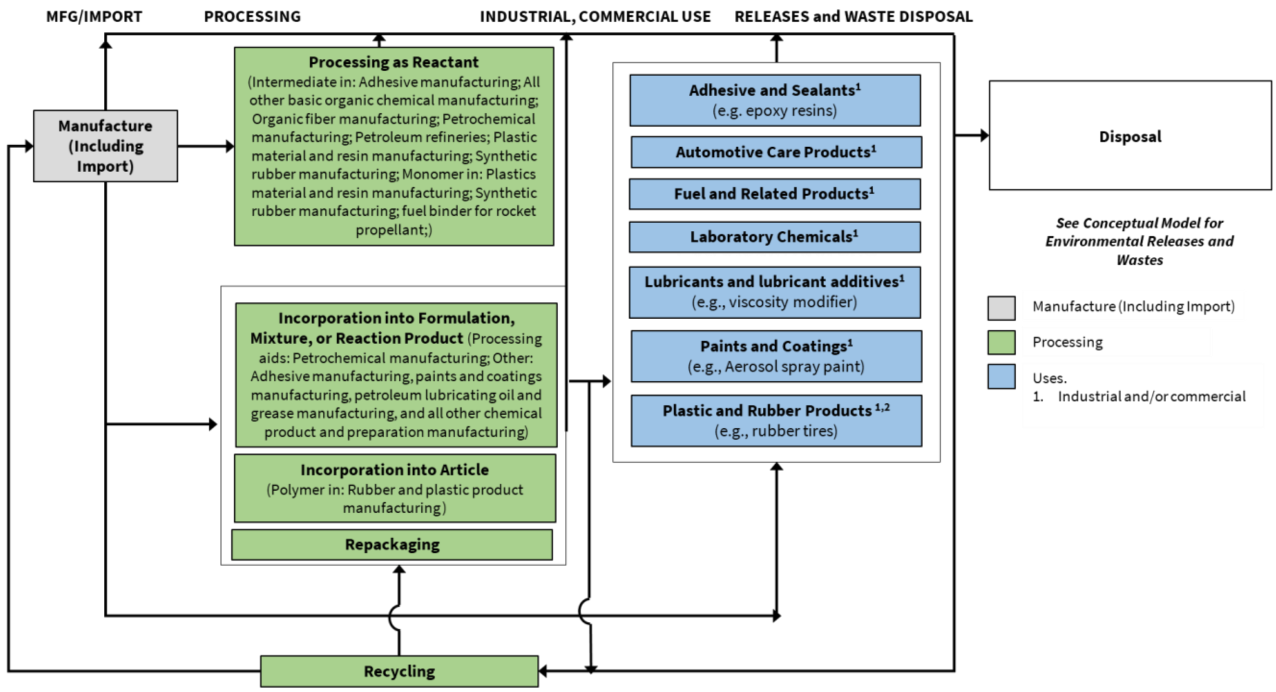


Figure 1-1. 1,3-Butadiene Life Cycle Diagram

This assessment addresses environmental releases and occupational exposures of 1,3-butadiene that may occur in industrial and commercial settings. Releases of 1,3-butadiene in consumer settings and the discussion of downstream environmental fate and transport factors used to estimate exposures to the general population and ecological species are not addressed in this assessment but can be found in other TSDs that support the risk evaluation of 1,3-butadiene. The risks associated with occupational exposures are calculated in the *Risk Calculator for Occupational Exposures for 1,3-Butadiene* (U.S. EPA, 2025k), which is discussed in the *Risk Evaluation for 1,3-Butadiene* (U.S. EPA, 2025l). In the sections that follow, the scope, methods used, and the results of this assessment are described in detail.

For more information on the reviewed sources used to build this assessment, as well as the evaluation strategies for these sources, refer to *Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure for 1,3-Butadiene* (U.S. EPA, 2025g) and EPA's *Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021a), respectively.

1.2 Scope of the Risk Evaluation

The TSCA risk evaluation of 1,3-butadiene comprises several human health, environmental, fate, and exposure assessments/TSDs, a risk evaluation document, and various supplemental files. A diagram showing the relationships between assessments is provided in Figure 1-2. This environmental release and occupational exposure assessment (highlighted in blue) is one of five TSDs outlined in green.

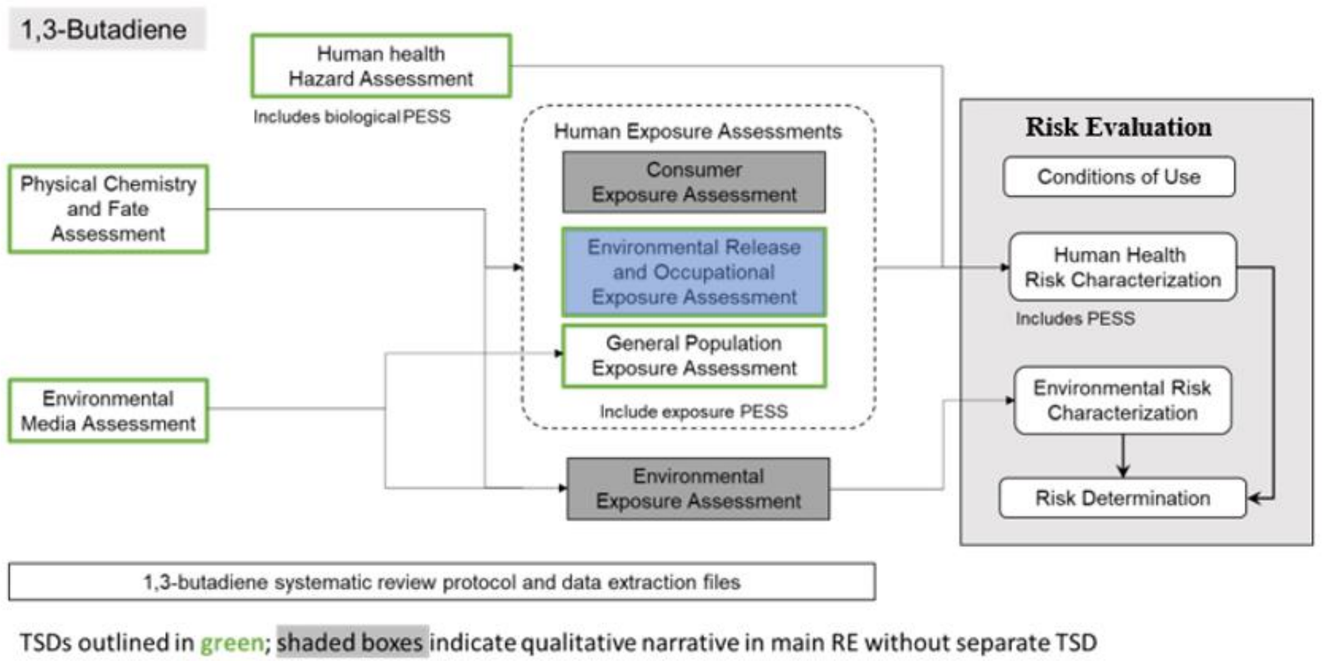


Figure 1-2. 1,3-Butadience Risk Assessment Document Map Summary
Note that this assessment is highlighted in blue.

EPA assessed environmental releases and occupational exposures for COUs as described in Table 2-1 of the *Risk Evaluation for 1,3-Butadiene* (U.S. EPA, 2025l). These COUs are also listed in Table 1-1 below. TSCA section 3(4) defines COUs as "the circumstances, as determined by the Administrator, under which a chemical substance is intended, known, or reasonably foreseen to be manufactured, processed, distributed in commerce, used, or disposed of." EPA identifies COUs for chemicals during the scoping phase and presents them in the *Final Scope of the Risk Evaluation for 1,3-Butadiene; CASRN 106-99-0* (also called the "scope document" of the "final scope") (U.S. EPA, 2020c)—though the COUs presented may change between the scope document and the risk evaluation itself as the assessment is conducted and more information about the chemical is gathered. Each COU has a unique combination of LCD stage, category, and subcategory that describes the chemical's use. As shown in Table 1-1, EPA has identified a total of 28 COUs for 1,3-butadiene.

Each COU for 1,3-butadiene was assigned an OES that characterizes its release and exposure potential. Although named for their utility when assessing occupational exposure, these scenarios are also used when assessing environmental releases from industrial and commercial facilities. OES is a term that is intended to describe the grouping or segmenting of COUs for assessment of releases and exposures. For example, EPA may assess a group of multiple COUs together as one OES due to similarities in release and exposure sources, worker activities, and use patterns. Alternatively, the Agency may assess multiple OESs for one COU because there are different release and exposure potentials within a given COU. OES determinations are largely driven by the availability of data and available modeling approaches to assess occupational releases and exposures. For example, even if there are similarities between multiple COUs and sufficient data to separately assess releases and exposures for each COU, EPA would not necessarily group them into the same OES (see more below). For each OES, environmental releases and occupational exposure results are provided and are expected to be representative of the population of workers and sites involved for the given OES in the United States. Figure 1-3 depicts the ways that COUs may be mapped to OESs.

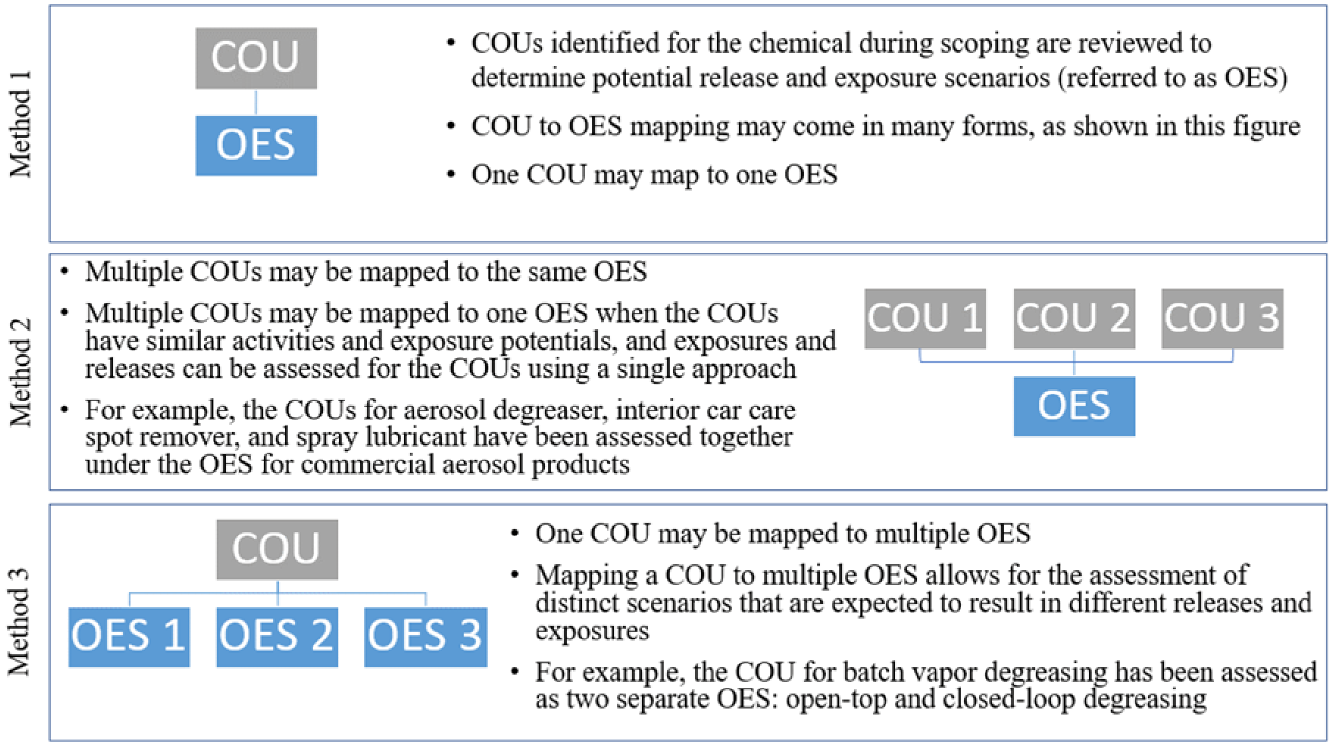


Figure 1-3. COUs to Occupational Exposure Mapping

Table 1-1 shows mapping between the COUs in Table 2-1 of the risk evaluation (U.S. EPA, 2025l) to the OESs assessed in this report. For 1,3-butadiene, EPA mapped OESs to COUs based on data and information gathered during systematic review, industry outreach, and public comments. 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; for example, Importing and Intermediate in: wholesale and retail trade were both assessed under the Repackaging OES. This grouping minimized repetitive assessments. In one case, the COU subcategory was further delineated into multiple OESs based on expected differences in process equipment and associated releases or exposure potentials between facilities. This case was Disposal, which was delineated into Waste handling, treatment, and disposal and Recycling. A total of 15 unique OESs were identified. Table 1-1 lists each COU (defined by its unique combination of a life cycle stage, category, and subcategory) and its corresponding OES.

Table 1-1. Crosswalk of Conditions of Use to Occupational Exposure Scenarios Assessed

Life Cycle Stage[a]	Category[b]	Subcategory[c]	OES
Manufacture	Domestic manufacturing	Domestic manufacturing	Domestic manufacturing
	Importing	Importing	Repackaging
Processing	Processing as a reactant	Intermediate: adhesive manufacturing; all other basic organic chemical manufacturing; fuel binder for solid rocket fuels; organic fiber manufacturing; petrochemical manufacturing; plastic material and resin manufacturing; propellant manufacturing; synthetic rubber manufacturing; paint and coating manufacturing	Processing as a reactant
		Monomer used in polymerization process in: synthetic rubber manufacturing; plastic material and resin manufacturing	Plastics and rubber polymerization
	Processing – incorporation into formulation, mixture, or reaction product	Intermediate (petrochemical manufacturing)	Processing – incorporation into formulation, mixture, or reaction product
		Other (oil and gas drilling, extraction, and support activities)	Processing – incorporation into formulation, mixture, or reaction product
		Monomers (plastic product manufacturing; plastic material and resin manufacturing; synthetic rubber manufacturing)	Plastics and rubber compounding and converting
		Plasticizer (asphalt paving, roofing, and coating materials manufacturing)	Plastics and rubber compounding and converting
	Processing – incorporation into article	Monomer (rubber product manufacturing)	Plastics and rubber compounding and converting
	Repackaging	Wholesale and retail trade (fuel) (*e.g.*, mold releasing agent); synthetic rubber manufacturing; petrochemical manufacturing	Repackaging
	Use – non-incorporative activities	Fuel (Petroleum Refineries)	Processing as a Reactant
	Recycling	Recycling	Processing as a Reactant
			Use of plastics and rubber products[e]
Distribution in Commerce	Distribution in commerce	Distribution in commerce	Distribution in commerce[d]

Life Cycle Stage[a]	Category[b]	Subcategory[c]	OES
Industrial Use	Adhesives and sealants	Adhesives and sealants, including epoxy resins	Application of adhesives and sealants
Commercial Use	Fuels and related products	Fuel additive; vehicular or appliance fuels; cooking and heating fuels	Fuels and related products
	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Use of plastics and rubber products[e]
	Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)	Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)	
	Synthetic Rubber	Synthetic Rubber (*e.g.*, rubber tires)	
	Furniture and furnishings including stone, plaster, cement, glass and ceramic articles; metal articles; or rubber articles	Furniture & furnishings including stone, plaster, cement, glass and ceramic articles; metal articles; or rubber articles	
	Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)	Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)	
	Other use	Laboratory chemicals	Use of laboratory chemicals
	Lubricants and lubricant additives	Lubricant additives, including viscosity modifier	Use of lubricants and greases[e]
	Paints and coatings	Paints and coatings, including aerosol spray paint	Application of paints and coatings
	Adhesives and sealants	Adhesives and sealants, including epoxy resins	Application of adhesives and sealants

Life Cycle Stage[a]	Category[b]	Subcategory[c]	OES
Consumer Use	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	Other articles with routine direct contact during normal use including rubber articles; plastic articles (hard)	N/A[f]
	Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)	Toys intended for children's use (and child dedicated articles), including fabrics, textiles, and apparel; or plastic articles (hard)	
	Synthetic rubber	Synthetic rubber (*e.g.*, rubber tires)	
	Furniture & furnishings including stone, plaster, cement, glass and ceramic articles; metal articles; or rubber articles	Furniture & furnishings including stone, plaster, cement, glass and ceramic articles; metal articles; or rubber articles	
	Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)	Packaging (excluding food packaging), including rubber articles; plastic articles (hard); plastic articles (soft)	
Disposal	Disposal	Disposal	Waste handling, treatment, and disposal
			Recycling

[a] LCD Use Definitions (40 CFR 711.3)

- "Industrial use" means use at a site at which one or more chemicals or mixtures are manufactured (including imported) or processed.
- "Commercial use" means the use of a chemical or a mixture containing a chemical (including as part of an article) in a commercial enterprise providing saleable goods or services.
- "Consumer use" means the use of a chemical or a mixture containing a chemical (including as part of an article, such as furniture or clothing) when sold to or made available to consumers for their use.
- Although EPA has identified both industrial and commercial uses here for purposes of distinguishing scenarios in this document, the Agency interprets the authority over "any manner or method of commercial use" under TSCA section 6(a)(5) to reach both.

[b] These categories of COU appear in the Life Cycle Diagram, reflect CDR codes, and broadly represent COUs of 1,3-butadiene in industrial and/or commercial settings.

[c] These subcategories reflect more specific COUs of 1,3-butadiene.

Life Cycle Stage[a]	Category[b]	Subcategory[c]	OES
- "Incorporation into article – polymer in rubber product manufacturing," as reported to the 2016 CDR, is a COU that EPA considered as manufacturing of articles involving butadiene-derived polymers, including plastics such as acrylonitrile butadiene styrene made using polybutadiene rubber. - "Monomer used in polymerization process," as reported to the 2016 CDR under commercial use, indicates processing of 1,3-butadiene for a polymerization reaction. This reported use was evaluated under processing as a reactant. [d] EPA considers the activities of loading and unloading of chemical product part of distribution in commerce, however these activities were assessed as part of each use's OES. EPA's current approach for quantitively assessing releases and exposures for the remaining aspects of distribution in commerce consists of searching Department of Transportation (DOT) and National Response Center (NRC) data for incident reports pertaining to 1,3-butadiene distribution. [e] Although these uses were identified during scoping, upon further investigation EPA made the decision to not quantitatively assess these uses of 1,3-butadiene. For a description of the rationale for not performing a quantitative assessment, and details for each decision, see Section 4.2. [f] Consumer uses are not assigned to an OES as they are not part of the occupational assessment. See Section 5.1.2 of the *Risk Evaluation for 1,3-Butadiene* (U.S. EPA, 2025l) for information on the consumer exposure assessment.			

After identifying those OESs that will be assessed, the next step was to describe the function of 1,3-butadiene within each OES (Table 1-2). This would be utilized in mapping release and exposure data to an OES as well as applying release modeling approaches. For more information on each OES, see the corresponding process descriptions in Section 3.

Table 1-2. Description of the Function of 1,3-Butadiene for Each OES

OES	Role/Function of 1,3-Butadiene
Manufacturing	This OES captures the Domestic manufacture COU category. 1,3-Butadiene can be produced by three processes: steam cracking of paraffinic hydrocarbons (the ethylene coproduct process), catalytic dehydrogenation of n-butane and n-butene (the Houdry process), and oxidative dehydrogenation of n-butene (the Oxo-D or O-X-D process). The predominant method of the three processes is the steam cracking process, which accounts for greater than 91% of the world's butadiene supply.
Repackaging	This OES captures the Importing and Repackaging COU categories. Import and repackaging sites are expected to distribute 1,3-butadiene to various downstream uses. Liquefied butadiene is shipped by pipelines, ships, barges, rail tank cars, tank trucks and bulk liquid containers. A portion of the 1,3-butadiene manufactured is also expected to be repackaged into smaller containers for commercial laboratory use.
Processing as a reactant	This OES captures the Processing as an Intermediate COU subcategory and part of the Recycling COU category. Processing as a reactant or intermediate is the use of 1,3-butadiene as a feedstock in the production of another chemical via a chemical reaction in which 1,3-butadiene is consumed to form the product. 1,3-Butadiene is used in the production of intermediate chemicals which are then used to make nylon and neoprene rubber among other products. 1,3-butadiene is also processed as a reactant in rocket propellant manufacturing by the U.S. Department of Defense (DOD). Also included in this OES is when ethylene manufacturers have excess butadiene supply, they can

OES	Role/Function of 1,3-Butadiene
	recycle the butadiene as a feedstock to produce ethylene.
Processing – incorporation into formulation, mixture, or reaction product	This OES captures the Processing – incorporation into formulation, mixture, or reaction product COU category. Incorporation into a formulation, mixture or reaction product refers to the process of mixing or blending of several raw materials to obtain a single product or preparation. 1,3-Butadiene may be used during lubricant manufacturing as a viscosity improver, as well as in paints, coatings, and adhesive manufacturing as a binder.
Plastic and rubber polymerization	This OES captures the Processing as a monomer COU subcategory. 1,3-Butadiene is used as a monomer in polymerization processes, often to produce rubbers and plastics such as styrene-butadiene, polybutadiene, acrylonitrile-butadiene-styrene, and nitrile rubber. This is the most common use of 1,3-butadiene.
Plastics and rubber compounding and converting	This OES captures the Processing –incorporation into article COU category. After the polymerization process that occurs during the plastic and rubber polymerization OES briefly described above, polymers are compounded, and the compounded plastic and rubber resins are converted into solid articles.
Distribution in commerce	This OES captures the Distribution in commerce COU category. 1,3-Butadiene is expected to be distributed in commerce for the purposes of each processing, industrial, and commercial use of 1,3-butadiene. EPA expects 1,3-butadiene to be transported from manufacturing sites to downstream processing and repackaging sites.
Use of laboratory chemicals	This OES captures the Laboratory chemicals COU subcategory. 1,3-Butadiene uses as a laboratory chemical may include demonstration of Diels Alder reactions, synthesis of thermoplastic resins, and synthesis of disilylated dimers by reacting with chlorosilanes.
Application of paints and coatings	This OES captures the Paints and coatings COU category. 1,3-Butadiene was identified as possibly being present in multiple paint and coating products, including aerosol propellants, architectural paints and coatings, latex paints, electro-dipping coatings, and automotive primers. The application procedure depends on the type of paint or coating formulation and the type of substrate, but may involve application via brush, spray, roll, dip, curtain, or syringe or bead.
Application of adhesives and sealants	This OES captures the Industrial use of adhesives and sealants, as well as the Commercial use of adhesives and sealants COU categories. 1,3-Butadiene was identified in multiple adhesive and sealant products, including aerosol propellants, epoxy resins (incorporated for their tensile and elastomeric properties), and adhesives for electrical and circuit boards. The application procedure depends on the type of adhesive or sealant formulation and the type of substrate but may involve application via brush, spray, roll, dip, curtain, or syringe or bead.
Fuels and related products	This OES captures the Fuels and related products COU category.

OES	Role/Function of 1,3-Butadiene
	1,3-Butadiene may be used at industrial sites for fueling purposes. This use of 1,3-butadiene is addressed in the Recycling OES. EPA did not find evidence that 1,3-butadiene in its monomer form is used as an additive to fuel, however it was found that 1,3-butadiene is present in butane. This use is discussed, but no release or exposure estimates provided.
Recycling	This OES captures part of the Disposal COU category. There are multiple ways 1,3-butadiene can be recycled during its life cycle. When finished 1,3-butadiene does not meet commercial specifications, it is often combined with crude streams for energy recovery. This is examined in this OES.
Waste handling, treatment, and disposal	This OES captures part of the Disposal COU category. Each of the OES may generate waste streams of 1,3-butadiene that are collected and transported to third-party sites for disposal or treatment, and these cases are assessed under this OES. Also handled under this OES are cases of 1,3-butadiene produced as a byproduct or impurity in an industrial setting and burned.
Use of plastics and rubber products	This OES captures the five plastic and rubber COU categories detailed in the Commercial use life cycle stage as well as the automative care products and part of the Recycling COU categories. 1,3-Butadiene may be present within rubber tires and articles produced with synthetic rubber. In addition, plastics containing 1,3-butadiene were identified in electronic appliances, furniture and furnishings, toys and recreational products, housewares, packaging, automotive parts, building materials, and 3D printing filament. Plastic and rubber products may be recycled mechanically (injection molding, extrusion, rotational molding and compression molding) into newly shaped products. Tires may also be recycled into tire crumbs for use on synthetic turf fields. It was determined that butadiene is present in rubber products at no greater amounts than 6.6 ppm, and after polymerization occurs it is nearly impossible to break the polymer chain back into individual units of 1,3-butadiene. No release or exposure numbers are provided for this OES.
Use of lubricants and greases	This OES captures the Lubricants and lubricant additive COU category. 1,3-Butadiene has been identified in automotive lubricants and aircraft lubricants. 1,3-Butadiene monomer is present at very low levels within the finished styrene-butadiene copolymer product. Further, due to lack of evidence otherwise, it was determined that 1,3-butadiene is not present within lubricants and greases for any purpose other than the amount that may be residual within the styrene-butadiene copolymer. No release or exposure numbers are provided for this OES.

EPA reviewed release data from TRI from 2016 to 2021 (U.S. EPA, 2021b) and the NEI from 2017 and 2020 (U.S. EPA, 2019b) to identify relevant releases of 1,3-butadiene to the environment. More recent years of TRI data have become available since the completion of this analysis. EPA reviewed the total releases from 2022, 2023, and 2024 and found that the yearly TRI releases are comparable to those releases that occurred from 2016 to 2021. The Agency also reviewed the Discharge Monitoring Report (DMR, data from 2016–2021) but found no evidence of 1,3-butadiene release within the timeframes assessed. While these databases sufficiently informed industrial and processing COUs, the databases are limited in data on environmental releases for commercial COUs and when necessary, EPA used modeling to estimate releases to the environment. These databases may not identify all 1,3-butadiene releases as some facilities may not be required to report due to reporting thresholds or other factors.

EPA's assessment of releases includes quantifying annual and daily releases of 1,3-butadiene to air, water, and land. Releases to air include both fugitive and stack air emissions and emissions resulting from on-site waste treatment equipment, such as incinerators. For purposes of this report, releases to water include both direct discharges from industrial facilities to surface water and indirect discharges to publicly owned treatment works (POTW) or non-POTW wastewater treatment (WWT). Note that indirect discharges are not released directly into the environment but instead transported to WWT plants. As stated in Section 3.5.2 of the *Physical Chemistry, Fate, and Transport Assessment for 1,3-Butadiene* (U.S. EPA, 2025j), due to the volatility of 1,3-butadiene, only small amounts are expected to enter WWT plants, and the small amounts that do enter a WWT plant are expected to be removed primarily by volatilization and possibly some biodegradation. Releases to land include any disposal of liquid or solids wastes containing 1,3-butadiene into landfills, land treatment, surface impoundments, or other land applications. Read more about 1,3-butadiene's fate in land releases in Section 3.4.5 of the *Physical Chemistry, Fate, and Transport Assessment for 1,3-Butadiene* (U.S. EPA, 2025j).

1,3-Butadiene is also generated as a byproduct from the incomplete combustion of fuel. EPA did not assess environmental releases or occupational exposures resulting from 1,3-butadiene formed as a byproduct (*e.g.*, exhaust emissions). EPA believes it is more appropriate to evaluate the potential risks arising from the byproduct within the scope of the risk evaluation for fuel from which the 1,3-butadiene is produced, rather than the 1,3-butadiene risk evaluation.

The purpose of this assessment is to quantify releases (along with occupational exposure, discussed below); therefore, downstream environmental fate and transport factors used to estimate exposures to the general population and ecological species are not discussed. Environmental fate and transport of 1,3-butadiene is discussed in the *Chemistry, Fate, and Transport Assessment for 1,3-Butadiene* (U.S. EPA, 2025j). The details on how these factors were considered when determining risk are described in the *Risk Evaluation for 1,3-Butadiene* (U.S. EPA, 2025l).

EPA's assessment of occupational exposures includes quantifying inhalation exposures to 1,3-butadiene. The Agency categorizes occupational exposures into two groups: exposures to workers and exposures to ONUs. Generally, EPA distinguishes workers as directly handling 1,3-butadiene as part of their duties and have direct contact with the chemical, while ONUs work in the general vicinity of workers but do not handle 1,3-butadiene and do not have direct contact with the 1,3-butadiene being handled by the workers. When data were available EPA provided exposure estimates for multiple tasks that occur within an OES, however in all cases EPA evaluated inhalation exposures to at least both workers and ONUs.

Due to the volatility and transport methods of 1,3-butadiene, EPA found that routine dermal exposure to workers and ONUs is unlikely and/or an insignificant source of exposure to workers compared to inhalation exposure, and so dermal exposures are not quantified in this assessment. For more information on dermal exposure to 1,3-butadiene, see Section 2.4.5.

2 APPROACH AND METHODOLOGY

An environmental release and occupational exposure assessment was conducted for each OES specified in Table 1-1. For each OES, the following components are presented:

- ***Process Description:*** A description of the OES, including the function of the chemical in the OES; physical forms and weight fractions of the chemical throughout the process; the total PV associated with the OES; per site throughputs/use rates of the chemical; operating schedules; and process vessels, equipment, and tools used during the COU.
- ***Estimates of Number of Facilities:*** An estimate of the number of sites that use 1,3-butadiene for the given OES.
- ***Environmental Release Sources:*** A description of each of the potential sources of environmental releases to air in the process for the given OES.
- ***Environmental Release Assessment Results:*** Estimates of chemical released into each environmental media (surface water, POTW, non-POTW WWT, fugitive air, stack air, and land disposal).
- ***Worker Activities:*** A description of the worker activities, including an assessment for potential points of worker and ONU exposure.
- ***Number of Workers and ONU:*** 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 exposure to workers and ONU. See Section 2.4.3 for a discussion of EPA's statistical analysis approach for assessing inhalation exposure.

For the remainder of this section, the approach and methodology for completing each of the above listed components is described in more detail.

2.1 Process Descriptions

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

- Total PV 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 1,3-butadiene-specific process descriptions were unclear or not available, EPA referenced generic process descriptions from literature, including relevant Emission Scenario Documents (ESDs) or Generic Scenarios (GSs). Process descriptions for each OES can be found in Section 3.

2.2 Number of Facilities

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

1. Identify or "map" each facility reporting for 1,3-butadiene in the 2016 and 2020 CDR (U.S. EPA, 2020b, 2016), 2016 through 2021 TRI (U.S. EPA, 2021b), and 2017 and 2020 NEI (U.S.

EPA, 2019b) to an OES. The full details of the methodology for mapping facilities from EPA reporting programs is described in Appendix F. In brief, mapping consists of using facility reported industry sectors (typically reported as either North American Industry Classification System (NAICS) or Standard Industrial Classification (SIC) codes), and chemical activity, 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 are expected to cover most or all the facilities within the OES. If so, no further action was required, and EPA assessed the total number of facilities in the OES as equal to the count of facilities mapped to the OES from each dataset. If not, EPA proceeded to Step 3. All OESs with quantified releases and exposures except for one obtained the number of facilities solely from reporting programs. See the *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of this count. For Application of Adhesives and Sealants, with only one reporting site, EPA proceeded to Step 3 and 4.
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 US Businesses (SUSB) data on total establishments by 6-digit NAICS.
    c. Use market penetration data to estimate the percentage of establishments likely to be using 1,3-butadiene instead of other chemicals.
    d. Combine the data generated in preceding Steps 3.a through 3.c to produce an estimate of the number of facilities using 1,3-butadiene in each 6-digit NAICS code and sum across all applicable NAICS codes for the OES to arrive at a total estimate of the 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 1,3-butadiene PV 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 provided the details of 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

Releases to the environment are a component of potential exposure and may be derived from reported data that are obtained through direct measurement via monitoring, calculations based on empirical data, and/or assumptions and models. For each OES, EPA, where possible, provided annual releases, daily releases, and the number of release days per year for each media of release (air, water, and land). Annual and daily releases are provided as central tendency and high-end estimates, which are typically estimated by taking the 50th and 95th percentiles respectively of release data.

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 or analogous 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's preference was to rely on facility-specific release data reported in TRI (U.S. EPA, 2021b) and NEI (U.S. EPA, 2019b), where available. For 1,3-butadiene, monitored and measured data from TRI and NEI provided release estimates for every OES except one—Application of adhesives and sealants—which used the relevant ESD and modeling. Specific details related to the use of release data or models for each OES can be found in Section 3. With release estimates identified for all OESs through the use of monitoring data and modeling, release limits were not used in this assessment.

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

- ***Deterministic Calculations:*** EPA used combinations of point estimates of each input parameter to estimate a central tendency and high-end for each final release result. The Agency documented the method and rationale for selecting parametric combinations to be representative of central tendency and high-end in the relevant OES subsections in Section 3. In general, central tendency is calculated as the 50th percentile of the releases reported to the OES, and high-end is the 95th percentile. Calculations for these results can be found in the Supplemental Release Files.
- ***Probabilistic (Stochastic) Calculations:*** EPA used Monte Carlo simulations using the full distribution of each input parameter to calculate a full distribution of the final release results and selecting the 50th and 95th percentiles of this resulting distribution as the central tendency and high-end, respectively.
- ***Combination of Deterministic and Probabilistic Calculations:*** EPA had full distributions for some parameters but point estimates of the remaining parameters. For example, the Agency used Monte Carlo modeling to estimate annual throughputs and PV but only had point estimates of release timing. In this case, EPA documented the approach and rationale for combining point estimates with distribution results for estimating central tendency and high-end results in the relevant OES subsections in Section 3.

2.3.1 Identifying Release Sources

EPA performed a literature search to identify process operations that could potentially result in releases of 1,3-butadiene to air, water, or land from each OES. For each OES, the Agency identified the release sources and the associated media of release. Where 1,3-butadiene release sources were unclear or not available, EPA referenced relevant ESDs or GSs. Descriptions of release sources for each OES can be found in Section 3.

2.3.2 Estimating Release Days per Year

EPA typically assumed the number of release days per year from any release source will be equal to the number of operating days at the facility unless information is available to indicate otherwise. To estimate the number of operating days, the Agency used the following hierarchy:

1. ***Facility-Specific Data:*** EPA used facility-specific operating days per year data if available. If facility-specific data were not available for one facility of interest but was available for other facilities within the same OES, EPA estimated the operating days per year using one of the following approaches:
    a. If other facilities have known or estimated average daily use rates, EPA calculated the days per year as: 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 estimate average daily use rates, EPA used the average number of days per year from the facilities with such data available.
2. ***Industry-Specific Data:*** EPA used industry-specific data available from GSs, ESDs, trade publications, or other relevant literature.
3. ***Manufacture of Large-PV Commodity Chemicals:*** Commodity chemicals are basic and relatively inexpensive compounds that are often produced in large quantities at plants built specifically to make one chemical. These plants are often run continuously, typically only shutting down for a few weeks a year for maintenance. Because of this, for the manufacture of the large-PV commodity chemicals, EPA used a value of 350 days per year. This assumes the plant runs 7 days per week and 50 weeks per year (with 2 weeks down for turnaround) and assumes that the plant is always producing the chemical.
4. ***Manufacture of Lower-PV Specialty Chemicals:*** Specialty chemicals are often more expensive and are produced less frequently, at smaller quantities, and on an "as needed" basis. Because of this, for the manufacture of lower-PV specialty chemicals, it is unlikely the chemical is being manufactured continuously throughout the year. Therefore, EPA 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. ***Processing as Reactant (Intermediate Use) in the Manufacture of Commodity Chemicals:*** Similar to #3, EPA assumed the manufacture of commodity chemicals occurs 350 days per year such that the use of a chemical as a reactant to manufacture a commodity chemical would also occur 350 days per year.
6. ***Processing as Reactant (Intermediate Use) in the Manufacture of Specialty Chemicals:*** Similar to #4, the manufacture of specialty chemicals is not likely to occur continuously throughout the year. Therefore, EPA used a value of 250 days per year.
7. ***Other Chemical Plant OESs (e.g., Processing into Formulation and Use of Industrial Processing Aids):*** For these OESs, EPA assumed that the chemical of interest is not always in use at the facility, even if the facility operates 24/7. Therefore, in general, EPA used a value of 300 days/year based on the "SpERC fact sheet – Formulation & (re)packing of substances and mixtures – Industrial (Solvent-borne)" which uses a default of 300 days/year for the chemical industry (ESIG, 2012). 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.
8. ***POTWs:*** Although EPA expects POTWs to operate continuously over 365 days per year, the discharge frequency of the chemical of interest from a POTW will be dependent on the discharge patterns of the chemical from the upstream facilities discharging to the POTW. However, there can be multiple upstream facilities (possibly with different OESs) discharging to the same POTW and information to determine when the discharges from each facility occur on the same

day or separate days is typically not available. Therefore, EPA could not determine an exact number of days per year the chemical of interest is discharged from the POTW and used a value of 365 days per year.

9. ***All Other OESs:*** Regardless of what the facility operating schedule is, other OESs are unlikely to use the chemical of interest every day. Therefore, EPA used a value of 250 days per year for these OESs.

2.3.3 Estimating Releases from Data Reported to EPA

Generally, EPA used the facility-specific release data reported in TRI, DMR, and NEI as annual releases in each dataset for each site and estimated the daily release by averaging the annual release over the expected release days per year. The Agency's approach to estimating release days per year is described in Section 2.3.2. The following supplemental files contain the calculations of the central tendency and high-end annual and daily releases for each OES that used EPA databases to estimate releases: Land release calculations (U.S. EPA, 2025h); water release calculations (U.S. EPA, 2025n); air release calculations using TRI are in (U.S. EPA, 2025e); and air release calculations using NEI, all annual and daily calculations from both years (2017 and 2020), are in (U.S. EPA, 2025c). The raw release data from NEI 2020 are in the *Air Releases (NEI2020) for 1,3-Butadiene* (U.S. EPA, 2025d) supplemental file.

TRI

Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) established the TRI. TRI tracks the waste management of designated toxic chemicals from facilities within certain industry sectors. Facilities are required to report to TRI if the facility has 10 or more full-time employees; is included in an applicable NAICS code; and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 lb for manufacturers and processors and 10,000 lb for users of 1,3-butadiene). Facilities provide on-site release information using readily available data (including monitoring data) collected pursuant to other provisions of law, or where such data are not readily available, "reasonable estimates" of the amounts released. EPA makes the reported information publicly available through TRI.

Each facility subject to the rule must report either using a Form R or a Form A. Facilities reporting using a Form R must report annually the volume of chemical released to the environment (*i.e.,* surface water, air, or land) and/or managed through recycling, energy recovery, and treatment (*e.g.,* incineration) from the facility. Facilities may submit a Form A if the volume of chemical manufactured, processed, or otherwise used does not exceed 1,000,000 lb per year (lb/year) and the total annual reportable releases do not exceed 500 lb/year. Facilities reporting using a Form A are not required to submit annual release and waste management volumes or use/sub-use information for the chemical. Due to reporting limitations, some sites that manufacture, process, or use 1,3-butadiene may not report to TRI and are therefore not included in EPA's assessment.

For each release quantity reported, TRI filers select a "basis of estimate" code to indicate the principal method used to determine the release quantity. TRI provides six basis of estimate codes, which in no particular order, are continuous monitoring, periodic monitoring, mass balance calculations, published emission factors, site-specific emission factors, and engineering calculations/best engineering judgment. For facilities that use a TRI chemical in multiple operations, the filer may use a combination of methods to calculate the overall release quantity. In such cases, TRI instructs the facility to enter the basis of estimate code for the method that corresponds to the largest portion of the reported release quantity.[1]

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[1] See TRI Program Guidance on EPA's GuideME website (accessed December 5, 2025) under Reporting Forms and Instructions, Section 5. Quantity of the Toxic Chemical Entering Each Environmental Medium On-Site (Form R).

Additional details on the basis for the reported release estimate (*e.g.*, calculations, underlying assumptions) are not reported in TRI.

EPA included both TRI Form R and Form A submissions in the analysis of environmental releases. For Form Rs, EPA assessed releases using the reported annual release volumes from each media. For Form As, EPA assessed releases using the 500 lb per year threshold for each release media; however, since this threshold is for total site releases, the 500 lb/year is attributed to one release media—not all (to avoid over counting the releases and exceeding the total release threshold for Form A). For this risk evaluation, EPA used TRI data from reporting years 2016 to 2021 to provide a basis for estimating releases (U.S. EPA, 2021b). Further details on EPA's approach to using TRI data for estimating releases are described in Section 2.3.3.1, Appendix F, and Appendix G.

EPA obtained 2016 to 2021 TRI data for 1,3-butadiene from EPA's Basic Plus Data Files. The Agency followed a similar approach to estimate air, water, and land releases. EPA used the reported annual releases directly as reported in TRI and then divided the annual releases over the number of estimated operating days to obtain daily average release estimates. The Agency presents the release data as high-end and central tendency estimates by calculating the 50th and 95th percentiles of the releases from all facilities mapped to a given OES. Release estimates are separated where relevant by stack and fugitive air emissions, surface water discharges, POTWs, non-POTW WWT, and land releases.

- Air emissions in TRI are reported separately for stack air and fugitive air and occur on-site at the facility. From 2016 to 2021, 288 facilities reported air emissions of 1,3-butadiene, and there were 1169 total reports.
- Water releases in TRI include both reports of annual direct discharges to surface water and annual indirect discharges to off-site POTWs and WWT facilities. A total of 31 facilities reported water releases of 1,3-butadiene, with a total of 114 reports over the 6 years that were assessed.
- Land releases in TRI provide the type of release media for a particular facility, as well as how the chemical is managed through recycling, energy recovery, or treatment. A total of 39 facilities reported land releases of 1,3-butadiene.

When this analysis was conducted, 2021 was the most recent TRI year available. EPA has since reviewed the total air releases to TRI for each available year from 2021 forward and has confirmed that the releases for 2022, 2023, and 2024 are comparable to the releases from the years used in this assessment. For stack air, the more recent releases all fell within the range that occurred between 2016 and 2021. For fugitive air, all of the more recent releases, except the releases in 2024, fell within the range that occurred between 2016 and 2021. The 2024 total fugitive air release was 139,104 kg and the next lowest amount was 140,612 kg in 2018. See the supplemental file, *Air Releases (TRI) for 1,3-Butadiene* (U.S. EPA, 2025e), which presents the total stack and fugitive releases to air for each year included in the assessment.

NEI

The NEI was established to track emissions of Criteria Air Pollutants (CAPs) and CAP precursors and assist with National Ambient Air Quality Standard (NAAQS) compliance under the CAA. Air emissions data for the NEI are collected at the state, local, and Tribal (SLT) level. SLT air agencies then submit these data to EPA through the Emissions Inventory System (EIS). In addition to CAP data, many SLT air agencies voluntarily submit data for pollutants on EPA's list of HAPs. EPA uses the data collected from SLT air agencies, in conjunction with supplemental HAP data, to build the NEI. The Agency makes an updated NEI publicly available every three years. For this risk evaluation, EPA used NEI data for reporting years 2017 and 2020 data to provide a basis for estimating releases. (U.S. EPA, 2019b)

NEI emissions data are categorized into (1) point source data, (2) area or nonpoint source data, (3) onroad mobile source data, and (4) nonroad mobile source data. EPA included only point source data categories in the assessment of environmental releases in this risk evaluation (see Appendix G.2.1 for more information on area or nonpoint and onroad mobile sources). Point sources are stationary sources of air emissions from facilities with operating permits under Title V of the CAA, also called "major sources." Major sources are defined as having actual or potential emissions at or above the major source thresholds. While thresholds can vary for certain chemicals in NAAQS non-attainment areas, the default threshold is 100 tons/year for non-HAPs, 10 tons per year for a single HAP, or 25 tons per year for any combination of HAPs. Point source facilities include large energy and industrial sites and are reported at the emission unit- and release point-level. Further details on EPA's approach to using NEI data for estimating releases are described in Section 2.3.3.2, Appendix F, and F.1.

Where available, EPA used NEI data to estimate annual and average daily fugitive and stack air emissions. Facility-level annual emissions are available for major sources in NEI. The Agency then divided the annual stack and fugitive emissions over the number of estimated operating days to develop daily release estimates. In some cases, the same facility reported air releases to both TRI and NEI for a given reporting year. EPA presented data from both sources for the air release assessment.

- In 2017, there were 735 facilities that reported point source air emissions of 1,3-butadiene to NEI and 5,120 point source reports.
- In 2020, there were 713 facilities that reported point source air emissions to NEI and 5,346 point source reports.

DMR

Because there were no reported releases of 1,3-butadiene submitted to DMR for the years of this assessment (2016–2021), DMR data were not included in the assessment of environmental releases in the risk evaluation.

2.3.3.1 Estimating Wastewater Discharges from TRI

Where available, EPA used TRI to estimate annual wastewater discharges, average daily wastewater discharges, and high-end daily wastewater discharges. Water releases in TRI include both reports of annual direct discharges to surface water and annual indirect discharges to off-site POTWs and WWT facilities. Direct discharges to surface water and indirect discharges to off-site POTWs and WWT facilities from TRI were assessed. Although surface water discharges are released to the environment, discharges to POTWs and WWT facilities are not directly released into the environment but rather to treatment facilities. As stated in Section 3.5.2 of the *Physical Chemistry, Fate, and Transport Assessment for 1,3-Butadiene* (U.S. EPA, 2025j), the removal of 1,3-butadiene from these facilities is expected to be greater than 99 percent, primarily due to volatilization of the chemical to air.

Annual Wastewater Discharges

For TRI, annual discharges are reported directly by facilities.

Average Daily Wastewater Discharges

To estimate average daily discharges, EPA used the following steps:

1. Obtained reported annual direct surface water discharges and indirect discharges to POTW and non-POTW WWT in TRI. Although all data are obtained, only direct discharges were included in the analysis.
2. For TRI reporters using Form A releases are not provided. EPA estimated annual releases using the threshold of 500 lb/year.

3. Divided the annual discharges over the number of estimated operating days (estimated as described in Section 2.3.2).
4. Estimated a release duration using facility-specific data available in models and/or literature sources. If no data were available, listed as "unknown."

2.3.3.2 Estimating Air Emissions from TRI and NEI

Where available, EPA used TRI and NEI data to estimate annual and average daily fugitive and stack air emissions. For air emissions, the Agency estimated both release patterns (*i.e.*, days per year of release) and release durations (*i.e.*, hours per day the release occurs).

Annual Emissions

Facility-level annual emissions are available for TRI reporters and major sources in NEI. EPA used the reported annual emissions directly as reported in TRI and NEI for major sources.

Average Daily Emissions

To estimate average daily emissions for TRI reporters and major sources in NEI, EPA used the following steps:

1. Obtain total annual fugitive and stack emissions for each TRI reporter and point sources in NEI.
2. For TRI reporters using a Form A, estimate annual releases using the threshold of 500 lb/year.
3. Divide the annual stack and fugitive emissions over the number of estimated operating days (Note that NEI data includes operating schedules for many facilities that can be used to estimate facility-specific days per year).
4. Estimate a release duration using facility-specific data available in NEI, models, and/or literature sources. If no data are available, list as "unknown."

2.3.3.3 Estimating Land Releases from TRI

Where available, EPA used TRI data to estimate annual and average daily land disposal volumes. TRI includes reporting of disposal volumes for a variety of land disposal methods, including underground injection, Resource Conservation and Recovery Act (RCRA) Subtitle C landfills, land treatment, RCRA Subtitle C surface impoundments, other surface impoundments, and other land disposal. TRI also provides the type of release media for a particular facility, as well as how the chemical is managed through recycling, energy recovery, or treatment. EPA provided estimates for the total aggregated land disposal volume. Read more about 1,3-butadiene's fate in land releases in Section 3.4.5 of the *Physical Chemistry, Fate, and Transport Assessment for 1,3-Butadiene* (U.S. EPA, 2025j).

Annual Land Disposal

Facility-level annual disposal volumes are available directly for TRI reporters. EPA used the reported annual land disposal volumes directly as reported in TRI for each land disposal method. The Agency combined totals from all land disposal methods from each facility to estimate a total annual aggregate disposal volume to land.

Average Daily Land Disposal

To estimate average daily disposal volumes, EPA used the following steps:

1. Obtain total annual disposal volumes for each land disposal method for each TRI reporter.
2. For TRI reporters using a Form A, estimate annual releases using the threshold of 500 lb/year.
3. Divide the annual disposal volumes for each land disposal method over the number of estimated operating days.

2.3.4 Estimating Releases from Models

Where releases were expected for an OES but TRI and/or NEI data were not available or where EPA determined they did not capture the entirety of environmental releases for an OES, the Agency utilized models to estimate environmental releases. Outputs from models may be the result of deterministic calculations, stochastic calculations, or a combination of both deterministic and stochastic calculations. For each OES with modeled releases, EPA followed these steps to estimate releases:

1. Identify release sources from process and associated release media.
2. Identify or develop model equations for estimating releases from each release 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[2] with 100,000 iterations and the Latin Hypercube sampling method. Detailed descriptions of the model approaches used for the relevant OESs, model equations, input parameter values and associated distributions are provided in Appendix D.

EPA used models to estimate environmental releases in one case—the OES Application of adhesives and sealants. See Section 3.10 for more detail on this scenario and the *Adhesives and Sealants Release Model for 1,3-Butadiene* (U.S. EPA, 2025b), detailing the calculations. All other releases were estimated using data reported to EPA as described in Section 2.3.3.

2.4 Occupational Exposure Approach and Methodology

For workplace exposures, EPA considered exposures to both workers who directly handle 1,3-butadiene and ONUs who do not directly handle 1,3-butadiene but may be exposed to vapors, particulates, or mists that enter their breathing zone while working in locations in close proximity to 1,3-butadiene. EPA evaluated inhalation exposures to both workers and ONUs. Note that the Agency's estimates of occupational exposure presented in this assessment do not assume the use of PPE; however, the effect of respiratory protection fit factors on EPA's occupational exposure estimates can be explored in the *Risk Calculator for Occupational Exposures for 1,3-Butadiene* (U.S. EPA, 2025k). For more discussion and information on respiratory protection and glove protection, refer to Appendix E.

Figure 2-1 presents the conceptual model for exposure pathways, exposure routes, and hazards to human populations from industrial and commercial activities and uses of 1,3-butadiene. There is potential for exposure to workers and/or ONUs via inhalation of vapor due to the activities and uses of 1,3-butadiene. Exposure may occur due to fugitive emissions present during activities such as the manufacture and processing of 1,3-butadiene or due to uses of 1,3-butadiene such as use as a laboratory chemical or the application of an adhesive or sealant containing 1,3-butadiene. EPA expects inhalation to be the primary route of exposure. Dermal exposure to liquid or vapor 1,3-butadiene is not expected, as discussed in Section 2.4.5 below.

[2] This software can be acquired from the following: *@Risk*; Palisade; https://www.palisade.com/risk/ (accessed December 1, 2025).

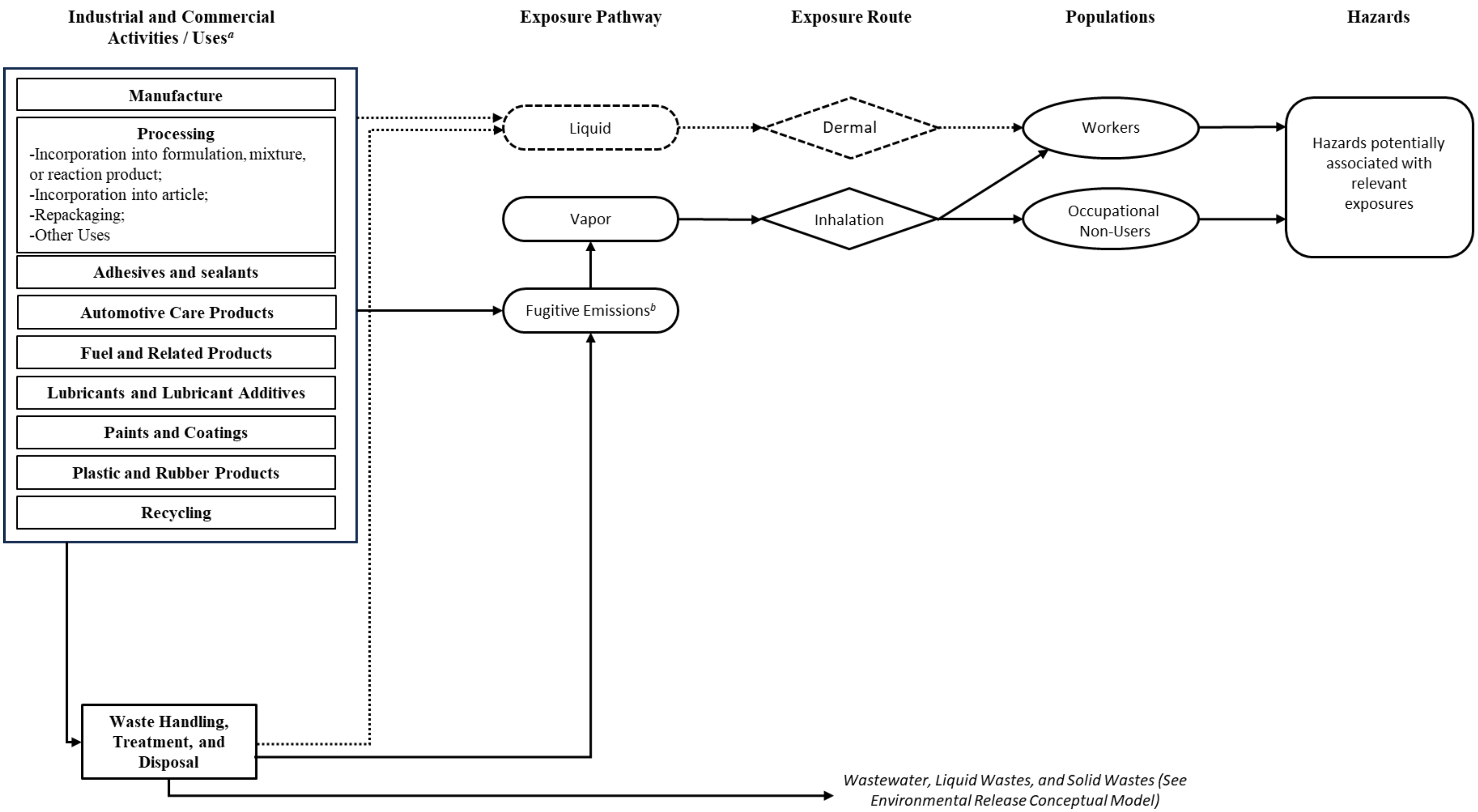

Figure 2-1. 1,3-Butadiene Conceptual Model for Industrial and Commercial Activities and Uses: Potential Exposure and Hazards

[a] "Industrial use" means use at a site at which one or more chemicals or mixtures are manufactured (including imported) or processed, and "Commercial use" means the use of a chemical or a mixture containing a chemical (including as part of an article) in a commercial enterprise providing saleable goods or services.

[b] Fugitive air emissions are emissions that are not routed through a stack and include fugitive equipment leaks from valves, pump seals, flanges, compressors, sampling connections and open-ended lines; evaporative losses from surface impoundment and spills; and releases from building ventilation systems.

EPA provided occupational inhalation exposure results representative of both *central tendency* and *high-end* conditions. A central tendency is assumed to be representative of occupational exposures in the center of the distribution for a given COU. For the risk evaluation, EPA used the 50th percentile (median), mean (arithmetic or geometric), mode, or midpoint values of a distribution as representative of the central tendency scenario. EPA's preference is to use the 50th percentile of the distribution. However, if the full distribution is not known, the Agency may assume that the mean, mode, or midpoint of the distribution represents the central tendency depending on the statistics available for the distribution.

A high-end is assumed to be representative of occupational exposures that occur at probabilities above the 90th percentile but below the exposure of the individual with the highest exposure (U.S. EPA, 1992). For the risk evaluation, EPA used high-end results at the 95th percentile. If the 95th percentile is not available, the Agency 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 available, EPA estimated a maximum or bounding estimate in lieu of the high-end.

For each OES, where possible, EPA provided high-end and central tendency, full shift time-weighted average (TWA) (typically as 8-hour TWA) inhalation exposure concentrations. The Agency follows the following hierarchy in selecting data and approaches for assessing occupational exposures:

1. Monitoring data:
    a. Personal and directly applicable
    b. Area and directly applicable
    c. Personal and potentially applicable or similar
    d. Area and potentially applicable or similar
2. Modeling approaches:
    a. Surrogate or analogous monitoring data
    b. Fundamental modeling approaches
    c. Statistical regression modeling approaches
3. Occupational exposure limits (OELs):
    a. Company-specific OELs (for site-specific exposure assessments, *e.g.*, there is only one manufacturer who provides to EPA their internal OEL but does not provide monitoring data)
    b. Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL)
    c. Voluntary limits (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 to calculate exposure metrics required for risk evaluation. Exposure metrics for inhalation exposures include acute concentrations (AC), intermediate average daily concentrations ($ADC_{intermediate}$), average daily concentrations (ADC), and lifetime average daily concentrations (LADC). Relevant equations and sample calculations can be found in Appendix B.1. The approach to estimating each exposure metric is described in Section 2.4.4.

For 1,3-butadiene, EPA calculated the estimated high-end and central tendency full shift TWA inhalation exposure concentrations using discrete inhalation data directly relevant to each OES. In a few cases, described in the sections that follow, inhalation data from different OESs are used as analog. This means that, though there may have been no 1,3-butadiene data directly applicable to some OESs, there was 1,3-butadiene data for a similar occupational scenario that could be used as a substitute. Because monitoring data were identified as being relevant to the applicable OESs, no fundamental or statistical regression modeling approaches were used in this assessment to estimate inhalation exposure, nor were OELs.

Dermal exposure was not assessed for 1,3-butadiene due to the volatility and transport method of the chemical. See Section 2.4.5 for further information.

See the *1,3-Butadiene Inhalation Monitoring Data Summary* (U.S. EPA, 2025a) for the inhalation data used in this assessment and the calculations that resulted in the estimates presented in this section.

2.4.1 Identifying Worker Activities

EPA performed a literature search 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. Worker activities for each OES can be found in Section 3.

For number of working days, EPA assumes these to be the same as facility operating days, discussed in Section 2.3.2, but with a maximum number of routine working days per year being 250 days.

2.4.2 Estimating Number of Workers and Occupational Non-Users

Where available, EPA used CDR data to provide 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:

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

There are uncertainties surrounding the estimated number of workers potentially exposed to 1,3-butadiene. First, BLS employment data for each industry/occupation combination are only available at the 3-, 4-, or 5-digit NAICS level, rather than at the full 6-digit NAICS level. This lack of specificity could result in an overestimate of the number of exposed workers if some 6-digit NAICS are included in the less granular BLS estimates but are not likely to use 1,3-butadiene for the assessed applications. EPA addressed this issue by refining the Occupational Employment Statistics data using total employment data from the U.S. Census' SUSB. However, this approach assumes that the distribution of occupation types (Standard Occupational Classification, or SOC, codes) in each 6-digit NAICS is equal to the distribution of occupation types at the parent 5-digit NAICS level. If the distribution of workers in occupations with 1,3-butadiene exposure differs from the overall distribution of workers in each NAICS, then this approach will result in inaccuracy. The effects of this uncertainty on the number of worker estimates are unknown, as the uncertainties may result in either over or underestimation of the estimates depending on the actual distribution.

Second, EPA's determinations of industries (represented by NAICS codes) and occupations (represented by SOC codes) that are associated with the OESs assessed in this report are based on EPA's understanding of how 1,3-butadiene is used in each industry. The designations of which industries and occupations have potential exposures is a matter of professional judgment; therefore, the possibility exists for the erroneous inclusion or exclusion of some industries or occupations. This may result in inaccuracy but would be unlikely to systematically either overestimate or underestimate the count of exposed workers.

2.4.3 Estimating Inhalation Exposures

2.4.3.1 Inhalation Monitoring Data

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 evaluation 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 "TSCA Systematic Review Protocol" (U.S. EPA, 2021a).

Where possible, central tendency and high-end exposures were estimated using the 50th and 95th percentile of the monitoring dataset.

Some of the datasets utilized for this risk evaluation are highly censored, meaning that there are many non-detects in the dataset, or measurements below the study method's limit of detection (LOD). The LOD will vary between studies and even between individual data points within a dataset, as it is dependent on the monitoring method and the individual volume of the sample. For datasets including exposure data that were reported as below the LOD, one of two methods was used to calculate a central tendency and high-end estimate from the dataset. In cases where a dataset had five or more uncensored data points, maximum likelihood estimation (MLE) assuming a lognormal distribution of concentrations was used to calculate 50th and 95th percentiles to represent central tendency and high-end respectively. More information about EPA's use of MLE, and a summary of the options for highly censored data considered for this risk evaluation, can be found in Appendix H. In cases where there were less than five measured data points to perform more robust analysis such as MLE, EPA estimated the exposure concentrations for these data following EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (EPA, 1994) which recommends using the $\frac{LOD}{\sqrt{2}}$ if the geometric standard deviation of the data is less than 3.0 and $\frac{LOD}{2}$ if the geometric standard deviation is 3.0 or greater. In cases where no measurements were above the LOD, EPA used the dataset for a screening level assessment using half the LOD as central tendency, and the LOD as high-end.

Some OESs did not have datasets of discrete data available to conduct the analyses described above. In these cases, where available, EPA utilized available summary statistics to estimate central tendency and high-end. Central tendency was estimated using a mean of the means, weighted to account for number of samples that contributed to each study's mean. The high-end was estimated by taking the 95th percentile of the maximum exposure values available from these studies.

For each OES, EPA attempted to distinguish exposures for workers and ONUs. A primary difference between workers and ONUs is that workers may handle 1,3-butadiene and have direct contact with the chemical, while ONUs are working in the general vicinity of workers but do not handle 1,3-butadiene and do not have direct contact with 1,3-butadiene being handled by the workers. EPA recognizes that worker job titles and activities may vary significantly from site to site; therefore, the Agency typically identified samples as worker samples unless it was explicitly clear from the job title (*e.g.*, inspectors) and the description of activities in the report that the employee was not directly involved in the scenario. Samples from employees determined not to be directly involved in the scenario were designated as ONU samples. Where EPA was not able to estimate ONU inhalation exposure from monitoring data or models, ONU exposure was assumed to be equivalent to the central tendency experience by workers for the corresponding OES.

The primary strength of the approach is that the monitoring data are chemical-specific and directly applicable to the exposure scenario. The use of applicable monitoring data is preferable to other assessment approaches such as modeling or the use of OELs/PELs.

The principal limitation of the monitoring data is the uncertainty in the representativeness of the data due to some scenarios having limited exposure monitoring data in literature. Where few data are available, the assessed exposure levels are unlikely to be representative of worker exposure across the entire job category or industry. This may particularly be the case when monitoring data were available for only one site. Additionally, site locations may introduce uncertainty because OSHA and NIOSH reports tend to target facilities with higher exposures. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of monitoring data.

Age of the monitoring data can also introduce uncertainty due to differences in workplace practices and equipment used at the time the monitoring data were collected compared to those currently in use. Therefore, older data may overestimate or underestimate exposures, depending on these differences. The effects of these uncertainties on the occupational exposure assessment are unknown, as the uncertainties may result in either overestimation or underestimation of exposures depending on the actual distribution of 1,3-butadiene air concentrations and the variability of work practices among different sites.

In some scenarios where monitoring data were available, EPA did not find sufficient data to determine complete statistical distributions. Ideally, the Agency will present 50th and 95th percentiles for each exposed population. In the absence of percentile data for monitoring, the mean or midpoint of the range may serve as a substitute for the 50th percentile of the actual distributions. Similarly, the highest value of a range may serve as a substitute for the 95th percentile of the actual distribution. However, these substitutes are uncertain. The effects of these substitutes on the occupational exposure assessment are unknown, as the substitutes may result in either overestimation or underestimation of exposures depending on the actual distribution.

OSHA Chemical Exposure Health Data

A key source of monitoring data is samples collected by OSHA during facility inspections. OSHA inspection data are compiled in an agency information system (OIS) for internal use. Air sampling data records from inspections are entered into the OSHA online Chemical Exposure Health Database (CEHD; accessed December 1, 2025). The database includes personal breathing zone (PBZ) monitoring data, area monitoring data, bulk samples, wipe samples, and serum samples. The collected samples are used for comparing to OSHA's PEL. OSHA's CEHD website indicates that they do not: perform routine inspections at every business that uses toxic/hazardous chemicals, completely characterize all exposures for all employees every day, or always obtain a sample for an entire shift. Rather, OSHA performs targeted inspections of certain industries based on national and regional emphasis programs, often attempts to evaluate worst case chemical exposure scenarios, and develop “snapshots” of chemical exposures and assess their significance (*e.g.,* comparing measured concentrations to PELs).

EPA took the following approach to analyzing OSHA CEHD:

1. *Download data for 1,3-butadiene between the years 2000 and 2020 in the CEHD:* This timeframe was chosen due to the changing of the OSHA PEL for 1,3-butadiene from 1,000 ppm 8-hour TWA to 1 ppm that occurred in 1997, with an implementation period that ended in November 1999.
2. *Organize data by site:* (group data collected at the same site together).
3. *Remove data in which all measurements taken at the site were recorded as “0” or below the LOD:* and there was no other evidence such as a bulk sample that shows the presence of the chemical at the site as EPA assumed that the chemical of interest may not have been at the site at the time of sampling.
4. *Remove serum samples, bulk samples, wipe samples, and blanks:* These data are not used in EPA’s assessment.
5. *Assign each data point to an OES:* Review NAICS codes, SIC codes, and as needed, company information available online, to map each sample to an OES. In some instances, EPA was not able to determine the OES from the information in the CEHD; in such cases, the Agency did not use the data in the assessment. EPA also removed data determined to be for non-TSCA uses or otherwise out of scope.
6. *Combine samples from the same worker:* In some instances, OSHA inspectors will collect multiple samples from the same worker on the same day (these are indicated by sample ID numbers). In these cases, EPA combined results from each sample to construct an exposure concentration based on the totality of exposures from each sample.
7. *Address less than LOD samples:* Occasionally, one or all the samples associated with a single sample number measured below the LOD. Because the samples were often on different time scales (*e.g.,* 1 vs. 4 hours), EPA did not include these data in the statistical analysis to estimate values below the LOD as described previously in this section. Sample results from different time scales may vary greatly as short activities my cause a large, short-term exposure that when averaged over a full shift are comparable to other full shift data. Therefore, including data of different time scales in the analysis may give the appearance of highly skewed data when in fact the full shift data are not skewed. Therefore, EPA performed the statistical analysis (as needed) using all the non-OSHA CEHD data for each OES and applied the approach determined by the analysis to the non-detects in the OSHA CEHD data. Where all the exposure data for an OES came from CEHD, EPA used only the 8-hour TWAs that did not include samples that measured below the LOD to perform the statistical analysis.
8. *Calculate 8-hour TWA results from combined samples:* Where the total sample time was less than 8 hours, EPA calculated an 8-hour TWA by assuming exposures were zero for the remainder of the shift.

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

Specific details related to the use of monitoring data for each COU can be found in Section 3.

2.4.3.2 Analogous Inhalation Monitoring Data

Where inhalation exposures are expected for an OES but monitoring data were not available, EPA utilized analogous monitoring data, which is monitoring data of the same chemical but for a different (similar) activity, to estimate occupational exposure to 1,3-butadiene.

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

For each COU, the estimated TWA exposures were used to calculate AC, $ADC_{intermediate}$, ADC for chronic, non-cancer risks, and LADC. These calculations require additional parameter inputs such as years of exposure, exposure duration and frequency, and lifetime years.

Equations, parameter inputs, and sample calculations for these exposures can be found in Appendix B and Appendix C.

2.4.5 Dermal Exposure

1,3-Butadiene is typically transported in a liquefied form by condensing the gaseous form under high pressure. Rapid evaporation of a liquid from a pressurized system will likely cause frostbite if it contacts the skin. Due to the severity of this hazard, standard operating procedures in the chemical industry require the use of chemical protective gloves and clothing if there is potential for skin contact, such as during transfer operations. Engineering controls also contribute to the prevention of these exposures, such as pressurized sample collection devices to ensure that the sample remains in its liquid form and prevents dermal contact during sample collection and analysis tasks. Due to these factors, it is not expected that dermal exposure to liquid 1,3-butadiene would regularly occur (EPA-HQ-OPPT-2018-0451-0038).

1,3-Butadiene will quickly volatilize from water and oil which causes the dermal exposure to 1,3-butadiene with a solution negligible. Relevant to the possibility of dermal exposure via vapor phase 1,3-butadiene, EPA cites Weschler and Nazaroff (2014) who calculated that the transdermal permeability coefficient (k_{p_g}) of a compound must be greater than or equal to 0.025 m/h for vapor to skin exposure to be considered relevant compared to inhalation exposure. Because 1,3-butadiene has a k_{p_g} of 5.02×10^{-5} m/hour, dermal exposure to vapor phase 1,3-butadiene is not considered a significant exposure pathway compared to inhalation and it is not considered further in this assessment.

2.5 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 inhalation 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 the Agency considered when integrating evidence includes the following:

1. ***Data Quality:*** EPA only integrated data or information rated as *high*, *medium*, *or low* obtained during the data evaluation phase. Data and information rated as *uninformative* are not used in exposure evidence integration. In general, higher rankings are given preference over lower ratings; however, lower ranked data may be used over higher ranked data when specific aspects of the data are carefully examined and compared. For example, a lower ranked dataset that precisely matches the OES of interest may be used over a higher ranked study that does not as closely match the OES of interest.

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 have given preference to high-quality modeled data directly applicable to the OES being assessed over low-quality measured 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.

3 ENVIRONMENTAL RELEASE AND OCCUPATIONAL EXPOSURES ASSESSMENTS BY OES

The following sections contain process descriptions and the specific details (worker activities, analysis for determining number of workers, exposure assessment approach and results, release sources, media of release, and release assessment approach and results) for the assessment of each OES.

Refer to Table 1-1 to see how each OES described below pairs with the COU stated in the final scope for 1,3-butadiene, published by EPA in August 2020 (U.S. EPA, 2020c).

For all cases except for Application of Adhesives and Sealants (which utilized release modeling), the annual and daily central tendencies and high-ends for releases can be found in the following locations:

- For surface water, POTW, and WWT releases (where applicable), see the "OES-Direct", "OES-Indirect POTW", or "OES-Indirect WWT" tabs, respectively, in *Water Releases for 1,3-Butadiene* (U.S. EPA, 2025n).
- For stack and fugitive air releases from TRI, see the "OES Summary" tab in *Air Releases (TRI) for 1,3-Butadiene* (U.S. EPA, 2025e).
- For stack and fugitive air releases from NEI, see the "OES Summary" tab in *Air Releases (NEI2017) for 1,3-Butadiene* (U.S. EPA, 2025c). This spreadsheet contains calculations for both years of NEI data. To see the raw release data used in the assessment from the 2020 NEI, see *Air Releases (NEI2020) for 1,3-Butadiene* (U.S. EPA, 2025d).
- For land releases, see the "OES Summary" tab of *Land Releases for 1,3-Butadiene* (U.S. EPA, 2025h).

For the Application of Adhesives and Sealants release model, see the *Adhesives and Sealants Release Model for 1,3-Butadiene* (U.S. EPA, 2025b).

For the central tendencies and high-ends for occupational exposure tables, see the *1,3-Butadiene Inhalation Monitoring Data Summary* (U.S. EPA, 2025k).

3.1 Manufacturing

3.1.1 Process Description

The final scope for 1,3-butadiene lists domestic manufacturing as an in-scope COU (U.S. EPA, 2020c). 1,3-Butadiene can be produced by three processes—steam cracking of paraffinic hydrocarbons (the ethylene coproduct process), catalytic dehydrogenation of n-butane and n-butene (the Houdry process), and oxidative dehydrogenation of n-butene (the Oxo-D or O-X-D process). The predominant method of the three processes is the steam cracking process, which accounts for greater than 91 percent of the world's butadiene supply (EPA-HQ-OPPT-2018-0451-0021). These manufacturing processes are performed in closed systems, many of which operate at high pressure and low temperature.

The ethylene coproduct process can use a variety of hydrocarbon feedstocks, the heavier fractions generally giving a higher 1,3-butadiene yield per amount of ethylene produced (Miller and Villaume, 1978). In this production process, the hydrocarbon feedstock is fed to a pyrolysis (steam cracking) furnace where it is heated to temperatures between approximately 1,450 and 1,525 °F (790–830 °C). Within this temperature range, the feedstock molecules "crack" to produce a variety of co-products including butadiene. After the pyrolysis reaction is quenched and additional refinery steps, a mixed C_4 hydrocarbon stream is obtained. Figure 3-1 provides an example process flow diagram of the ethylene coproduct process to manufacture 1,3-butadiene.

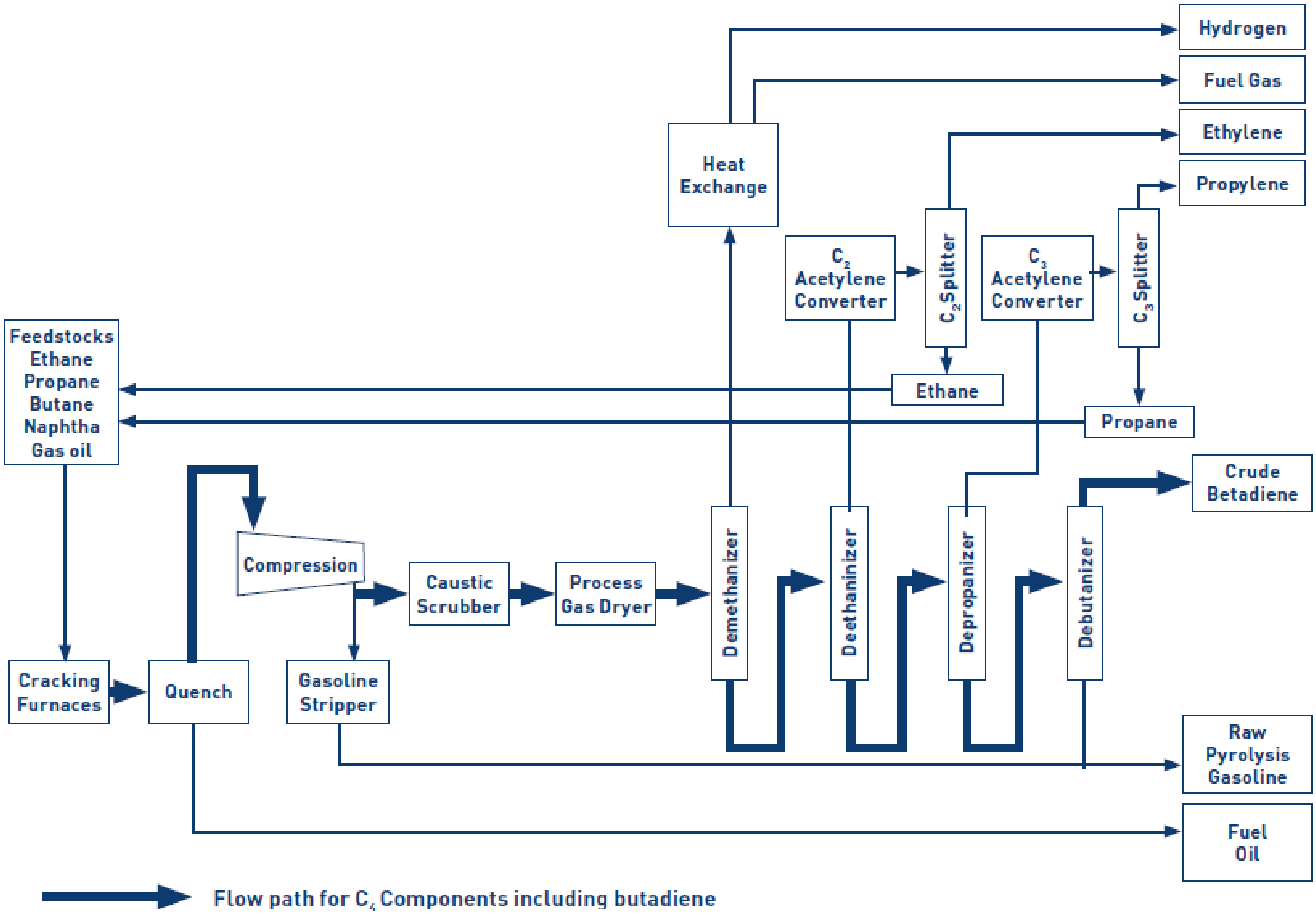

Figure 3-1. Process Flow Diagram for the Manufacture of 1,3-Butadiene in a Typical Olefins Plant
Source: ACC (EPA-HQ-OPPT-2018-0451-0041)

In the Houdry process, n-butane is dehydrogenated over chromium/alumina catalysts. Several packed-bed reactors, arranged parallel to each other, are operated alternatingly (Grub and Löser, 2011). The reactors normally operate at 12 to 15 cm Hg absolute pressure and approximately 1,100 to 1,260 °F (600–680 °C). Three or more reactors can be used in this process to simulate continuous operation: while the first reactor is on-line, the second is being regenerated, and the third is being purged prior to regeneration. Residence time for feed in the reactor is approximately 5 to 15 minutes. As the endothermic reaction proceeds, the temperature of the catalyst bed decreases, and a small amount of coke is deposited. In the regeneration cycle, this coke is burned with preheated air, which can supply essentially all the heat required to bring the reactor up to the desired reaction temperature. The reactor effluent goes directly to a quench tower, where it is cooled. This stream is compressed before feeding an absorber/stripper system, where a C4 concentrate is produced to be fed to a butadiene extraction system for the recovery of high purity butadiene (EPA-HQ-OPPT-2018-0451-0021).

The Oxo-D process most often uses n-butene as feedstock due to its greater reactivity, which results in the same amount of product produced under less severe operating conditions when compared to n-butane, though processes and catalyst systems have been developed for both. In general, in an oxydehydrogenation process, a mixture of n-butenes, air and steam is passed over a catalyst bed generally at low pressure and approximately 930 to 1,110 °F (500–600 °C). The heat from the exothermic reaction can be removed by circulating molten heat transfer salt, or by using the stream externally for steam generation. An alternate method is to add steam to the feed to act as a heat sink. The heat can then be recovered from the reactor effluent. After the reactor effluent is cooled, the C_4 components are recovered in an absorber/degasser/stripper column combination. The lean oil flows from the bottom of the stripper back to the absorber, with a small amount passing through a solvent purification area. Crude butadiene is stripped from the oil, recovered in the overhead of the stripper, then it is sent to a purification system to recover the butadiene product. Reaction yields can range from 70 to 90 percent, making it unnecessary to recover and recycle feedstock (yield losses can produce the CO_2) (EPA-HQ-OPPT-2018-0451-0021). The advantages of this method are the low consumption of steam and heating energy, high conversion and selectivity per reactor cycle, longer life span of the catalyst, and no requirement for catalyst regeneration (Grub and Löser, 2011).

Each of these processes produces a stream commonly referred to as crude butadiene that has a 1,3-butadiene content as high as 75 percent (EPA-HQ-OPPT-2018-0451-0004, EPA-HQ-OPPT-2018-0451-0021). Separation and purification of the butadiene stream is typically carried out by extractive distillation since the boiling points of the various C_4 components are so close to each other that 1,3-butadiene cannot normally be obtained from the mixed C_4-stream by simple distillation. In this process, a polar solvent (*e.g.,* furfural, acetonitrile, cuprous ammonium acetate, dimethylformamide, a furfuralmethoxypropionitrile system, dimethylacetamide or n-methylpyrrolidone) is added to change the relative volatilities of the components of the mixture (IARC, 1986; Peterson et al., 1980; Miller and Villaume, 1978). The final concentration in the purified butadiene product is typically more than 99 weight percent pure and is stored liquefied in a pressurized sphere (ToxStrategies, 2021).

1,3-Butadiene is manufactured as a liquid and stored in a pressurized container. The product is expected to be repackaged and/or sent for processing as a reactant, rubber polymerization, or incorporation into a formulation, mixture, or reaction product. 1,3-Butadiene is produced as reagent grade, 99.5 percent or higher purity with permitted impurity levels of 1,2-butadiene, acetylenes, water, and C_5s specified by the company (Sun and Wristers, 2002).

3.1.2 Facility Estimates

The 2020 CDR estimates 13 sites domestically manufacturing 1,3-butadiene (U.S. EPA, 2020b). However, using TRI and NEI to supplement the data from CDR, EPA identified 63 manufacturing facilities in total. Many of these additional facilities are due to TRI facilities that report the manufacture of 1,3-butadiene as a byproduct. Facilities may report to multiple databases under different names, and in these cases, EPA used reported addresses and company information to match facilities with their equivalents across databases but note that there is some uncertainty to the facility estimate due to this.

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of this assessment each site can only be assigned one OES. The OES was chosen based on the process described in Appendix F, and (if there was not a clear answer) based on professional judgment of what seemed the most prominent activity according to TRI and NEI reporting and the information on the company website. Because deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting the release sites in TRI (which was then adapted to NEI). Aside from a CDR indication that a site is a manufacturer, other factors that contributed to the decision of sorting a site into the Manufacturing OES included if the production of a butadiene feedstock was indicated on the company website, or if the facility indicated in TRI that it participated in both the production as well as the sale and distribution of 1,3-butadiene.

In three cases companies that reported manufacturing to CDR were assigned a different OES depending on the indicated activities on the site. The Goodyear Tire & Rubber Company in Akron Ohio, Firestone Polymers LLC/Lion Elastomers Orange LLC in Orange, Texas, and Lion Elastomers LLC in Port Neches, Texas, were all reported to CDR 2020 as manufacturers but were mapped to Plastic and rubber polymerization instead of manufacturing. One site from CDR, Invista S.A.R.L. in Wichita, Kansas, did not report releases to TRI or NEI.

See the supplemental file, *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i), for a list of all facilities mapped to manufacturing that reported to CDR, TRI, and/or NEI.

For facility operating schedules, 1,3-butadiene is a large-PV commodity chemical most commonly used to manufacture other chemicals, so as described in Section 2.3.2, the Agency assumes that the facility operates 7 days per week, 50 weeks per year (2 weeks down for turnaround) and that the facility is producing and releasing the chemical daily during operation. This results in an estimated 350 days/year of operation.

3.1.3 Release Assessment

3.1.3.1 Environmental Release Points

Potential releases to air, wastewater, and land include equipment cleaning, transport container cleaning and sampling waste. Additionally, EPA expects stack air releases from vented losses to air during process operations, and fugitive air releases from leakage of pipes, flanges, and accessories used for transport. Fugitive emissions may also occur at loading racks and container filling from equipment leaks, sampling, and displaced vapor as containers are filled.

3.1.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI data to estimate environmental releases during the manufacture of 1,3-butadiene, as presented in Table 3-1. According to reported data, 1,3-butadiene is released through the following environmental media: surface water, indirectly through the transfer to a non-POTW WWT facility, fugitive air, stack air, and land disposal.

Table 3-1. Summary of Environmental Releases During the Manufacture of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	2.3	371	350	6.5E−03	1.1	4	TRI
WWT	7,500	2.1E04		22	59	3	TRI
Fugitive air	360	8,419		1.0	24	37	TRI
Fugitive air	649	7,139		1.9	20	40	NEI
Stack air	1,142	3.3E04		3.3	95	39	TRI
Stack air	665	1.7E04		2.0	46	34	NEI
Land	0.45	120		1.3E−03	0.34	9	TRI

3.1.4 Occupational Exposure Assessment

3.1.4.1 Worker Activities

During manufacture, workers are potentially exposed to 1,3-butadiene via inhalation of vapors during equipment cleaning, container cleaning, and packaging and loading of 1,3-butadiene into transport containers for shipment. ACC, in the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076), reported the following activities from the workers within the consortium's manufacturing and processing facilities.

- ***Infrastructure/Distribution Operations Similar Exposure Group (SEG):*** Responsible for the infrastructure systems required to run the manufacturing and processing facilities including power utilities, water supply, WWT, as well as distribution of incoming raw materials or outgoing products. The activities carried out by these individuals include handling streams with low content of butadiene (such as utilities and waste streams) to potentially higher concentrations, when loading/unloading tanks/trucks. During their daily activities, workers might carry out tasks that involve opening process equipment, which tend to be controlled by the implementation of engineering controls and/or PPE. The tasks performed by workers in this job group include loading and unloading materials from railcars and barges, sample collection, cleaning filters, and handling hoses. Loading and unloading may occur between one and six times per day for railcars, and between one and eight times per month for barges.
- ***Instrument and Electrical SEG:*** Responsible for the set up and maintenance of various electrical equipment including analyzers and various instruments throughout the facility.
- ***Laboratory Technician SEG:*** Responsible for sample collection and chemical analysis of process and product samples for the facility and conduct their work in laboratories.
- ***Machinery & Specialists Mechanical SEG:*** Skilled workers such as millwrights, boilermakers, pipefitters, and welders who work throughout the manufacturing and processing facilities. In general, these workers perform activities in equipment that has been cleared and cleaned—especially because of the hazards associated with the heat/sparks generated during hot work such as welding and grinding. Exposures are typically associated with the brief activities involved in opening process equipment prior to maintenance activities. Because of the potential for exposures, these activities tend to be conducted with PPE.
- ***Maintenance SEG:*** Responsible for a variety of preventative maintenance activities on process equipment, as well as addressing malfunctions. Some of the tasks performed by workers in this job group include connecting and disconnecting lines, and draining, clearing, and venting equipment.
- ***Operations Onsite SEG:*** Responsible for operations of manufacturing and processing equipment throughout the facilities. These workers may be indoors inside of control rooms where they monitor chemical feeds, process temperatures, vessel pressure, etc. or outdoors where the process equipment is located to where they may collect process samples, drain/vent/clear process equipment and prepare it for maintenance. Additionally, workers in this job group may also assist the IH team in conducting air monitoring to establish the restricted areas. They may also perform routine visual inspections two to three times per day, in which they will observe process operational parameters such as temperatures, pressures, check pumps and gauge levels, and make adjustments as necessary.
- ***Safety, Health, and Environment (SHE) SEG:*** Responsible for assuring safety, health and environmental protection protocols are being followed in all areas of the facility. Workers in this job group may include industrial hygienists who conduct exposure assessments of workers in the various job groups using leak detection and air monitoring, leak detection and repair (LDAR) technicians, environmental engineers and safety technicians. SHE workers may be indoors inside of offices or in various control rooms or outdoors where the process equipment is located to monitor other workers or processes.

Some tasks reported within the *Analysis of 1,3-Butadiene Industrial Hygiene Data* may occur within several of the SEGs above. For example, cleaning and maintenance tasks are done by both the Maintenance SEG and the Operations onsite SEG. These tasks may include disassembly and re-assembly of process equipment (*e.g.*, valves, pumps, and analyzers), piping (occurs ≤ 1 time per week), storage tank cleaning (occurs between 1 and 6 times per year), line purging, and filter and strainer removal and cleaning (occurs once per day or less). It may also include maintenance on pumps, compressors, and values that each piece of equipment having its own safety requirements reduce possible exposure. This maintenance on pumps, compressors, and valves may occur once per day or 10 times per year depending on maintenance schedules.

Sample collection tasks, which involve the collection of process stream samples and analysis for 1,3-butadiene, may be done by the Laboratory technician SEG or the Operations onsite SEG. For gaseous samples, workers connect pressurized cylinders that have ports to allow the sample to flow in and to allow excess gas to vent to safe location. Based on participating company reports, most samples are collected utilizing a closed loop system. Collection of samples may occur on average once per day for gas samples, and between once per day and once per week for liquid samples. Analysis of samples occurs about once per day.

Handling, transporting, and disposal of 1,3-butadiene waste is also a task that may occur at a manufacturing or processing facility. This task is associated with potential contact of facility waste streams containing 1,3-butadiene including disposing of analytical samples, loading of recycled oil, and operations conducted at the onsite waste-water treatment plant. The presence of 1,3-butadiene in waste streams is highly dependent on facility operations, for example, some processing operations have no 1,3-butadiene in waste streams since nearly all of it is consumed in the processing and any residual is sent for destruction via flares or boilers. This task may occur one to three times per day (ToxStrategies, 2021).

For routine exposure for these job groups, EPA assumes 250 exposure days for workers with 8-hour shifts, which portrays a typical worker schedule (working 5 days per week for 50 weeks per year with 2 weeks of vacation time). For workers with 12-hour shifts the Agency assumes 167 exposure days, which results in the equivalent hours per year as a worker on an 8-hour schedule. For job groups with exposure during turnaround operations, the Agency assumes 14 days of these exposure per year. And for job groups with exposure during non-routine tasks, EPA assumes 5 days of exposure per year.

EPA identified examples of engineering controls (*e.g.*, process flow leak prevention technology) used at some 1,3-butadiene manufacturing sites during product sampling, laboratory analysis, and product loading; however, the Agency did not identify the extent to which these engineering controls are used at all sites that manufacture 1,3-butadiene (Krishnan et al., 1987). While EPA does not have any information to suggest that respirators are worn for the entirety of the work day for any job group/SEG within a manufacturing facility, the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) does indicate what exposure controls, including PPE, apply to tasks that are undertaken by each SEG described above. Widely varying levels of respirator protection are associated with each task. This is likely based on sub-task and facility-specific industrial hygiene decisions and may vary from worker to worker. Table 3-2 lists the various job groups at manufacturing and processing facilities, their expected tasks and activities, and the listed exposure controls.

Table 3-2. Exposure Control Crosswalk for Job Group/SEGs and Tasks

Job Group/SEG	Tasks/Activities	Exposure Controls
Infrastructure/ Distribution/ Transportation Operations	**Unloading and Loading materials** to and from storage containers to process vessels	Vapor recovery systems chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face air-purifying respirator (APR)
	Opening process equipment (*e.g.*, storage vessels)	
	Sample collection	
	Cleaning filters	
	Handling hoses (*e.g.*, connections to truck tankers)	
	Loading/unloading tanks/trucks (*e.g.*, rail cars or cargo vessels and pumping material)	
	Handling utilities and waste streams	
	Handling of waste (transporting and disposing)	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: full/half face APR
Instrument and Electrical	**Performing other work activities**	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
	Set up and maintenance of electrical equipment (analyzers and instruments across the facility)	
	Opening the lines (like calibration and equipment maintenance)	
Laboratory Technician	**Collecting and analyzing samples**	Chemical protective gloves suits and boots (to prevent dermal contact) enclosed sample boxes pressurized sample containers laboratory ventilation cabinets respirators: supp air, full/half face APR, no respirator
Machinery & Specialists Mechanical Group	**Performing other work activities**	Chemical protective gloves
	Opening process equipment prior to maintenance activities	Suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
Maintenance	**Cleaning and maintaining equipment**	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
	Connecting and disconnecting lines	
	Draining, clearing and venting equipment	

Job Group/SEG	Tasks/Activities	Exposure Controls
Operations Onsite	**Cleaning and maintaining equipment** monitor chemical feeds, process temperatures, vessel pressure, etc.	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
	Collecting and analyzing samples	Chemical protective gloves
	Drain/vent/clear process equipment and prepare it for maintenance	Suits and boots (to prevent dermal contact)
	Prepare process equipment for maintenance	Enclosed sample boxes pressurized sample containers laboratory ventilation cabinets respirators: supp air, full/half face APR, no respirator
SHE	**Performing other work activities** Conduct exposure assessments of workers Monitor other workers or processes	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
ONUs	**Performing other work activities** Supervisory personnel associated with all of the worker job groups	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076).		

ONUs include employees (*e.g.*, supervisors, managers) that work at the manufacturing facility, but do not directly handle 1,3-butadiene. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) describes their ONUs as supervisory personnel associated with all of the previously described worker job groups. In the Manufacturing and Processing as a Reactant OESs, administrative type employees (*e.g.*, accountants, salespersons, etc.) do not access the operational parts of a facility.

3.1.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during manufacturing (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325199 – All Other Basic Organic Chemical Manufacturing

Table 3-3 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.1.2.

Table 3-3. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Manufacturing

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
63	325199 – All Other Basic Organic Chemical Manufacturing	39	5
[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.			

3.1.4.3 Occupational Inhalation Exposure Results

For manufacturing of 1,3-butadiene, EPA was provided inhalation monitoring data by ACC in the report *Analysis of 1,3-Butadiene Industrial Hygiene Data*. This report includes 5,675 full shift PBZ samples for workers and ONUs collected from 2010 to 2019 (ToxStrategies, 2021). Note that public comment EPA-HQ-OPPT-2024-0425-0076 contains an update of the initial report that removed an erroneous datapoint from the dataset and provided additional information about the worker activities. After an initial review was conducted, the additional information did not change the original data extraction and evaluation; therefore, it was determined that it should not be put through systematic review. The report includes a compilation and analyses of existing air concentrations of 1,3-butadiene from 47 consortium member facilities.

As listed in the previous section, this report includes air concentration samples of the following worker descriptions:

- Infrastructure/Distribution Operations;
- Instrument and Electrical;
- Laboratory Technician;
- Machinery and Specialists Group;
- Maintenance;
- Operations Onsite;
- Safety, Health and Engineering; and
- ONU.

The report includes samples taken during routine operations, which reflect exposures that may occur daily over the long-term, as well as those collected during nonroutine and turnaround operations. Nonroutine operations encompass process upsets and unplanned maintenance, while turnaround operations refer to planned maintenance shutdowns of process units. Both types of conditions are infrequent.

The *Analysis of 1,3-Butadiene Industrial Hygiene Data* did not differentiate between samples obtained from sites that manufacturing vs. those that process 1,3-butadiene, so EPA used all the full shift data from relevant tasks for this Manufacturing OES. The full shift samples, ranging from 8 to 12 hours, covered tasks such as maintenance, sample collection, and process condition monitoring. The dataset presented 50th and 95th percentile TWAs for each worker description (ToxStrategies, 2021).

While the EPA identified other data sources containing inhalation monitoring data for workers involved in the manufacturing of 1,3-butadiene, data from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* were ultimately used due to its higher data quality and recentness. The dataset focuses on U.S. sites and includes comprehensive metadata (*e.g.,* sample times, worker descriptions), while the other identified data were often from other countries, were older (some collected before the OSHA PEL was established), and/or lacked critical metadata needed for an occupational exposure assessment.

EPA compiled the 50th and 95th percentile 8- and 12-hour TWA concentrations from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8- and 12-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-4 and Table 3-5. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-4. 8-Hour Duration of Inhalation Exposures to 1,3-Butadiene During Manufacturing

Worker Description [a]	# of Total Samples [b]	# Detected Samples	8-Hour TWA Exposure Concentrations		AC		ADC_{intermediate}		ADC		LADC	
			Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)
Infrastructure/ Distribution Operations	455	102	5.5E−03	0.44	3.8E−03	0.30	2.8E−03	0.22	2.6E−03	0.21	6.3E−04	6.5E−02
Infrastructure/Distribution Operations – Nonroutine/Other [c]	3	2	0.37	0.78	0.25	0.53	4.2E−02	8.9E−02	3.4E−03	7.3E−03	8.5E−04	2.3E−03
Instrument and Electrical	313	29	2.6E−04	0.10	1.8E−04	6.9E−02	1.3E−04	5.1E−02	1.2E−04	4.7E−02	3.0E−05	1.5E−02
Instrument and Electrical – Nonroutine [c]	5	0	0.13	0.13	9.1E−02	9.1E−02	1.5E−02	1.5E−02	1.2E−03	1.2E−03	3.1E−04	3.9E−04
Instrument and Electrical – Turnaround [c]	4	2	1.7E−02	0.14	1.2E−02	9.5E−02	5.4E−03	4.4E−02	4.4E−04	3.6E−03	1.1E−04	1.2E−03
Laboratory Technician	215	57	6.8E−03	0.24	4.6E−03	0.16	3.4E−03	0.12	3.2E−03	0.11	7.8E−04	3.5E−02
Machinery & Specialists Mechanical Group	222	44	9.2E−04	0.25	6.2E−04	0.17	4.6E−04	0.12	4.3E−04	0.12	1.1E−04	3.7E−02
Machinery & Specialists Mechanical Group – Turnaround [c]	8	3	8.0E−03	1.2E−02	5.4E−03	8.2E−03	2.5E−03	3.8E−03	2.1E−04	3.1E−04	5.1E−05	9.9E−04
Maintenance Technician	354	109	1.5E−02	0.70	1.0E−02	0.48	7.5E−03	0.35	7.0E−03	0.33	1.7E−03	0.10
Maintenance – Nonroutine/Other [c]	2	1	0.34	0.62	0.23	0.42	3.9E−02	7.0E−02	3.2E−03	5.8E−03	7.8E−04	1.8E−03
Worker – Maintenance – Turnaround	33	15	1.7E−02	5.1	1.2E−02	3.5	5.4E−03	1.6	4.4E−04	0.13	1.1E−04	4.2E−02
Operations Onsite	1,952	229	3.6E−04	0.13	2.0E−04	9.1E−02	1.8E−04	6.7E−02	1.7E−04	6.2E−02	4.1E−05	2.0E−02
Operations Onsite – Nonroutine/Other [c]	38	2	3.2E−02	0.13	2.2E−02	9.1E−02	3.6E−03	1.5E−02	3.0E−04	1.3E−03	7.3E−05	3.9E−04
Operations Onsite – Turnaround	1,633	116	2.0E−05	7.0E−02	1.4E−05	4.7E−02	6.4E−06	2.2E−02	5.2E−07	1.8E−03	1.3E−07	5.7E−04

Worker Description [a]	# of Total Samples [b]	# Detected Samples	8-Hour TWA Exposure Concentrations		AC		$ADC_{intermediate}$		ADC		LADC	
			Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)
Safety, Health, and Engineering	21	6	1.7E−02	0.49	1.1E−02	0.33	8.3E−03	0.24	7.7E−03	0.23	1.9E−03	7.2E−02
ONU	39	9	5.8E−03	2.0E−02	3.9E−03	1.4E−02	2.9E−03	1.0E−02	2.7E−03	9.5E−03	6.6E−04	3.0E−03

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076).
[a] When not specified as non-routine, turnaround, or other, the SEG represents routine operation. Routine operations reflect exposures that may occur daily over the long-term. Nonroutine operations encompass process upsets and unplanned maintenance, while turnaround operations refer to planned maintenance shutdowns of process units.
[b] The total number of samples may not add up to 5,675 due to missing job group labels in some provided datasets
[c] Due to the high percentage of non-detect samples, in most cases EPA used MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively. When the dataset had less than five detected samples, a substitution method was used instead of MLE. These cases are indicated with this footnote. See Section 2.4.3.1 for more information.

Table 3-5. 12-Hour Duration of Inhalation Exposures to 1,3-Butadiene Manufacturing

Worker Description [a]	# of Total Samples [b]	# Detected Samples [c]	12-Hour TWA Exposure Concentrations		AC		$ADC_{intermediate}$		ADC		LADC	
			Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	High-End (ppm)	Central Tendency (ppm)	Central Tendency (ppm)	High-End (ppm)
Infrastructure/ Distribution Operations	455	102	5.5E−03	0.44	5.6E−03	0.45	4.1E−03	0.33	2.6E−03	0.21	6.3E−04	6.5E−02
Infrastructure/Distribution Operations – Nonroutine/Other [c]	3	2	0.37	0.78	0.38	0.8	6.3E−02	0.13	5.2E−03	1.1E−02	1.3E−03	3.5E−03
Instrument and Electrical	313	29	2.6E−04	0.10	2.7E−04	0.10	2.0E−04	7.6E−02	1.2E−04	4.7E−02	3.0E−05	1.5E−02

Worker Description [a]	# of Total Samples [b]	# Detected Samples [c]	12-Hour TWA Exposure Concentrations		AC		ADC$_{intermediate}$		ADC		LADC	
			Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	High-End (ppm)	Central Tendency (ppm)	Central Tendency (ppm)	High-End (ppm)
Instrument and Electrical – Nonroutine [c]	5	0	0.13	0.13	0.14	0.14	2.3E−02	2.3E−02	1.9E−03	1.9E−03	5.0E−04	5.9E−04
Instrument and Electrical – Turnaround [c]	4	2	1.7E−02	0.14	1.7E−02	0.14	8.1E−03	6.6E−02	6.7E−04	5.4E−03	1.6E−04	1.7E−03
Laboratory Technician	215	57	6.8E−03	0.24	7.0E−03	0.24	5.1E−03	0.18	3.2E−03	0.11	7.8E−04	3.5E−02
Machinery & Specialists Mechanical Group	222	44	9.2E−04	0.25	9.4E−04	0.25	7.0E−04	0.19	4.3E−04	0.12	1.1E−04	3.7E−02
Machinery & Specialists Mechanical Group – Turnaround [c]	8	3	8.0E-03	1.2E-02	8.2E−03	1.2E−02	3.8E−03	5.7E−03	3.1E−04	4.7E−04	7.7E−05	1.5E−04
Maintenance Technician	354	109	1.5E−02	0.70	1.5E−02	0.72	1.1E−02	0.53	7.0E−03	0.33	1.7E−03	0.10
Maintenance – Nonroutine/Other [c]	2	1	0.34	0.62	0.35	0.63	5.8E−02	0.11	4.8E−03	8.7E−03	1.2E−03	2.7E−03
Worker – Maintenance – Turnaround	33	15	1.7E−02	5.1	1.7E−02	5.2	8.1E−03	2.4	6.6E−04	0.20	1.6E−04	6.3E−02
Operations Onsite	1,952	229	3.6E−04	0.13	3.7E−04	0.14	2.7E−04	0.10	1.7E−04	6.2E−02	4.1E−05	2.0E−02
Operations Onsite – Nonroutine/Other [c]	38	2	3.2E-02	0.13	3.3E−02	0.14	5.4E−03	2.3E−02	4.4E−04	1.9E−03	1.1E−04	5.9E−04
Operations Onsite – Turnaround	1,633	116	2.0E−05	7.0E−02	2.1E−05	7.1E−02	9.6E−06	3.3E−02	7.9E−07	2.7E−03	1.9E−07	8.6E−04
Safety, Health, and Engineering	21	6	1.7E−02	0.49	1.7E−02	0.50	1.2E−02	0.36	7.7E−03	0.23	1.9E−03	7.2E−02
ONU	39	9	6.0E−03	2.0E−02	5.9E−03	2.1E−02	4.3E−03	1.5E−02	2.7E−03	9.5E−03	6.6E−04	3.0E−03

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076).
[a] When not specified as non-routine, turnaround, or other, the SEG represents routine operation. Routine operations reflect exposures that may occur daily over the long-term. Nonroutine operations encompass process upsets and unplanned maintenance, while turnaround operations refer to planned maintenance shutdowns of process units.
[b] The total number of samples may not add up to 5,675 due to missing job group labels in some provided datasets

Worker Description [a]	# of Total Samples [b]	# Detected Samples [c]	12-Hour TWA Exposure Concentrations		AC		ADC$_{intermediate}$		ADC		LADC	
			Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)	High-End (ppm)	Central Tendency (ppm)	Central Tendency (ppm)	High-End (ppm)

[c] Due to the high percentage of non-detect samples, in most cases EPA used MLE method to determine the 95th and 50th percentile for the high-end and central tendency respectively. When the dataset had less than five detected samples, a substitution method was used instead of MLE. These cases are indicated with this footnote. See Section 2.4.3.1 for more information.

3.2 Repackaging

3.2.1 Process Description

Repackaging is listed as a COU in final scope for 1,3-butadiene (U.S. EPA, 2020c). EPA expects that 1,3-butadiene and 1,3-butadiene-containing products may be distributed throughout commerce from import sites, or from manufacturing to processing repackaging sites. Import and repackaging sites are expected to distribute 1,3-butadiene to various downstream uses. According to EPA-HQ-OPPT-2018-0451-0021, liquefied butadiene is shipped by pipelines, ships, barges, rail tank cars, tank trucks and bulk liquid containers. 1,3-butadiene is transported in pressurized containers of various sizes and is required to be inhibited (current industry-wide recognized inhibitor is tertiary butyl catechol or TBC). Also, to minimize the formation of peroxides in 1,3-butadiene during shipping and handling, the oxygen level in the vapor space of loaded equipment is not to exceed 1,000 ppm (EPA-HQ-OPPT-2018-0451-0021). Storage of 1,3-butadiene, which may occur at a repackaging facility, along with other light hydrocarbons are highly specialized. 1,3-Butadiene should be stored in a cool, dry, well-ventilated area in tightly sealed and pressurized containers. Outside, isolated, or detached storage is preferred; inside storage should be in a non-combustible location as 1,3-butadiene is explosive when mixed with air (U.S. EPA, 1996; NIOSH, 1992).

One facility that processes 1,3-butadiene as a reactant reports their unloading activities, which EPA expects are activities that may occur as a repackaging or import site. At this facility, 1,3-butadiene is largely purchased domestically, with a small amount purchased internationally and imported. 1,3-Butadiene arrives at the site in a pressurized barge, where it is unloaded to an unloading facility dedicated to 1,3-butadiene and stored on-site. The site receives approximately one to two barges per week. 1,3-Butadiene is unloaded from a barge into one of two storage spheres via hard pipe using equipment such as unloading marine arms, a steam vaporizer, and an unloading pump. During unloading, a dedicated flare is operated to destroy any 1,3-butadiene before it is released to the environment (EPA-HQ-OPPT-2018-0451-0068).

In general, EPA assessed the transport activities resulting in releases and exposures (*e.g.*, loading, unloading) throughout the various life cycle stages and COUs rather than a single distribution and transport scenario. While this process description includes general language about the transport and storage of 1,3-butadiene that may be relevant to transport activities within other OESs as well, the quantifications for this Repackaging OES only address releases and exposures that may result at import and repackaging facilities. Data for assessing releases and exposures occurring during transportation of 1,3-butadiene, such as releases from accidental spills that occur during transport, are presented in Section 3.7, which discusses distribution in commerce.

1,3-Butadiene may be imported neat or as a component in a formulation. Figure 3-2 below provides typical release and exposure points during the repackaging of 1,3-butadiene.

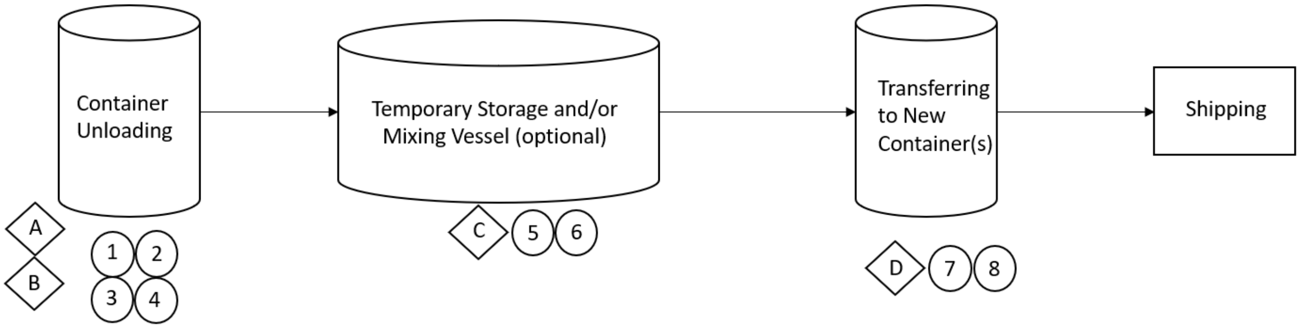

Figure 3-2. Typical Release and Exposure Points During the Repackaging of 1,3-Butadiene
Source: (U.S. EPA, 2022)

Environmental Releases:

1. Releases to air, water, incineration, or landfill from unloading from transport containers.
2. Releases to water, incineration or land from transport container residue (via container cleaning or direct disposal of empty containers).
3. Releases to air from cleaning transport containers containing volatile chemicals
4. Releases to water, incineration or land from cleaning of storage/mixing vessels and other equipment.
5. Releases to air from cleaning equipment used to process volatile chemicals.
6. Releases to air, water, incineration, or landfill from loading into transport containers.

Occupational Exposures:

A. Inhalation exposures from unloading transport containers.
B. Inhalation exposures from transport container cleaning.
C. Inhalation exposures from equipment cleaning.
D. Inhalation exposures from loading transport containers.

3.2.2 Facility Estimates

In the 2020 CDR, seven companies chose to report process volumes. They reported importing between 5 and 200 million lb each of neat 1,3-butadiene that was at least 90 percent purity by weight (U.S. EPA, 2020b). Using CDR, TRI, and NEI, EPA identified 115 facilities that potentially repackaged 1,3-butadiene.

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of EPA's assessment, each site can only be assigned one OES. The OES was selected using professional judgment to reflect the most prominent activity according to TRI and NEI reporting and the information on the company website. Because deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting these release sites in TRI (which was then adapted to NEI). A site was sorted into the Repackaging OES if it reported to one of the following three NAICS codes: 424690, (Other Chemical and Allied Products Merchant Wholesalers), 424710 (Petroleum Bulk Stations and Terminals), and 486910 (Pipeline Transportation of Refined Petroleum Products). For other repackaging facilities, factors that may have contributed to the decision include if the name of the facility included "Tank farm" or "Terminal" or if the company information indicated that the facility was primarily a repackaging facility.

See the supplemental file, *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i), for a list of all facilities mapped to repackaging that reported to CDR, TRI, and/or NEI.

EPA did not identify data on facility operating schedules; therefore, the Agency assumes that repackaging occurs 7 days/week and 50 weeks/year (with 2 weeks down for turnaround), which results in an estimate of 350 days/year of operation (Section 2.3.2).

3.2.3 Release Assessment

3.2.3.1 Environmental Release Points

Potential releases to air, water, or land may occur from loading and unloading of 1,3-butadiene from transport containers, cleaning transport containers, cleaning of storage or mixing vessels and other equipment, cleaning equipment used to process the chemical, and loading into transport containers.

3.2.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI data to estimate environmental releases during the repackaging of 1,3-butadiene, as presented in Table 3-6. According to reported data, 1,3-butadiene is released through the following environmental media: surface water, fugitive air, stack air, and land disposal.

Table 3-6. Summary of Environmental Releases During the Repackaging of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	2.3	4.3	350	6.5E−03	1.2E−02	1	TRI
Fugitive air	18	3,559		5.1E−02	10	22	TRI
Fugitive air	1.6	999		4.6E−03	2.8	74	NEI
Stack air	21	1,970		5.9E−02	5.6	24	TRI
Stack air	23	1,127		7.4E−02	3.2	51	NEI
Land	2.3	6.8		6.5E−03	1.9E−02	2	TRI

3.2.4 Occupational Exposure Assessment

3.2.4.1 Worker Activities

During repackaging, worker exposures via inhalation of 1,3-butadiene vapors may occur when transferring 1,3-butadiene from the import vessels (*e.g.*, chemical tankers, rail cars, intermodal tank containers) into smaller containers, cleaning import vessels, sampling, and cleaning equipment. One facility that processes 1,3-butadiene as a reactant reports their unloading activities, which EPA expects are activities that may occur as a repackaging or import site. At this facility, 1,3-butadiene is unloaded from a barge into one of two storage spheres using equipment such as unloading marine arms, a steam vaporizer, and an unloading pump. Engineer controls noted during this process include that the marine arms are equipped with tight fitting values, so that once the marine arms are connected, all 1,3-butadiene remains in the process piping. Also, during the process all vapors are routed to a butadiene flare for destruction.

Administrative controls include conducting the process so that unloading occurs in sequenced, proceduralized steps to minimize risk of personnel exposure while the marine arm is connected to the barge. Also, prior to removing marine arms, there are sequenced, proceduralized steps in place to clear lines to a flare or back to the barge to minimize the risk to personnel. PPE worn during these processes, based on an exposure survey, include flame resistance clothing and a half mask respirator with organic vapor cartridges which are worn during connection and disconnection. Relevant to barge unloading at a site that processes 1,3-butadiene as a reactant, the barge unloading can take between 10 to 15 hours depending on the size of the barge; however, the workers are reported to typically be present less than

15 minutes per activity (connecting and disconnecting), 30 minutes per barge, two barges per week (EPA-HQ-OPPT-2018-0451-0068).

ACC also provided information about loading and unloading from their member sites, stating that based on reports from participating companies, minimum PPE requirements for loading and unloading 1,3-butadiene from railcars are a half-facepiece respirator with organic vapor cartridges and chemical protective gloves. When there is a splashing hazard or potential for trapped materials, full face-piece respirators with organic vapor cartridges and chemical protective gloves are typically required, and one company reported requiring supplied air respirators during disconnection. Railcar unloading and loading is reported to take between 15 and 45 minutes and occur between one and six time per day (average of two and a half), with one worker typically involved for one to two shifts per day. The PPE reported for barges is similar, including a half-facepiece respirator with organic vapor cartridges and either leather, butyl rubber, fluoroelastomer, or nitrile gloves. Some companies also report requiring a full-facepiece respirator. Barge unloading and loading is reported to take an average of 30 minutes, occur one-and-a-half to eight times per month, and requires one to five workers to be present per shift (EPA-HQ-OPPT-2024-0425-0076).

EPA did not find any information on the extent to which engineering controls and worker PPE are used at facilities that repackage 1,3-butadiene into smaller containers such as for laboratory use.
ONUs include employees (*e.g.*, supervisors, managers) that work at the import site where repackaging occurs but do not directly handle 1,3-butadiene. Therefore, EPA expects the ONUs to have lower inhalation exposures than workers who handle the chemicals directly.

3.2.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during repackaging (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. 0Appendix includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers
- 424690 – Other Chemical and Allied Products Merchant Wholesalers
- 424710 – Petroleum Bulk Stations and Terminals
- 424720 – Petroleum and Petroleum Products Merchant Wholesalers (except Bulk Stations and Terminals)
- 486910 – Pipeline Transportation of Refined Petroleum Products

Table 3-7 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.2.2.

Table 3-7. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Repackaging

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
115	424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers	4	1
	424690 – Other Chemical and Allied Products Merchant Wholesalers		
	424710 – Petroleum Bulk Stations and Terminals		
	424720 – Petroleum and Petroleum Products Merchant Wholesalers (except Bulk Stations and Terminals)		
	486910 – Pipeline Transportation of Refined Petroleum Products		

[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.

3.2.4.3 Occupational Inhalation Exposure Results

EPA did not identify monitoring data for the Repackaging OES; however, EPA expects the exposures to be similar to loading and unloading worker activities during the manufacturing and processing of 1,3-butadiene. Therefore, EPA used specific data points relevant to the task "unloading and transferring 1,3-butadiene to and from storage containers to process vessels" from the manufacturing and processing monitoring dataset provided by ACC in the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) as "analogous data" for repackaging. EPA defines analogous monitoring data as monitoring data for the same chemical, but for a similar OES.

For loading and unloading of 1,3-butadiene, EPA identified 158 task-based worker PBZ samples from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). The worker samples collected include loading and unloading of product which involves opening of storage vessels, hose connections to truck tankers, rail cars or cargo vessels and pumping of pressurized liquid 1,3-butadiene. The sample durations ranged from 16 to 218 minutes.

Since EPA only had task-based samples with task-length durations, rather than full shift samples with full shift durations, EPA needed to make assumptions on how best to obtain full shift exposure estimates using these task-based samples. EPA made two assumptions to capture the range of possible exposures for this OES. The first assumption addressed the possibility that a facility specifically focused on repackaging, and the bulk of the day may be spent performing repackaging tasks such that the task-based samples may be representative of a full shift exposure. To capture this possibility, the estimate assumes that the worker is exposed to the concentration of 1,3-butadiene measured during the task for an entire 8-hour shift (full shift assumption).

The second assumption is based on information from the *Analysis of 1,3-Butadiene Industrial Hygiene Data*, which reports that at a manufacturing or processing facility routine task-based samples (such as the repackaging dataset used in this assessment) occur for only the length of the task. For rail cars, unloading or loading may occur between one to six times per day, with an average of two and a half railcars per day. For barges, loading and unloading may occur one and a half to eight times per month (EPA-HQ-OPPT-2024-0425-0076). This barge loading and unloading frequency of occurrence matches another commenter that processes 1,3-butadiene as a reactant and reported barge loading and unloading occurs approximately one to two times per week (EPA-HQ-OPPT-2018-0451-0068). Because the loading and unloading data used as analogous did not differentiate between railcar and barge, EPA defaulted to the assumption that the estimated unloading and loading task occurs once per day, only for the duration of the task, and for the remainder of their shift the worker receives no exposure to 1,3-butadiene (task-length assumption).

Using each of these assumptions, EPA presents two estimates that capture the range of exposures a worker may experience.

The Agency did not identify any ONU PBZ samples during data evaluation. Therefore, EPA used the central tendency from workers to represent ONU exposures.

EPA compiled the 50th and 95th percentile 8-hour TWA concentrations from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B, The results of these calculations are shown in Table 3-8 for the full shift assumption and Table 3-9 for the task-length assumption. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-8. Inhalation Exposure to Workers to 1,3-Butadiene During Repackaging (Full Shift Assumption)

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of Samples[a]	158		0	
8-hour TWA Exposure Concentrations	0.45	22	0.45	0.45
AC	0.31	15	0.31	0.31
$ADC_{intermediate}$	0.22	11	0.22	0.22
ADC	0.21	10	0.21	0.21
LADC	5.3E−02	3.3	5.3E−02	6.6E−02

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)
[a] 87 of the 158 data points for workers were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.

Table 3-9. Inhalation Exposures of Workers to 1,3-Butadiene During Repackaging (Task-Length Assumption)

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of Samples[a]	158		0	
8-hour TWA Exposure Concentrations	2.6E−02	1.1	2.6E−02	2.6E−02
AC	1.7E−02	0.78	1.7E−02	1.7E−02
$ADC_{intermediate}$	1.3E−02	0.57	1.3E−02	1.3E−02
ADC	1.2E−02	0.53	1.2E−02	1.2E−02
LADC	2.9E−03	0.17	2.9E−03	3.8E−03

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)
[a] 87 of the 158 data points for workers were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.

3.3 Processing as a Reactant

3.3.1 Process Description

The final scope for 1,3-butadiene lists processing as a reactant as an in-scope COU (U.S. EPA, 2020c). Processing as a reactant or intermediate is the use of 1,3-butadiene as a feedstock in the production of another chemical via a chemical reaction in which 1,3-butadiene is consumed to form the product. When used as a reactant, 1,3-butadiene is received in liquid form in pressurized containers by tank truck or railcar. EPA assumes that 1,3-butadiene is used as reagent grade, 99.5 percent or higher purity from the manufacturing process (Sun and Wristers, 2002).

ACC provided comments on ways 1,3-butadiene is used as a chemical intermediate (EPA-HQ-OPPT-2018-0451-0021). One use is in the production of nylon. In this process, 1,3-butadiene is subjected to direct hydrocyanation to form pentenitrile compounds and adiponitrile, which are further hydrocyanated to form hexamethylenediamine. This compound is polymerized to manufacture nylon resins. INVISTA, a company that manufactures adiponitrile, provided a comment describing that 1,3-butadiene remains in liquid phase during their processes, and is unloaded from barges via a closed pumping system to butadiene spheres which are pressurized vessels which store liquid 1,3-butadiene at ambient conditions. Liquid 1,3-butadiene is then pumped to the first process area from storage via above-ground hard pipes with automated controls, operated from within a control room. Liquid 1,3-butadiene stays in hard piping and is continuously pumped from storage spheres through a 1,3-butadiene filter, osmotic water removal, and molecular sieve before it reaches the closed reactor for the first hydrocyanation and isomerization steps, which results in the synthesis of adiponitrile. This is a fully closed system that occurs fully outdoors. Management of this process is done remotely by the control room operator. All 1,3-butadiene is expected to be consumed within the process or removed during the refining step for adiponitrile, and trace quantities in vapor or liquid wastes are sent to boilers for destruction, thereby eliminating the need for routine disposal. For safety purposes and as a failsafe, a routine operations flare is continually in use to destroy any 1,3-butadiene emissions from this process. A flare is also used for the destruction of the vapors generated in the unloading process, maintenance, startup, and shutdown of the plant. These flares achieve a 98 percent destruction removal efficiency (DRE) for volatile organic compounds (VOCs), including 1,3-butadiene. 1,3-Butadiene vapors may also be sent to site boilers, which achieve 99.99

percent DRE. INVISTA noted that the described process has been updated in 2021, with 2022 being the first full year of operation with new technology aimed to lower the amount of 1,3-butadiene needed per pound of adiponitrile produced (EPA-HQ-OPPT-2018-0451-0068).

Another process in which 1,3-butadiene is used as a chemical intermediate is in the production of neoprene rubber, which involves 1,3-butadiene being chlorinated to form chloroprene and then polymerized to form neoprene. 1,3-Butadiene is also used to produce 1,4-hexadiene (used to create ethylene-propylene terpolymer), sulfolane (an extraction solvent), and 1,5,9-cyclodecatriene (used in the production of nylon fibers and resins). Based on inter/intra-agency comments, 1,3-butadiene is also processed as a reactant in rocket propellant manufacturing by the DOD.

1,3-Butadiene may be recycled during processing when ethylene manufacturers have excess butadiene supply. They can recycle the butadiene as a feedstock to produce ethylene.

Figure 3-3, provided by the ACC, illustrates an example adiponitrile production process. Adiponitrile is then used to form hexamethylenediamine and finally nylon resins. As the diagram indicates, 1,3-butadiene is reacted to near completion (EPA-HQ-OPPT-2018-0451-0041).

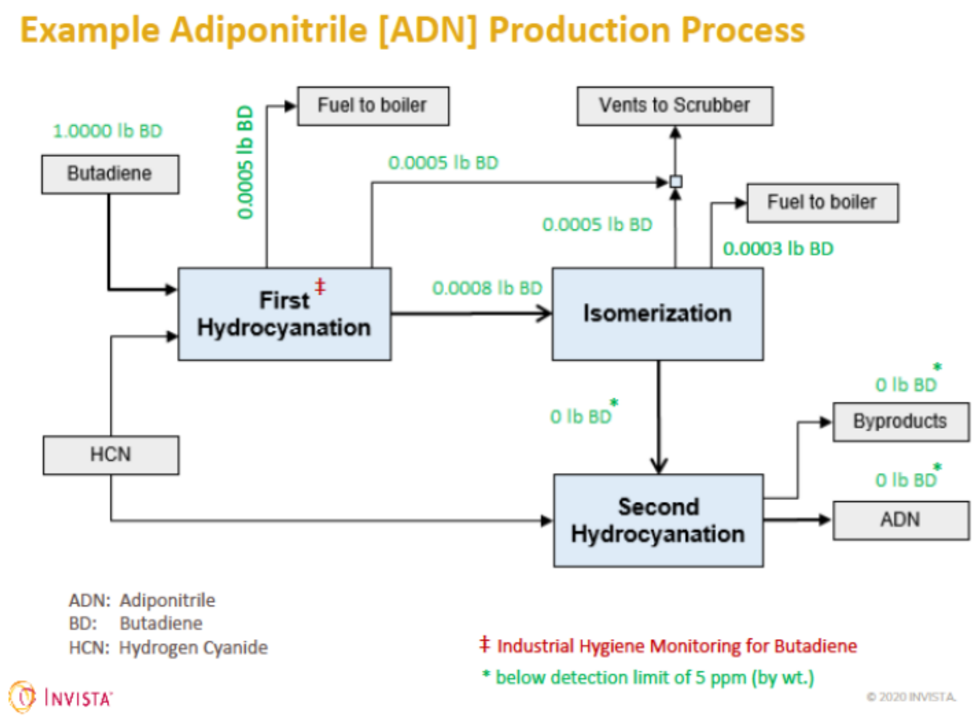

Figure 3-3. Illustration of an Adiponitrile Production Process
Source: ACC/Invista.

3.3.2 Facility Estimates

Between 2016 and 2021, EPA used TRI, NEI, and CDR to identify 103 facilities that potentially process 1,3-butadiene as a reactant. In 1993, the domestic production capacity for adiponitrile was 712,000 tons/yr (U.S. EPA, 1996). It was reported by the ACC in 2018 that roughly 26 to 32 percent of 1,3-butadiene PV goes toward the production of intermediate chemicals such as adiponitrile and chloroprene (EPA-HQ-OPPT-2018-0451-0021). Taking the high estimate of PV from CDR (5 billion lb), it can be estimated that up to 1.6 billion lb of 1,3-butadiene goes toward an activity covered by this OES. EPA did not identify production capacities for the production of nylon resins, neoprene rubber, or rocket propellants.

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of EPA's assessment each site can only be assigned one OES. The OES was chosen based generally on what seemed the most prominent activity according to TRI and NEI reporting and the information on the company website. Since deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting these release sites in TRI (which was then adapted to NEI). Reviewing the company information for each facility was an important step in sorting a site into Processing as a reactant OES. If the company information indicated the production of a plastic/rubber product in which 1,3-butadiene is known to be in an intermediate stage (such as nylon) or if the product was indicated to be an intermediate product (such as emulsion, liquid, or dispersion), then processing as a reactant was chosen. Within TRI, reported uses that indicated to EPA that processing as a reactant may be the appropriate OES for the facility include the presence of "Use as a Reactant," particularly along with uses/sub-uses such as "Feedstock," "Raw Material," and "Intermediate."

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to processing as a reactant that reported to CDR, TRI, and/or NEI.

For facility operating schedules, 1,3-butadiene is a large-PV commodity chemical most commonly used to manufacture other chemicals, so as described in Section 2.3.2, the Agency assumes that the facility operates 7 days per week, 50 weeks per year (2 weeks down for turnaround) and that the facility is producing and releasing the chemical daily during operation. This results in an estimated 350 days/year of operation.

3.3.3 Release Assessment

3.3.3.1 Environmental Release Points

EPA expects releases to occur during container and equipment cleaning, maintenance, and sampling. Environmental releases may also occur during the unloading of 1,3-butadiene from transport containers into intermediate storage tanks and process vessels. Equipment leaks may occur while connecting and disconnecting hoses and transfer lines. Additionally, EPA expects stack air releases from vented losses to air during process operations, and fugitive air releases from leakage of pipes, flanges, and accessories used for transport.

3.3.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI data to estimate environmental releases during the processing as a reactant of 1,3-butadiene, as presented in Table 3-10. According to reported data, 1,3-butadiene is released through the following environmental media: surface water, indirectly through the transfer to a POTW, indirectly through the transfer to a non-POTW WWT facility, fugitive air, stack air, and land disposal.

Table 3-10. Summary of Environmental Releases During the Processing as a Reactant of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites(kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	2.3	21	350	6.5E−03	6.0E−02	4	TRI
POTW	1.2	6.3		3.5E−03	1.8E−02	3	TRI
WWT	0.5	0.5		1.3E−03	1.3E−03	1	TRI
Fugitive air	64	1,778		0.18	5.1	54	TRI
Fugitive air	60	2,774		0.17	7.6	57	NEI
Stack air	94	4,419		0.27	13	53	TRI
Stack air	56	7,281		0.16	20	54	NEI
Land	0.69	207		2.0E−03	0.59	13	TRI

3.3.4 Occupational Exposure Assessment

3.3.4.1 Worker Activities

While processing 1,3-butadiene as a reactant, worker exposures may occur via inhalation of vapors during container unloading and loading, product sampling, transport container cleaning, maintenance operations, and general onsite operations. Routine activities at a site that processes 1,3-butadiene as a reactant may include connecting and disconnecting unloading lines at barge docks and changing filters. Non-routine activities with the potential for 1,3-butadiene exposures include non-routine sampling activities, which involves the manual sampling of streams containing more than 1 percent 1,3-butadiene, cleaning equipment for maintenance, and troubleshooting equipment malfunctions. In addition, one site reported to have a trained emergency response team that would respond in the event of an emergency release with proper equipment and PPE (EPA-HQ-OPPT-2018-0451-0068).

EPA received a comment (EPA-HQ-OPPT-2018-0451-0066) that describes some engineering controls and worker PPE used at an adiponitrile manufacturing facility, where 1,3-butadiene is processed as a reactant. During barge unloading at processing sites, marine arms used during the unloading process are equipped with tight fitting values, and once connected all the butadiene remains in process piping, with all vapors routed to a butadiene flare for destruction. During routine operations, 1,3-butadiene is pumped from storage into the process area using automated controls, operated from within a control room. The process area is a closed piping reaction system with automated controls and no manual sampling activities occur in this section of the unit. For butadiene filter change-out, which occurs once a year, hard-piped connections exit to the flare system and Closed Sump system to allow for venting of vapors with no exposure during the clearing step. During non-routine activities (such as clearing of equipment containing 1,3-butadiene for maintenance, which may occur around two times per month (limited to 10 activities by any individual per year), or troubleshooting), engineering controls include a venting of all vapors from equipment with a hard-piped connection to a flare system, after which testing occurs to ensure the efficacy of the vent. Workers may then open equipment. The commenter emphasized that at this site, routine operators spend approximately 41 percent of their time in areas where 1,3-butadiene is present (including the area where the butadiene process occurs, the barge docks, and near the butadiene storage spheres). Mechanics perform tasks relevant to 1,3-butadiene as-needed, and controls ensure that any given employee does not perform more than 10 butadiene-related activities per year.

PPE worn during the initial opening of the equipment during non-routine activities and 1,3-butadiene filter changes (which occur once per year) include a chemical suit, gloves, and respirator with breathing air, however (relevant to the yearly filter changes) once verification is made, PPE is downgraded to a full-face respirator with organic vapor cartridge. PPE worn during barge unloading of 1,3-butadiene may include flame resistant clothing and half mask respirators with organic vapor cartridges worn during connection/disconnection. At a processing facility, workers may be present less than 15 minutes per activity, 30 minutes total per barge, two barges per week. When doing routine work, a full-face respirator with an organic vapor cartridge is used based on time allowances in the OSHA 1910.1051 chart, which specifies maximum concentrations and maximum time between cartridge changes. Chemical resistant gloves are rated for use with 1,3-butadiene. Non-routine work conducted on an infrequent basis or emergency situations will use breathing air (EPA-HQ-OPPT-2018-0451-0068).

While EPA does not have any information to suggest that respirators are worn for the entirety of the work day for any job group/SEG within a processing facility, the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) does indicate what exposure controls, including PPE, apply to tasks that are undertaken by each job group. Varying levels of respirator protection are associated with each task. Table 3-11 lists the various job groups at manufacturing and processing facilities, their expected tasks and activities, and the listed exposure controls.

Table 3-11. Exposure Control Crosswalk for Job Group/SEGs and Tasks

<table>
<tr><th>Job Group/SEG</th><th>Tasks/Activities</th><th>Exposure Controls</th></tr>
<tr><td rowspan="8">Infrastructure/ Distribution/ Transportation Operations</td><td>Unloading and Loading materials to and from storage containers to process vessels</td><td rowspan="7">Vapor recovery systems
chemical protective gloves
suits and boots (to prevent dermal contact)
<u>respirators:</u> supp air, full/half face APR</td></tr>
<tr><td>Opening process equipment (e.g., storage vessels)</td></tr>
<tr><td>Sample collection</td></tr>
<tr><td>Cleaning filters</td></tr>
<tr><td>Handling hoses (e.g., connections to truck tankers)</td></tr>
<tr><td>Loading/unloading tanks/trucks (e.g., rail cars or cargo vessels and pumping material)</td></tr>
<tr><td>Handling utilities and waste streams</td></tr>
<tr><td>Handling of waste (transporting and disposing)</td><td>Chemical protective gloves
suits and boots (to prevent dermal contact)
<u>respirators:</u> full/half face APR</td></tr>
<tr><td rowspan="2">Instrument and Electrical</td><td>Performing other work activities</td><td rowspan="2">Chemical protective gloves
suits and boots (to prevent dermal contact)
<u>respirators:</u> supp air, full/half face APR, no respirator</td></tr>
<tr><td>Set up and maintenance of electrical equipment (analyzers and instruments across the facility)</td></tr>
</table>

Job Group/SEG	Tasks/Activities	Exposure Controls
	opening the lines (like calibration and equipment maintenance)	
Laboratory Technician	**Collecting and analyzing samples**	Chemical protective gloves suits and boots (to prevent dermal contact) enclosed sample boxes pressurized sample containers laboratory ventilation cabinets respirators: supp air, full/half face APR, no respirator
Machinery & Specialists Mechanical Group	**Performing other work activities**	Chemical protective gloves
	Dpening process equipment prior to maintenance activities	Suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
Maintenance	**Cleaning and maintaining equipment**	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
	Donnecting and disconnecting lines	
	Draining, clearing and venting equipment	
Operations Onsite	**Cleaning and maintaining equipment**	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
	Monitor chemical feeds, process temperatures, vessel pressure, etc.	
	Collecting and analyzing samples	Chemical protective gloves
	Drain/vent/clear process equipment and prepare it for maintenance	Suits and boots (to prevent dermal contact)
	Prepare process equipment for maintenance	Enclosed sample boxes pressurized sample containers laboratory ventilation cabinets respirators: supp air, full/half face APR, no respirator
Safety, Health, and Environment	**Performing other work activities**	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
	Conduct exposure assessments of workers	
	Monitor other workers or processes	
ONUs	**Performing other work activities**	Chemical protective gloves suits and boots (to prevent dermal contact) respirators: supp air, full/half face APR, no respirator
	Supervisory personnel associated with all of the worker job groups	
Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076).		

ONUs include supervisors, managers, and other employees who work in the processing area but do not directly contact 1,3-butadiene received or processed onsite or handle polymerized product. Therefore, EPA expects the ONUs to have lower inhalation exposures than workers who handle the chemicals directly.

3.3.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during processing as a reactant (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325110 – Petrochemical Manufacturing
- 325199 – All Other Basic Organic Chemical Manufacturing
- 325211 – Plastics Material and Resin Manufacturing

Table 3-12 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.3.2.

Table 3-12. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Processing as a Reactant

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
103	325110 – Petrochemical Manufacturing	43	8
	325199 – All Other Basic Organic Chemical Manufacturing		
	325211 – Plastics Material and Resin Manufacturing		

[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.

3.3.4.3 Occupational Inhalation Exposure Results

For processing as a reactant, EPA used the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) described in Section 3.1.4.3, which includes 5,675 full shift PBZ samples for workers and ONUs collected from 2010 to 2019. The dataset included routine, nonroutine, and turnaround operations. The sample durations ranged from 8 to 12 hours. The worker samples collected include maintenance of electrical equipment and process equipment, sample collection, and process condition monitoring. The source presented 50th and 95th percentiles per worker description. All relevant full shift data were applied to the exposure estimates because the EPA cannot distinguish whether the data pertained specifically to manufacturing or processing.

While the EPA identified other data sources containing inhalation monitoring data for workers involved in the processing of 1,3-butadiene as a reactant, which can be reviewed in the *Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure for 1,3-*

Butadiene (U.S. EPA, 2025g) and the *1,3-Butadiene Inhalation Monitoring Data Summary* (U.S. EPA, 2025a) the data from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) was ultimately used due to its higher data quality, recency, and the presence of discrete data. The *Analysis of 1,3-Butadiene Industrial Hygiene Data* also focuses on U.S. sites and includes comprehensive metadata (*e.g.,* sample times, worker descriptions), while the other identified data were often from other countries, were older (with some collected before the OSHA PEL was established), and/or lacked critical metadata needed for an occupational exposure assessment. One other source, INVISTA, provided discrete data relevant to this OES (EPA-HQ-OPPT-2018-0451-0068). This source measured inhalation exposure at a facility where 1,3-butadiene was used to manufacture adiponitrile. This source provided 14 full shift discrete data points collected between 2019 and 2021 from 1 site (3 for instrumentation and electrical staff, 3 for mechanics, and 8 for operators), providing details about activities conducted during some shifts. EPA chose the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) to calculate risk due to the large number of samples and various sites represented; however, the Agency also includes here the results from this source for comparison to the relevant SEGs to bolsters EPA's confidence in the risk assessment.

EPA compiled the 50th and 95th percentile 8- and 12-hour TWA concentrations from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8- and 12-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-4 and Table 3-5. Note that since manufacturing and processing facilities could not be differentiated, this dataset is used to estimate exposure for both Manufacturing and Processing as a reactant OESs. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

EPA compared the TWA exposure concentrations from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) used in the risk evaluation and the TWA exposure concentrations provided by INVISTA. Although the INVISTA dataset represents only one facility and has fewer data points, this facility conducts only the processing of 1,3-butadiene as a reactant, as opposed to the *Analysis of 1,3-Butadiene Industrial Hygiene Data*, which also includes exposure from manufacturing facilities in the exposure estimates. Comparing these datasets allows EPA to examine the reasonableness of using the *Analysis of 1,3-Butadiene Industrial Hygiene Data* to represent the Processing as a reactant OES despite the uncertainties that come from using a dataset that is comprised of both manufacturing and processing as a reactant data. Table 3-13 shows the worker descriptions, the number of samples from each dataset, and the TWA exposure concentrations from each. In general, the INVISTA concentrations fell between the high-end and central tendency concentrations of the *Analysis of 1,3-Butadiene Industrial Hygiene Data*. Both the high-end and central tendency of the INVISTA dataset fell within the same order of magnitude, or one order of magnitude below, the calculated high-end value from the *Analysis of 1,3-Butadiene Industrial Hygiene Data*.

Table 3-13. Comparison of Inhalation Exposure Estimates from *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ACC) and Inhalation Exposure Estimates from the INVISTA Dataset for Three Similar Exposure Groups

Worker Description[a]	Number of Samples from ACC Report[b]	Number of Samples from INVISTA[c]	TWA Exposure Concentrations (ACC)		TWA Exposure Concentrations (INVISTA)	
			Central Tendency (ppm)	High-End (ppm)	Central Tendency (ppm)	High-End (ppm)
Instrument and Electrical	313	3	2.6E−04	0.10	03.2E−02	03.2E−02
Machinery & Specialists Mechanical Group[a]	222	3	9.2E−04	0.25	03.3E−02	03.3E−02
Operations Onsite	1,952	8	3.6E−04	0.13	8.1E−02	0.12

[a] "Machinery & Specialists Mechanical Group" was matched with the job description of "Mechanic" present in the INVISTA dataset
[b] "ACC" refers to the *Analysis of 1,3-Butadiene Industrial Hygiene Data*, a report provided to EPA by the ACC. Dataset source: ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076
[c] INVISTA dataset source: EPA-HQ-OPPT-2018-0451-0068

3.4 Processing – Incorporation into Formulation, Mixture or Reaction Product

3.4.1 Process Description

Incorporation into a formulation, mixture or reaction product refers to the process of mixing or blending of several raw materials to obtain a single product or preparation. In the 2016 CDR, companies reported use of 1,3-butadiene in the manufacture of petrochemicals, as well as in the manufacturing of rubber products (U.S. EPA, 2020b). The final scope for 1,3-butadiene also lists that the chemical is used in adhesive manufacturing, paints and coatings manufacturing, and oil and grease lubricant manufacturing (U.S. EPA, 2020c).

Finished lubricants processing consists of blending base stock lubricants with additive chemicals to create a finished product. The three most common blending methods include batch, partial in-line, and continuous in-line blending (OECD, 2020). 1,3-Butadiene is used as a viscosity improver in automotive lubricants, and products made with 1,3-butadiene are typically added in concentrations of 2 to 15 percent. The formulation of paints and coatings typically involves dispersion, milling, finishing and filling into final packages (OECD, 2010). Polybutadiene is specifically used as a cationic binder in paint primers and is present at concentrations of less than 10 percent.

In adhesive manufacturing, 1,3-butadiene is used as a binder. One company reporting to CDR (U.S. EPA, 2020b) indicated that the chemical is used as an intermediate in the adhesive manufacturing sector. Substances in Preparations in Nordic Countries (SPIN, 2019; accessed December 1, 2025) also identified use of 1,3-butadiene in adhesives and binding agents in Nordic countries. According to the Aerospace Industries Association (AIA), 1,3-butadiene is used in adhesives critical to electrical and circuit boards for its thermal properties and low outgassing properties (important for space applications).

They also note that it is a component of epoxy resin adhesive systems for bonding and sealing of glass to metal components (EPA-HQ-OPPT-2018-0451-0009). 1,3-Butadiene-specific formulation processes were not identified for the manufacture of adhesives; however, ESDs published by the Organization for Economic Co-operation and Development (OECD) have been identified that provide general process descriptions for these types of products. Adhesive formulation involves mixing together volatile and non-volatile chemical components in sealed, unsealed or heated processes (OECD, 2009a). Sealed processes are most common for adhesive formulation because many adhesives are designed to set or react when exposed to ambient conditions (OECD, 2009a). Figure 3-4 below provides typical release and exposure points during the incorporation of 1,3-butadiene into adhesives.

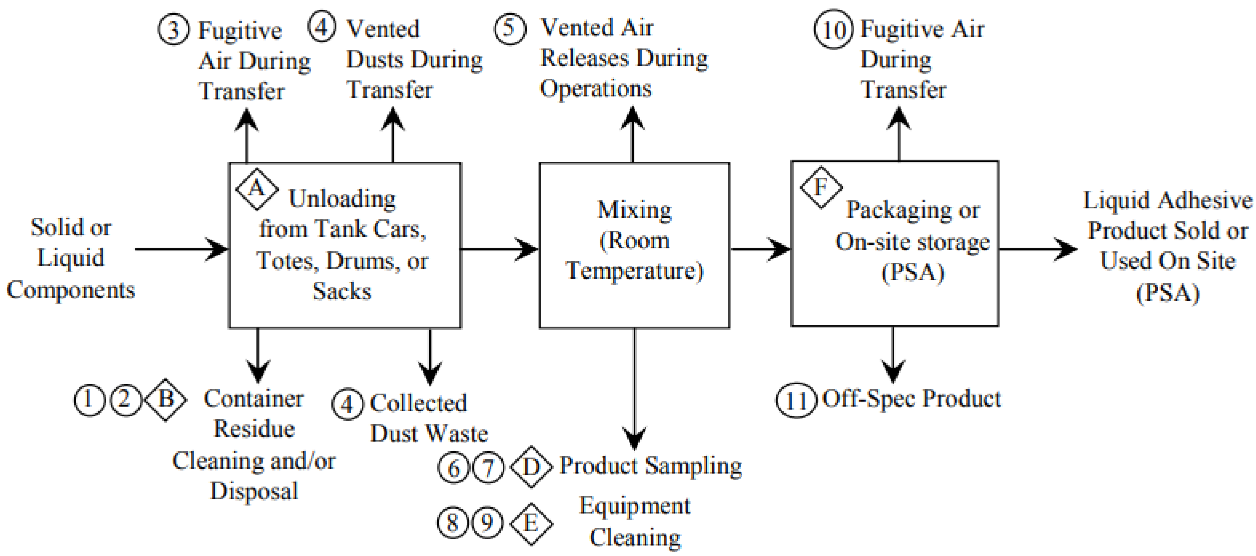

Figure 3-4. Typical Release and Exposure Points During Adhesive and Sealant Formulation

Source: (OECD, 2009a)

Environmental Releases:

1. Container residue from adhesive component transport container released to water, incineration, or landfill.
2. Open surface losses of volatile chemicals to air during container cleaning
3. Transfer operation losses to air of volatile chemicals from unloading the adhesive component.
4. Dust losses vented to outside air from the transfer of a solid/powdered adhesive component into the process. Alternatively, these dusts are captured on vent filters or settle within the workspace, and are subsequently collected and released to water, incineration, or landfill.
5. Vented losses of volatile chemicals to air during mixing operations.
6. Product sampling wastes disposed to water, incineration or landfill (not quantified in this ESD).
7. Open surface losses of volatile chemicals during product sampling.
8. Equipment cleaning releases to water, incineration, or landfill.
9. Open surface losses of volatile chemicals to air during equipment cleaning.
10. Transfer operation losses of volatile chemicals to air from loading adhesive product into transport containers.
11. Off-spec adhesive product released to water, incineration, or landfill.

Occupational Exposures:

A. Inhalation exposure from unloading solid or liquid adhesive components.
B. Inhalation exposure to solid or liquid adhesive components during container cleaning.
C. Inhalation exposure to liquid adhesive product during sampling activities.
D. Inhalation exposure to liquid during equipment cleaning of mixing and other process equipment.
E. Inhalation exposure to liquids during the packaging of adhesive formulations into containers.

1,3-Butadiene is also listed as a processing aid in petrochemical manufacture, but EPA found no butadiene-specific formulation processes or resources on this use. In the 2016 CDR, one company reported a 2014 PV of 2,751,366 lb of 1,3-butadiene used in the production of petrochemical processing aids (U.S. EPA, 2016). SPIN also identified use of 1,3-butadiene in aerosol propellants in Nordic countries up to year 2017, though all at 0 "tonnes," which indicates that the registered volume of the substance in the particular year used in the particular part of the industry in the reporting country is at a volume below the limit of accuracy, which is 100 kg. The American Coatings Association noted in a public comment that "Manufacturers note residual amounts of the chemical in aerosol propellants" (EPA-HQ-OPPT-2018-0451-0005). Plastic and rubber production are covered in Sections 3.5 and 3.6.

3.4.2 Facility Estimates

Using TRI and NEI, EPA identified 178 facilities that potentially process 1,3-butadiene by incorporation into formulation, mixture or reaction product. Due to confidential business information (CBI) claims on the annual PV of 1,3-butadiene, EPA does not present annual or daily site throughputs for adhesive manufacturing, paints and coatings manufacturing, and oil and grease lubricant manufacturing. The ESD on Adhesive Formulation estimates the number of operating days based on PV information and an annual adhesive production rate of 1.6 to 17 million kg/site-yr (OECD, 2009a). The ESD on Chemical Additives in Automotive Lubricants estimates 256 operating days/year for formulation and an annual processing rate of 19 million kg lubricant/site-yr (OECD, 2020).

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of EPA's assessment each site can only be assigned one OES. The OES was chosen using professional judgment to reflect the most prominent activity according to TRI and NEI reporting and the information on the company website. Because deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting these release sites in TRI (which was then adapted to NEI). If a facility has the NAICS code of 325520 (Adhesive Manufacturing), the OES of Processing – incorporation into formulation, mixture, or reaction product is assigned to the facility. Otherwise, within TRI, if a facility indicates that they produce 1,3-butadiene as a byproduct or manufactured impurity, and no specific on-site use for the chemical is indicated, the OES of Processing – incorporation into formulation, mixture, or reaction product may be chosen.

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to incorporation into formulation, mixture, or reaction product that reported to CDR, TRI, and/or NEI.

The ESD on Formulation of Radiation Curable Coatings, Inks and Adhesives estimates 250 operating days/year (or calculation based on PV information) and an annual production rate of 130,000 kg formulation/site-yr (OECD, 2010).

3.4.3 Release Assessment

3.4.3.1 Environmental Release Points

EPA expects releases to occur to water, incineration, or landfill due to container residue in transport containers, product sample wastes, and equipment cleaning. Due to the chemical's volatility the Agency also expects losses to air during container and equipment cleaning, transfer operations such as loading and unloading, product sampling, and mixing operations. EPA also expects stack air releases from vented losses during process operations and packaging into transport containers.

3.4.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI to estimate environmental releases during the Processing – incorporation into formulation, mixture or reaction product of 1,3-butadiene, as presented in Table 3-14. According to reported data, 1,3-butadiene is released through the following environmental media: surface water, indirectly through the transfer to a POTW, fugitive air, stack air, and land disposal.

Table 3-14. Summary of Environmental Releases During the Incorporation into Formulation, Mixture or Reaction Product of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	7.7	8.8	250	3.1E−02	3.5E−02	2	TRI
POTW	1.4	2.5		5.4E−03	1.0E−02	2	TRI
WWT	79	120		0.32	0.48	1	TRI
Fugitive air	10	712		4.0E−02	2.8	47	TRI
Fugitive air	3.9	282		1.5E−02	0.89	114	NEI
Stack air	56	1,349		0.22	5.4	49	TRI
Stack air	12	455		3.7E−02	1.2	107	NEI
Land	27	1.0E04		0.11	40	4	TRI

3.4.4 Occupational Exposure Assessment

3.4.4.1 Worker Activities

During the formulation of products containing 1,3-butadiene, worker exposures via inhalation of vapors may occur when transferring 1,3-butadiene from transport containers into process vessels, cleaning transport containers, product sampling, equipment cleaning, and packaging formulated products into containers (OECD, 2009a) (U.S. EPA, 2014). EPA did not identify information on engineering controls or worker PPE used at 1,3-butadiene-containing product formulation facilities.

For this OES, ONUs may include supervisors, managers, and other employees who work in the formulation area but do not directly contact 1,3-butadiene that is received or processed onsite or handle the formulated product. Therefore, EPA expects the ONUs to have lower inhalation exposures than workers who handle 1,3-butadiene or the formulations directly.

3.4.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during incorporation into formulation, mixture or reaction product (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325510 – Paint and Coating Manufacturing
- 325520 – Adhesive Manufacturing
- 424690 – Other Chemical and Allied Products Merchant Wholesalers

Table 3-15 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.4.2.

Table 3-15. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Incorporation into Formulation, Mixture or Reaction Product

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
178	325510 – Paint and Coating Manufacturing 325520 – Adhesive Manufacturing 424690 – Other Chemical and Allied Products Merchant Wholesalers	11	3

[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.

3.4.4.3 Occupational Inhalation Exposure Results

For Processing – incorporation into formulation, mixture, or reaction product, EPA used the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) described in Section 3.1.4.3 as analogous. The dataset includes 5,675 full shift PBZ samples for workers and ONUs collected from 2010 to 2019 and included routine, nonroutine, and turnaround operations. The sample durations ranged from 8 to 12 hours. The worker samples collected include maintenance of electrical equipment and process equipment, sample collection, and process condition monitoring. The 50th and 95th percentiles per worker activity were presented in the report.

While the EPA identified other data sources containing inhalation monitoring data for workers involved in the incorporation of 1,3-butadiene into formulation, the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) was ultimately used due to its higher data quality and recentness. This dataset focuses on U.S. sites and includes comprehensive metadata (*e.g.*, sample times, worker descriptions).

EPA compiled the 50th and 95th percentile 8-hour TWA concentrations to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8- and 12-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-4 and Table 3-5. Note that this dataset for the Manufacturing and Processing as a reactant OESs is used as analagous to estimate exposure during Processing – incorporation into formulation, mixture, or reaction product. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

3.5 Plastics and Rubber Polymerization

3.5.1 Process Description

Rubber and plastics product manufacturing was listed as an in-scope COU in the final scope for 1,3-butadiene (U.S. EPA, 2020c). 1,3-Butadiene is most commonly used as a monomer in polymerization processes, often to produce rubbers and plastics such as styrene-butadiene, polybutadiene, acrylonitrile-butadiene-styrene, and nitrile rubber (Sun and Wristers, 2002). Here, dry solvent, initiator, other monomers, and 1,3-butadiene are loaded into a reactor until all monomers are depleted. Then, the chain ends are terminated, and the resulting polymer solution is pumped to a blend tank. These processes can be run in batch or continuous operation (EPA-HQ-OPPT-2018-0451-0022).

Unreacted 1,3-butadiene monomer is recovered and recycled during the process and according to a comment submitted by the International Institute of Synthetic Rubber Producers (IISRP), synthetic rubber such as butadiene rubber (BR) and solution styrene-butadiene rubber (SSBR) polymers contain less than 50 ppb of residual 1,3-butadiene monomer (EPA-HQ-OPPT-2018-0451-0027).

Figure 3-5, provided by IISRP, illustrates one type of a typical emulsion process, in this case producing emulsion styrene-butadiene rubber (ESBR). In this process conversion may be between 60 to 80 percent, with the 1,3-butadiene being recovered and recycled back into the process. 1,3-Butadiene content in the stream after stripping is between 20 and 30 ppb (EPA-HQ-OPPT-2018-0451-0027).

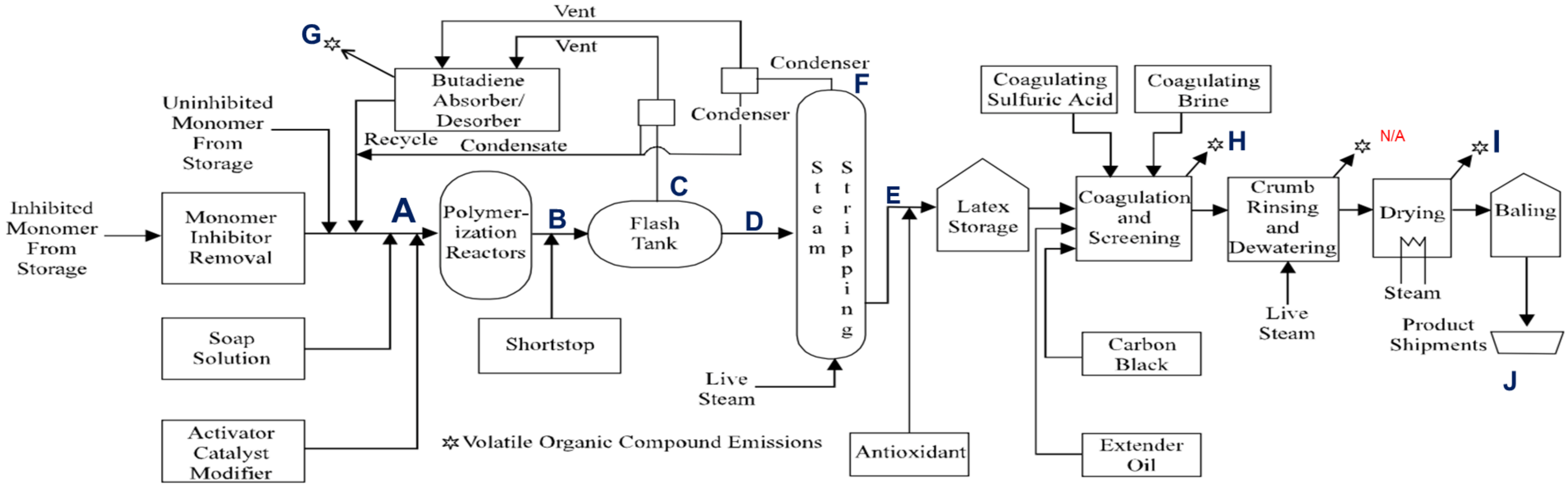

Figure 3-5. Illustration of a Typical Emulsion Process
Source: IISRP

3.5.2 Facility Estimates

EPA used TRI, NEI, and CDR data between 2016 and 2021 to identify 72 facilities that potentially use 1,3-butadiene during Plastics and rubber polymerization. It was reported by ACC in 2018 that roughly 63 to 69 percent of 1,3-butadiene PV goes toward the production of polymers and copolymers such as polybutadiene and styrene-butadiene rubber. Taking the high estimate of PV from CDR (5 billion lb), it can be estimated that up to 3.45 billion lb of 1,3-butadiene goes toward activities that are covered by this OES (EPA-HQ-OPPT-2018-0451-0021).

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of this assessment each site can only be assigned one OES. The OES was chosen using professional judgment to reflect the most prominent activity according to TRI and NEI reporting and the information on the company website. Since deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting these release sites in TRI (which was then adapted to NEI). Reviewing the company information for each facility was an important step in sorting a site into the Plastics and rubber polymerization OES. If the company information indicated the production of a plastic or rubber product in which 1,3-butadiene is known to be involved in the polymerization stage such as the products listed in the previous paragraph, the Plastics and rubber polymerization OES was chosen, particularly if the TRI report indicated that 1,3-butadiene is manufactured and/or used as a reactant at the facility. If a facility has a primary NAICS code of 325211 (Plastics Material and Resin Manufacturing) or 325212 (Synthetic Rubber Manufacturing), plastics and rubber polymerization was assumed unless the company information indicated through the specific product produced that processing as a reactant was a more appropriate assignment.

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to Plastic and rubber polymerization that reported to CDR, TRI, and/or NEI.

EPA did not identify data on facility operating schedules. The ESD on Plastic Additives references European technical guidance, which estimates up to 300 operating days/year for the polymers industry (OECD, 2009b). EPA assumes 300 days/year of operation.

3.5.3 Release Assessment

3.5.3.1 Environmental Release Points

EPA expects releases to occur to air, water, incineration, or landfill from container transfers from connecting and disconnecting of hoses from trucks to storage tanks, container residue cleaning and disposal, vapor emissions from the polymerization operation, equipment cleaning residue losses, direct contact cooling, and loading compounded plastics into final containers.

3.5.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI data to estimate environmental releases during the plastic and rubber polymerization of 1,3-butadiene, as presented in Table 3-16. According to reported data, 1,3-butadiene is released through the following environmental media: surface water, indirectly through the transfer to a non-POTW WWT facility, fugitive air, stack air, and land disposal.

Table 3-16. Summary of Environmental Releases During the Plastic and Rubber Polymerization of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	22	51	300	7.5E−02	0.17	4	TRI
WWT	2.3	266		7.6E−03	0.89	3	TRI
Fugitive air	635	8,385		2.1	28	31	TRI
Fugitive air	375	8,339		1.5	23	44	NEI
Stack air	903	1.7E04		3.0	56	33	TRI
Stack air	122	9,233		0.41	34	57	NEI
Land	49	366		0.16	1.2	7	TRI

3.5.4 Occupational Exposure Assessment

3.5.4.1 Worker Activities

Worker exposures during the polymerization process may occur via inhalation of vapors during unloading and loading and transport container cleaning (U.S. EPA, 2021c). Exposure may also occur when sampling, cleaning reactor vessels and tanks, or during process operation. Albertini et al. (2003) observed in one study of Czech workers the highest exposures were to rotating relief workers, operators, and pipe fitters who performed tasks such as adjusting and operating equipment, collecting samples, and installing and repairing pipes.

PPE that may be worn at plastic polymerization sites includes safety glasses, hard hats, flame-retardant clothing, face shields, half-face respirators with organic cartridges, and chemical resistant coated gloves.

ONUs include supervisors, managers, and other employees who work in the polymerization area but do not directly contact 1,3-butadiene received or processed onsite or handle compounded product. Therefore, EPA expects the ONUs to have lower inhalation exposures than workers who handle 1,3-butadiene or compounded products directly.

3.5.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during plastic and rubber polymerization (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325211 – Plastics Material and Resin Manufacturing
- 325212 – Synthetic Rubber Manufacturing
- 325991 – Custom Compounding of Purchased Resins
- 326211 – Tire Manufacturing (except Retreading)

- 326220 – Rubber and Plastics Hoses and Belting Manufacturing
- 326299 – All Other Rubber Product Manufacturing
- 424690 – Other Chemical and Allied Products Merchant Wholesalers

Table 3-17 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.5.2.

Table 3-17. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Plastics and Rubber Polymerization

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
73	325211 – Plastics Material and Resin Manufacturing	26	11
	325212 – Synthetic Rubber Manufacturing		
	325991 – Custom Compounding of Purchased Resins		
	326211 – Tire Manufacturing (except Retreading)		
	326220 – Rubber and Plastics Hoses and Belting Manufacturing		
	326299 – All Other Rubber Product Manufacturing		
	424690 – Other Chemical and Allied Products Merchant Wholesalers		

[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.

3.5.4.3 Occupational Inhalation Exposure Results

For plastics and rubber polymerization, EPA did not have a discrete dataset from which to calculate the 50th and 95th percentiles for use as central tendency and high-end estimates respectively. A variety of studies from systematic review, however, did provide summary statistics that characterized occupational exposure at facilities that polymerize 1,3-butadiene. To estimate central tendency for workers and ONUs, EPA calculated the overall mean of the 8-hour TWA exposures from the considered studies, weighing it to account for the number of samples that contributed to the mean of each study. To estimate high-end for workers, EPA calculated the 95th percentile of the provided maximum measured values across the relevant monitoring studies. While several studies reported the mean of ONU exposures, most did not include information on the distribution of the ONU exposure values. Only one study provided the range of ONU exposure values, and this study provided two maximums from two sub-groups that were exposed. In this case, EPA used the greater of the two maximums as the ONU high-end for this OES but acknowledges that this value may be an overestimate of a typical high-end ONU exposure.

The studies included in these estimates specified that their exposure results were obtained from a facility that performs polymerization of 1,3-butadiene and were full shift PBZ samples. They also were studies that used datasets from after 1997, which is the year when the current PEL was established for 1,3-butadiene (studies prior to the current PEL may skew the estimate high due to the higher limit) and included the number of samples within the statistics so that a weighted average could be calculated. The full list of studies used to assess this OES is summarized in Table 3-18. For more information about the exposure calculations, see *1,3-Butadiene Inhalation Monitoring Data Summary* (U.S. EPA, 2025a).

Table 3-18. Summary of Studies Used to Estimate Occupational Exposure for the Plastic and Rubber Polymerization OES

Reference and Country	Systematic Review Rating[a]	Data Used In Risk Evaluation[b]	Notes
(Abdel-Rahman et al., 2001) United States	Medium	2.24 ppm (mean) from 16 data points for workers; 0.02 ppm (mean) from 33 data points for ONUs.	SBR manufacturing from 2 facilities. Worker job descriptions or areas included: reactor, recovery, tank farm, laboratory and polymerization.
(Albertini et al., 2003) Czech Republic	High	Various means and maximums are provided ranging between 0.02 ppm and 4.18 ppm (means); 0.05 ppm and 17.64 ppm (maximums) from 319 total data points for workers.	SBR manufacturing from 1 facility. Worker job descriptions or areas included: operator, pipe fitter, shift foreman, rotating relief worker, polymerization line, degassing, additive preparation, adsorption compressors, and control room.
(Albertini et al., 2007) Czech Republic	High	Various means and maximums are provided ranging between 0.18 ppm and 0.37 ppm (means); 4.43 ppm and 5.69 ppm (maximums) from 530 data points for workers. 0.003 ppm and 0.004 ppm (means); 0.07 ppm and 0.099 ppm (maximums) from 509 data points for ONUs.	Process description indicates a polymerization facility. Sampling occurred between sets of facility exposed workers and control groups (ONUs).
(Ammenheuser et al., 2001) United States	High	3.18 ppm (mean) from 22 data points for workers; 0.15 ppm (mean) from 24 data points for ONUs.	SBR manufacturing from one facility. Worker job descriptions or areas included: reactor, recovery, tank farm, laboratory. ONU job descriptions or areas included: blending[c], coagulation, balancing, shipping, control room and utility.
(Anttinen-Klemetti et al., 2006) Finland	High	Various means are provided ranging between 0.07 ppm and 0.30 ppm from 885 data points for workers.	SB latex manufacturing from 3 facilities. Worker job descriptions listed as operators.
(Carrieri et al., 2014) Italy	High	0.03 ppm (mean) and 0.61 ppm (maximum) from 38 data points for workers.	One polymerization plant where BD is used. Worker job description or areas included: "Production unit."

Reference and Country	Systematic Review Rating[a]	Data Used In Risk Evaluation[b]	Notes
(Cheng et al., 2013) China	High	1.08 ppm (mean) and 5.6 ppm (maximum) from 44 data points for workers.	BD-exposed workers from the polybutadiene rubber workshop of one rubber factory. Process description/worker activities include measurement of quantities and polymerization.
(Ma et al., 2000) United States	Medium	20.8 ppm (maximum from 12 data points for workers.	One styrene-butadiene polymer plant. Worker activities were not described.
(Van Sittert, 2000) Czech Republic	Medium	0.82 ppm (mean) and 4.2 ppm (maximum) from 34 data points for workers.	One SBR manufacturing plant.
(Ward et al., 2001) United States	High	Various means are provided ranging between 0.29 ppm and 4.04 ppm from 23 data points for workers; 0.05 ppm (mean) from 14 data points for ONUs.	One SBR manufacturing plant. Worker job descriptions or areas included: tank farm, reactor, recovery, laboratory, and blending[c]. ONU job descriptions or areas labeled as "low areas" included: coagulation, bailing, packaging, water plant, shipping, warehouse and control room.
(Wickliffe et al., 2009) United States	High	0.09 ppm (mean) and 1.68 ppm (maximum) from 30 data points for workers.	One facility manufacturing polymerized polybutadiene rubber. Worker job descriptions or areas included production and recovery areas.

[a] See the *Systematic Review Protocol for 1,3-Butadiene* (U.S. EPA, 2025m) to learn about the systematic review process and the *Data Quality Evaluation and Data Extraction Information for Environmental Release and Occupational Exposure for 1,3-Butadiene* (U.S. EPA, 2025g) for the complete extraction from each of these studies.
[b] Most studies assigned non-detects with a value of 1/2 the LOD or limit of quantitation (LOQ). (Wickliffe et al., 2009) set non-detect values to the LOD. Ma, 2000 and (Van Sittert, 2000) did not specify the method of addressing non-detects.
[c] Note that "blending" was classified as a low exposure activity (used to estimate ONU exposure) in (Ammenheuser et al., 2001) and as a worker activity in (Ward et al., 2001). EPA defaulted to the individual source's judgement of what activities are high or low exposure at a particular facility.

Using the 8-hour TWA exposure concentrations estimated from the studies, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-19.

Table 3-19. 8-Hour Duration of Inhalation Exposures to Workers and ONUs to 1,3-Butadiene During Plastic and Rubber Polymerization

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of Samples[a]	1,953	1,007	580	509
8-hour TWA Exposure Concentrations	0.40	16.9	1.1E−02	9.9E−02
AC	0.27	11.5	7.8E−03	6.7E−02
$ADC_{intermediate}$	0.20	8.4	5.7E−03	5.0E−02
ADC	0.18	7.9	5.3E−03	4.6E−02
LADC	4.5E−02	2.5	1.3E−03	1.5E−02

Source: summary statistics from 11 occupational monitoring studies (Abdel-Rahman et al., 2001), (Albertini et al., 2003), (Albertini et al., 2007), (Ammenheuser et al., 2001), (Anttinen-Klemetti et al., 2006), (Carrieri et al., 2014), (Cheng et al., 2013), (Ma et al., 2000), (Van Sittert, 2000), (Ward et al., 2001), (Wickliffe et al., 2009).
[a] The number of non-detect samples among the total number of samples was not always specified in the studies, and so the total number of non-detect samples is unknown. Most studies reported to have assigned non-detects with a value of 1/2 the LOD or limit of quantitation (LOQ). Wickliffe et al., 2009 set non-detect values to the LOD. Ma et al., 2000 and Van Sittert, 2000 did not specify the method of addressing non-detects.

3.6 Plastics and Rubber Compounding and Converting

3.6.1 Process Description

After the polymerization process described in Section 3.5, compounding occurs which involves the blending into the polymers of various types of additives, including fillers, reinforcements, and colors to meet the requirements of specific applications for plastic materials (OECD, 2009b). Polymers that are manufactured using 1,3-butadiene include acrylonitrile butadiene styrene (ABS), polybutadiene, and styrene-butadiene, which are then involved in the compounding processes to produce final plastic and rubber products. Copolymers of styrene and butadiene containing over 45 percent 1,3-butadiene possess rubber like properties, while copolymers containing over 45 percent styrene have plastic or latex-like qualities (U.S. EPA, 1996).

ABS polymers can be compounded using batch and continuous melt mixers, and both single- and twin-screw extruders. The selected machine depends on the additives that are being mixed with the polymer, and whether the mixture requires dispersive mixing, distributive mixing, or both. ABS plastics and rubbers can be made in the compounding process by combining emulsion polymers having a high rubber content with mass- or suspension-polymerized styrene-acrylonitrile resin (Sun and Wristers, 2002).

For other types of 1,3-butadiene-containing plastics and rubbers, the ESD on Plastic Additives (OECD, 2009b) by OECD and the Draft Generic Scenario for Use of Additives in Plastics Compounding (U.S. EPA, 2021c) currently in development by EPA provide generic process descriptions for the compounding of plastics and rubbers. The GS indicates that during plastics compounding, a polymer resin is blended with additives and other raw materials to form a masterbatch in either open or closed blending processes (U.S. EPA, 2021c). Tumble blenders, ball blenders, gravity mixers, paddle/double arm mixers, intensive vortex action mixers, and Banbury internal mixers are all closed systems and are considered to be blending processes. Two-roll mills and extruders are partially open systems and represent all-in-one processes that perform blending and forming of the final compounded plastic or rubber (*e.g.*, pellets or sheets) (U.S. EPA, 2021c; OECD, 2009b). Figure 3-6 highlights typical release and exposure points during the use of 1,3-butadiene in plastics compounding.

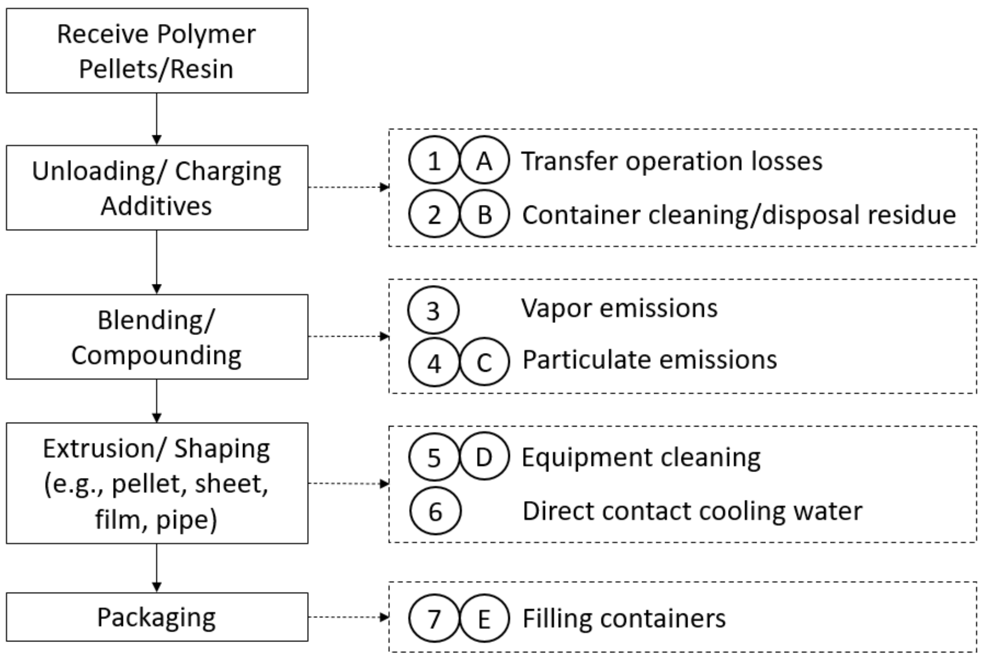

Figure 3-6. Typical Release and Exposure Points During Plastics Compounding
Source: (U.S. EPA, 2021c)

Environmental Releases:

1. Transfer operations losses to air, water, incineration, or landfill from container transfers of additives
2. Container residue cleaning/disposal losses to water, landfill, or incineration
3. Vapor emissions from blending/compounding to fugitive or stack air (liquid additives only)
4. Equipment cleaning residue losses to water, landfill, or incineration
5. Direct contact cooling water releases to water
6. Transfer operations losses to air, water, incineration, or landfill from loading compounded plastics into final containers (only applicable to pellets, granules, flakes, and other similar shapes)

Occupational Exposure:

A. Inhalation exposures to solids during unloading of additive chemicals
B. Inhalation exposure to solids during container cleaning
C. Inhalation exposure to dusts generated during blending/compounding process operations
D. Inhalation exposure to solids during packaging of compounded plastics containing additive chemical (only applicable to pellets, granules, flakes, and other similar shapes)

After the compounding process, compounded plastic and rubber resins are converted into solid articles. For butadiene-containing plastics and rubbers, common converting processes include injection molding, extrusion, calendaring, blow molding, and thermoforming (Sun and Wristers, 2002). In injection molding, heated resin is injected into a cold mold where the plastic takes the shape of the mold as it solidifies. In extrusion, heated resin is forced through a die and then quenched to form products such as pipe, profiles, sheets, and wire coating. In calendaring, heated resin is fed onto rolls that compress the material into a thin layer to form sheets and films (OECD, 2009b). There are two types of blow molding that plastic and rubber producers use: extrusion and injection blow molding. In extrusion blow molding, an extruder delivers a tubular extrudate (parison) between two halves of a mold which are brought together around the hot extrudate, closing its top and bottom. Air is blown into the parison, forcing the polymer melt against the sides of the mold. In injection blow molding, the parison, usually in a preform shape, is formed by injection molding. The parison is normally transferred directly to a blow molding unit or it may be cooled and stored as a preform. In thermoforming, a plastic sheet is locked in a frame and is heated to the forming temperature when it is brought into contact with a mold whose shape it assumes. In some cases, the process is assisted by drawing the sheet on to the form using vacuum, in others, pressure is applied. For all methods, in some cases the plastic product may undergo subsequent trimming to remove excess material. Other finishing operations, such as paint, coating, and bonding, may occur (these are covered under other COUs) (OECD, 2009b). Figure 3-7 below highlights typical release and exposure points during the use of 1,3-butadiene in plastics converting.

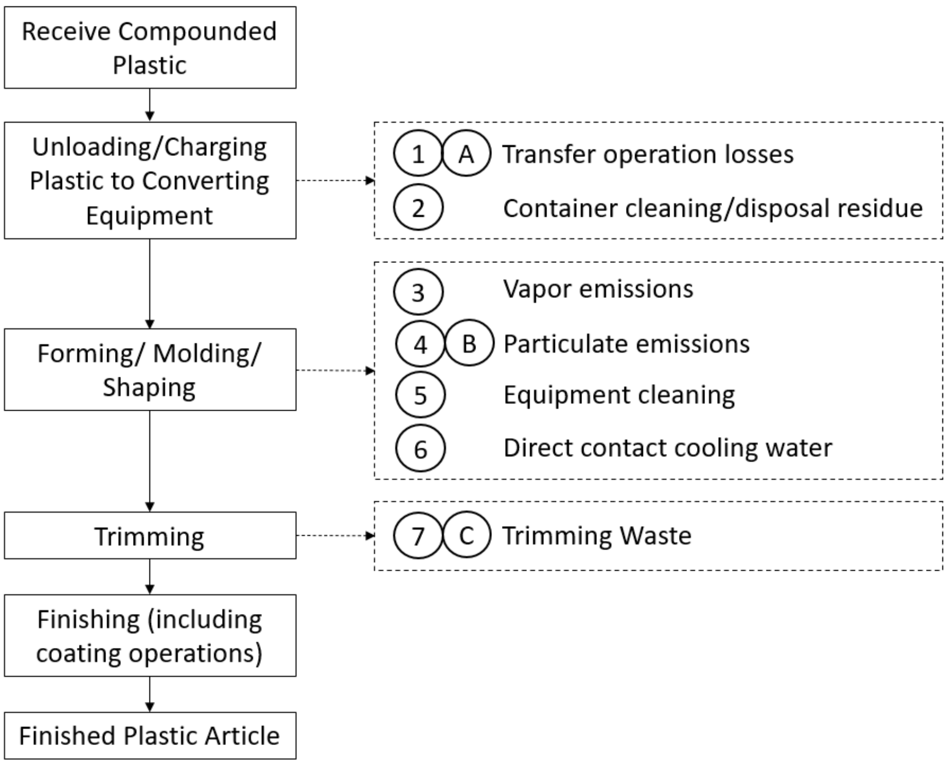

Figure 3-7. Typical Release and Exposure Points During Plastics Converting

Source: (U.S. EPA, 2004)

Environmental Releases:

1. Transfer operation losses to air, water, landfill or incineration from container transfers of compounded resin
2. Container residue cleaning/disposal losses to water, landfill, or incineration
3. Vapor emissions from converting to stack or fugitive air (liquid additives only)
4. Particulate emissions from converting to air, water, incineration, or landfill (all additive types)
5. Equipment cleaning losses to water, landfill, or incineration
6. Direct contact cooling water release to water
7. Solid waste from trimming operations to landfill or incineration

Occupational Exposure:

E. Inhalation exposures to solids during unloading of compounded resins
F. Inhalation exposure to dusts generated during converting processes

G. Inhalation exposure to solids during trimming activities

According to a comment submitted by the IISRP, at this point in the plastic and rubber manufacturing process, polymers that are compounded and converted such as BR and SSBR polymers contain less than 50 ppb of residual 1,3-butadiene monomer (EPA-HQ-OPPT-2018-0451-0027).

3.6.2 Facility Estimates

EPA used TRI, NEI, and CDR data between 2016 and 2021 to identify 77 facilities that potentially use 1,3-butadiene during plastic and rubber compounding and converting.

The IISRP estimates that 1,883,000 tons of butadiene-containing synthetic rubbers were compounded and converted. Of this capacity, 47.6 percent were styrene-butadiene rubbers, 33.2 percent were BRs, 18.1 percent were styrene block copolymers, 1.3 percent were acrylonitrile butadiene rubbers, and an unknown percentage was styrene isoprene butadiene rubbers (EPA-HQ-OPPT-2018-0451-0022). The ESD on Plastic Additives estimates 78 to 428 metric tons of ABS produced per site per year (78,000–428,000 kg/site-yr) (OECD, 2009b).

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of this assessment, each site can only be assigned to one OES. The OES was chosen using professional judgment to reflect the most prominent activity according to TRI and NEI reporting and the information on the company website. Because deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting these release sites in TRI (which was then adapted to NEI). If a facility had a primary NAICS code of 326113 (Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing), 326220 (Rubber and Plastics Hoses and Belting Manufacturing), or 326299 (All Other Rubber Product Manufacturing), plastics and rubber compounding and converting was assumed.

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to plastic and rubber compounding and converting that reported to CDR, TRI, and/or NEI.

EPA did not identify data on facility operating schedules. The ESD on Plastic Additives references European technical guidance, which estimates up to 300 operating days/year for the polymers industry (OECD, 2009b). EPA assumes 300 days/year of operation.

3.6.3 Release Assessment

3.6.3.1 Environmental Release Points

EPA expects releases to occur to air, water, landfill, or incineration from container transfers of compounded resin, container residue cleaning/disposal, vapor emissions from compounding and converting, equipment cleaning. EPA also expects releases to wastewater from direct contact cooling and incineration as well as landfill releases from solid waste trimming.

3.6.3.2 Environmental Release Assessment Results

EPA used 2016 through 2021 TRI, 2017 NEI, and 2020 NEI data to estimate environmental releases during the plastic and rubber compounding and converting of 1,3-butadiene, as presented in Table 3-20. According to reported data, 1,3-butadiene is released through the following environmental media: surface water, fugitive air, stack air, and land disposal. Note that two sites from TRI were assigned to the Plastic and rubber compounding and converting OES, one being a Form A facility where no release was reported but a release of 500 lb/year is assumed. See Section 2.3.3.2 for more information on EPA's handling of Form A facilities, and the *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) to see all facilities mapped to this OES.

Table 3-20. Summary of Environmental Releases During the Plastic and Rubber Compounding and Converting of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	– [a]	–	300	–	–	–	TRI
Fugitive air	113	215		0.38	0.72	2	TRI
Fugitive air	0.57	18		1.9E−03	7.3E−02	50	NEI
Stack air	113	215		0.38	0.72	2	TRI
Stack air	6	46		1.9E−02	0.14	57	NEI
Land	113	113		0.38	0.38	1	TRI

[a] Dashes (–) indicate that no data were reported to the respective source for the method of release.

3.6.4 Occupational Exposure Assessment

3.6.4.1 Worker Activities

Workers are potentially exposed to 1,3-butadiene via inhalation during the compounding and converting process. Additionally, workers may be exposed to 1,3-butadiene via inhalation of vapors during unloading and loading, transport container cleaning, and trimming of excess plastic (U.S. EPA, 2021d). EPA identified examples of engineering controls used at some plastic compounding and converting sites during rubber mixing and curing, such as a local exhaust ventilation for various operations including mixers (which are also generally enclosed with dedicated exhaust), mills, grinding or machining, and curing ovens to control emissions and limit worker exposure; however, the Agency did not identify the extent to which these engineering controls are used at other plastic compounding and converting sites (USTMA, 2020). One monitoring report from 1996 indicated that when exposure sampling occurred, workers sampled did not wear protective clothing or respirators (Anderson et al., 1996). Another report, encompassing exposure information from three companies that conduct operations associated with tire manufacturing, indicated that though PPE has not been specifically designated to control exposures to butadiene due to the low expected exposure potential, the standard PPE requirements in main operational areas of the factories (*i.e.*, raw materials weighing and transfer, rubber mixing, milling, calendaring, extrusion, and curing) include safety glasses, steel toe shoes, work gloves and in some areas hearing protection (USTMA, 2020).

ONUs include supervisors, managers, and other employees who work in the compounding and converting area but do not directly contact the plastic and rubber additives or products. Therefore, EPA expects the ONUs to have lower inhalation exposures than workers who handle the plastic and rubber additives or products.

3.6.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during plastics and rubber compounding and converting (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325212 – Synthetic Rubber Manufacturing
- 326100 – Plastics Product Manufacturing
- 326211 – Tire Manufacturing (except Retreading)
- 326220 – Rubber and Plastics Hoses and Belting Manufacturing
- 326299 – All Other Rubber Product Manufacturing

Table 3-21 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.6.2.

Table 3-21. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Plastics and Rubber Compounding and Converting

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
77	325212 – Synthetic Rubber Manufacturing	18	12
	326100 – Plastics Product Manufacturing		
	326211 – Tire Manufacturing (except Retreading)		
	326220 – Rubber and Plastics Hoses and Belting Manufacturing		
	326299 – All Other Rubber Product Manufacturing		

[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.

3.6.4.3 Occupational Inhalation Exposure Results

Within the Plastic and rubber compounding and converting OES, EPA estimated occupational exposure for both plastic and rubber compounding and plastic and rubber converting separately.

For plastic and rubber compounding, EPA found one full shift worker PBZ sample from OSHA CEHD and identified full shift PBZ worker samples from two studies which had high data quality ratings from systematic review (USTMA, 2020; Lee et al., 2012). The studies collected samples from workers at various rubber product manufacturing sites such as tire and tube manufacturing. The worker samples collected were described as block cutters, mill operators, lab operators, and chipper operators. From these datasets, EPA identified 53 8-hour samples and 44 12-hour samples (USTMA, 2020; Lee et al., 2012).

EPA did not identify any full shift ONU PBZ samples during data evaluation. Therefore, the Agency used the central tendency from workers to represent ONU exposures.

From the discrete monitoring data for plastic and rubber compounding, EPA calculated the 50th and 95th percentile 8- and 12-hour TWA concentrations to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these TWA exposure concentrations, the Agency calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-22 and Table 3-23 for an 8-hour and 12-hour duration respectively for rubber compounding. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-22. 8-Hour Duration of Inhalation Exposures of Workers to 1,3-Butadiene During Plastic and Rubber Compounding

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of Samples[a]	53		0	
8-hour TWA exposure concentrations	6.9E−04	0.21	6.9E−04	6.9E−04
AC	4.7E−04	0.14	4.7E−04	4.7E−04
$ADC_{intermediate}$	3.5E−04	0.10	3.5E−04	3.5E−04
ADC	3.2E−04	9.6E−02	3.2E−04	3.2E−04
LADC	7.9E−05	3.0E−02	7.9E−05	1.0E−04

Source: OSHA's CEHD (https://www.osha.gov/opengov/health-samples; accessed December 3, 2025) and discrete data from two monitoring studies (USTMA, 2020; Lee et al., 2012)
[a] Seven of the 53 data points for workers were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.

Table 3-23. 12-Hour Duration of Inhalation Exposures of Workers to 1,3-Butadiene During Plastic and Rubber Compounding

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of Samples[a]	44		0	
12-hour TWA exposure concentrations	0.10	0.30	0.10	0.10
AC	0.10	0.31	0.10	0.10
$ADC_{intermediate}$	7.6E−02	0.23	7.6E−02	7.6E−02
ADC	4.7E−02	0.14	4.7E−02	4.7E−02
LADC	1.2E−02	4.5E−02	1.2E−02	1.5E−02

Source: OSHA's CEHD (https://www.osha.gov/opengov/health-samples; accessed December 3, 2025) and discrete data from two monitoring studies (USTMA, 2020; Lee et al., 2012)
[a] Tenty-five of the 44 data points for workers were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.

For plastic and rubber converting, the same dataset was utilized for the estimation, except the one 8-hour datapoint obtained from OSHA CEHD, and two 8-hour data points within the Lee and colleagues study that were specifically labeled as rubber compounding. Therefore, to estimate occupational exposure for plastic and rubber converting, EPA identified 50 8-hour samples and 44 12-hour samples (USTMA, 2020; Lee et al., 2012).

From this discrete monitoring data for plastic and rubber converting EPA calculated the 50th and 95th percentile 8- and 12-hour TWA concentrations to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-24 and Table 3-25 for an 8-hour and 12-hour duration respectively. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-24. 8-Hour Duration of Inhalation Exposures of Workers to 1,3-Butadiene During Plastics and Rubber Converting

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of Samples[a]	50		0	
8-hour TWA Exposure Concentrations	5.0E−04	0.18	5.0E−04	5.0E−04
AC	3.4E−04	0.12	3.4E−04	3.4E−04
$ADC_{intermediate}$	2.5E−04	9.0E−02	2.5E−04	2.5E−04
ADC	2.3E−04	8.4E−02	2.3E−04	2.3E−04
LADC	5.7E−05	2.6E−02	5.7E−05	7.3E−05

Source: OSHA's CEHD (https://www.osha.gov/opengov/health-samples; accessed December 3, 2025) and discrete data from two monitoring studies (USTMA, 2020; Lee et al., 2012)
[a] Six of the 50 data points for workers were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.

Table 3-25. 12-Hour Duration of Inhalation Exposures of Workers to 1,3-Butadiene During Plastic and Rubber Converting

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	44		0	
12-hour TWA exposure concentrations	0.10	0.30	0.10	0.10
AC	0.10	0.31	0.10	0.10
$ADC_{intermediate}$	7.6E−02	0.23	7.6E−02	7.6E−02
ADC	4.7E−02	0.14	4.7E−02	4.7E−02

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
LADC	1.2E−02	4.5E−02	1.2E−02	1.5E−02

Source: OSHA's CEHD (https://www.osha.gov/opengov/health-samples; accessed December 3, 2025) and discrete data from two monitoring studies (USTMA, 2020; Lee et al., 2012)

[a] Twenty-five of the 44 data points for workers were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.

3.7 Distribution in Commerce

3.7.1 Process Description

EPA expects that 1,3-butadiene and 1,3-butadiene-containing products are distributed throughout commerce from manufacturing sites to processing repackaging sites. Repackaging sites are expected to distribute 1,3-butadiene for laboratory use or other downstream uses. Liquified 1,3-butadiene is transported in pressurized containers via railroads, tankers, pipelines, ships, barges, and bulk liquid containers. Before transport, 1,3-butadiene is required to be inhibited. The current recognized inhibitor is TBC. Also, to minimize the formation of peroxides in 1,3-butadiene during shipping and handling, the oxygen level in the vapor space of loaded equipment is not to exceed 1,000 ppm (EPA-HQ-OPPT-2018-0451-0021). Storage of 1,3-butadiene along with other light hydrocarbons are highly specialized. 1,3-Butadiene should be stored in a cool, dry, and well-ventilated area in tightly sealed and pressurized containers. Outside, isolated, or detached storage is preferred; inside storage should be in a non-combustible location as 1,3-butadiene is explosive when mixed with air (U.S. EPA, 1996; NIOSH, 1992).

Distribution of 1,3-butadiene in commerce may include loading and unloading activities that occur during other life cycle stages (*e.g.*, manufacturing, processing, repackaging), transit activities that involve the movement of the chemical (*e.g.*, via trucks, railcars, barges), and temporary storage and warehousing of the chemical during distribution—excluding repackaging and other processing activities that are included in other COUs. In all cases EPA assessed the distribution in commerce activities resulting in releases and exposures such as loading/unloading within the relevant COUs rather than as a single separate distribution scenario. The purpose of including this OES is to present available data from accidental spills that have occurred during the transportation of 1,3-butadiene between facilities.

Figure 3-8 shows an illustration of the distribution in commerce. The illustration shows red shading indicating loading and unloading activities related to distribution in commerce included in the assessment of the COUs within other life cycle stages. The red arrows indicate transport activities of distribution in commerce, which include the transit via trucks, railcars, and barges, and any temporary storage or warehousing, relabeling, and redistribution. The transport activities are what connect the life cycle stages (manufacture, processing, use, and disposal) together.

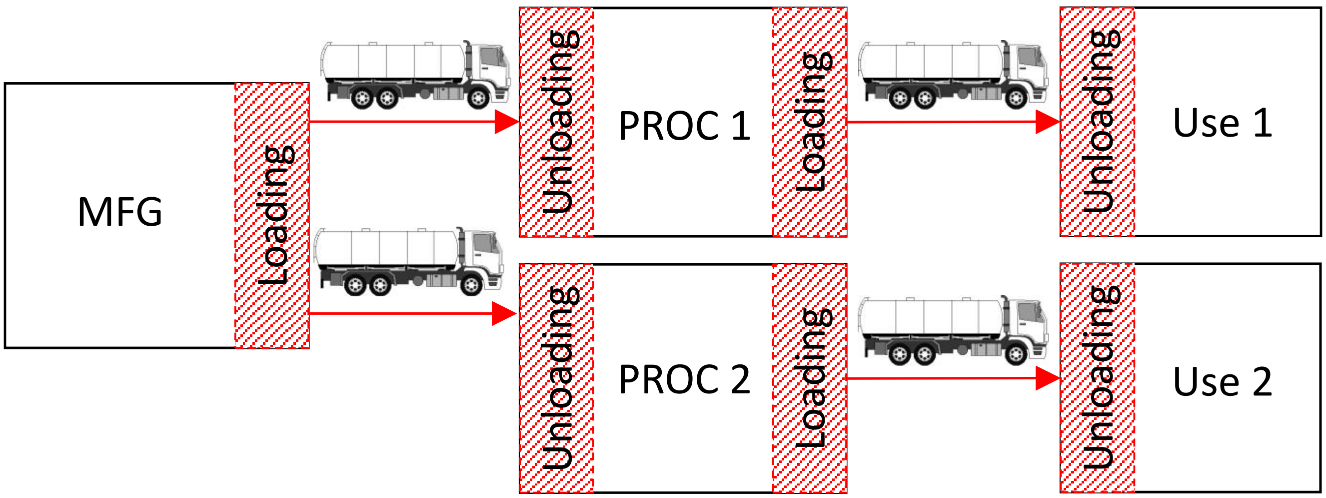

Figure 3-8. Illustration of Distribution in Commerce and its Relation to Other Life Cycle Stages

EPA did not identify data on the total volume of 1,3-butadiene distributed in commerce nor volumes typically transported by a transportation company over any timeframe. As discussed above, because the Agency is not separately assessing releases and exposures in a single distribution in commerce scenario, EPA did not estimate 1,3-butadiene volumes or operating days for this COU.

In this section EPA includes reported accidental spills and releases, as these are releases that occur during the distribution in commerce. However, these releases are not predictable or regular occurrences, and so information such as estimated release range, release days, and number of facilities are indeterminable.

3.7.2 Facility Estimates

Distribution in commerce involves transportation of 1,3-butadiene between facilities that manage 1,3-butadiene at the various life cycle stages. Other OESs address the facility information relevant to handling 1,3-butadiene in each of these life cycle stages. EPA did not quantify the number of transportation/warehousing companies or facilities, volume of 1,3-butadiene transported, or number of transport vehicles. The amount of 1,3-butadiene distributed in commerce will scale with the demand for 1,3-butadiene and 1,3-butadiene-containing products.

3.7.3 Release Assessment

3.7.3.1 Environmental Release Points

During transportation, releases may occur from accidental releases of the compound during spill events. This section provides further information on these release sources. Additional information associated with accidental spill cleanup can be found in the following sources.[3] [4]

3.7.3.2 Environmental Release Assessment Results

When evaluating releases related to distribution in commerce of 1,3-butadiene, EPA considered two sources: NRC data and DOT data from the Hazmat Incident Report Search Tool.[5] EPA examined data

[3] 40 CFR 300.415 Hazardous Substance Response; eCFR: 40 CFR 300.415 – Removal action (accessed October 20, 2025)
[4] Traffic Incident Management in Hazardous Materials Spills in Incident Clearance. Chapter 4.0 Hazard Materials Incident Clearance Compliance Requirements; https://ops.fhwa.dot.gov/publications/fhwahop08058/40.htm (accessed October 20, 2025)
[5] DOT Hazmat Incident Report Search Tool (accessed December 1, 2025)

corresponding to the 2016 to 2021 calendar years for these data sources.

Section 103 of CERCLA requires the person in charge of a vessel or an onshore or offshore facility immediately notify the NRC when a CERCLA hazardous substance is released at or above the reportable quantity (RQ) in any 24-hour period, unless the release is federally permitted.[6] The NRC is an emergency call center maintained and operated by the U.S. Coast Guard that fields initial reports for pollution and railroad incidents. Information reported to the NRC is available on itswebsite.[7]

EPA downloaded NRC data for the 2016 to 2021 calendar years and reviewed it for reports pertaining to distribution of 1,3-butadiene. Upon review, the Agency found that 26 of reported releases for 1,3-butadiene appeared to occur during distribution of the chemical. Note that loading and unloading activities are covered in other COUs, and incident reports during those activities are not included in the totals below. Information on these incidents is summarized in Table 3-26, noting that amounts are estimates from initial reports.

Table 3-26. Releases of 1,3-Butadiene from Spills, Reported to NRC Between 2016–2021

Year of Incident	Amount Released (lb, Unless Otherwise Noted)	Type of Incident	State
2016	48	VESSEL	TX
2016	UNKNOWN AMOUNT	RAILROAD	TN
2016	2 (gallons)	MOBILE	CO
2016	UNKNOWN AMOUNT	RAILROAD	AR
2016	UNKNOWN AMOUNT	RAILROAD	AL
2017	1	VESSEL	LA
2017	UNKNOWN AMOUNT	VESSEL	LA
2017	UNKNOWN AMOUNT	RAILROAD	TN
2017	UNKNOWN AMOUNT	RAILROAD	OH
2017	UNKNOWN AMOUNT	RAILROAD	TX
2017	UNKNOWN AMOUNT	RAILROAD	LA
2017	UNKNOWN AMOUNT	MOBILE	NC
2018	UNKNOWN AMOUNT	RAILROAD	OH
2018	261	MOBILE	LA
2018	0.5 (cups)	VESSEL	LA
2018	UNKNOWN AMOUNT	RAILROAD	OH
2018	17.5	PIPELINE	TX
2019	10	MOBILE	TX
2019	UNKNOWN AMOUNT	VESSEL	IL
2019	UNKNOWN AMOUNT	RAILROAD	LA

[6] CERCLA 103 – Release Notification (accessed December 1, 2025)
[7] U.S. Coast Guard National Response Center (accessed December 1, 2025)

Year of Incident	Amount Released (lb, Unless Otherwise Noted)	Type of Incident	State
2019	UNKNOWN AMOUNT	PIPELINE	TX
2019	UNKNOWN AMOUNT	RAILROAD	LA
2020	10	PIPELINE	LA
2020	10	VESSEL	TX
2021	UNKNOWN AMOUNT	RAILROAD	WV
2021	UNKNOWN AMOUNT	RAILROAD	TN

It is important to note that the data reported to NRC in the past does not correlate to possible spills in the future. Due to the lack of correlation, EPA is unable to estimate the frequency or volume of any spills that may occur in the future or provide estimates representative of a "typical" spill, as each spill represents a unique scenario.

EPA downloaded DOT data from the Hazmat Incident Report Search Tool for the 2016 to 2021 calendar years and reviewed it for reports pertaining to distribution of 1,3-butadiene. Upon review, EPA found four reported releases for 1,3-butadiene that appeared to occur during distribution of the chemical. Note that loading and unloading activities are covered in other COUs and incident reports during those activities are not included in the below totals. Information on these incidents is summarized in Table 3-27, noting amount is the estimate from initial reports. Since these releases are not predictable or regular occurrences, information such as estimated release range, release days, and number of facilities are indeterminable. Due to this, further analysis was not performed on these incidental releases occurring due to distribution of 1,3-butadiene in commerce.

Table 3-27. Releases of 1,3-Butadiene Reported to DOT Between 2016–2021 Through the Hazmat Incident Report Search Tool

Year of Incident	Amount Released (cubic foot of gas)	Type of Incident	State
2016	1.3E−02	Rail	TN
2019	0.13	Rail	TX
2019	0.27	Rail	LA
2021	1.7E−05	Rail	TX

3.7.4 Occupational Exposure Assessment

EPA did not identify data to estimate the magnitude or frequency of worker exposures from spill cleanup activities occurring from distribution in commerce of 1,3-butadiene. The Agency expects the magnitude of exposure to be dependent on the size and location of the spill and may have large variability. For example, the 0.5 cups spilled from a vessel in Louisiana cited in Table 3-27 above may have resulted in relatively low exposures due to the small volume of 1,3-butadiene released, whereas a much larger spill, such as the 261 lb spilled from a mobile source in the same state, may result in significantly higher exposures to cleanup workers.

Similarly, the duration of spill cleanups is expected to be dependent on the specifics of each chemical spill and could take minutes or days after the spill event to complete.

Although EPA generally considers loading and unloading activities as part of distribution in commerce, in this assessment the exposures resulting from these activities are covered within each individual OES where the activity occurs (*i.e.*, unloading of 1,3-butadiene at a manufacturing facility is covered under the Manufacturing OES). Similarly, tank cleaning activities, which occur after unloading of 1,3-butadiene, are also assessed as part of the individual OES where the activity occurs.

3.8 Use of Laboratory Chemicals

3.8.1 Process Description

The final scope for 1,3-butadiene lists laboratory use as an in-scope COU (U.S. EPA, 2020c). A safety data sheet (SDS) for 1,3-butadiene (>99% percent purity) indicates recommended use as a laboratory chemical. Specific uses include demonstration of Diels Alder reactions, synthesis of thermoplastic resins, and synthesis of disilylated dimers by reacting with chlorosilanes. 1,3-Butadiene for use in a laboratory may be transported in a steel cylinder with a brass needle valve at volumes of 100 g up to 1 kg (Sigma-Aldrich, 2024). EPA expects 1,3-butadiene to arrive as a pressurized liquid in these small containers or drums received from the manufacturer or repackager. 1,3-Butadiene is used in these laboratory procedures and then disposed of with other laboratory wastes. Figure 3-9 below highlights the typical release and exposure points during the use of 1,3-butadiene as a laboratory chemical.

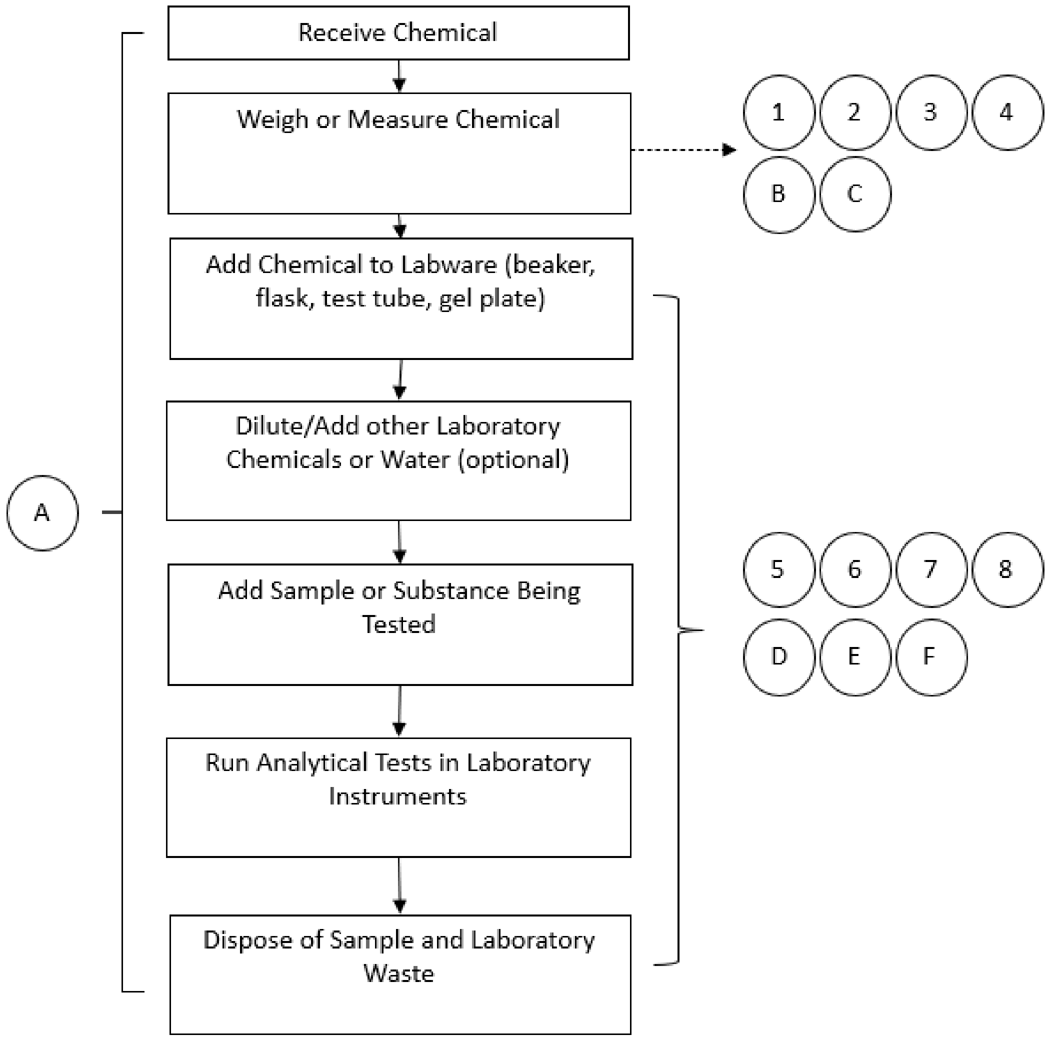

Figure 3-9. Typical Release and Exposure Points During the Laboratory Use of 1,3-Butadiene

Source: (U.S. EPA, 2023)

Environmental Releases:

1. Release to air from transferring volatile chemicals from transport containers.
2. Release to air, water, incineration, or landfill from transferring solid powders.
3. Release to water, incineration, or land from cleaning or disposal of transport containers.
4. Release to air from cleaning containers used for volatile chemicals.
5. Labware equipment cleaning residuals released to water, incineration, or landfill.
6. Release to air during labware equipment cleaning for volatile chemicals.
7. Release to air from laboratory analyses for volatile chemicals.
8. Release to water, incineration, or landfill from laboratory waste disposal.

Occupational Exposures:

A. Full shift inhalation exposure from all activities.
B. Inhalation exposure from unloading chemicals from transport containers (if full shift estimates are not used).
C. Inhalation exposure during container cleaning throughout sample preparation and testing activities (if full shift estimates are not used).
D. Inhalation exposure during equipment cleaning (if full shift estimates are not used).
E. Inhalation exposure during laboratory analyses (if full shift estimates are not used).
F. Inhalation exposure during disposal of laboratory chemicals (non-quantifiable).

3.8.2 Facility Estimates

Between 2017 and 2020, EPA used NEI to identify five facilities that potentially use 1,3-butadiene as a laboratory chemical (no facilities were found in TRI or CDR). The Agency did not identify data on facility operating schedules; therefore, EPA assumes operation 5 days/week for 50 weeks/year. This results in 250 days/year of operation (see Section 2.3.2).

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to use as a laboratory chemical that reported to CDR, TRI, and/or NEI.

3.8.3 Release Assessment

3.8.3.1 Environmental Release Points

EPA expects releases to air, water, incineration, or landfill from transferring volatile chemicals from transport containers, cleaning or disposal of transport containers, cleaning containers used for volatile chemicals, labware equipment cleaning residuals, labware equipment cleaning, laboratory analyses, and laboratory waste disposal.

3.8.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI to estimate environmental releases during the use of 1,3-butadiene as a laboratory chemical, as presented in Table 3-28. No facilities were found in TRI and so no information was found on water or land releases. According to reported data, 1,3-butadiene is released through the fugitive air and stack air.

Table 3-28. Summary of Environmental Releases for the Use as Laboratory Chemical of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	–[a]	–	250	–	–	–	TRI
Fugitive air	–	–		–	–	–	TRI
Fugitive air	6.4E−02	6.3		2.6E−04	2.5E−02	4	NEI
Stack air	–	–		–	–	–	TRI
Stack air	37	53		0.1	0.14	1	NEI
Land	–	–		–	–	–	TRI

[a] Dashes (–) indicate that no data were reported to the respective source for the method of release.

3.8.4 Occupational Exposure Assessment

3.8.4.1 Worker Activities

Worker exposures to 1,3-butadiene may occur through the inhalation of vapors while unloading and transferring laboratory chemicals, container cleaning, labware and labware equipment cleaning, laboratory analysis, and disposal of laboratory wastes (U.S. EPA, 2023). EPA did not find information on the extent to which laboratories that use 1,3-butadiene-containing chemicals also use engineering controls and/or worker PPE.

ONUs include supervisors, managers, and other employees who do not directly handle the laboratory chemical or laboratory equipment but may be present in the laboratory or analysis area. ONU inhalation exposures may occur while the ONU is present in the laboratory; however, EPA expects the ONUs to have lower inhalation exposures than workers who handle the laboratory chemicals and perform the analyses.

3.8.4.2 Number of Workers and Occupational Non-users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during use of laboratory chemicals (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 541380 – Testing Laboratories
- 541712 – Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)

Table 3-29 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.8.2.

Table 3-29. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Use as a Laboratory Chemical

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
5	541380 – Testing Laboratories 541712 – Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)	2	2

[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.

3.8.4.3 Occupational Inhalation Exposure Results

EPA did not identify monitoring data for the Laboratory use OES; however, the Agency expects the exposures to be similar to laboratory technician worker activities during the Manufacturing OES. Therefore, EPA used the manufacturing monitoring data as "analogous data" for laboratory use. The Agency refers to analogous monitoring data as monitoring data for the same chemical and a similar OES.

EPA identified 215 full shift laboratory technician PBZ samples from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). Laboratory technicians are responsible for sample collection and chemical analysis of process and product samples for the facility. The Agency did not identify any full shift ONU PBZ samples during data evaluation. Therefore, EPA used the central tendency from workers to represent ONU exposures.

EPA compiled the 50th and 95th percentile 8- and 12-hour TWA concentrations to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8-hour TWA exposure concentrations, the Agency calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-30 and Table 3-31 for an 8- and 12-hour duration respectively. The Agency calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-30. 8-Hour Duration of Inhalation Exposures of Workers to 1,3-Butadiene During Use as a Laboratory Chemical

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	215		39	
8-Hour TWA exposure concentrations	6.8E−03	0.24	5.8E−03	2.0E−02
AC	4.6E−03	0.16	3.9E−03	1.4E−02
Intermediate Average Daily Concentration ($ADC_{intermediate}$)	3.4E−03	0.12	2.9E−03	1.0E−02
Average Daily Concentration (ADC)	3.2E−03	0.11	2.7E−03	9.5E−03
Lifetime Average Daily Concentration (LADC)	7.8E−04	3.5E− 02	6.6E−04	3.0E−03

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)
[a] A total of 57 of the 215 data points for workers were above the method's LOD. Nine of the 39 data points for ONUs were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.

Table 3-31. 12-Hour Duration of Inhalation Exposures of Workers to 1,3-Butadiene During Use as a Laboratory Chemical

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	215		39	
12-Hour TWA exposure concentrations	6.8E−03	0.24	5.8E−03	2.0E−02
AC	7.0E−03	0.24	5.9E−03	2.1E−02
Intermediate Average Daily Concentration ($ADC_{intermediate}$)	5.1E−03	0.18	4.3E−03	1.5E−02
Average Daily Concentration (ADC)	3.2E−03	0.11	2.7E−03	9.5E−03

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Lifetime Average Daily Concentration (LADC)	7.8E−04	3.5E− 02	6.6E−04	3.0E−03
Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) [a] A total of 57 of the 215 data points for workers were above the method's LOD. Nine of the 39 data points for ONUs were above the method's LOD. EPA used the MLE method to determine the 50th and 95th percentile for the central tendency and high-end respectively.				

3.9 Application of Paints and Coatings

3.9.1 Process Description

The final scope for 1,3-butadiene lists that the chemical is used in industrial and commercial application of paints and coatings (U.S. EPA, 2020c). 1,3-Butadiene was identified as possibly being present in multiple paint and coating products, including aerosol propellants, architectural paints and coatings, latex paints, electro-dipping coatings, and automotive primers (ACA, 2019; OECD, 2009c).

The application procedure depends on the type of paint or coating formulation and the type of substrate. In some types of application, the formulation is loaded into the application reservoir or apparatus and applied to the substrate via brush, spray, roll, dip, curtain, or syringe or bead application. Application may be manual or automated. After application, the adhesive, sealant, paint, or coating is allowed to dry or cure (OECD, 2015b). The drying/curing process may be promoted through the use of heat or radiation (radiation can include ultraviolet [UV] and electron beam radiation (OECD, 2010). EPA did not find specific container information for 1,3-butadiene used in the application of paints, coatings, adhesives, and sealants. A diagram of the radiation curable application process is show below in Figure 3-10.

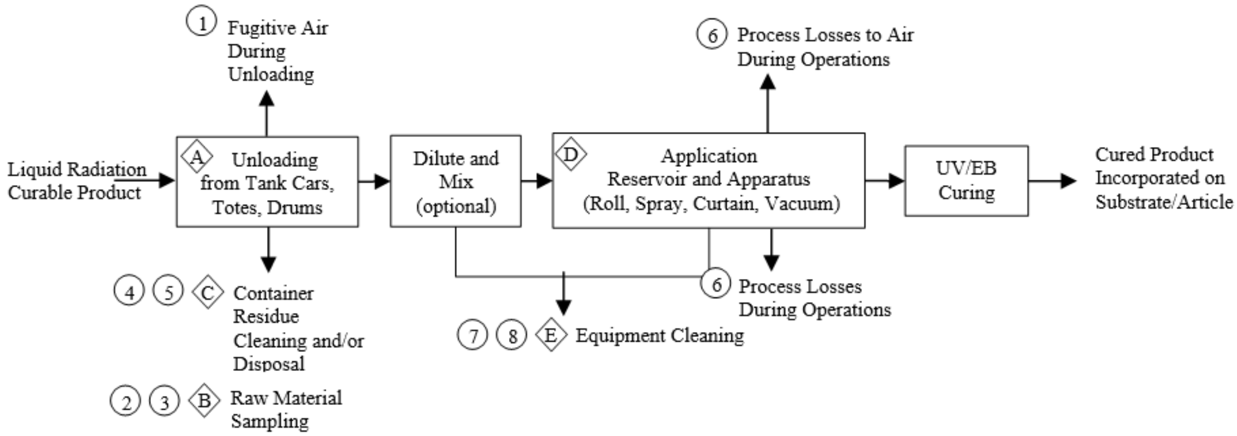

Figure 3-10. General Radiation Curable Coating Process

Source: (OECD, 2011b)

Environmental Releases:

1. Transfer operation losses of volatilized 1,3-butadiene to air from unloading the radiation curable product.
2. Raw material sampling losses to water, incineration, or landfill.
3. Open surface losses of volatilized 1,3-butadiene to air during raw material sampling.
4. Container residue losses to water, incineration, or landfill from radiation curable product transport containers.
5. Open surface losses of volatilized 1,3-butadiene to air during container cleaning.
6. Process losses to air from vented or captured overspray during spray coating operations. Process losses to water, land, or incineration from disposal of spent coating during roll, spray, or curtain coating.
7. Equipment cleaning losses to incineration or landfill.
8. Open surface losses of volatilized 1,3-butadiene to air during equipment cleaning.

Occupational Exposures:

A. Inhalation exposure from unloading chemicals from transport containers.
B. Inhalation exposure during sampling activities.
C. Inhalation exposure during container cleaning.
D. Inhalation exposure during coating application.
E. Inhalation exposure during equipment cleaning.

The American Coatings Association noted in a public comment that "Manufacturers note residual amounts of the chemical in … architectural paints and coatings" (EPA-HQ-OPPT-2018-0451-0005). SPIN identified use of 1,3-butadiene in paints, lacquers and varnishes up to year 2016 in Nordic countries. SPIN also identifies use of 1,3-butadiene in surface treatment in Nordic countries up to year 2016.

EPA initially identified two paints and coatings products containing 1,3-butadiene—an asphalt emulsion coating and a shellac sealer—however, upon further investigation and discussions with the manufacturers, 1,3-butadiene was erroneously reported on the SDSs for the products. Despite the lack of products, 1,3-butadiene releases are still present at some NEI facilities mapped to the Paints and coatings OES, indicating 1,3-butadiene's presence in the industry.

3.9.2 Facility Estimates

EPA used 2017 and 2020 NEI data to identify 28 facilities that potentially use 1,3-butadiene during the application of paints and coatings (no facilities were found in TRI or CDR). The Agency did not locate any chemical-specific throughputs or use rates for 1,3-butadiene in the application of paints and coatings. However, typical consumption rates of coating components in automobile refinishing are provided in the ESD on the Coating Industry. To coat the whole body of a vehicle, 0.62 to 9.0 L of coating are needed, depending on the size of the vehicle. The average annual facility use rate for all automotive refinishing coating products is 54,633,000 gallons/yr, and the estimated daily volume use rate per site is 0.25 to 15 gallons of coating/site-day (OECD, 2011a, 2009c).

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to application of paints and coatings that reported to CDR, TRI, and/or NEI.

EPA did not identify data on facility operating schedules. The ESD on the Application of Radiation Curable Coatings, Inks, and Adhesives provides an estimate of 250 operating days/year (OECD, 2010).

3.9.3 Release Assessment

3.9.3.1 Environmental Release Points

Environmental releases may occur during the processes of unloading, material sampling, transport, container cleaning, air that is vented or captured during the spray operation, during the drying or curing processes, and during the cleaning and disposal of equipment. EPA expects releases to wastewater, incineration, or landfill from small container residue, equipment cleaning waste, application process waste, and trimming waste.

3.9.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI data to estimate environmental releases during the use of 1,3-butadiene in the application of paints, coatings, adhesives, and sealants (Table 3-32). No facilities were found in TRI and so no information was found on water or land releases. According to reported data, 1,3-butadiene is released through the following environmental media: fugitive air and stack air, incineration, and land disposal.

Table 3-32. Summary of Environmental Releases of 1,3-Butadiene During Use in the Application of Paints and Coatings

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	–[a]	–	250	–	–	–	TRI
Fugitive air	–	–		–	–	–	TRI
Fugitive air	0.20	31		5.7E−04	0.12	14	NEI
Stack air	–	–		–	–	–	TRI
Stack air	13	370		4.4E−02	1.1	19	NEI
Land	–	–		–	–	–	TRI

[a] Dashes (–) indicate that no data were reported to the respective source for the method of release.

3.9.4 Occupational Exposure Assessment

3.9.4.1 Worker Activities

During the use of 1,3-butadiene-containing paints and coatings, workers are potentially exposed to 1,3-butadiene mist when roll, curtain, or spray coating. Vapor inhalation exposures for workers may also occur during product unloading, raw material sampling, application, 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 1,3-butadiene-containing paints and coatings.
For this OES, ONUs would include supervisors, managers, and other employees who do not directly handle paint or coating equipment but may be present in the spray application area. EPA expects the ONUs to have lower inhalation exposures than workers who handle the paint and coating products.

3.9.4.2 Number of Workers and Occupational Non-users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during the application of paints and coatings (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 337110 – Wood Kitchen Cabinet and Countertop Manufacturing
- 337122 – Nonupholstered Wood Household Furniture Manufacturing
- 337124 – Metal Household Furniture Manufacturing
- 337127 – Institutional Furniture Manufacturing
- 337211 – Wood Office Furniture Manufacturing
- 337212 – Custom Architectural Woodwork and Millwork Manufacturing
- 337214 – Office Furniture (except Wood) Manufacturing
- 337215 – Showcase, Partition, Shelving, and Locker Manufacturing
- 811120 – Automotive Body, Paint, Interior, and Glass Repair

Table 3-33 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.9.2.

Table 3-33. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Applications of Paints and Coatings

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
228 (median) 1,530 (high-end)	337110 – Wood Kitchen Cabinet and Countertop Manufacturing	8	3
	337122 – Nonupholstered Wood Household Furniture Manufacturing		
	337124 – Metal Household Furniture Manufacturing		
	337127 – Institutional Furniture Manufacturing		
	337211 – Wood Office Furniture Manufacturing		
	337212 – Custom Architectural Woodwork and Millwork Manufacturing		
	337214 – Office Furniture (except Wood) Manufacturing		

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
	337215 – Showcase, Partition, Shelving, and Locker Manufacturing		
	811120 – Automotive Body, Paint, Interior, and Glass Repair		
[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.			

3.9.4.3 Occupational Inhalation Exposure Results

For exposure during the application of paints and coatings containing 1,3-butadiene, EPA identified 43 worker PBZ samples from OSHA CEHD (https://www.osha.gov/opengov/health-samples; accessed December 1, 2025). The data spanned five facilities ranging from 2000 to 2016. However, all samples tested were below the reportable LOD. Based on facility information, EPA assumes that butadiene is present in the paint, coating, adhesive, or sealant formulations used at the facilities. Therefore, the Agency assessed the high-end inhalation exposures as the LOD and the central tendency as the LOD ÷ 2. The LOD was from the OSHA 56 air sampling method for 1,3-butadiene. EPA did not identify any ONU PBZ samples during data evaluation. Therefore, the Agency used the central tendency from workers to represent ONU exposures.

Using these 8-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-34. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-34. Inhalation Exposures of Workers to 1,3-Butadiene During Use of Paints and Coatings

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	43		0	
8-hour TWA exposure concentrations	4.5E−02	9.0E−02	4.5E−02	4.5E−02
AC	3.1E−02	6.2E−02	3.1E−02	3.1E−02
$ADC_{intermediate}$	2.3E−02	4.5E−02	2.3E−02	2.3E−02
ADC	2.1E−02	4.2E−02	2.1E−02	2.1E−02
LADC	5.2E−03	1.3E−02	5.2E−03	6.7E−03

Source: OSHA data from https://www.osha.gov/opengov/health-samples (accessed December 1, 2025)
[a] All values were below the LOD. Used LOD ÷ 2 for the central tendency and the LOD for the central tendency. ONU data not available; used the central tendency from worker estimates.

3.10 Application of Adhesives and Sealants

3.10.1 Process Description

The final scope for 1,3-butadiene lists that the chemical is used in industrial and commercial application of adhesives and sealants (U.S. EPA, 2020c). 1,3-Butadiene was identified in multiple adhesive and sealant products, including aerosol propellants, adhesive films, epoxy resins (incorporated for their tensile and elastomeric properties), tackifier solution, and adhesives for electrical and circuit boards (ACA, 2019; OECD, 2009c), (EPA-HQ-OPPT-2018-0451-0009). One public comment stated that 1,3-butadiene-containing conformal coating plays a vital role in protecting circuit boards and is applied to various components to prevent electrical shorts and premature failures; while a polyurethane potting compound formulation is used to encapsulate electronic parts for electrical insulation. Additionally, composite systems that include 1,3-butadiene are used in structural components such as landing gear doors, fairings, wing flaps, and certain interior elements on the aircraft (EPA-HQ-OPPT-2024-0425-0081).

EPA initially identified four adhesive and sealant products that contained 1,3-butadiene. Upon further investigation and discussions with the manufacturers, it was confirmed that all but one of these products had reported the presence of 1,3-butadiene erroneously. The remaining product is a tire patch that contains 23 to 24 percent 1,3-butadiene (Highline Warren, 2015).

The application procedure depends on the type of adhesive or sealant formulation and the type of substrate. In some types of application, the formulation is loaded into the application reservoir or apparatus and applied to the substrate via brush, spray, roll, dip, curtain, or syringe or bead application. Application may be manual or automated. After application, the adhesive, sealant, paint, or coating is allowed to dry or cure (OECD, 2015b). The drying/curing process may be promoted through the use of heat or radiation; the latter can include UV light and electron beam radiation (OECD, 2010). EPA did not find specific container information for 1,3-butadiene used in the application of adhesives and sealants. A diagram of the radiation curable application process is shown in Figure 3-10 in the previous section is also applicable to describing possible releases and exposures due to application of adhesives and sealants.

3.10.2 Facility Estimates

EPA used 2017 and 2020 NEI data to identify one facility that potentially uses 1,3-butadiene during the application of adhesives and sealants (no facilities were found in TRI or CDR). Because a single site would not provide a representative sample of the possible releases of facilities that may use 1,3-butadiene in the application of adhesives and sealants, EPA used NAICS codes and Monte Carlo modeling to determine a reasonable estimate for the number of facilities. The range of the number of facilities representing the 50th and 95th percentiles estimated using Monte Carlo modeling was 60 to 1,133 sites.

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to application of adhesives and sealants that reported to CDR, TRI, and/or NEI.

EPA estimated the PV for the application of adhesives and sealants OES using the national production range according to 2020 CDR data, an ACC report detailing 1,3-butadiene use, and a technical report estimating air emissions of 1,3-butadiene (ToxStrategies, 2021; U.S. EPA, 2020a, 1996). The ACC report provided conversion rates for several end formulation product types including but not limited to styrene-butadiene rubber, adiponitrile, and neoprene rubber (EPA-HQ-OPPT-2018-0451-0041). EPA provided a percentage breakdown of 1,3-butadiene use within each formulation product type for specific end use categories, including adhesives and sealants (U.S. EPA, 1996). The Agency used the conversion rate and end use percentages with the 2020 CDR PV range (1–5 billion lb) to estimate the PV for use within the Application of adhesives and sealants OES. Based on this calculation, the estimated range for the Application of adhesives and sealants OES is 339,000 to 7,820,000 lb.

Table 3-35 provides the PV estimation for the application of adhesives and sealants.

Table 3-35. PV Estimation for Application of Adhesives and Sealants OES

Formulation Product Type	Formulation Product Percentage of PV (%)	Adhesive and Sealant Use Rate (%)	Formulation Product Conversion Rate	PV (lb)	Rationale
Styrene-butadiene rubber	30	3	0.999	9,000–45,000	According to ACC, the butadiene monomer is recovered and recycled during the manufacturing process. It is assumed that only 0.001% of the butadiene used in the SBR manufacturing process is present as residual in the final product (EPA-HQ-OPPT-2018-0451-0041).
Polybutadiene	20	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Adiponitrile	15	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Styrene-butadiene latex	10	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Neoprene rubber	5	12	0.95	300,000–1,500,000	According to the EPA published technical report, the conversion rate of 1,3-butadiene in the chloroprene/neoprene manufacturing process is 95%. (U.S. EPA, 1996)
ABS resin	5	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Nitrile rubber	5	10	0.999	5,000–25,000	According to the EPA published technical report, the conversion rate of 1,3-butadiene in the nitrile rubber manufacturing process ranges from 75–90%. However, the source also indicates that unreacted monomer is reacted and recycled into the manufacturing stream and assumes that a maximum of 0.001% 1,3-butadiene is residual in the product stream (U.S. EPA, 1996).
Miscellaneous	10	25	0.95 to 0.999	25,000–6,250,000	SBS and SEBS polymers are assumed to fall under the miscellaneous polymer use category. 1,3-Butadiene conversion was estimated by taking the reported range of all other polymer conversion percentages used in PV estimation (U.S. EPA, 1996).

EPA did not find any chemical-specific throughputs or use rates for 1,3-butadiene in the application of adhesives and sealants. The annual throughput of adhesive and sealant product is modeled using a triangular distribution with a lower bound of 1,000 kg/yr, an upper bound of 1,000,000 kg/yr, and mode of 13,500 kg/yr. This is based on the ESD on the Use of Adhesives (OECD, 2015b). That ESD provides default adhesive use rates based on end-use category. EPA compiled the end-use categories that were relevant to downstream uses for adhesives and sealants containing 1,3-butadiene—which included general assembly, motor and non-motor vehicles, vehicle parts, tire manufacturing (except retreading), and computer/electronic and electrical product manufacturing. The lower and upper bound adhesive use rates for these categories was 1,000 to 1,000,000 kg/yr. The mode is based on the ESD default for unknown end-use markets.

EPA modeled the operating days per year using a triangular distribution with a lower bound of 50 days/year, an upper bound of 365 days/year, and a mode of 260 days/year. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 50 to 365 days/year. This is based on the ESD on Use of Adhesives (OECD, 2015b).

3.10.3 Release Assessment

3.10.3.1 Environmental Release Points

Environmental releases may occur during the processes of unloading, material sampling, transport, container cleaning, air that is vented or captured during the spray operation, during the drying or curing process, and during the cleaning and disposal of equipment. EPA 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

EPA estimated releases using a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method using the models and approaches described in Appendix D for this OES. Input parameters for the models were determined using data from literature and the ESD on the Industrial Use of Adhesives for Substrate Bonding (OECD, 2013). Table 3-36 summarizes the estimated release results for 1,3-butadiene use in adhesives and sealants based on the scenario applied. The high-ends are the 95th percentile of the respective simulation output and the central tendencies are the 50th percentile.

Table 3-36. Summary of Environmental Releases in the Application of Adhesives and Sealants Use of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range (kg-site/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/site-day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Fugitive or stack air	19	205	250	0.11	1.0	2–299,581 generic sites	Monte Carlo Modeling
Stack air	108	108		0.41	0.43	1	NEI
Incineration or landfill	589	2,878		2.7	15	2–299,581 generic sites	Monte Carlo Modeling
Air, incineration, or landfill	2.7E04	1.2E05		124	631	2–299,581 generic sites	Monte Carlo Modeling

3.10.4 Occupational Exposure Assessment

3.10.4.1 Worker Activities

During the use of adhesives and sealants containing 1,3-butadiene, worker exposures to 1,3-butadiene mist may occur while spraying or roll coating adhesives and sealants. Worker exposures may also occur via inhalation of vapors during product unloading, product container cleaning, application equipment cleaning, and curing or drying (OECD, 2015a). EPA did not identify information on engineering controls or worker PPE used at 1,3-butadiene-containing adhesive and sealant sites.

ONUs include supervisors, managers, and other employees who work in the application area but do not directly handle or apply products. ONUs are potentially exposed via inhalation while present in the application area; however, EPA expects ONUs to have lower inhalation exposures than workers who handle or apply the products.

3.10.4.2 Number of Workers and Occupational Non-users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during application of adhesives and sealants (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 322220 – Paper Bag and Coated and Treated Paper Manufacturing
- 334100 – Computer and Peripheral Equipment Manufacturing
- 334200 – Communications Equipment Manufacturing
- 334300 – Audio and Video Equipment Manufacturing
- 334400 –Semiconductor and Other Electronic Component Manufacturing
- 334500 – Navigational, Measuring, Electromedical, and Control Instruments Manufacturing

- 334600 – Manufacturing and Reproducing Magnetic and Optical Media
- 335100 – Electric Lighting Equipment Manufacturing
- 335200 – Household Appliance Manufacturing
- 335300 – Electrical Equipment Manufacturing
- 335900 – Other Electrical Equipment and Component Manufacturing
- 336100 – Motor Vehicle Manufacturing
- 336200 – Motor Vehicle Body and Trailer Manufacturing
- 336300 – Motor Vehicle Parts Manufacturing
- 336400 – Aerospace Product and Parts Manufacturing
- 336500 – Railroad Rolling Stock Manufacturing
- 336600 – Ship and Boat Building
- 336900 – Other Transportation Equipment Manufacturing

Table 3-37 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.10.2.

Table 3-37. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Application of Adhesives and Sealants

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
60 (median) 1,133 (high-end)	322220 – Paper Bag and Coated and Treated Paper Manufacturing	51	7
	334100 – Computer and Peripheral Equipment Manufacturing		
	334200 – Communications Equipment Manufacturing		
	334300 – Audio and Video Equipment Manufacturing		
	334400 –Semiconductor and Other Electronic Component Manufacturing		
	334500 – Navigational, Measuring, Electromedical, and Control Instruments Manufacturing		
	334600 – Manufacturing and Reproducing Magnetic and Optical Media		
	335100 – Electric Lighting Equipment Manufacturing		
	335200 – Household Appliance Manufacturing		
	335300 – Electrical Equipment Manufacturing		
	335900 – Other Electrical Equipment and Component Manufacturing		
	336100 – Motor Vehicle Manufacturing		
	336200 – Motor Vehicle Body and Trailer Manufacturing		
	336300 – Motor Vehicle Parts Manufacturing		
	336400 – Aerospace Product and Parts Manufacturing		
	336500 – Railroad Rolling Stock Manufacturing		

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
	336600 – Ship and Boat Building		
	336900 – Other Transportation Equipment Manufacturing		
[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.			

3.10.4.3 Occupational Inhalation Exposure Results

For exposure during the application of adhesives and sealants containing 1,3-butadiene, EPA used the same dataset referenced in Section 3.9.4.3. This approach was taken because the Agency cannot distinguish whether the data pertained specifically to paints and coatings, or to adhesives and sealants. Due to the lack of discrete sample data above the reportable LOD, EPA assessed the high-end estimate to be equal to the LOD and the central tendency equivalent to half of the LOD.

Using these 8-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-38. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-38. Inhalation Exposures of Workers to 1,3-Butadiene During Application of Adhesives and Sealants

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of Samples[a]	43		0	
8-hour TWA Exposure Concentrations	4.5E−02	9.0E−02	4.5E−02	4.5E−02
AC	3.1E−02	6.2E−02	3.1E−02	3.1E−02
$ADC_{intermediate}$	2.3E−02	4.5E−02	2.3E−02	2.3E−02
ADC	2.1E−02	4.2E−02	2.1E−02	2.1E−02
LADC	5.2E−03	1.3E−02	5.2E−03	6.7E−03

Source: OSHA data from https://www.osha.gov/opengov/health-samples (accessed December 3, 2025).
[a] All values were below the LOD. Used LOD ÷ 2 for the central tendency and the LOD for central tendency. ONU data not available; used the central tendency from worker estimates.

3.11 Use in Fuels and Related Products

3.11.1 Process Description

The 2016 CDR submission from one reporter indicated a 2014 PV of 183,032,673 lb of gaseous 1,3-butadiene for fuels and related products at concentrations of at least 1 but less than 30 percent by weight (U.S. EPA, 2016). In addition, the European Union's Registration, Evaluation, Authorization and Restriction of Chemicals program estimated that 500,000 tons per year (1,000,000,000 lb/yr) of 1,3-butadiene were used at industrial sites for fueling purposes (Penman et al., 2015).

The CDR product category code for fuels and related products includes cooking and heating fuels, fuel additives, and vehicle and appliance fuels. EPA did not identify information on how 1,3-butadiene is used in fuels and related products. One company reporting to CDR indicated that the chemical is used in the aerospace sector, as a fuel binder for solid rocket fuels. The National Library of Medicine's (NLM) Hazardous Substance Databank (HSDB) (NLM, 2003) confirms that polybutadiene (a polymer formed from the polymerization of 1,3-butadiene) is used as a matrix for rocket propellant as a binder, rather than the 1,3-butadiene monomer itself.

Evidence was found however, of 1,3-butadiene's presence within butane liquified petroleum gas (LPG) product, which is used as a fuel (Valero, 2018). The SDS for butane LPG states the product "is intended for use as a fuel in devices designed for combustion of butane, or for use in industrial processes," and is a mixture of the chemicals listed in Table 3-39.

Table 3-39. Chemical Makeup of LPG

Chemical Name	CASRN	Percent
n-Butane	106-97-8	0–95
Isobutane	75-28-5	0–95
1,3-Butadiene	106-99-0	0–0.1

This SDS is used as the basis for the assessment of 1,3-butadiene use in fuels.

LPG can be used for the same domestic, commercial and industrial applications as natural gas, with the largest market for LPG being the domestic/commercial market. Furthermore, one of the main LPG uses is in rural areas for domestic cooking and heating. For commercial and industrial settings, LPG is used as a primary or backup fuel in small boilers and space heating equipment and is used to generate heat and process steam. Pressurized cylinder sizes will vary depending on the application (*i.e.*, larger cylinders would be used for industrial applications vs. smaller cylinders for consumer cooking).

Using 2017 NAICS data, LPG is typically manufactured at sites identifying as the following:

- 132199 Natural Gas Liquids;
- 211130 Natural Gas Extraction/Natural Gas Liquids; and
- 324110 Petroleum Refineries.

These producers may use the LPG for heating or steam generation as noted above or sell the LPG to wholesalers and distributers identified within the following NAICS categories:

- 221210 Natural Gas Distribution (which includes LPG);
- 424710 Petroleum Bulk Stations and Terminals;
- 424720 Petroleum and Petroleum Products Merchant Wholesalers (except Bulk Stations and Terminals); and
- 457210 Fuel Dealers (retail sale of heating oils, LPG, and other fuels via direct sale (home delivery).

Because of LPG uses within commercial, industrial and consumer sectors, specific NAICS codes for downstream use sites cannot be quantified. Furthermore, the consumer use for cooking and heating, paired with the fact that LPG can be used at any industrial or commercial site with equipment compatible to combust LPG, would indicate use at a large number of unknown sites. For these reasons, an accurate number of use site determinations could not be completed.

3.11.2 Release Assessment

When evaluating releases related to fuel use of 1,3-butadiene in LPG, CDR and the SDS for the LPG butane containing 0-0.1 percent 1,3-butadiene were considered. From CDR, the 2019 nationally aggregated PV estimate for butane was 80,000,000,000 to less than 90,000,000,000 lb. To determine the amount of 1,3-butadiene in LPG, the following assumptions were made:

- PV range for butane assumed to be 80 to 90 billion lb;
- All (100%) of the butane PV is used for LPG product;
- All (100%) of the butane PV LPG is used domestically (none is exported);
- The LPG butane product is 99.9 percent butane;
- The concentration of 1,3-butadiene in the LPG butane product is 0.1 percent; and
- All LPG butane product is used domestically (none exported) and used as a fuel.

Taking the above into account, a rough estimate for 1,3-butadiene in the LPG butane product would equal:

$$Amount\ BD = 80{,}000{,}000{,}000\ -\ 90{,}000{,}000{,}000\ lb\ x\ 0.1\%\ BD$$
$$80{,}000{,}000 - 90{,}000{,}000\ lb\ BD$$

Where:

BD	=	1,3-Butadiene
Lb	=	Pounds

This assumes the amount of the LPG product ranges from 80,080,000,000 to 90,090,000,000 lb.

Limitations and uncertainties associated with the 1,3-butadiene PV estimate include

- It is unlikely the entire PV reported for butane is used in the LPG product.
- It is unlikely none of the reported PV for butane is exported.
- The 1,3-butadiene concentration of 0.1 percent is an overestimate as the SDS states the concentration may range from 0 to 0.1 percent.

Next, potential release sources and estimates were considered. Potential sources of 1,3-butadiene release during LPG fuel use include the following

- connecting/disconnecting LPG cylinders from combustion equipment;
- container/cylinder leaks and spills; and
- incomplete combustion of LPG fuel.

All releases are expected to air as the LPG is a liquified gas under pressure within pressurized cylinders. Due to the volatility of the components, including 1,3-butadiene, when released from the pressurized container to atmospheric pressure, the LPG volatilizes to a gas.

LPG Connections

Pressurized LPG containers require connections with regulators to reduce the pressure of the cylinder contents before routing to the combustion equipment. Releases are only likely to occur if connection equipment is damaged or worn. Releases from this source are expected to be minimal.

Cylinder Leaks

LPG is sold in various size containers holding 4.5 to over 250 gallons. The amount of LPG in a cylinder and the storage pressure would both be factors to consider when estimating leaks. However, cylinder leaks are not typical. LPG cylinders are designed with a self-closing valve to prevent leaks. Based on the range of cylinder sizes and lack of information on LPG cylinder leaks, releases from this source were not quantified.

Combustion
LPG is highly combustible with a theoretical conversion of 99.5 percent of the fuel carbon converted to CO_2 gas during combustion. However, some incomplete combustion of the fuel may occur. Conditions that can lead to incomplete combustion, include, but are not limited to the following:

- insufficient oxygen availability;
- extreme excess air levels leading to quenching;
- poor fuel/air mixing;
- cold wall flame quenching;
- reduced combustion temperature;
- decreased combustion gas residence time; and
- reduced combustion intensity.

No estimation method for the level of incomplete combustion was found. However, it is assumed LPG systems are designed to maximize fuel combustion efficiency. For these reasons, it is assumed most 1,3-butadiene in the LPG product would be combusted.

Environmental releases of 1,3-butadiene in LPG used as a fuel could not be quantified based on the following:

- uncertainty of the amount of 1,3-butadiene in the LPG product;
- potential dispersed use of the LPG product across domestic, commercial and industrial applications;
- inability to determine a reasonable number of use sites;
- projected minimal/unquantifiable environmental releases;
  - from connecting equipment and cylinder leaks; and
  - high combustion efficiency of LPG fuel.

3.11.3 Occupational Exposure Assessment

Potential sources of 1,3-butadiene occupational exposure during LPG fuel use include

- connecting/disconnecting LPG cylinders from combustion equipment;
- spills/leaks from LPG cylinders; and
- 1,3-butadiene released due to incomplete combustion.

LPG Connections
Exposures during connecting/disconnecting cylinders are minimized based on existing LPG cylinder connections. It is also expected that the time spent connecting/disconnecting LPG cylinders is short. Therefore, occupational exposures from routine connecting/disconnecting cylinders are expected to be minimal.

Cylinder Leaks
The amount spilled/leaked is dependent on the storage pressure and amount of LPG in a cylinder. Furthermore, because leaks are uncommon based on cylinder design, occupational exposures from cylinder leaks were not quantified.

Incomplete Combustion
Although LPG has a high theoretical conversion of over 99 percent, workers may be exposed to 1,3-

butadiene during use as a fuel due to incomplete combustion as discussed above. No exposure data or estimation methods for occupational exposure from incomplete combustion were found. Furthermore, workers at industrial and commercial facilities using LPG fuel are not expected to be routinely in proximity of the combustion area—only for short, sporadic time periods. Therefore, it is assumed worker exposure to 1,3-butadiene from incomplete combustion would be minimal.

3.12 Recycling

3.12.1 Process Description

There are multiple ways 1,3-butadiene can be recycled during its life cycle. This OES examines releases and exposures due to the to the recycling of 1,3-butadiene for energy recovery. When finished, 1,3-butadiene does not meet commercial specifications, it is often combined with crude streams for energy recovery. This activity is classified under the Disposal COU.

The final scope for 1,3-butadiene lists recycling as an in-scope COU under the Processing life cycle stage (U.S. EPA, 2020c). 2019 TRI data indicates that sites recycle 1,3-butadiene both on- and off-site (U.S. EPA, 2021b). When finished, 1,3-butadiene does not meet commercial specifications, it is often combined with crude streams for energy recovery. Similarly, when ethylene manufacturers have excess butadiene supply, they can recycle the butadiene as a feedstock for the production of ethylene. In polymer production, unreacted butadiene-containing monomers are recycled back to the reactors to improve the process yield (Sun and Wristers, 2002). For discussion of this use, see the Processing as a reactant OES discussion in Section 3.3.

Note that the term "recycling" within this assessment and the risk evaluation may also refer to the recycling of plastic and rubber products. For a discussion of this use, see Section 4.2.1.

3.12.2 Facility Estimates

Between 2016 and 2021, EPA used TRI and NEI to identify 10 facilities that potentially use 1,3-butadiene during recycling.

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of EPA's assessment each site can only be assigned one OES. The OES was chosen using professional judgment to reflect the most prominent activity according to TRI and NEI reporting and the information on the company website. Because deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting these release sites in TRI (which was then adapted to NEI). The Recycling OES may have been selected if a facility indicated that there was on-site use, or ancillary or other use of 1,3-butadiene coupled with an indication of use as fuel.

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to recycling that reported to CDR, TRI, and/or NEI.

EPA did not identify data on recycling facility operating schedules; therefore, EPA assumes facility operates 7 days/week and 50 weeks/year (with 2 weeks down for turnaround), which is 350 days per year of operation (Section 2.3.2).

3.12.3 Release Assessment

3.12.3.1 Environmental Release Points

Sources of potential environmental release include the unloading of solid or liquid waste containers.

Releases may also occur while connecting and disconnecting transfer lines and hoses, and during the recycling of 1,3-butadiene for energy recovery. EPA expects releases of 1,3-butadiene to air during recycling, including stack air releases from vented losses to air during process operations and fugitive air releases from leakage of pipes, flanges, and accessories used for transport.

3.12.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI to estimate environmental releases during the recycling of 1,3-butadiene, as presented in Table 3-40. According to reported data, 1,3-butadiene is released through the following environmental media: surface water, fugitive air, stack air, and land disposal.

Table 3-40. Summary of Environmental Releases in the Recycling of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Surface water	5.2	11	350	1.5E−02	3.1E−02	2	TRI
Fugitive air	20	160		5.8E−02	0.46	9	TRI
Fugitive air	20	183		5.8E−02	0.52	7	NEI
Stack air	13	475		3.6E−02	1.4	11	TRI
Stack air	4.5	460		1.3E−02	1.3	7	NEI
Land	1.6E−04	1.6E−04		4.6E−07	4.6E−07	1	TRI

3.12.4 Occupational Exposure Assessment

3.12.4.1 Worker Activities

EPA expects that the worker exposure activities that occur at a facility that recycles 1,3-butadiene for energy recovery would be similar to the activities at a facility for waste handling, treatment, and disposal of 1,3-butadiene. For more information on expected worker activities, see Section 4.1.4.1.

ONUs for this scenario include supervisors, managers, and other employees who may be in the waste handling or treatment area. ONUs do not directly handle the chemical and are therefore expected to have lower inhalation exposures than workers who engage in tasks related to the handling or treatment of waste containing 1,3-butadiene.

3.12.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during recycling (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 562211 – Hazardous Waste Treatment and Disposal.

Table 3-41 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.12.2.

Table 3-41. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Recycling

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
10	562211 – Hazardous Waste Treatment and Disposal	18	5
[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.			

3.12.4.3 Occupational Inhalation Exposure Results

No discrete monitoring data were found for workers or ONUs during the recycling of 1,3-butadiene. Therefore, EPA used exposure monitoring data from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* discussed in Section 3.1.4.3 as analogous for this OES. Specifically, the Agency used data associated with waste handling at manufacturing sites because these activities are also expected to occur at recycling sites (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). Note that this analysis was also used in Section 4.1.4 to assess occupational exposures to 1,3-butadiene during waste handling, treatment, and disposal.

EPA identified 10 task-based worker PBZ samples associated with "handling, transporting and disposing of waste containing 1,3-butadiene" waste handling from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). The worker activities associated with these data include handling facility waste streams containing 1,3-butadiene—including disposing of analytical samples, loading of recycled oil, and operations conducted at the onsite waste-water treatment plant. The sample durations ranged from 18 to 135 minutes. One of the 10 samples was above the sample method's LOD. The other nine non-detects were estimated using a substitution method as described in Section 2.4.3.1. Due to the lack of quantifiable samples collected for this OES, more sophisticated methods of characterizing the dataset could not be employed.

Since EPA only had task-based samples with task-length durations, rather than full shift sample with full shift durations, the Agency needed to make assumptions on how best to obtain a full shift exposure estimates using these task-based samples. EPA made two assumptions to capture the range of possible exposures for this OES. The first assumption addressed the possibility that at a facility specifically focused on waste handling, the bulk of the day may be spent handling waste such that the task-based samples may be representative of a full shift exposure. The second assumption is based on information from the *Analysis of 1,3-Butadiene Industrial Hygiene Data*, which reports that at a manufacturing or processing facility routine task-based samples occur 5 days per week for only the length of the task. Using each of these assumptions, EPA presents two estimates. The first assumes that the worker is exposed to the concentration of 1,3-butadiene measured during the task for their entire 8-hour shift (full shift assumption). The second estimate assumes that the worker is exposed to 1,3-butadiene for the duration of the task and that for the remainder of their 8-hour shift they receive no exposure to 1,3-butadiene (task-length exposure). EPA assumes that these two estimates capture the range of exposures that a worker may experience.

EPA did not identify any ONU PBZ samples during data evaluation.

EPA compiled the 50th and 95th percentile 8-hour TWA concentrations to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 3-42 for the full shift assumption and Table 3-43 for the task-based assumption. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 3-42. Summary of Occupational Inhalation Exposures to 1,3-Butadiene During Recycling of 1,3-Butadiene (Full Shift Assumption)

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	10		0	
8-Hour TWA exposure concentrations	0.23	1.3	0.23	0.23
AC	0.16	0.88	0.16	0.16
$ADC_{intermediate}$	0.11	0.65	0.11	0.11
ADC	0.11	0.61	0.11	0.11
LADC	2.6E−02	0.19	2.6E−02	3.4E−02

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)
[a] One of the 10 data points for workers was above the method's LOD. EPA applied the substitution method to the non-detects in the dataset and used the 50th and 95th percentile of the dataset for the central tendency and high-end respectively. ONU data not available; used the central tendency from worker estimates

Table 3-43. Summary of Occupational Inhalation Exposures to 1,3-Butadiene During Recycling of 1,3-Butadiene (Task-Based Assumption)

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	10		0	
8-Hour TWA exposure concentrations	1.7E−02	9.6E−02	1.7E−02	1.7E−02
AC	1.2E−02	6.6E−02	1.2E−02	1.2E−02
$ADC_{intermediate}$	8.5E−03	4.8E−02	8.5E−03	8.5E−03
ADC	7.9E−03	4.5E−02	7.9E−03	7.9E−03
LADC	1.9E−03	1.4E−02	1.9E−03	2.5E−03

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)
[a] One of the 10 data points for workers was above the method's LOD. EPA applied the substitution method to the non-detects in the dataset and used the 50th and 95th percentile of the dataset for the central tendency and high-end respectively. ONU data not available; used the central tendency from worker estimates

4 SUMMARY OF OCCUPATIONAL EXPOSURE ESTIMATES

Table 4-1 summarizes the occupational inhalation exposure results for each OES. EPA's general approach for estimating occupational exposures is explained in Section 2.4, and the specific basis for each estimate is discussed in the relevant subsection of Section 3. See the *1,3-Butadiene Inhalation Monitoring Data Summary* (U.S. EPA, 2025a) for the calculations associated with this table.

Table 4-1. Summary of Occupational Inhalation Exposure Results by OES

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Manufacturing – 8-hour	Infrastructure/ Distribution Operations	250	250	5.5E−03	0.44	455	102	Dataset assessed using MLE	*Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) for manufacturing and processing facilities
	Infrastructure/ Distribution Operations – Nonroutine	5	5	0.37	0.78	3	2	Substitution method used for non-detects	
	Instrument and Electrical	250	250	2.6E−04	0.10	313	29	Dataset assessed using MLE	
	Instrument and Electrical – Nonroutine	5	5	0.13	0.13	5	0	Substitution method used for non-detects	
	Instrument and Electrical – Turnaround	14	14	1.7E−02	0.14	4	2	Substitution method used for non-detects	
	Laboratory Technician	250	250	6.8E−03	0.24	215	57	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group	250	250	9.2E−04	0.25	222	44	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group – Turnaround	14	14	8.0E−03	1.2E−02	8	3	Substitution method used for non-detects	
	Maintenance	250	250	1.5E−02	0.70	354	109	Dataset assessed using MLE	
	Maintenance – Nonroutine/ Other	5	5	0.34	0.62	2	1	Substitution method used for non-detects	
	Maintenance – Turnaround	14	14	1.7E−02	5.1	33	15	Dataset assessed using MLE	
	Operations Onsite	250	250	3.6E−04	0.13	1,952	229	Dataset assessed using MLE	
	Operations Onsite – Nonroutine/Other	5	5	3.2E−02	0.13	38	2	Substitution method used for non-detects	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Manufacturing – 8-hour	Operations Onsite – Turnaround	14	14	2.0E−05	7.0E−02	1,633	116	Dataset assessed using MLE	*Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) for manufacturing and processing facilities
	Safety and Health Engineering	250	250	1.7E−02	0.49	21	6	Dataset assessed using MLE	
	ONU	250	250	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	
Manufacturing – 12-hour	Infrastructure/ Distribution Operations	167	167	5.5E−03	0.44	455	102	Dataset assessed using MLE	
	Infrastructure/ Distribution Operations – Nonroutine	5	5	0.37	0.78	3	2	Substitution method used for non-detects	
	Instrument and Electrical	167	167	2.6E−04	0.10	313	29	Dataset assessed using MLE	
	Instrument and Electrical – Nonroutine	5	5	0.13	0.13	5	0	Substitution method used for non-detects	
	Instrument and Electrical – Turnaround	14	14	1.7E−02	0.14	4	2	Substitution method used for non-detects	
	Laboratory Technician	167	167	6.8E−03	0.24	215	57	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group	167	167	9.2E−04	0.25	222	44	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group – Turnaround	14	14	8.0E−03	1.2E−02	8	3	Substitution method used for non-detects	
	Maintenance	167	167	1.5E−02	0.70	354	109	Dataset assessed using MLE	
	Maintenance – Nonroutine/ Other	5	5	0.34	0.62	2	1	Substitution method used for non-detects	
	Maintenance – Turnaround	14	14	1.7E−02	5.1	33	15	Dataset assessed using MLE	
	Operations Onsite	167	167	3.6E−04	0.13	1,952	229	Dataset assessed using MLE	
	Operations Onsite – Nonroutine/ Other	5	5	3.2E−02	0.13	38	2	Substitution method used for non-detects	
	Operations Onsite – Turnaround	14	14	2.0E−05	7.0E−02	1,633	116	Dataset assessed using MLE	
	Safety and Health Engineering	167	167	1.7E−02	0.49	21	6	Dataset assessed using MLE	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
	ONU	167	167	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	
Repackaging	Worker (full shift assumption)	250	250	0.45	22	158	87	Dataset assessed using MLE	Used task-length data from loading/ unloading during manufacturing and processing from *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)as analogous. ONU data not available; used the central tendency from worker estimates
	ONU (full shift assumption)	250	250	0.45	0.45	0	0	N/A	
	Worker (task-length assumption)	250	250	2.6E−02	1.1	158	87	Dataset assessed using MLE	
	ONU (task-length assumption)	250	250	2.6E−02	2.6E−02	0	0	N/A	
Processing as a reactant – 8-hour	Infrastructure/ Distribution Operations	250	250	5.5E−03	0.44	455	102	Dataset assessed using MLE	*Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) for manufacturing and processing facilities
	Infrastructure/ Distribution Operations – Nonroutine	5	5	0.37	0.78	3	2	Substitution method used for non-detects	
	Instrument and Electrical	250	250	2.6E−04	0.10	313	29	Dataset assessed using MLE	
	Instrument and Electrical – Nonroutine	5	5	0.13	0.13	5	0	Substitution method used for non-detects	
	Instrument and Electrical – Turnaround	14	14	1.7E−02	0.14	4	2	Substitution method used for non-detects	
	Laboratory Technician	250	250	6.8E−03	0.24	215	57	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group	250	250	9.2E−04	0.25	222	44	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group – Turnaround	14	14	8.0E−03	1.2E−02	8	3	Substitution method used for non-detects	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Processing as a reactant – 8-hour	Maintenance	250	250	1.5E−02	0.70	354	109	Dataset assessed using MLE	*Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) for manufacturing and processing facilities
	Maintenance – Nonroutine/Other	5	5	0.34	0.62	2	1	Substitution method used for non-detects	
	Maintenance – Turnaround	14	14	1.7E−02	5.1	33	15	Dataset assessed using MLE	
	Operations Onsite	250	250	3.6E−04	0.13	1,952	229	Dataset assessed using MLE	
	Operations Onsite – Nonroutine/Other	5	5	3.2E−02	0.13	38	2	Substitution method used for non-detects	
	Operations Onsite – Turnaround	14	14	2.0E−05	7.0E−02	1,633	116	Dataset assessed using MLE	
	Safety and Health Engineering	250	250	1.7E−02	0.49	21	6	Dataset assessed using MLE	
	ONU	250	250	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	
Processing as a reactant – 12-hour	Infrastructure/ Distribution Operations	167	167	5.5E−03	0.44	455	102	Dataset assessed using MLE	
	Infrastructure/ Distribution Operations – Nonroutine	5	5	0.37	0.78	3	2	Substitution method used for non-detects	
	Instrument and Electrical	167	167	2.6E−04	0.10	313	29	Dataset assessed using MLE	
	Instrument and Electrical – Nonroutine	5	5	0.13	0.13	5	0	Substitution method used for non-detects	
	Instrument and Electrical – Turnaround	14	14	1.7E−02	0.14	4	2	Substitution method used for non-detects	
	Laboratory Technician	167	167	6.8E−03	0.24	215	57	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group	167	167	9.2E−04	0.25	222	44	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group – Turnaround	14	14	8.0E−03	1.2E−02	8	3	Substitution method used for non-detects	
	Maintenance	167	167	1.5E−02	0.70	354	109	Dataset assessed using MLE	
	Maintenance – Nonroutine/ Other	5	5	0.34	0.62	2	1	Substitution method used for non-detects	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Processing as a reactant – 12-hour	Maintenance – Turnaround	14	14	1.7E−02	5.1	33	15	Dataset assessed using MLE	*Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) for manufacturing and processing facilities
	Operations Onsite	167	167	3.6E−04	0.13	1,952	229	Dataset assessed using MLE	
	Operations Onsite – Nonroutine/ Other	5	5	3.2E−02	0.13	38	2	Substitution method used for non-detects	
	Operations Onsite – Turnaround	14	14	2.0E−05	7.0E−02	1,633	116	Dataset assessed using MLE	
	Safety and Health Engineering	167	167	1.7E−02	0.49	21	6	Dataset assessed using MLE	
	ONU	167	167	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	
Processing – polymerization	Worker	250	250	0.40	17	1,953	Unknown	N/A	Based on summary statistics from 11 occupational monitoring studies: (Abdel-Rahman et al., 2001), (Albertini et al., 2003), (Albertini et al., 2007), (Ammenheuser et al., 2001), (Anttinen-Klemetti et al., 2006), (Carrieri et al., 2014), (Cheng et al., 2013), (Ma et al., 2000), (Van Sittert, 2000), (Ward et al., 2001), (Wickliffe et al., 2009)
	ONU	250	250	1.1E−02	9.9E−02	580	Unknown	N/A	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Processing – incorporation into formulation – 8-hour	Infrastructure/ Distribution Operations	250	250	5.5E−03	0.44	455	102	Dataset assessed using MLE	Used *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) for manufacturing and processing facilities as analogous
	Infrastructure/ Distribution Operations – Nonroutine	5	5	0.37	0.78	3	2	Substitution method used for non-detects	
	Instrument and Electrical	250	250	2.6E−04	0.10	313	29	Dataset assessed using MLE	
	Instrument and Electrical – Nonroutine	5	5	0.13	0.13	5	0	Substitution method used for non-detects	
	Instrument and Electrical – Turnaround	14	14	1.7E−02	0.14	4	2	Substitution method used for non-detects	
	Laboratory Technician	250	250	6.8E−03	0.24	215	57	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group	250	250	9.2E−04	0.25	222	44	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group – Turnaround	14	14	8.0E−03	1.2E−02	8	3	Substitution method used for non-detects	
	Maintenance	250	250	1.5E−02	0.70	354	109	Dataset assessed using MLE	
	Maintenance – Nonroutine/ Other	5	5	0.34	0.62	2	1	Substitution method used for non-detects	
	Maintenance – Turnaround	14	14	1.7E−02	5.1	33	15	Dataset assessed using MLE	
	Operations Onsite	250	250	3.6E−04	0.13	1,952	229	Dataset assessed using MLE	
	Operations Onsite – Nonroutine/ Other	5	5	3.2E−02	0.13	38	2	Substitution method used for non-detects	
	Operations Onsite – Turnaround	14	14	2.0E−05	7.0E−02	1,633	116	Dataset assessed using MLE	
	Safety and Health Engineering	250	250	1.7E−02	0.49	21	6	Dataset assessed using MLE	
	ONU	250	250	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Processing – incorporation into formulation – 12-hour	Infrastructure/ Distribution Operations	167	167	5.5E−03	0.44	455	102	Dataset assessed using MLE	Used *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) for manufacturing and processing facilities as analogous
	Infrastructure/ Distribution Operations – Nonroutine	5	5	0.37	0.78	3	2	Substitution method used for non-detects	
	Instrument and Electrical	167	167	2.6E−04	0.10	313	29	Dataset assessed using MLE	
	Instrument and Electrical – Nonroutine	5	5	0.13	0.13	5	0	Substitution method used for non-detects	
	Instrument and Electrical – Turnaround	14	14	1.7E−02	0.14	4	2	Substitution method used for non-detects	
	Laboratory Technician	167	167	6.8E−03	0.24	215	57	Substitution method used for non-detects	
	Machinery & Specialists Mechanical Group	167	167	9.2E−04	0.25	222	44	Dataset assessed using MLE	
	Machinery & Specialists Mechanical Group – Turnaround	14	14	8.0E−03	1.2E−02	8	3	Substitution method used for non-detects	
	Maintenance	167	167	1.5E−02	0.70	354	109	Dataset assessed using MLE	
	Maintenance – Nonroutine/Other	5	5	0.34	0.62	2	1	Substitution method used for non-detects	
	Maintenance – Turnaround	14	14	1.7E−02	5.1	33	15	Dataset assessed using MLE	
	Operations Onsite	167	167	3.6E−04	0.13	1,952	229	Dataset assessed using MLE	
	Operations Onsite – Nonroutine/Other	5	5	3.2E−02	0.13	38	2	Substitution method used for non-detects	
	Operations Onsite – Turnaround	14	14	2.0E−05	7.0E−02	1,633	116	Dataset assessed using MLE	
	Safety and Health Engineering	167	167	1.7E−02	0.49	21	6	Dataset assessed using MLE	
	ONU	167	167	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Plastics and rubber compounding – 8-hour	Worker	250	250	6.9E−04	0.21	53	7	Dataset assessed using MLE	Based on OSHA's CEHD [c] and discrete data from two monitoring studies. (USTMA, 2020; Lee et al., 2012)
	ONU	250	250	6.9E−04	6.9E−04	0	0	N/A	
Plastics and rubber compounding – 12-hour	Worker	167	167	0.10	0.30	44	25	Dataset assessed using MLE	
	ONU	167	167	0.10	0.10	0	0	N/A	
Plastics and rubber converting – 8-hour	Worker	250	250	5.0E−04	0.18	50	6	Dataset assessed using MLE	
	ONU	250	250	5.0E−04	5.0E−04	0	0	N/A	
Plastics and rubber converting – 12-hour	Worker	167	167	0.10	0.30	44	25	Dataset assessed using MLE	
	ONU	167	167	0.10	0.10	0	0	N/A	
Use of laboratory chemicals – 8-hour	Laboratory Technician	174	250	6.8E−03	0.24	215	57	Dataset assessed using MLE	Used full shift laboratory technician data during manufacturing and processing from *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) as analogous.
	ONU	174	250	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	
Use of laboratory chemicals – 12-hour	Laboratory Technician	167	167	6.8E−03	0.24	215	57	Dataset assessed using MLE	
	ONU	167	167	5.8E−03	2.0E−02	39	9	Dataset assessed using MLE	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		
Application of paints, coatings, adhesives, and sealants	Worker	250	250	4.5E−02	9.0E−02	43	0	Substitution method used for non-detects	Based on OSHA's CEHD [c]. All values were below the LOD. Used LOD for the HE and LOD ÷ 2 for CT. ONU data not available; used the central tendency from worker estimates.
	ONU	250	250	4.5E−02	4.5E−02	0	0	N/A	
Recycling	Worker (full shift assumption)	250	250	0.23	1.3	10	1	Substitution method used for non-detects	Used task-length data from waste handling during manufacturing and processing from *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) as analogous. ONU data not available; used the central tendency from worker estimates
	ONU (full shift assumption)	250	250	0.23	0.23	0	0	N/A	
	Worker (task-length assumption)	250	250	1.7E−02	9.6E−02	10	1	Substitution method used for non-detects	
	ONU (task-length assumption)	250	250	1.7E−02	1.7E−02	0	0	N/A	
Waste handling, treatment, and disposal	Worker (full shift assumption)	250	250	0.23	1.3	10	1	Substitution method used for non-detects	Used task-length data from waste handling during manufacturing and processing from *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) as analogous. ONU data not available; used the central tendency from worker estimates
	ONU (full shift assumption)	250	250	0.23	0.23	0	0	N/A	
	Worker (task-length assumption)	250	250	1.7E−02	9.6E−02	10	1	Substitution method used for non-detects	
	ONU (task-length assumption)	250	250	1.7E−02	1.7E−02	0	0	N/A	

Occupational Exposure Scenario (OES)	Worker Description/ Job Group[a]	Exposure Frequency (day/yr)		Time Weighted Average (TWA) Exposures $C_{8\text{- or }12\text{-hr TWA}}$ (ppm)				Method for Addressing Censored Data (Substitution or MLE[b])	Source(s)
		Central Tendency	High-End	Central Tendency (ppm)	High-End (ppm)	# Data Points	# Detected Points		

NIOSH = National Institute for Occupational Safety and Health; OSHA = Occupational Safety and Health Administration
[a] "Laboratory Technician – Non-routine" was an SEG in the draft risk evaluation but is not present in the final because the source of the data clarified that the data on which that SEG was based was miscategorized.
[b] Maximum likelihood estimation (MLE)
[c] OSHA CEHD can be accessed at this address: https://www.osha.gov/opengov/health-samples (accessed December 2, 2025).

4.1 Waste Handling, Treatment, and Disposal

4.1.1 Process Description

Each of the COUs of 1,3-butadiene may generate waste streams of the chemical that are collected and transported to third-party sites for disposal or treatment (see Figure 4-1). Industrial sites that treat and/or dispose of onsite wastes that they themselves generate are assessed in each COU assessment (Sections 3.1 through 3.12). Wastes of 1,3-butadiene that are generated during a COU and sent to a third-party site for treatment, disposal, or recycling may include the following:

- ***Wastewater:*** 1,3-Butadiene may be contained in wastewater discharged to POTW or other, non-public treatment works for treatment. Off-site transfers may include aqueous streams that were collected and destined for off-site treatments. These include particulate matter collected in air pollution control devices, wastewater and slurries from equipment cleaning, plastic pellet spills, and container residue (OECD, 2005). Industrial wastewater containing 1,3-butadiene discharged to a POTW may be subject to EPA or authorized NPDES state pretreatment programs. The assessment of wastewater discharges to POTWs and non-public treatment works of 1,3-butadiene is included in each of the preceding COU assessments in Sections 3.1 through 3.12.
- ***Solid Wastes:*** Solid wastes are defined under RCRA as any material that is discarded by being abandoned, inherently waste-like, a discarded military munition, or recycled in certain ways (certain instances of the generation and legitimate reclamation of secondary materials are exempted as solid wastes under RCRA). Solid wastes may subsequently meet RCRA's definition of hazardous waste by either being listed as a waste at 40 CFR 261.30 to 261.35 or by meeting waste-like characteristics as defined at 40 CFR 261.20 to 261.24. Solid wastes that are hazardous wastes are regulated under the more stringent requirements of Subtitle C of RCRA, whereas non-hazardous solid wastes are regulated under the less stringent requirements of Subtitle D of RCRA. Similar to wastewater streams, off-site transfers from plastic compounding and mixing may include solids that are collected and destined for off-site treatments (OECD, 2005).
- ***Wastes Exempted as Solid Wastes Under RCRA:*** Certain COUs of 1,3-butadiene may generate wastes of 1,3-butadiene that are exempted as solid wastes under 40 CFR 261.4(a). For example, the generation and legitimate reclamation of hazardous secondary materials of 1,3-butadiene may be exempt as a solid waste.

EPA evaluated occupational exposures for disposal. Section 4.1.3 describes the environmental releases related to waste handling, disposal, and treatment, which may lead to exposures of the general population and environmental organisms.

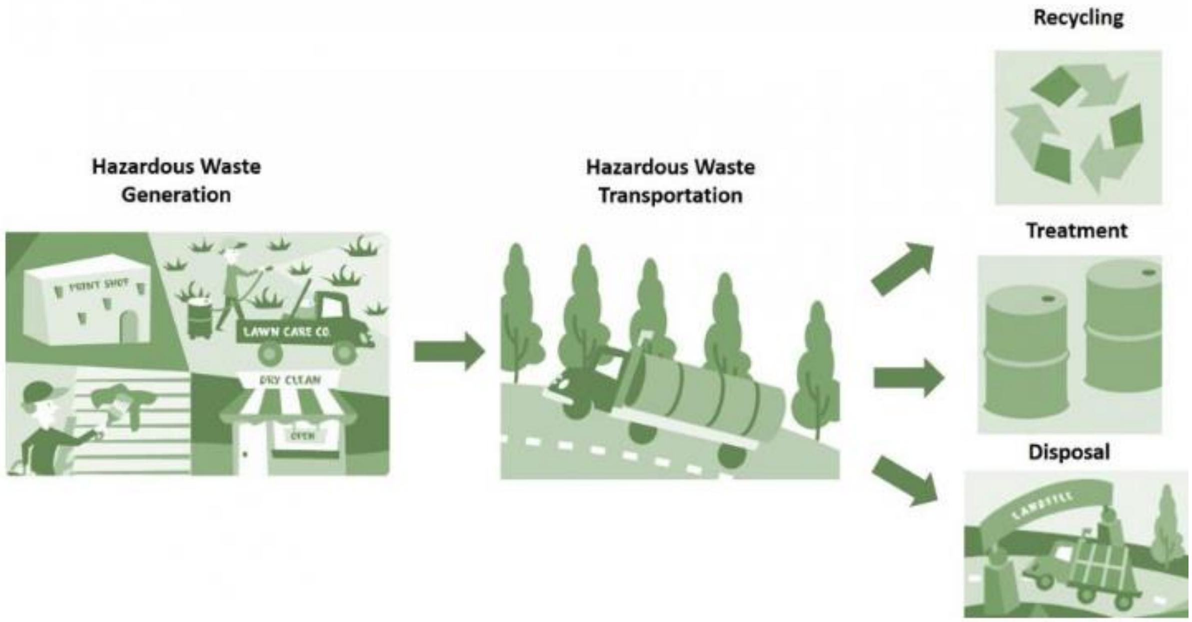

Figure 4-1. Typical Waste Disposal Process
Source: (U.S. EPA, 2019a)

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

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

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

Hazardous Waste Incineration
A typical industrial incineration process is illustrated in Figure 4-2. Commercial scale hazardous waste incinerators are generally two-chamber units—a rotary kiln followed by an afterburner that accept both solid and liquid waste. Liquid wastes are pumped through pipes and are fed to the unit through nozzles that atomize the liquid for optimal combustion. Solids may be fed to the kiln as loose solids, gravity-fed to a hopper, or in drums or containers using a conveyor (Center, 2018; Heritage, 2018).

Incoming hazardous waste is usually received by truck or rail, and an inspection is required for all waste received. Receiving areas for liquid waste generally consist of a docking area, pumphouse, and storage facilities. For solids, conveyor devices are typically used to transport incoming waste (Center, 2018; Kitto and Stultz, 1992)

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.

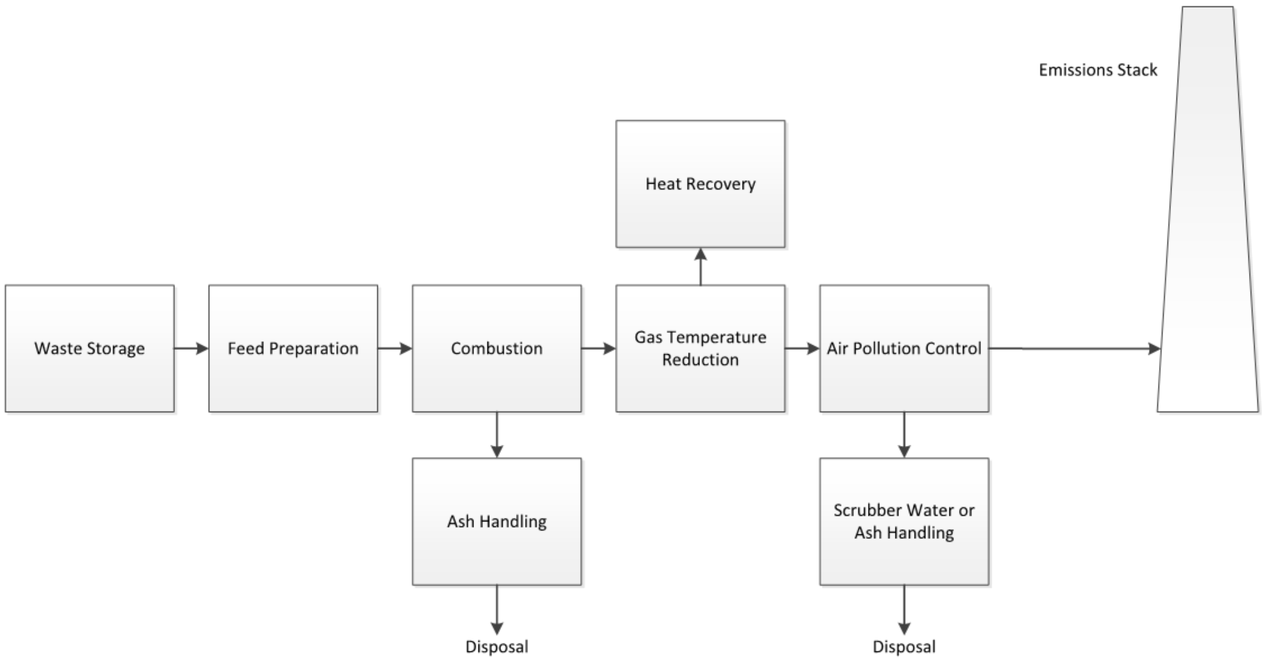

Figure 4-2. Typical Industrial Incineration Process

Municipal Waste Landfill

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

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

Hazardous Waste Landfill

Hazardous waste landfills are excavated or engineered sites specifically designed for the final disposal of non-liquid hazardous wastes. Design standards for these landfills require double 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.

4.1.2 Facility Estimates

EPA used TRI, NEI, and CDR data between 2016 and 2021 to identify 289 facilities that potentially use 1,3-butadiene during waste handling, treatment, and disposal. Off-site transfers of 1,3-butadiene may go to WWT, incineration, or recycling facilities; see Figure 4-1. Most off-site transfers for 1,3-butadiene were incinerated (U.S. EPA, 2021b).

Facilities that produce or handle 1,3-butadiene may have several uses for the chemical on-site. Despite this, for the purposes of EPA's assessment each site can only be assigned one OES. The OES was chosen using professional judgment to reflect the most prominent activity according to TRI and NEI reporting and the information on the company website. Because deciding the "most prominent activity" is subjective, EPA developed a systematic approach to sorting these release sites in TRI (which was then adapted to NEI). The Waste handling, disposal, treatment, and recycling OES may have been selected if the facility indicated waste disposal on the company website, or in TRI if a site fell under the NAICS code 562211 (Hazardous Waste Treatment and Disposal).

See *Number of Sites for 1,3-Butadiene* (U.S. EPA, 2025i) for a list of all facilities mapped to waste handling, treatment, and disposal that reported to CDR, TRI, and/or NEI.

EPA did not identify data on facility operating schedules; therefore, EPA assumes operation 5 days/week for 50 weeks/year, which is 250 days/year of operation (Section 2.3.2).

4.1.3 Release Assessment

4.1.3.1 Environmental Release Points

Sources of potential environmental release include the unloading of solid or liquid waste containers. Releases may occur while connecting and disconnecting transfer lines and hoses, and during the treatment of waste. EPA expects releases to air of volatile 1,3-butadiene during waste handling, treatment, and disposal. Additionally, the Agency expects releases of solid or liquid waste to land.

4.1.3.2 Environmental Release Assessment Results

EPA used 2016 to 2021 TRI, 2017 NEI, and 2020 NEI to estimate environmental releases during the waste handling and treatment of 1,3-butadiene, as presented in Table 4-2. According to reported data, 1,3-butadiene is released through the following environmental media: fugitive air, stack air, and land disposal (the 2 reporting sites release to an on-site underground injection well and an on-site RCRA Subtitle C landfill).

Table 4-2. Summary of Environmental Releases in the Waste Handling, Disposal, and Treatment of 1,3-Butadiene

Environmental Media	Estimated Annual Release Range Across Sites (kg/yr)		Number of Release Days	Estimated Daily Release Range Across Sites (kg/day)		Number of Facilities	Source(s)
	Central Tendency	High-End		Central Tendency	High-End		
Fugitive air	4.5E−02	3.6	250	1.8E−04	1.4E−02	6	TRI
Fugitive air	0.54	20		1.5E−03	7.8E−02	49	NEI
Stack air	0.17	113		6.9E−04	0.45	6	TRI
Stack air	1.4E−03	0.42		5.4E−06	1.7E−03	251	NEI
Land	5,781	6,226		23	25	2	TRI

4.1.4 Occupational Exposure Assessment

4.1.4.1 Worker Activities

Workers are potentially exposed to 1,3-butadiene via inhalation of vapors during the unloading and cleaning of transport containers. They also may dispose of analytical samples, load recycled oil, or conduct operations at onsite wastewater treatment plants. In a manufacturing setting the presence of 1,3-butadiene in waste streams is highly dependent on facility operations, for example, some processing operations have no 1,3-butadiene in waste streams since nearly all of it is consumed in the processing and any residual is sent for destruction via flares or boilers (ToxStrategies, 2021).

According to the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021), in a manufacturing setting the exposure controls implemented for the waste handling task include chemical protective gloves, suits and boots to prevent dermal contact, and respirators—either full face APR or half face APR depending on the concentration range. EPA did not find information that indicates the extent that engineering controls are used specifically at facilities that handle, treat, and dispose of waste containing 1,3-butadiene.

ONUs for this scenario include supervisors, managers, and other employees who may be in the waste handling or treatment area. ONUs do not directly handle the chemical and are therefore expected to have lower inhalation exposures than workers who engage in tasks related to the handling or treatment of waste containing 1,3-butadiene.

4.1.4.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to 1,3-butadiene during waste handling, disposal, and treatment (U.S. BLS, 2023). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 562211 – Hazardous Waste Treatment and Disposal

Table 4-3 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 4.1.2.

Table 4-3. Estimated Average Number of Workers per Site Potentially Exposed to 1,3-Butadiene During Waste Handling, Disposal, and Treatment

Potential Number of Sites	NAICS Code	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
289	562211 – Hazardous Waste Treatment and Disposal	18	5

[a] Number of workers and ONU per site are calculated by dividing the exposed number of workers or ONU by the number of establishments.

4.1.4.3 Occupational Inhalation Exposure Results

No discrete monitoring data were found for workers or ONUs during the waste handling, treatment, and disposal of 1,3-butadiene. One source was found for waste handling but lacked critical metadata needed for an occupational exposure assessment. Therefore, EPA used exposure monitoring data from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* discussed in Section 3.1.4.3 as analogous for this OES. Specifically, EPA used the data associated with waste handling at manufacturing sites because these activities are also expected to occur at waste handling sites (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). Note that this analysis is also used in Section 3.12.4.3 to assess occupational exposures during recycling.

EPA identified 10 task-based worker PBZ samples associated with "handling, transporting and disposing of waste containing 1,3-butadiene" from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). The worker activities associated with these data include handling facility waste streams containing 1,3-butadiene including disposing of analytical samples, loading of recycled oil, and operations conducted at the onsite WWT plant. The sample durations ranged from 18 to 135 minutes. One of the 10 samples was above the sample method's LOD. The other nine non-detects were estimated using a substitution method as described in Section 2.4.3.1. Due to the lack of quantifiable samples collected for this OES, more sophisticated methods of characterizing the dataset could not be employed.

Since EPA only had task-based samples with task-length durations, rather than full shift sample with fulls shift durations, the Agency needed to make assumptions on how best to obtain a full shift exposure estimate using these task-based samples. EPA made two assumptions to capture the range of possible exposures for this OES. The first assumption addressed the possibility that at a facility specifically focused on waste handling, the bulk of the day may be spent handling waste such that the task-based samples may be representative of a full shift exposure. The second assumption is based on information from the *Analysis of 1,3-Butadiene Industrial Hygiene Data*, which reports that at a manufacturing or processing facility routine task-based samples occur 5 days per week for only the length of the task. Using each of these assumptions, EPA presents two estimates: (1) the first assumes that the worker is exposed to the concentration of 1,3-butadiene measured during the task for their entire 8-hour shift (full shift assumption); (2) the second estimate assumes that the worker is exposed to 1,3-butadiene for the duration of the task and for the remainder of their 8-hour shift they receive no exposure to 1,3-butadiene (task-length exposure). EPA assumes that both estimates capture the range of exposures that a worker may experience.

EPA did not identify any ONU PBZ samples during data evaluation.

EPA compiled the 50th and 95th percentile 8-hour TWA concentrations to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8-hour TWA exposure concentrations, EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC as described in Appendix B. The results of these calculations are shown in Table 4-4 for the full shift assumption and Table 4-5 for the task-based assumption. EPA calculated the AC, $ADC_{intermediate}$, ADC, and LADC for ONUs using the central tendency exposure value from worker inhalation estimates.

Table 4-4. Summary of Occupational Inhalation Exposures to 1,3-Butadiene During Waste Handling, Treatment, and Disposal of 1,3-Butadiene (Full Shift Assumption)

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	10		0	
8-Hour TWA exposure concentrations	0.23	1.3	0.23	0.23
AC	0.16	0.88	0.16	0.16
$ADC_{intermediate}$	0.12	0.65	0.12	0.12
ADC	0.11	0.61	0.11	0.11
LADC	2.6E−02	0.19	2.6E−02	3.4E−02

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)
[a] 1 of the 10 data points for workers was above the method's LOD. EPA applied the substitution method to the non-detects in the dataset and used the 50th and 95th percentile of the dataset for the central tendency and high-end respectively. ONU data not available; used the central tendency from worker estimates

Table 4-5. Summary of Occupational Inhalation Exposures to 1,3-Butadiene During Waste Handling, Treatment, and Disposal of 1,3-Butadiene (Task-Based Assumption)

Exposure Type	Worker Inhalation Estimates (ppm)		ONU Inhalation Estimates (ppm)	
	Central Tendency	High-End	Central Tendency	High-End
Number of samples[a]	10		0	
8-Hour TWA exposure concentrations	1.7E−02	9.6E−02	1.7E−02	1.7E−02
AC	1.2E−02	6.6E−02	1.2E−02	1.2E−02
$ADC_{intermediate}$	8.5E−03	4.8E−02	8.5E−03	8.5E−03
ADC	7.9E−03	4.5E−02	7.9E−03	7.9E−03
LADC	1.9E−03	1.4E−02	1.9E−03	2.5E−03

Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)
[a] One of the 10 data points for workers was above the method's LOD. EPA applied the substitution method to the non-detects in the dataset and used the 50th and 95th percentile of the dataset for the central tendency and high-end respectively. ONU data not available; used the central tendency from worker estimates.

4.2 Uses Identified During Scoping but Not Quantitatively Assessed

As the risk evaluation process moved past scoping and a deeper understanding of each COU was developed, it was at times determined that a use identified during scoping would not be assessed. In the case of 1,3-butadiene, the following is a list of factors that contributed to these determinations:

1. ***Lack of Reasonably Available Information:*** EPA used systematic review to gather reasonably available information and conducted targeted searches when systematic review left gaps in the Agency's understanding of a given COU. If EPA was unable to find evidence of a use occuring, and further investigation into the rationale for the use's inclusion in the scope did not indicate a true use of the chemical, the Agency decided not to assess the use.
2. ***Industry Comments and Outreach:*** In some cases, EPA received comments or reached out to industry to request further information on certain uses. The industries to reach out to were chosen for a variety of reasons, including if they left a public comment that was relevant to the use in question and EPA needed more clarification, or if it was indicated in a database, company website, or SDSs that a particular entity may have knowledge of the suspected use. These communications sometimes led to the decision to not assess a use in cases where more information from industry indicated that the suspected use is not relevant to the chemical.
3. ***Increased Understanding of 1,3-Butadiene's Place in the Use:*** Although 1,3-butadiene may have been reported as being present in a particular use, there were cases when it was found upon further investigation that 1,3-butadiene was only present in "up-stream" steps of the processing, and by the time in a product's life cycle it reached the reported COU, 1,3-butadiene was no longer a component or present only in residual amounts. As detailed in Sections 3.3 and 3.5, 1,3-butadiene is often reacted to near completion during processing.

The following sections describe each use that was not assessed and details the specific rationale for why the use was included in the scope but was ultimately excluded from the risk evaluation.

4.2.1 Use of Plastic and Rubber Products

Use of Plastic and Rubber Products

In the final scope, EPA identified rubber tires and articles produced with synthetic rubber containing 1,3-butadiene (U.S. EPA, 2020c). It is estimated that more than 3 million metric tons of natural and synthetic rubber are used annually. Half of this use volume is expected to be from the use of styrene-butadiene-rubber (SBR). Half of this SBR is used to make tires (Burgess, 1991). In addition, plastics containing 1,3-butadiene were identified in electronic appliances, furniture and furnishings, toys and recreational products, housewares, packaging, automotive parts, building materials, and 3D printing filament (Steinle, 2016; Pfäffli and Säämänen, 1993).

As 1,3-butadiene is a building block for many plastics and rubbers, it may be present as a residual within plastic and rubber products. However, the conversion of 1,3-butadiene in these processes is near complete, as discussed in Section 3.3 and Section 3.5. IISRP submitted to EPA the results of a survey conducted in the first quarter of 2020 with manufacturers of synthetic rubber in the United States providing the residual 1,3-butadiene content in their final synthetic rubber product. The highest concentration of the survey was for emulsion styrene butadiene rubber where manufacturers reported less than 50 ppb residual butadiene present in the final product using the method of Head Space-Gas Chromatography/Mass Spectrometry (EPA-HQ-OPPT-2018-0451-0027). In another comment, IISRP informed that a synthetic rubber product produced in Europe may have residual butadiene content of less than 1 ppm (EPA-HQ-OPPT-2018-0451-0003). The highest residual 1,3-butadiene content that EPA found in a plastic or rubber product was 6.6 ppm found in 1,3-butadiene rubber-modified acrylonitrileacrylic bottles used for olive oil (ATSDR, 2012). The U.S. Tire Manufacturers Association stated in another public comment that 1,3-butadiene cannot be created from the use of synthetic rubber in the manufacture of a tire because once polymerization has occurred it is nearly impossible to break the polymer chain back into individual units of 1,3-butadiene (EPA-HQ-OPPT-2018-0451-0046). Due to this lack of evidence that 1,3-butadiene is present at any higher amounts, EPA did not quantify these releases or exposures.

Recycling of Plastic and Rubber Products

The final scope for 1,3-butadiene lists recycling as an in-scope COU (U.S. EPA, 2020c). The recycling of 1,3-butadiene monomer is discussed in Section 3.12. The recycling of plastic and rubber products is sorted under this OES. One example is the recycling of acrylonitrile-butadiene-styrene (ABS) that is often recovered from waste electrical and electronic equipment (WEEE). In this process, the plastic components of the equipment are separated from metals and electronic components. Next, thermoplastics like ABS are commonly recycled via mechanical recycling (injection molding, extrusion, rotational molding, and compression molding) into newly shaped products (Suresh et al., 2018). Another example is tire crumb—specifically the recycling of tires for use on synthetic turf fields (U.S. EPA, 2019c).

In a July 2019 report on synthetic turf field recycled tire crumbs, EPA collected tire crumb rubber from multiple tire recycling facilities producing tire crumb rubber as well as tire crumb infill from synthetic turf fields. These samples were analyzed for 1,3-butadiene via chamber emission testing at 25 and 60 °C. The study found that all 1,3-butadiene measurements from recycling plants were below the LOD, and on synthetic turf fields, only the 90th percentile of samples was above quantifiable limits, with the maximum measurement being 0.23 ng/g/h (U.S. EPA, 2019c). This indicates low potential for 1,3-butadiene release or occupational exposure at these tire recycling facilities.

4.2.2 Use of Lubricants and Greases

1,3-butadiene has been identified in automotive lubricants and aircraft lubricants (OECD, 2020; Envirologic Data, 1992). Specifically, styrene-butadiene copolymers are added to lubricants to act as viscosity modifiers. The copolymers are solids that are incorporated into a liquid lubricant. They reduce the rate of viscosity change with temperature and reduce cold starting effort and oil and fuel consumption. Some products also combine viscosity improvement with pour depressing and/or dispersant properties. These viscosity modifiers are present in lubricants in concentrations of 2 to 15 percent. EPA did not find any chemical-specific throughputs or use rates for 1,3-butadiene in the use of lubricants and greases.

As described in Section 3.5, which discusses 1,3-butadiene's role in the manufacturing of styrene-butadiene copolymers, the 1,3-butadiene monomer is present at very low levels within the finished styrene-butadiene copolymer product. Further, due to lack of evidence otherwise, it was determined that 1,3-butadiene is not present within lubricants and greases for any purpose other than the amount that may be residual within the styrene-butadiene copolymer. EPA did not find evidence in an SDS or other standard source database that 1,3-butadiene is present in lubricant or grease products.

5 SUMMARY OF ENVIRONMENTAL RELEASE ESTIMATES

Table 5-1 provides a summary for each OES by indicating the type of release and number of facilities, which is a conglomeration of all related tables presented throughout Section 3. EPA provides high-end and central tendency daily as well as yearly release estimates. The relevant supplemental files contain the calculations of the central tendency and high-end annual and daily releases for each OES that used EPA databases to estimate releases. Land release calculations are in *Land Releases for 1,3-Butadiene* (U.S. EPA, 2025h). Water release calculations are in *Water Releases for 1,3-Butadiene* (U.S. EPA, 2025n). Air release calculations using TRI are in *Air Releases (TRI) for 1,3-Butadiene* (U.S. EPA, 2025e). Air release calculations using NEI, all annual and daily calculations from both years (2017 and 2020), are in *Air Releases (NEI2017) for 1,3-Butadiene* (U.S. EPA, 2025c). The raw release data from NEI 2020 are in the *Air Releases (NEI2020) for 1,3-Butadiene* (U.S. EPA, 2025d).

Table 5-1. Summary of Environmental Releases by OES

OES	Estimated Annual Release (kg/site-yr)		Type of Discharge [b], Air Emission [c], or Transfer for Disposal [d]	Estimated Daily Release (kg/site-day) [e]		Number of Facilities	Source(s)
	Central Tendency	High-End [a]		Central Tendency	High-End		
Manufacturing	2.3	371	Surface water	6.5E−03	1.1	4	TRI
	7,500	2.1E04	WWT	22	59	3	TRI
	360	8,419	Fugitive air	1.0	24	37	TRI
	649	7,139	Fugitive air	1.9	20	40	NEI
	1,142	3.3E04	Stack air	3.3	95	39	TRI
	665	1.7E04	Stack air	2.0	46	34	NEI
	0.45	120	Land	1.3E−03	0.34	9	TRI
Repackaging	2.3	4.3	Surface water	6.5E−03	1.2E−02	1	TRI
	18	3,559	Fugitive air	5.1E−02	10	22	TRI
	1.6	999	Fugitive air	4.6E−03	2.8	74	NEI
	21	1,970	Stack air	5.9E−02	5.6	24	TRI
	23	1,127	Stack air	7.4E−02	3.2	51	NEI
	2.3	6.8	Land	6.5E−03	1.9E−02	2	TRI

OES	Estimated Annual Release (kg/site-yr)		Type of Discharge [b], Air Emission [c], or Transfer for Disposal [d]	Estimated Daily Release (kg/site-day) [e]		Number of Facilities	Source(s)
	Central Tendency	High-End [a]		Central Tendency	High-End		
Processing as a reactant	2.3	21	Surface water	6.5E−03	6.0E−02	4	TRI
	1.2	6.3	POTW	3.5E−03	1.8E−02	3	TRI
	0.5	0.5	WWT	1.3E−03	1.3E−03	1	TRI
	64	1,778	Fugitive air	0.18	5.1	54	TRI
	60	2,774	Fugitive air	0.17	7.6	57	NEI
	94	4,419	Stack air	0.27	13	53	TRI
	56	7,281	Stack air	0.16	20	54	NEI
	0.69	207	Land	2.0E−03	0.59	13	TRI
Processing – incorporation into formulation, mixture, or reaction product	7.7	8.8	Surface water	3.1E−02	3.5E−02	2	TRI
	1.4	2.5	POTW	5.4E−03	1.0E−02	2	TRI
	79	120	WWT	0.32	0.48	1	TRI
	10	712	Fugitive air	4.0E−02	2.8	47	TRI
	3.9	282	Fugitive air	1.5E−02	0.89	114	NEI
	56	1,349	Stack air	0.22	5.4	49	TRI
	12	455	Stack air	3.7E−02	1.2	107	NEI
	27	1.0E04	Land	0.11	40	4	TRI
Plastics and rubber polymerization	22	51	Surface water	7.5E−02	0.17	4	TRI
	2.3	266	WWT	7.6E−03	0.89	3	TRI
	635	8,385	Fugitive air	2.1	28	31	TRI
	375	8,339	Fugitive air	1.5	23	44	NEI
	903	1.7E04	Stack air	3.0	56	33	TRI
	122	9,233	Stack air	0.41	34	57	NEI
	49	366	Land	0.16	1.2	7	TRI

OES	Estimated Annual Release (kg/site-yr)		Type of Discharge [b], Air Emission [c], or Transfer for Disposal [d]	Estimated Daily Release (kg/site-day) [e]		Number of Facilities	Source(s)
	Central Tendency	High-End [a]		Central Tendency	High-End		
Plastics and rubber compounding and converting	113	215	Fugitive air	0.38	0.72	2	TRI
	0.57	18	Fugitive air	1.9E−03	7.3E−02	50	NEI
	113	215	Stack air	0.38	0.72	2	TRI
	6	46	Stack air	1.9E−02	0.14	57	NEI
	113	113	Land	0.38	0.38	1	TRI
Use of laboratory chemicals	6.4E−02	6.3	Fugitive air	2.6E−04	2.5E−02	4	NEI
	37	53	Stack air	0.1	0.14	1	NEI
Application of paints and coatings	0.2	31	Fugitive air	5.7E−04	0.12	14	NEI
	13	370	Stack air	4.4E−02	1.1	19	NEI
Application of adhesives and sealants	108	108	Stack air	0.41	0.43	1	NEI
	19	205	Fugitive or stack air	0.11	1.0	2–299,581 generic sites	Environmental release modeling
	589	2,878	Incineration or landfill	2.7	15		
	2.7E04	1.2E05	Air, incineration, or landfill	124	631		
Recycling	5.2	11	Surface water	1.5E−02	3.1E−02	2	TRI
	20	160	Fugitive air	5.8E−02	0.46	9	TRI
	20	183	Fugitive air	5.8E−02	1.3E−02	7	NEI
	13	475	Stack air	3.6E−02	1.4	11	TRI
	4.5	460	Stack air	1.3E−02	1.3	7	NEI
	1.6E−04	1.6E−04	Land	4.6E−07	4.6E−07	1	TRI
Waste handling, disposal, and treatment	4.5E−02	3.6	Fugitive air	1.8E−04	1.4E−02	6	TRI
	0.54	20	Fugitive air	1.5E−03	7.8E−02	49	NEI
	0.17	113	Stack air	6.9E−04	0.45	6	TRI
	1.4E−03	0.42	Stack air	5.4E−06	1.7E−03	251	NEI
	5,781	6,226	Land	23	25	2	TRI
Distribution in commerce	N/A[f]						

[a] "High-End" are defined as 95th percentile releases.

OES	Estimated Annual Release (kg/site-yr)		Type of Discharge [b], Air Emission [c], or Transfer for Disposal [d]	Estimated Daily Release (kg/site-day) [e]		Number of Facilities	Source(s)
	Central Tendency	High-End [a]		Central Tendency	High-End		

[b] Direct discharge to surface water and indirect discharges to WWT or POTW are included.
[c] Emissions via fugitive air; stack air; or treatment via incineration.
[d] Transfer to surface impoundment, land application, or landfills.
[e] Where available, EPA used peer-reviewed literature (*e.g.*, GSs or ESDs) to provide a basis to estimate the number of release days of 1,3-butadiene within an OES.
[f] While EPA considers distribution of commerce activities such as loading and unloading as part of each uses' OES, EPA also reviewed NRC data (NRCe, 2009) and DOT data (U.S. Department of Transportation, 2024) for the 2016–2021 calendar years for incident reports pertaining to distribution of 1,3-butadiene. Discussion and results on this topic are in Section 3.7.

6 WEIGHT OF SCIENTIFIC EVIDENCE CONCLUSIONS FOR ENVIRONMENTAL RELEASES AND 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 (WOSE) rating. The Agency also 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. The best professional judgment is summarized using the descriptors of robust, moderate, slight, or indeterminant, according to EPA's Draft Systematic Review Protocol (U.S. EPA, 2021a). For example, a conclusion of moderate is appropriate where there is 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. A conclusion of slight is appropriate where there is limited information that does not sufficiently cover all sites within the OES, and the assumptions and uncertainties are not fully known or documented. See EPA's Draft Systematic Review Protocol (U.S. EPA, 2021a) for additional information on weight of scientific evidence conclusions.

Weight of scientific evidence ratings for the environmental release and occupational exposure estimates for each OES, including details on the basis EPA used to determine the rating, are provided in the sections and tables that follow.

6.1 Environmental Releases

EPA estimated air, water, and land releases of 1,3-butadiene using various methods and information sources, including TRI and NEI data as well as ESD modeling with Monte Carlo. TRI was determined to have an overall data quality rating of high through EPA's systematic review process, and NEI was determined to have a medium-quality rating. EPA determined that the ESD used in the evaluation had an overall data quality rating of high.

Strengths

TRI (which reports releases to air, land, and water) and NEI (which reports releases to air) provided a comprehensive amount of release data for 1,3-butadiene. A strength of using TRI is that it compiles the best readily available release data for all facilities that reported to EPA. For air releases, NEI data captures additional sources that are not included in TRI due to reporting thresholds. Additionally, point sources in NEI report at the emission-unit level.

Although 1,3-butadiene monitoring data are preferred to modeled data, in the case when modeling was needed to estimate releases, EPA strengthened model estimates by using Monte Carlo modeling to allow for variation in environmental release calculation input parameters according to the ESD and other literature sources.

Limitations

When using TRI data to analyze chemical releases, it is important to acknowledge that TRI reporting does not include all releases of the chemical and therefore, the number of sites for a given OES may be underestimated. For each OES that had TRI or NEI data, the analysis of releases for those OESs was limited to the facilities that reported releases to TRI or NEI. Therefore, it is uncertain the extent to which sites not captured in these databases have air, water, or land releases of 1,3-butadiene.

EPA was unable to map certain facilities in NEI to an OES due to the lack of information regarding the activity of 1,3-butadiene at the site. Therefore, some facilities are mapped to the Unknown OES.

For the modeled release, 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 facility PV data, and there are uncertainties in the representativeness of the industry-provided data as well as the operating parameters used in the ESD.

Assumptions

To assess daily air and water discharges, EPA assumed that the number of facility operating days was equal to the number of release days. The Agency has developed generic estimates of operating days for each OES, as described in Section 2.3.2. For the Commercial use of laboratory chemicals OES, EPA assumed the number of operating days based on the Draft GS on Use of Laboratory Chemicals.

There is uncertainty that all sites for a given OES operate for the assumed duration; therefore, the average daily releases may be higher if sites have fewer release days or lower if they have greater release days. Furthermore, 1,3-butadiene concentrations in air emissions and wastewater release to receiving water bodies at each facility may vary from day-to-day such that on any given day the actual daily releases may be higher or lower than the estimated average daily discharge. Thus, this approach minimizes variations in emissions and discharges from day to day. EPA did not estimate daily land releases due to the high level of uncertainty in the number of release days associated with land releases. The Agency expects that sites may not send waste to landfills every day and are more likely to accumulate waste for periodic shipments to landfills. However, sites that release to municipal landfills may have more frequent release days based on the frequency of shipments.

Uncertainties

Uncertainties with using TRI and NEI data include underestimation of the number of sites for a given OES due to reporting thresholds in TRI, the accuracy of EPA's mapping of sites reporting to TRI and NEI to a specific OES, and quality of the data reported to TRI and NEI.

Some uncertainties of using NEI data include the accuracy of EPA's mapping of sites reporting to NEI to a specific OES. For point sources, there may be multiple feasible OESs at a single facility. Additionally, there is uncertainty due to the voluntary reporting of HAP data. As a result, EPA augments SLT-provided HAP data with other information to better estimate point source HAP emissions. NEI does not require stack testing or continuous emissions monitoring, and reporting agencies may use a number of different emission estimation methods with varying degrees of reliability. These methodologies include continuous emissions monitoring, stack testing, site- and vendor-specific emission factors, SLT and/or other emission factors, and engineering judgment.

One uncertainty for using GS is the lack of specific 1,3-butadiene data. Because GSs are generic, assessed parameter values may not always be representative of applications specific to 1,3-butadiene use in each OES. Another uncertainty is lack of consideration for release controls. The GS assume that all activities occur without any release controls, and in an open-system environment where vapor freely escape (OECD, 2013). Actual releases may be less than estimated if facilities utilize pollution control methods.

In some cases, the number of facilities for a given OES was estimated using data from the U.S. Census. In such cases, the average daily release calculated from sites reporting to TRI or NEI was applied to the total number of sites reported (U.S. BLS, 2023). It is uncertain how accurate this average release is to actual releases at these sites; therefore, releases may be higher or lower than the calculated amount.

Table 6-1 provides a summary of EPA's overall confidence in the environmental release estimates for each OES.

Table 6-1. Summary of Assumptions, Uncertainty, and Overall Confidence in Release Estimates by OES

OES[a]	Weight of Scientific Evidence Conclusion in Release Estimates
Manufacturing	For this OES, EPA had release information for water, land, and air from TRI and for air from NEI. Water releases are assessed using reported releases from the 2016–2021 TRI, which has a high data quality rating from the systematic review process. The primary strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. The primary limitation is that the water release assessment is based on 7 reporting sites, and EPA did not have additional sources to estimate water releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 56 additional manufacturing sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. The primary limitation is that the land releases assessment is based on 4 reporting sites, and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 59 additional manufacturing sites that report releases to other media but do not report releases to land. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Repackaging	For this OES, EPA had release information for water, land, and air from TRI and for air from NEI. Water releases are assessed using reported releases from the 2016–2021 TRI, which has a high data quality rating from the systematic review process. The primary strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. The primary limitation is that the water release assessment is based on 1 reporting site, and EPA did not have additional sources to estimate water releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 114 additional repackaging sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. The primary limitation is that the land releases assessment is

OES[a]	Weight of Scientific Evidence Conclusion in Release Estimates
	based on 2 reporting sites, and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 113 additional manufacturing sites that report releases to other media but do not report releases to land. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Processing as a reactant	For this OES, EPA had release information for water, land, and air from TRI and for air from NEI. Water releases are assessed using reported releases from the 2016–2021 TRI, which has a high data quality rating from the systematic review process. The primary strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. The primary limitation is that the water release assessment is based on 9 reporting sites, and EPA did not have additional sources to estimate water releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 94 additional processing as a reactant sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. The primary limitation is that the land releases assessment is based on 13 reporting sites, and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 90 additional processing as a reactant sites that report releases to other media but do not report releases to land. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Processing – incorporation into formulation, mixture, or reaction product	For this OES, EPA had release information for water, land, and air from TRI and for air from NEI. Water releases are assessed using reported releases from the 2016–2021 TRI, which has a high data quality rating from the systematic review process. The primary strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. The primary limitation is that the water release assessment is based on 4 reporting sites, and EPA did not have additional sources to estimate water releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 174 additional sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI

OES[a]	Weight of Scientific Evidence Conclusion in Release Estimates
	due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. The primary limitation is that the land releases assessment is based on 8 reporting sites, and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 170 additional sites that report releases to other media but do not report releases to land. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Plastics and rubber polymerization	For this OES, EPA had release information for water, land, and air from TRI and for air from NEI. Water releases are assessed using reported releases from the 2016–2021 TRI, which has a high data quality rating from the systematic review process. The primary strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. The primary limitation is that the water release assessment is based on 7 reporting sites, and EPA did not have additional sources to estimate water releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 66 additional manufacturing sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. The primary limitation is that the land releases assessment is based on 8 reporting sites, and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 65 additional sites that report releases to other media but do not report releases to land. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Plastics and rubber compounding and converting	For this OES, EPA had release information for land and air from TRI and for air from NEI. There were no reported water releases in TRI for this OES. Based on other reporting databases (CDR, NEI, etc.), there are 77 additional sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI, which has a medium-data quality

OES[a]	Weight of Scientific Evidence Conclusion in Release Estimates
	rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. The primary limitation is that the land releases assessment is based on 1 reporting site, and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 76 additional sites that report releases to other media but do not report releases to land. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Use of laboratory chemicals	For this OES, EPA had release information for air from NEI. There were no reported air, water, or land releases in TRI for this OES. Based on other reporting databases (CDR, NEI, etc.), there are 4 additional sites that report releases to air but do not report releases to water or land. Air releases are assessed using reported releases from 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Application of paints and coatings	For this OES, EPA had release information for air from NEI. There were no reported air, water, or land releases in TRI for this OES. Based on other reporting databases (CDR, NEI, etc.), there are 28 additional sites that report releases to air but do not report releases to water or land. Air releases are assessed using 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.

OES[a]	Weight of Scientific Evidence Conclusion in Release Estimates
Application of adhesives and sealants	EPA identified 1 facility in NEI reporting air releases of 1,3-butadiene. EPA determined this data are not sufficient to capture the entirety of environmental releases for this scenario. Therefore, releases to the environment are assessed using the ESD on the Industrial Use of Adhesives for Substrate Bonding (OECD, 2013). This ESD has a high data quality rating from the systematic review process. EPA used this ESD combined with Monte Carlo modeling to estimate releases to the environment, with media of release assessed using assumptions from the ESD model. More information about the details and assumptions of the model can be found in Appendix D. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values and a range of potential releases values is more likely than a discrete value to capture actual releases at sites. EPA believes the primary uncertainty to be the reasonableness of the product on which this assessment is based. It is unlikely that 1,3-butadiene monomer would be present at concentrations of up to 24% in a non-pressurized commercial product as is stated in the SDS used in this assessment. This is due to the physical properties of 1,3-butadiene, which is a gas at room temperature and would not remain within the product at such high concentrations. In addition, there is uncertainty in the representativeness of values toward the true distribution of potential releases. In addition, EPA lacks 1,3-butadiene chemical throughput data and number of facilities; therefore, number of facilities and throughput estimates are based on stock throughputs provided by the ESD and applying conservative assumptions to public comments provided to EPA (see Section 3.10.2). Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is slight and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Recycling	For this OES, EPA had release information for water, land, and air from TRI and for air from NEI. Water releases are assessed using reported releases from the 2016–2021 TRI, which has a high data quality rating from the systematic review process. The primary strength of TRI data is that TRI compiles the best readily available release data for all reporting facilities. No TRI facilities that were mapped to this OES reported releases to water and EPA did not have additional sources to estimate water releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 10 additional sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI, which has a medium data quality rating from the systematic review process. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. No TRI facilities that were mapped to this OES reported releases to land and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 10 additional sites that report releases to other media but do not report releases to land.

OES[a]	Weight of Scientific Evidence Conclusion in Release Estimates
	Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.
Waste handling, disposal, and treatment	For this OES, EPA had release information for land and air from TRI and for air from NEI. There were no reported water releases in TRI for this OES. Based on other reporting databases (CDR, NEI, etc.), there are 289 additional sites that report releases to other media but do not report releases to water. Air releases are assessed using reported releases from 2016–2021 TRI, and 2017 and 2020 NEI. A strength of NEI data is that NEI captures additional sources that are not included in TRI due to reporting thresholds. Factors that decrease the overall confidence for this OES include the uncertainty in the accuracy of reported releases, and the limitations in representativeness to all sites because TRI and NEI may not capture all relevant sites. Additionally, EPA made assumptions on the number of operating days to estimate daily releases. Land releases are assessed using reported releases from 2016–2021 TRI. The primary limitation is that the land releases assessment is based on 2 reporting sites, and EPA did not have additional sources to estimate land releases from this OES. Based on other reporting databases (CDR, NEI, etc.), there are 287 additional sites that report releases to other media but do not report releases to land. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust and provides a plausible estimate of releases in consideration of the strengths and limitations of reasonably available data.

[a] OESs for Distribution in commerce, Use in fuels and related products, Use of plastic and rubber products, and Use of lubricants and greases are not present in this table because they were not quantitatively assessed.

6.2 Occupational Exposure

EPA estimated occupational exposure using several sources of air monitoring data; however, the source used the most in this assessment was an inhalation exposure monitoring study submitted to EPA by ACC, *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). These data were determined to have overall data quality ratings of high through EPA's systematic review process. Other studies used had data quality ratings of high or medium.

Number of Workers

There are several uncertainties surrounding the estimated number of workers potentially exposed to 1,3-butadiene, as outlined below. Most are unlikely to result in a systematic underestimate or overestimate but could result in an inaccurate estimate.

CDR data are used to estimate the number of workers associated with manufacturing. There are inherent limitations to the use of CDR data as they are reported by manufacturers and importers of 1,3-butadiene. Manufacturers and importers are only required to report if they manufactured or imported 1,3-butadiene in excess of 25,000 lb at a single site during any calendar year; as such, CDR may not capture all sites and workers.

There are also uncertainties with BLS data, which are used to estimate the number of workers for the remaining COUs. First, BLS' Occupational Employment and Wage Statistics program's employment data for each industry/occupation combination are only available at the 3-, 4-, or 5-digit NAICS level, rather than the full 6-digit NAICS level. This lack of granularity could result in an overestimate of the number of exposed workers if some 6-digit NAICS are included in the less granular BLS estimates but are not likely to use 1,3-butadiene for the assessed applications. EPA addressed this issue by refining the OES estimates using total employment data from the U.S. Census' SUSB. However, this approach assumes that the distribution of occupation types (SOC codes) in each 6-digit NAICS is equal to the distribution of occupation types at the parent 5-digit NAICS level. If the distribution of workers in occupations with 1,3-butadiene exposure differs from the overall distribution of workers in each NAICS, then this approach will result in inaccuracy.

Second, EPA's judgments about which industries (represented by NAICS codes) and occupations (represented by SOC codes) are associated with the uses assessed in this report are based on EPA's understanding of how 1,3-butadiene is used in each industry. Designations of which industries and occupations have potential exposures is nevertheless subjective, and some industries/occupations with few exposures might erroneously be included, or some industries/occupations with greater exposures might erroneously be excluded. This would result in inaccuracy but would be unlikely to systematically overestimate or underestimate the number of exposed workers.

Analysis of Exposure Monitoring Data

For several OESs, measurement studies of 1,3-butadiene exposure were directly applicable and used to estimate inhalation exposures. The primary strength of these data is the use of personal and applicable data. The primary limitation is that EPA assumed 250 exposure days per year based on 1,3-butadiene exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures.

For the remaining OESs, segments of the monitoring data from the OESs mentioned above were used as analog. The principal limitation of the monitoring data is the uncertainty in the representativeness of the data. Where few data are available, the assessed exposure levels are unlikely to be representative of worker exposure across the entire job category or industry. This may particularly be the case when monitoring data were available for only one site. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of monitoring data. Age of the monitoring data can also introduce uncertainty due to differences in workplace practices and equipment used at the time the monitoring data were collected compared to those currently in use. Therefore, older data may overestimate or underestimate exposures, depending on these differences. The effects of these uncertainties on the occupational exposure assessment are unknown, as the uncertainties may result in either overestimation or underestimation of exposures depending on the actual distribution of 1,3-butadiene air concentrations and the variability of work practices among different sites.

This report uses existing worker exposure monitoring data to assess exposure to 1,3-butadiene during several COUs. To analyze the exposure data, EPA categorized each data point as either "worker" or "ONU". The categorizations are based on descriptions of worker job activity as provided in literature and EPA's professional judgment. In general, samples for employees who are expected to have the highest exposure from direct handling of 1,3-butadiene are categorized as "worker" and samples for employees who are expected to have the lower exposure and do not directly handle 1,3-butadiene are categorized as ONU.

Table 6-2 provides a summary of EPA's overall confidence in its inhalation exposure estimates for each OES.

Table 6-2. Summary of Assumptions, Uncertainty, and Overall Confidence in Inhalation Exposure Estimates by OES

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
Manufacturing	For this OES, EPA had monitoring data from manufacturing and processing facilities provided by the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). 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 of the inhalation exposure estimates for this OES is that it used directly applicable monitoring data, which are preferrable to other assessment approaches such as modeling. The monitoring data were full shift PBZ air concentration data of 1,3-butadiene with the data source having a high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from 47 facilities that manufacture and/or process 1,3-butadiene, and over 5,500 individual samples. These samples were divided into several different worker activities, which allowed for a granular assessment that accounted for a variety of tasks. The number of full shift samples per task varied from 2 samples to 1,952 samples. Despite the high number of samples across many facilities, there is uncertainty as to whether the measured concentrations and exposure frequencies from the single industry source accurately represent the entire industry and the true distribution of inhalation concentrations in this scenario. Also, the 47 facilities included in the source may manufacture or process 1,3-butadiene, and since this could not be differentiated, EPA assumed this dataset relevant to both scenarios. The inclusion of data from the processing of 1,3-butadiene rather than just the manufacturing could impact the results in a way that is not possible to know. EPA also assumed 250 exposure days per year for 8-hour TWAs and 167 days per year for 12-hour TWAs based on 1,3-butadiene exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. The primary limitation of this assessment however, is the high number of non-detect samples present in the provided dataset. When 4 or more samples were above the sampling method's LOD, EPA was able to use MLE to determine central tendency and high-end estimates. However, for all nonroutine and some turnaround activities, there were very few detected samples (in the case of Instrument and Electrical-nonroutine worker, there were no detected samples). Using a substitution method, EPA was still able to provide an estimate in these cases, but there is less confidence in these conclusions. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for a majority of activities in the Manufacturing OES is robust and provides a plausible estimate of exposures. Due to the lack of detected samples to be used in the assessment, the estimates associated with the following activities have a weight of scientific evidence conclusion of moderate: Infrastructure/Distribution Operations – Nonroutine/Other, Instrumental and Electrical – Nonroutine, Instrument and Electrical – Turnaround, Machinery & Specialists Mechanical Group – Turnaround, Maintenance – Nonroutine/Other, Operations Onsite – Nonroutine/Other).

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
Repackaging	For this OES, EPA used analogous monitoring data from loading/unloading during the manufacturing and processing of 1,3-butadiene from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). ONU data were not available, so EPA used the central tendency from worker estimates. 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 Repackaging OES. The primary strength of the inhalation exposure estimates for this OES is that it used chemical-specific monitoring data in a setting expected to be similar, which are preferrable to other assessment approaches such as modeling. The monitoring data were task-based PBZ air concentration data of 1,3-butadiene with the data source having a high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from 47 facilities that manufacture and/or process 1,3-butadiene, and there were 158 samples specifically relevant to loading/unloading activities greater than 15 minutes (activities less than or equal to 15 minutes were not considered in this assessment) expected to occur on a routine basis (5 days per week). There are 3 primary limitations of this assessment. The first is the high number of non-detect samples present in the provided dataset. Since there were 87 detects out of 158 samples, EPA used MLE to determine central tendency and high-end estimates. The second primary limitation is the fact that the monitoring data are not full shift, but task-length. Due to this limitation in the dataset, EPA made 2 separate estimates. The first estimate captures the possibility that workers at a facility specifically focused on repackaging may spend the bulk of their day performing repackaging activities. Due to this, the full shift estimate assumes that the measured task-length concentration occurs for the full 8-hour shift. The second estimate captures the possibility that the workers at a facility may only perform one repackaging activity per day and assumes that a worker is exposed to the measured concentration for the length of the task and has zero exposure for the remainder of the 8-hour shift. These 2 estimates provide both an upper and lower bound of possible worker exposure. The third primary limitation is that the data are analogous, and there is uncertainty that the activities that occur during this task at a manufacturing or processing facility are representative of the true distribution of inhalation exposures that may occur at a facility that more regularly repackages 1,3-butadiene. Other limitations include that despite the high number of samples across many facilities, there is uncertainty as to whether the measured concentrations and exposure frequencies from the single industry source accurately represent the entire industry and the true distribution of inhalation concentrations in this scenario. EPA also assumed 250 exposure days per year for 8-hour TWAs 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 the Repackaging OES is moderate and provides a plausible estimate of exposures.

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
Processing as a reactant	For this OES, EPA had monitoring data from manufacturing and processing facilities provided by the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). 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 Processing as a reactant OES. The primary strength of the inhalation exposure estimates for this OES is that it used directly applicable monitoring data, which are preferrable to other assessment approaches such as modeling. The monitoring data were full shift PBZ air concentration data of 1,3-butadiene with the data source having a high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from 47 facilities that manufacture and/or process 1,3-butadiene, and over 5,500 individual samples. These samples were divided into several different worker activities, which allowed for a granular assessment that accounted for a variety of tasks. The number of full shift samples per task varied from 2 samples to 1,952 samples. Despite the high number of samples across many facilities, there is uncertainty as to whether the measured concentrations and exposure frequencies from the single industry source accurately represent the entire industry and the true distribution of inhalation concentrations in this scenario. Also, the 47 facilities included in the source may manufacture or process 1,3-butadiene, and since this could not be differentiated, EPA assumed this dataset relevant to both scenarios. The inclusion of data from the manufacturing of 1,3-butadiene rather than just the processing could impact the results in a way that is not possible to know, though some confidence is added because the estimates used in the assessment are comparable to exposure estimates relevant to the same OES obtained independently from another source. EPA also assumed 250 exposure days per year for 8-hour TWAs and 167 days per year for 12-hour TWAs based on 1,3-butadiene exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. The primary limitation of this assessment, however, is the high number of non-detect samples present in the provided dataset. When 4 or more samples were above the sampling method's LOD, EPA was able to use MLE to determine central tendency and high-end estimates. However, for all nonroutine and some turnaround activities, there were very few detected samples (in the case of Instrument and Electrical-nonroutine worker, there were no detected samples). Using a substitution method, EPA was still able to provide an estimate in these cases, but there is less confidence in some of these conclusions. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for a majority of activities in the Processing OES is robust and provides a plausible estimate of exposures. Due to the lack of detected samples to be used in the assessment, the estimates associated with the following activities have a weight of scientific evidence conclusion of moderate: Infrastructure/Distribution Operations – Nonroutine/Other, Instrumental and Electrical – Nonroutine, Instrument and Electrical – Turnaround, Machinery & Specialists Mechanical Group –

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
	Turnaround, Maintenance – Nonroutine/Other, Operations Onsite – Nonroutine/Other).
Processing – incorporation into formulation, mixture, or reactant product	For this OES, EPA had monitoring data from manufacturing and processing facilities provided by the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). EPA considered the assessment approach, the quality of the data, and the uncertainties in assessment results to determine a weight of scientific evidence conclusion for the full shift TWA inhalation exposure estimates for the Processing – incorporation into formulation, mixture, or reactant product OES. The primary strength of the inhalation exposure estimates for this OES is that it used chemical-specific monitoring data in a setting expected to be similar, which are preferrable to other assessment approaches such as modeling. The monitoring data were full shift PBZ air concentration data of 1,3-butadiene with the data source having a high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from 47 facilities that manufacture and/or process 1,3-butadiene, and over 5,500 individual samples. These samples were divided into several different worker activities, which allowed for a granular assessment that accounted for a variety of tasks. The number of full shift samples per task varied from 2 samples to 1,952 samples. There are 2 primary limitations of this assessment. The first is the high number of non-detect samples present in the provided dataset. When 5 or more samples were above the sampling method's LOD, EPA was able to use MLE to determine central tendency and high-end estimates. However, for all nonroutine and some turnaround activities, there were very few detected samples (in the case of Instrument and Electrical-nonroutine worker, there were no detected samples). Using a substitution method, EPA was still able to provide an estimate in these cases, but there is less confidence in some of these conclusions. The second limitation is the fact that the monitoring data used in this assessment is not directly from the OES of Processing – incorporation into formulation, mixture, or reactant product. Due to the similarity in expected activities, and that it is expected that a smaller amount of 1,3-butadiene would be going toward this scenario as opposed to processing, EPA believes this dataset to be a reasonable conservative estimate. The central tendency is likely more representative of worker exposure to this scenario rather than the high-end. Other limitations include that despite the high number of samples across many facilities, there is uncertainty as to whether the measured concentrations and exposure frequencies from the single industry source accurately represent the entire industry and the true distribution of inhalation concentrations in this scenario. EPA also assumed 250 exposure days per year for 8-hour TWAs and 167 days per year for 12-hour TWAs based on 1,3-butadiene 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 a majority of activities in the Processing – incorporation into formulation, mixture, or reactant product OES is moderate and provides

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
	a plausible estimate of exposures. Due to the lack of detected samples to be used in the assessment, the estimates associated with the following activities have a weight of scientific evidence conclusion of slight to moderate: Infrastructure/Distribution Operations – Nonroutine/Other, Instrumental and Electrical – Nonroutine, Instrument and Electrical – Turnaround, Machinery & Specialists Mechanical Group – Turnaround, Maintenance – Nonroutine/Other, Operations Onsite – Nonroutine/Other). As mentioned above, central tendencies are likely to be more representative than high-end in the case of this OES.
Plastics and rubber polymerization	For this OES, EPA had summary statistics from 11 sources that conducted full shift PBZ monitoring at facilities that perform 1,3-butadiene polymerization. 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 Plastics and rubber polymerization OES. The primary strength of the inhalation exposure estimates for this OES are that they used directly applicable, chemical-specific monitoring data, which are preferrable to other assessment approaches such as modeling. The monitoring data were full shift PBZ air concentration data of 1,3-butadiene from multiple data sources, each with a medium or high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from a multitude of facilities that polymerize 1,3-butadiene, and there were 1,953 samples specifically relevant to worker exposure, and 580 samples specifically relevant to ONU exposure. The primary limitation of this assessment is the lack of discrete data. The studies provided averages and number of samples among other summary information, but without the discrete data EPA does not know whether the handling of non-detects, among other data processing, is consistent across the studies, nor can EPA differentiate between the many different tasks that occur at polymerization facilities. While the number of sources is a strength of the estimate, some of the information from older sources, or sources from outside of the country, introduces uncertainty about the representativeness of the estimates to the United States in the present day. Other limitations include that despite the high number of samples across many facilities, there is uncertainty as to whether the measured concentrations and assumed exposure frequencies accurately represent the entire industry and the true distribution of inhalation concentrations in this scenario. EPA assumed 250 exposure days per year for 8-hour TWAs 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 the Plastics and rubber polymerization OES is robust and provides a plausible estimate of exposures.

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
Plastics and rubber compounding and converting	For this OES, EPA had NIOSH/OSHA data and monitoring data from facilities that perform rubber compounding and converting. ONU data were not available, so EPA used the central tendency from worker estimates. 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 this OES. The primary strength of the inhalation exposure estimates for this OES is that it used directly applicable, chemical-specific monitoring data, which are preferrable to other assessment approaches such as modeling. The monitoring data were full shift PBZ air concentration data of 1,3-butadiene from multiple data sources, each with a medium or high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from multiple facilities that perform plastics and rubber compounding and converting. Separate estimates were made for plastics and rubber compounding and plastics and rubber converting, though they used largely the same dataset aside from 3 8-hour data points that were included in the plastics and rubber compounding analysis but excluded for converting (due to their specific mention of compounding). There were 53 8-hour worker samples relevant to plastics and rubber compounding, 50 8-hour samples relevant to plastics and rubber converting, and 44 12-hour samples used for both. The primary limitation is the high number of non-detect samples present in the datasets. For rubber compounding, out of 53 samples for an 8-hour shift, there were 7 above the LOD. For rubber converting, out of 50 samples for an 8-hour shift, there were 6 above the LOD. For the 12-hour estimates, out of 44 samples, 25 were above the LOD. EPA used MLE to determine central tendency and high-end estimates in all cases. Another limitation is that the bulk of the data for plastic and rubber compounding is analogous from plastics and rubber converting. There is also uncertainty in the representativeness of this data toward the true distribution of inhalation concentrations in these scenarios. Also, EPA assumed 250 exposure days per year 8-hour TWAs and 167 days per year for 12-hour TWAs based on 1,3-butadiene 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 to robust and provides a plausible estimate of exposures.
Use of laboratory chemicals	For this OES, EPA used analogous monitoring data for laboratory technicians collected from 1,3-butadiene manufacturing and processing facilities from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). 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 this OES. The primary strength of the inhalation exposure estimates for this OES is the use of chemical-specific monitoring data in a setting expected to be similar, which are preferrable to other assessment approaches such as modeling. The

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
Use of laboratory chemicals *(continued)*	monitoring data were full shift PBZ air concentration data of 1,3-butadiene with the data source having a high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from 47 facilities that manufacturing and/or process 1,3-butadiene, and there were 215 routine samples obtained from laboratory technicians. There are 2 primary limitations of this assessment. The first is the high number of non-detect samples present in the provided dataset. Since there were 57 detects out of 215 samples, EPA used MLE to determine central tendency and high-end estimates. The second primary limitation is the assumption that the exposures to a laboratory technician in a manufacturing and processing facility are comparable to the exposures to a laboratory technician in a commercial lab. While many tasks may be similar (analysis of samples), the lab technicians at manufacturing/processing sites perform some tasks that would not be expected in a commercial setting such as the collection of samples from the manufacturing or processing process. The physical state of 1,3-butadiene may also differ between these 2 scenarios (1,3-butadiene samples may be a liquified vapor in a manufacturing or processing setting, while 1,3-butadiene used in a commercial lab may be in gaseous form). Despite this limitation, EPA did not find data more applicable to this scenario, though due to this it is expected that the central tendency would be more representative of lab workers in a commercial setting, rather than the high-end which may portray exposure to these tasks that are exclusive to manufacturing and process facilities. An additional limitation is the assumption of 250 exposure days per year for 8-hour TWAs and 167 days per year for 12-hour TWAs based on 1,3-butadiene 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 in consideration of the strengths and limitations of reasonably available data.
Application of paints and coatings	For this OES, EPA had NIOSH/OSHA data. However, all values were below the LOD. EPA used the LOD for the high-end and LOD ÷ 2 for central tendency. ONU data were not available; thus, EPA used the central tendency from worker estimates. 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 exposure estimates. EPA used inhalation data to assess inhalation exposures. The primary strength of the data is the use of personal monitoring data, which is preferrable to other assessment approaches such as modeling. In addition, the sampling data spanned multiple facilities. The primary limitation is that the data were below the LOD. There is also uncertainty in the representativeness of this data toward the true distribution of inhalation concentrations in this scenario, since OSHA CEHD does not provide

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
	worker activity descriptions. EPA also assumed 250 exposure days per year based on 1,3-butadiene 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 slight to moderate and provides a plausible estimate of exposures.
Application of adhesives and sealant	For this OES, EPA had NIOSH/OSHA data. However, all values were below the LOD. EPA used LOD for the high-end and LOD ÷ 2 for central tendency. ONU data were not available thus EPA used the central tendency from worker estimates. 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 exposure estimates. EPA used inhalation data to assess inhalation exposures. The primary strength of the data is the use of personal and potentially applicable data, which is preferrable to other assessment approaches such as modeling. In addition, the sampling data spanned multiple facilities. The primary limitation is that the data points were all below the LOD. There is uncertainty in the representativeness of this data toward the true distribution of inhalation concentrations in this scenario, since OSHA CEHD does not provide worker activity descriptions. EPA also assumed 250 exposure days per year based on 1,3-butadiene 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 slight to moderate and provides a plausible estimate of exposures.
Recycling	For this OES, EPA used analogous monitoring data from the activity of handling, transporting, and disposing of waste containing 1,3-butadiene during the manufacturing and processing of 1,3-butadiene from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). EPA assumes that for 1,3-butadiene waste handling activities would be similar to recycling for the purpose of energy recovery. ONU data were not available, so EPA used the central tendency from worker estimates. 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 Recycling OES. The primary strength of the inhalation exposure estimates for this OES is that it used chemical-specific monitoring data in a setting expected to be similar, which are preferrable to other assessment approaches such as modeling. The monitoring data were task-based PBZ air concentration data of 1,3-butadiene with the data source having a high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from 47 facilities that manufacture and/or process 1,3-butadiene. There were 10 samples specifically relevant to waste handling activities, also used to represent recycling, greater than 15 minutes (activities less than or equal to 15 minutes were not considered in this assessment) expected to occur on a routine basis (5 days per week).

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
Recycling *(continued)*	There are 3 primary limitations of this assessment. The first is the high number of non-detect samples present in the provided dataset. Of 10 samples collected, only one sample was above the LOD. Due to this, EPA used a substitution method to characterize those data points below the LOD and obtain the central tendency and high-end estimates. The second limitation is the fact that the monitoring data is not full shift, but task-length. Due to this limitation in the dataset, EPA made 2 separate estimates. The first estimate captures the possibility that workers at a facility specifically focused on recycling may spend the bulk of their day performing recycling activities. Due to this, the full shift estimate assumes that the measured task-length concentration occurs for the full 8-hour shift. The second estimate captures the possibility that the workers at a facility may only perform one recycling activity per day and assumes that a worker is exposed to the measured concentration for the length of the task and has zero exposure for the remainder of the 8-hour shift. These 2 estimates provide both an upper and lower bound of possible worker exposure based on the existing data. The third limitation is the uncertainty that the activities that occur during this task at a manufacturing/processing facility are representative of the true distribution of inhalation exposures that may occur at a facility that recycles 1,3-butadiene. Other limitations include that EPA assumed 250 exposure days per year for 8-hour TWAs 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 the Recycling OES is slight to moderate and provides a plausible estimate of exposures.
Waste handling, disposal, and treatment	For this OES, EPA used analogous monitoring data from the activity of handling, transporting, and disposing of waste containing 1,3-butadiene during the manufacturing and processing of 1,3-butadiene from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076). ONU data were not available, so EPA used the central tendency from worker estimates. EPA considered the assessment approach, the quality of the data, and the uncertainties in assessment results to determine a weight of scientific evidence conclusion for the full shift TWA inhalation exposure estimates for this OES. The primary strength of the inhalation exposure estimates for this OES is that it used chemical-specific monitoring data in a setting expected to be similar, which are preferrable to other assessment approaches such as modeling. The monitoring data were task-based PBZ air concentration data of 1,3-butadiene with the data source having a high data quality rating from the systematic review process. Another strength is that the source contained monitoring data from 47 facilities that manufacture and/or process 1,3-butadiene. There were 10 samples specifically relevant to waste handling activities greater than 15 minutes (activities less than or equal to 15 minutes were not considered in this assessment) expected to occur on a routine basis (5 days per week). There are 3 primary limitations of this assessment. The first is the high number of non-detect samples present in the

OES[a]	Weight of Scientific Evidence Conclusion in Exposure Estimates
Waste handling, disposal, and treatment *(continued)*	provided dataset. Of 10 samples collected, only one sample was above the LOD. Due to this, EPA used a substitution method to characterize those data points below the LOD and obtain the central tendency and high-end estimates. The second limitation is the fact that the monitoring data is not full shift, but task-length. Due to this limitation in the dataset, EPA made 2 separate estimates. The first estimate captures the possibility that workers at a facility specifically focused on waste handling may spend the bulk of their day performing waste handling activities. Due to this, the full shift estimate assumes that the measured task-length concentration occurs for the full 8-hour shift. The second estimate captures the possibility that the workers at a facility may only perform one waste handling activity per day and assumes that a worker is exposed to the measured concentration for the length of the task and has zero exposure for the remainder of the 8-hour shift. These 2 estimates provide both an upper and lower bound of possible worker exposure based on the existing data. The third limitation is the uncertainty that the activities that occur during this task at a manufacturing/processing facility are representative of the true distribution of inhalation exposures that may occur at a facility that handles 1,3-butadiene waste. Other limitations include that EPA assumed 250 exposure days per year for 8-hour TWAs 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 the Waste handling, treatment, and disposal OES is slight to moderate and provides a plausible estimate of exposures.

[a] The OESs for Distribution in commerce, Use in fuels and related products, Use of plastic and rubber products, and Use of lubricants and greases are not present in this table because they were not quantitatively assessed.

7 CONCLUSIONS

EPA considered all reasonably available information identified by the Agency through its systematic review process under TSCA (U.S. EPA, 2025m) to characterize the environmental release and occupational exposure of 1,3-butadiene. 1,3-Butadiene has a total PV in the United States between 1 and 5 billion lb from the 2020 CDR reporting period (U.S. EPA, 2020b), and is primarily used as a monomer in the production of a wide range of polymers and copolymers. It is also used as an intermediate in the production of several chemicals.

EPA evaluated environmental releases and occupational exposures for each OES, which are developed based on a set of occupational activities and conditions such that similar occupational exposures and environmental releases are expected from the use(s) covered under each OES. The Agency provided environmental release and occupational exposure results for each OES, which are expected to be representative of the population of workers and sites for the given OES in the United States. EPA used release data from the TRI and NEI databases to assess releases to air, land, and water for a majority of 1,3-butadiene uses. One exception was the release from the use of adhesives and sealants, for which modeling approaches were used.

The OESs with the highest expected releases were Manufacturing, Plastics and rubber polymerization, and Application of adhesives and sealants (though the releases from the last listed have only slight confidence). EPA used inhalation monitoring data to evaluate acute, intermediate, and chronic exposures to workers and ONUs for each OES. Where no monitoring data existed relevant to certain OESs, analogous monitoring data were used. Inhalation exposures to 1,3-butadiene are expected to be highest from repackaging activities and from plastics and rubber polymerization.

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APPENDICES

Appendix A 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 1,3-butadiene in each of its COUs. The method consists of the following steps:

1. Check relevant ESDs and GSs for estimates on the number of workers potentially exposed.
2. Identify the NAICS codes for the industry sectors associated with each COU.
3. Estimate total employment by industry/occupation combination using BLS Occupational Employment Statistics data (U.S. BLS, 2023).
4. Refine the Occupational Employment Statistics data estimates where they are not sufficiently granular by using U.S. Census (U.S. BLS, 2023) SUSB data on total employment by 6-digit NAICS.
5. Estimate the percentage of employees likely to be using 1,3-butadiene instead of other chemicals (*i.e.*, the market penetration of 1,3-butadiene in the COU).
6. Estimate the number of sites and number of potentially exposed employees per site.
7. Estimate the number of potentially exposed employees within the COU.

Step 1: Identifying Affected NAICS Codes

As a first step, EPA identified NAICS industry codes associated with each COU. EPA generally identified NAICS industry codes for a COU by

- Querying the U.S. Census Bureau's *NAICS Search* tool (accessed December 1, 2025) using keywords associated with each COU to identify NAICS codes with descriptions that match the COU.
- Referencing EPA GSs and Organisation for Economic Co-operation and Development (OECD) ESDs for a COU 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 (accessed December 1, 2025) (U.S. EPA, 2020b).

Each COU section in the main body of this assessment identifies the NAICS codes EPA identified for the respective COU.

Step 2: Estimating Total Employment by Industry and Occupation

BLS's Occupational Employment Statistics data provide employment data for workers in specific industries and occupations (U.S. BLS, 2023). Industries are classified by NAICS codes (identified previously) and occupations are classified by 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 1,3-butadiene. Table_Apx A-1 shows the SOC codes EPA classified as occupations potentially exposed to 1,3-butadiene. These occupations are classified as workers (W) and ONU (O). All other SOC codes are assumed to represent occupations where exposure is unlikely.

Table_Apx A-1. SOCs with Worker and ONU Designations for All COU 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
O = ONU designation; SOC = Standard Occupational Classification (code); W = worker 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 COU. 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
O = ONU designation; SOC = Standard Occupational Classification (code); W = worker 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 (Dry Cleaning 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- or 5-digit NAICS level; therefore, further refinement of this approach may be needed (see Step 3).

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's SUSB (U.S. BLS, 2023). In some cases, BLS's Occupational Employment Statistics' occupation-specific data are only available at the 4-digit 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 1,3-butadiene exposure are included. As an example, Occupational Employment Statistics 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 is 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 Occupational Employment Statistics data to further refine EPA 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 ONUs						**22,551**

NAICS = North American Industry Classification System (codes); O = ONU designation; SOC = Standard Occupational Classification (code); W = worker designation
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 1,3-Butadiene 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 1,3-butadiene may be only one of multiple chemicals used for the applications of interest. EPA's Office of Pollution Prevention and Toxics (OPPT) did not identify market penetration data for any COU. In the absence of market penetration data for a given COU, EPA assumed 1,3-butadiene 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.

Step 5: Estimating the Number of Workers per Site

EPA calculated the number of workers and ONU 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. BLS, 2023) data at the 6-digit NAICS level.

The Agency then summed the number of workers and ONU 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 ONU per site.

Step 6: Estimating the Number of Workers and Sites for a COU

EPA estimated the number of workers and ONU potentially exposed to 1,3-butadiene and the number of sites that use 1,3-butadiene in a given COU through the following steps:

1. Obtaining the total number of establishments by:
    a. Obtaining the number of establishments from SUSB at the 6-digit NAICS level (Step 5) for each NAICS code in the COU and summing these values; or
    b. Obtaining the number of establishments from the TRI, DMR, NEI, or literature for the COU.
2. Estimating the number of establishments that use 1,3-butadiene 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 ONU potentially exposed to 1,3-butadiene by taking the number of establishments calculated in 1b and multiplying it by the average number of workers and ONU per site from Step 5.

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

This report assesses 1,3-butadiene inhalation exposures to workers in occupational settings, presented as 8-hour (*i.e.*, full shift) and 12-hour time-weighted average (TWA). The full shift TWA exposures are then used to calculate AC, $ADC_{intermediate}$, ADC for chronic, non-cancer risks, and LADC for chronic, 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, and Cancer) Inhalation Exposures

AC is used to estimate workplace inhalation exposures for acute risks (*i.e.*, risks occurring as a result of exposure for less than 1 day), per Equation_Apx B-1.

Equation_Apx B-1.

$$AC = \frac{C \times ED \times BR}{AT_{acute}}$$

Where:

AC	=	Acute exposure concentration
C	=	Contaminant concentration in air (TWA)
ED	=	Exposure duration (hs/day)
BR	=	Breathing rate ratio (unitless)
AT_{acute}	=	Acute averaging time (h)

$ADC_{intermediate}$ is used to estimate workplace exposures for intermediate risks and is estimated as follows:

Equation_Apx B-2.

$$ADC_{intermediate} = \frac{C \times ED \times EF_{intermediate} \times BR}{AT_{intermediate}}$$

Equation_Apx B-3.

$$AT_{intermediate} = D_{intermediate} \times 24\,\frac{hr}{day}$$

Where:

$ADC_{intermediate}$	=	Intermediate average daily concentration
$EF_{intermediate}$	=	Intermediate exposure frequency
$AT_{intermediate}$	=	Averaging time (h) for intermediate exposure
$D_{intermediate}$	=	Days for intermediate duration (day)

ADC and LADC are used to estimate workplace exposures for non-cancer and cancer risks, respectively. These exposures are estimated as follows:

Equation_Apx B-4.

$$ADC\ or\ LADC = \frac{C \times ED \times EF \times WY \times BR}{AT\ or\ AT_c}$$

Equation_Apx B-5.

$$AT = WY \times 365 \frac{day}{yr} \times 24 \frac{hr}{day}$$

Equation_Apx B-6.

$$AT_C = LT \times 365 \frac{day}{yr} \times 24 \frac{hr}{day}$$

Where:

ADC	=	Average daily concentration used for chronic non-cancer risk calculations
LADC	=	Lifetime average daily concentration used for chronic cancer risk calculations
ED	=	Exposure duration (h/day)
EF	=	Exposure frequency (day/yr)
WY	=	Working years per lifetime (yr)
AT	=	Averaging time (h) for chronic, non-cancer risk
AT_C	=	Averaging time (h) for cancer risk
LT	=	Lifetime years (yr) for cancer risk

B.2 Acute, Intermediate, and Chronic (Non-Cancer and Cancer) Equation Inputs

The input parameter values in Table_Apx B-1 are used to calculate each of the above acute, intermediate, and chronic exposure estimates. Where exposure is calculated using probabilistic modeling, the calculations are integrated into the Monte Carlo simulation. Where multiple values are provided for ED, it indicates that EPA may have used different values for different COUs. The EF and $EF_{intermediate}$ used for each OES can differ, and the values used are described in the appropriate sections of this report. The maximum values used in the equations as well as a general summary for these differences are described below in this section.

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

Parameter Name	Symbol	Value	Unit
Exposure Duration	*ED*	8	h/day
Breathing Rate Ratio	*BR*	2.04	unitless
Exposure Frequency	*EF*	5–250 [a]	days/yr
Exposure Frequency, intermediate	$EF_{intermediate}$	22	days
Days for Intermediate Duration	$D_{intermediate}$	30	days
Working Years	*WY*	31 (50th percentile) 40 (95th percentile)	years
Lifetime Years, Cancer	*LT*	78	years
Averaging Time, Intermediate	$AT_{intermediate}$	720	hours
Averaging Time, Non-Cancer	*AT*	271,560 (central tendency) [b] 350,400 (high-end) [c]	hours
Averaging Time, Cancer	AT_c	683,280	hours
Body Weight	*BW*	80 (average adult worker) 72.4 (female of reproductive age)	kg

Parameter Name	Symbol	Value	Unit
[a] Varies between different OESs [b] Calculated using the 50th percentile value for working years (WY) [c] Calculated using the 95th percentile value for working years (WY)			

B.2.1 Exposure Duration (ED)

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

B.2.2 Breathing Rate Ratio

EPA uses a breathing rate ratio, which is the ratio between the worker breathing rate and resting breathing rate, to account for the amount of air a worker breathes during exposure. A typical worker breathes about 10 m^3 of air in 8 hours, or 1.25 m^3/h (CEB, 1991), while the resting breathing rate is 0.6125 m^3/h (CEB, 1991). The ratio of these two values is equivalent to 2.04.

B.2.3 Exposure Frequency (EF)

EPA generally uses a maximum exposure frequency of 250 days per year for 8-hour TWA estimates, and 167 days/year for 12-hour TWA estimates.

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 estimate a worker's exposure to the chemical occurs during a subset of the worker's annual working days. The relationship between exposure frequency and annual working days can be described mathematically as follows:

Equation_Apx B-7.

$$EF = f \times AWD$$

Where:

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

BLS (U.S. BLS, 2023) provides data on the total number of hours worked and total number of employees by each industry NAICS code. These data are available 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 has identified approximately 140 NAICS codes applicable to the multiple COUs for the first ten chemicals that underwent risk evaluation. For each NAICS code of interest, the Agency 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 days per year worked, 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. Two hundred-fifty days per year is approximately the 75th percentile. In the absence of industry- and 1,3-

butadiene-specific data, EPA assumes the parameter *f* is equal to one for all COUs.

B.2.4 Intermediate Exposure Frequency ($EF_{intermediate}$)

For 1,3-butadiene, the $D_{intermediate}$ was set at 30 days. EPA estimated the maximum number of working days within the $D_{intermediate}$, using the following equation and assuming 5 working days/week:

Equation_Apx B-8.

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

B.2.5 Intermediate Duration ($D_{intermediate}$)

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

B.2.6 Working Years (WY)

EPA has developed a triangular distribution for working years. EPA has defined the parameters of the triangular distribution as follows:

- ***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 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 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 for central tendency and high-end ADC and LADC calculations, respectively.

The BLS (U.S. BLS, 2023) 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 years and over; CPS data are released every 2 years. The data are available by demographics and by generic industry sectors but are not available by NAICS codes.

The U.S. Census' (U.S. Census Bureau, 2019a) 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. Census Bureau, 2019a). 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. Census Bureau, 2019a, b). For that panel, lifetime tenure data are available by Census Industry Codes, which can be crosswalked 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.[8] Census household surveys use different industry codes than the NAICS codes

[8] 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). The Agency then subtracted any intervening months when not working (ETIMEOFF).

used in its firm surveys, so these were converted to NAICS using a published crosswalk. EPA calculated the average tenure for the following age groups: (1) workers aged 50 years and older, (2) workers aged 60 years 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 years 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 years 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+ Years)

Industry Sectors	Working Years			
	Average	50th Percentile	95th Percentile	Maximum
All industry sectors relevant to the 10 chemicals undergoing risk evaluation	35.9	36	39	44
Manufacturing sectors (NAICS 31–33)	35.7	36	39	40
Non-manufacturing sectors (NAICS 42–81)	36.1	36	39	44

Source: (U.S. Census Bureau, 2019a).
Note: Industries where sample size is less than 5 are excluded from this analysis.

BLS CPS data provides the median years of tenure that wage and salary workers had been with their current employer. Table_Apx B-3 presents CPS data for all demographics (men and women) by age group from 2008 to 2012. To estimate the low-end value on number of working years, EPA uses 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 wth Current Employer by Age Group

Age (years)	January 2008	January 2010	January 2012	January 2014
16+	4.1	4.4	4.6	4.6
16–17	0.7	0.7	0.7	0.7
18–19	0.8	1.0	0.8	0.8
20–24	1.3	1.5	1.3	1.3
25+	5.1	5.2	5.4	5.5
25–34	2.7	3.1	3.2	3.0

Age (years)	January 2008	January 2010	January 2012	January 2014
35–44	4.9	5.1	5.3	5.2
45–54	7.6	7.8	7.8	7.9
55–64	9.9	10.0	10.3	10.4
65+	10.2	9.9	10.3	10.3
Source: (U.S. BLS, 2014)				

B.2.7 Lifetime Years (LT)

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

B.2.8 Body Weight (BW)

EPA assumes a body weight of 80 kg for average adult workers. EPA assumed a body weight 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 AND CANCER) INHALATION EXPOSURES

Sample calculations for high-end (HE) and central tendency (CT) acute and chronic (non-cancer and cancer) exposure concentrations for one COU, Manufacturing, are demonstrated below. The explanation of the equations and parameters used is provided in Appendix B.

C.1 Example High-End AC, ADC, LADC Calculations

Calculate AC_{HE}:

$$AC_{HE} = \frac{C_{HE} \times ED \times BR}{AT_{acute}}$$

$$AC_{HE} = \frac{0.45\ ppm \times 8\ hr/day \times 2.04}{24\ hr/day} = 0.31\ ppm$$

Calculate $ADC_{Intermediate,\ HE}$:

$$ADC_{Intermediate} = \frac{C_{HE} \times ED \times EF_{Intermediate} \times BR}{AT_{Intermediate}}$$

$$ADC_{Intermediate,HE} = \frac{0.45\ ppm \times 8\frac{hr}{day} \times 22\frac{days}{year} \times 2.04}{24\frac{hr}{day} \times 30\frac{days}{year}} = 0.22\ ppm$$

Calculate ADC_{HE}:

$$ADC_{HE} = \frac{C_{HE} \times ED \times EF \times WY \times BR}{AT}$$

$$ADC_{HE} = \frac{0.45\ ppm \times 8\frac{hr}{day} \times 350\frac{days}{year} \times 40\ years \times 2.04}{40\ years \times 365\frac{days}{yr} \times 24\frac{hr}{day}} = 0.22\ ppm$$

Calculate $LADC_{HE}$:

$$LADC_{HE} = \frac{C_{HE} \times ED \times EF \times WY \times BR}{AT_c}$$

$$LADC_{HE} = \frac{0.45\ ppm \times 8\frac{hr}{day} \times 350\frac{days}{year} \times 40\ years \times 2.04}{78\ years \times 365\frac{days}{year} \times 24\ hr/day} = 5.5 \times 10^{-2}\ ppm$$

C.2 Example Central Tendency AC, ADC, LADC, and SADC Calculations

Calculate AC_{CT}:

$$AC_{CT} = \frac{C_{CT} \times ED \times BR}{AT_{acute}}$$

$$AC_{CT} = \frac{2.5 \times 10^{-2}\ ppm \times 8\ hr/day \times 2.04}{24\ hr/day} = 1.7 \times 10^{-2}\ ppm$$

Calculate $ADC_{Intermediate,\ CT}$:

$$ADC_{Int,CT} = \frac{C_{CT} \times ED \times EF_{Intermediate} \times BR}{AT_{Intermediate}}$$

$$ADC_{Intermediate,CT} = \frac{2.5 \times 10^{-2}\ ppm \times 8\frac{hr}{day} \times 22\frac{days}{year} \times 2.04}{24\frac{hr}{day} \times 30\frac{days}{year}} = 1.2 \times 10^{-2}\ ppm$$

Calculate ADC_{CT}:

$$ADC_{CT} = \frac{C_{CT} \times ED \times EF \times WY \times BR}{AT}$$

$$ADC_{CT} = \frac{2.5 \times 10^{-2}\ ppm \times 8\frac{hr}{day} \times 350\frac{days}{year} \times 31\ years \times 2.04}{31\ years \times 365\frac{days}{yr} \times 24\frac{hr}{day}} = 1.2 \times 10^{-2}\ ppm$$

Calculate $LADC_{CT}$:

$$LADC_{CT} = \frac{C_{CT} \times ED \times EF \times WY \times BR}{AT_c}$$

$$LADC_{CT} = \frac{2.5 \times 10^{-2}\ ppm \times 8\frac{hr}{day} \times 350\frac{days}{year} \times 31\ years \times 2.04}{78\ years \times 365\frac{days}{year} \times 24\ hr/day} = 2.4 \times 10^{-3}\ ppm$$

Appendix D MODEL APPROACHES AND PARAMETERS

This appendix presents the modeling approach and model equations used in estimating environmental releases and occupational exposures for each of the applicable OESs. The models were developed through review of the literature and consideration of existing EPA/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.

For 1,3-butadiene, only one site in NEI mapped to the Application of adhesives and sealants OES, which EPA did not believe was sufficient to be representative of all possible releases that may occur from this OES. Therefore, the Agency developed a Monte Carlo simulation using EPA/OPPT standard models, 1,3-butadiene product SDSs, CDR data, and GSs or ESDs to represent the potential releases typical of the Application of adhesives and sealants OES.

D.1 EPA/OPPT Standard Models

This appendix section discusses the standard models used by EPA to estimate environmental releases of chemicals. The Agency did not use any standard models to estimate occupational exposure to workers. 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, 2013), Chemical Engineering Branch Manual for the Preparation of Engineering Assessments, Volume 1 (CEB, 1991), Evaporation of Pure Liquids from Open Surfaces (Arnold and Engel, 2001), and Releases During Cleaning of Equipment (PEI Associates, 1988). The models include loss fraction models as well as models for estimating chemical vapor generation rates used in subsequent model equations to estimate the volatile releases to air. The parameters in the equations of this appendix section are specific to calculating environmental releases of 1,3-butadiene.

The EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model are used to estimate volatile chemical releases from an open, exposed liquid surface; however, these models cannot be used for chemicals with a vapor pressure above 35 torr. Therefore, these models cannot be used for 1,3-butadiene. Instead, to assess air releases that would otherwise be assessed with these models, EPA used a mass balance approach by assuming 100 percent release and subtracting the releases that could be quantified with other models/approaches from the daily 1,3-butadiene use rate.

The EPA Office of Air Quality Planning and Standards (OAQPS) AP-42 Loading Model estimates releases to air from the displacement of air containing chemical vapor as a container/vessel is filled with a liquid. This model assumes that the rate of evaporation is negligible compared to the vapor loss from the displacement and is used as the default for estimating volatile air releases during both loading activities and unloading activities. This model is used for unloading activities because it is assumed while one vessel is being unloaded another is assumed to be loaded. The EPA/OAQPS AP-42 Loading Model calculates the average vapor generation rate from loading or unloading using the following equation:

Equation_Apx D-1.

$$G_{activity} = \frac{F_{saturation\_factor} * MW_{1,3-BD} * V_{container} * 3785.4\frac{cm^3}{gal} * F_{correction\_factor} * VP * \frac{RATE_{fill}}{3600\frac{s}{hr}}}{R * T}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
$F_{saturation\_factor}$	=	Saturation factor (unitless)
$MW_{1,3-BD}$	=	1,3-butadiene (1,3-BD) molecular weight (g/mol)
$V_{container}$	=	Volume of container (gal/container)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	1,3-butadiene vapor pressure (torr)
$RATE_{fill}$	=	Fill rate of container (containers/h)
R	=	Universal gas constant (L*torr/mol-K)
T	=	Temperature (K)

The vapor pressure correction factor ($F_{correction\_factor}$) can be estimated using Raoult's Law and the mole fraction of 1,3-butadiene in the liquid of interest.

When calculating an environmental release, the vapor generation rate from Equation_Apx D-1 is then used along with an operating time to calculate the release amount:

Equation_Apx D-2.

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

Where:

$Release\_Year_{activity}$	=	1,3-Butadiene 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 EPA/OAQPS AP-42 Loading Model, 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 Multiple Process Vessel Residual Model; and
- EPA/OPPT Single Process Vessel Residual Model.

The loss fraction models apply a given loss fraction to the overall throughput of 1,3-butadiene 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:

Equation_Apx D-3.

$$Release\_Year_{activity} = Q_{1,3-BD,yr} * F_{activity\_loss}$$

Where:

$Release\_Year_{activity}$	=	1,3-Butadiene released for activity per site-year (kg/site-yr)
$Q_{1,3-BD,yr}$	=	Annual facility throughput of 1,3-butadiene (kg/site-yr)
$F_{activity\_loss}$	=	Loss fraction for activity (unitless)

EPA references the model equations by model name and/or equation number within the rest of this appendix.

D.2 Application of Adhesives and Sealants Model Approaches and Parameters for Environmental Release

This appendix presents the modeling approach and equations used to estimate environmental releases of 1,3-butadiene during the Application of adhesives and sealants OES. This approach utilizes the ESD on the Use of Adhesives (OECD, 2013) combined with Monte Carlo simulation (a type of stochastic simulation). To review the Application of Adhesives and Sealants release model, see the *Adhesives and Sealants Release Model for 1,3-Butadiene* (U.S. EPA, 2025b).

Based on the ESD, EPA identified the following release sources from the application of adhesives and sealants:

- Release source 1: Adhesive Component Container Residue.
- Release source 2: Open Surface Losses During Container Cleaning (N/A – due to chemical's volatility, assessed as part of a 100% release scenario and incorporated into release source 6).
- Release source 3: Transfer Operation Losses to Air from Unloading the Adhesive Formulation.
- Release source 4: Equipment Cleaning Releases.
- Release source 5: Open Surface Losses During Equipment Cleaning (N/A – due to chemical's volatility, assessed as part of a 100% release scenario and incorporated into release source 6).
- Release source 6: All Other Process Releases, Including Volatilization, Application, and Curing.

Environmental releases for 1,3-butadiene during the application of adhesives and sealants are a function of 1,3-butadiene'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: ventilation rate, mixing factor, air speed, saturation factor, loss factor, container sizes, working years, and drum fill rates. The Agency used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts and exposure concentrations for this OES.

D.2.1 Model Equations

Table_Apx D-1 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Application of adhesives and sealants OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix D.2.2. The Monte Carlo simulation calculated the total 1,3-butadiene release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx D-1. Models and Variables Applied for Release Sources in the Application of Adhesives and Sealants OES

Release Source	Model(s) Applied	Variables Used
Release source 1: Adhesive Component Container Residue	EPA/OPPT Small Container Residual Model (Equation_Apx D-3)	$F_{1,3-BD}$; $N_{cont\_unload\_day}$; $F_{residue}$; RHO; V_{cont}; $Q_{1,3-BD\_day}$
Release source 2: Open Surface Losses During Container Cleaning (not assessed).	N/A; assessed as part of a 100% release scenario.	N/A
Release source 3: Transfer Operation Losses to Air from Unloading the Adhesive Formulation	EPA/OAQPS AP-42 Loading Model (Equation_Apx D-1)	$F_{1,3-BD}$; VP; f_{sat}; MW; V_{cont}; R; T; $RATE_{fill}$
Release source 4: Equipment Cleaning Releases.	EPA/OPPT Single Process Residual Model (Equation_Apx D-3)	$Q_{1,3\text{-}BD}$; $F_{equipment\_cleaning}$
Release source 5: Open Surface Losses During Equipment Cleaning (not assessed)	This release was assessed with release source 6, as part of a 100% release scenario.	N/A
Release source 6: All Other Process Releases, Including Volatilization, Application, and Curing	100% release scenario (Equation_Apx D-4)	$Q_{1,3\text{-}BD\_day}$

For 1,3-butadiene, release source 6 (all other process releases, including volatilization, application, and curing) is calculated via a mass balance, via the following equation:

Equation_Apx D-4.

$$Release\_perDay_{RP6} = Q_{1,3-BD\_day} - Release_{perDay}{}_{RP1} - Release_{perDay}{}_{RP3} - Release\_perDay_{RP4}$$

Where:

$Release\_perDay_{RP6}$	=	1,3-Butadiene released for release source 6 (kg/site-day)
$Q_{1,3\text{-}BD\_day}$	=	Facility daily throughput of 1,3-butadiene (kg/site-day)
$Release\_perDay_{RP1}$	=	1,3-Butadiene released for release source 1 (kg/site-day)
$Release\_perDay_{RP3}$	=	1,3-Butadiene released for release source 3 (kg/site-day)
$Release\_perDay_{RP4}$	=	1,3-Butadiene released for release source 4 (kg/site-day)

D.2.2 Model Input Parameters

Table_Apx D-2 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 following this table.

Table_Apx D-2. Summary of Parameter Values and Distributions Used in the Application of Adhesives and Sealants OES

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale/Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Container Residue Loss Fraction	$F_{residue}$	kg/kg	0.003	0.0003	0.006	0.003	Triangular	See Appendix D.2.12
Saturation Factor	F_{sat}	unitless	0.5	0.5	1.45	0.5	Triangular	See Appendix D.2.10
Container Volume	V_{cont}	gal/container	55	20	100	55	Triangular	See Appendix D.2.11
Maximum Number of Sites	Ns_{max}	sites	905,620	–	–	–	–	See Appendix D.2.5
PV	PV_{total}	kg/year	3,547,092	153,768	3,547,092	–	Uniform	See Appendix D.2.3
Adhesive/Sealant 1,3-Butadiene Concentration	$F_{1,3\text{-}BD}$	kg/kg	0.24	0.001	0.24	–	Uniform	See Appendix D.2.8
Annual Facility Throughput of Adhesive/Sealants	$Q_{product\_yr}$	kg/site-yr	13,500	1,000	1,000,000	13,500	Triangular	See Appendix D.2.4
Temperature	T	Kelvin	298	–	–	–	–	Process parameter
Pressure	P	torr	760	–	–	–	–	Process parameter
Gas Constant	R	L*torr/(mol*K)	62.36367	–	–	–	–	Universal constant
Vapor Pressure	VP	mmHg	2.11E03	–	–	–	–	Physical property
Density	RHO	kg/L	0.6149	–	–	–	–	Physical property
Molecular Weight	MW	g/mol	54.09	–	–	–	–	Physical property
Fill Rate of Containers	$RATE_{fill\_cont}$	containers/h	20	–	–	–	–	See Appendix D.2.13
Diameter of Opening for Container Cleaning	$D_{opening\_cont}$	cm	5.08	–	–	–	–	See Appendix D.2.14

D.2.3 Production Volume

EPA estimated the PV for the Application of adhesives and sealants OES using the national production range according 2020 CDR data, an ACC report detailing 1,3-butadiene use a technical report estimating air emissions of 1,3-butadiene (U.S. EPA, 2020a, 1996) (EPA-HQ-OPPT-2018-0451-0041). The ACC report provided conversion rates for several end formulation product types including, but not limited to, styrene-butadiene rubber, adiponitrile, and neoprene rubber. EPA published technical report provided a percentage breakdown of 1,3-butadiene use within each formulation product type for specific end use categories, including adhesives and sealants. The Agency used the conversion rate and end use percentages with the 2020 CDR PV range to estimate the PV for use within the Application of adhesives and sealants OES. Table_Apx D-3 provides the PV estimation for the application of adhesives and sealants.

Table_Apx D-3. PV Estimation for Application of Adhesives and Sealants OES

Formulation Product Type	Formulation Product Percentage of PV (%)	Adhesive and Sealant Use Rate (%)	Formulation Product Conversion Rate	PV (lb)	Rationale
2020 CDR 1,3 Butadiene PV Range			1–5 billion lb		
Styrene-Butadiene Rubber	30	3	0.999	9,000 to 45,000	According to ACC, the butadiene monomer is recovered and recycled during the manufacturing process. It is assumed that only 0.001% of the butadiene used in the SBR manufacturing process is present as residual in the final product (EPA-HQ-OPPT-2018-0451-0041).
Polybutadiene	20	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Adiponitrile	15	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Styrene-Butadiene Latex	10	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Neoprene Rubber	5	12	0.95	300,000 to 1,500,000	According to the EPA published technical report, the conversion rate of 1,3-butadiene in the Chloroprene/Neoprene manufacturing process is 95%. (U.S. EPA, 1996)
ABS Resin	5	N/A – no adhesive and sealant use	N/A	N/A	No adhesive and sealant use expected using this polymer.
Nitrile Rubber	5	10	0.999	5,000 to 25,000	According to the EPA published technical report, the conversion rate of 1,3-butadiene in the nitrile rubber manufacturing

Formulation Product Type	Formulation Product Percentage of PV (%)	Adhesive and Sealant Use Rate (%)	Formulation Product Conversion Rate	PV (lb)	Rationale
					process ranges from 75–90%. However, the source also indicates that unreacted monomer is reacted and recycled into the manufacturing stream. Assume that a maximum of 0.001% 1,3-butadiene is residual in the product stream (U.S. EPA, 1996).
Miscellaneous	10	25	0.95 to 0.999	25,000 to 6,250,000	SBS and SEBS polymers are assumed to fall under the miscellaneous polymer use category. 1,3-Butadiene conversion was estimated by taking the reported range of all other polymer conversion percentages used in PV estimation (U.S. EPA, 1996).
PV Range for Application of adhesives and sealants OES			339,000 to 7,820,000 lb 153,768 to 3,547,092 kg		

D.2.4 Throughput Parameters

The annual throughput of adhesive and sealant product is modeled using a triangular distribution with a lower bound of 1,000 kg/yr, an upper bound of 1,000,000 kg/yr, and mode of 13,500 kg/yr. This is based on the ESD on the Use of Adhesives (OECD, 2013). The ESD provides default adhesive use rates based on end-use category. EPA compiled the end-use categories that were relevant to downstream uses for adhesives and sealants containing 1,3-butadiene, which included general assembly, motor and non-motor vehicles, vehicle parts, tire manufacturing (except retreading), and computer/electronic and electrical product manufacturing. The lower- and upper-bound adhesive use rates for these categories was 1,000 to 1,000,000 kg/yr. The mode is based on the ESD default for unknown end-use markets.

The annual throughput of 1,3-butadiene in adhesives/sealants is calculated using Equation_Apx D-5 by multiplying the annual throughput of all adhesives and sealants by the concentration of 1,3-butadiene in the adhesives or sealants.

Equation_Apx D-5.

$$Q_{1,3\text{-}BD\_year} = Q_{product\_yr} * F_{1,3\text{-}BD}$$

Where:

$Q_{1,3\text{-}BD\_year}$ = Facility annual throughput of 1,3-butadiene (kg/site-yr)
$Q_{product\_yr}$ = Facility annual throughput of all adhesives/sealants (kg/batch)
$F_{1,3\text{-}BD}$ = Concentration of 1,3-butadiene in adhesives/sealants (Appendix D.2.8) (kg/kg)

The daily throughput of 1,3-butadiene is calculated using Equation_Apx D-6 by dividing the annual PV by the number of operating days. The number of operating days is determined according to Appendix D.2.9.

Equation_Apx D-6.

$$Q_{1,3-BD\_day} = \frac{Q_{1,3-BD\_year}}{OD}$$

Where:

$Q_{1,3\text{-}BD\_day}$	=	Facility daily throughput of 1,3-butadiene (kg/site-day)
$Q_{1,3\text{-}BD\_year}$	=	Facility annual throughput of 1,3-butadiene (kg/site-yr)
OD	=	Operating days (Appendix D.2.9) (days/yr)

D.2.5 Number of Sites

For the NAICS codes identified in the ESD on the Use of Adhesives there are 905,620 adhesive and sealants application sites (OECD, 2015a). Therefore, this value is used as a bounding limit, not to be exceeded by the calculation. Number of sites is calculated using the following equation:

Equation_Apx D-7.

$$N_s = \frac{PV}{Q_{1,3-BD\_yr}}$$

Where:

N_s	=	Number of sites (sites)
PV	=	Production volume (see Section D.2.3) (kg/year)
$Q_{1,3-BD-year}$	=	Facility annual throughput of 1,3-butadiene (see Section D.2.4) (kg/site-yr)

D.2.6 Number of Containers per Year

The number of 1,3-butadiene raw material containers received and unloaded by a site per year is calculated using the following equation:

Equation_Apx D-8.

$$N_{cont\_unload\_yr} = \frac{Q_{1,3-BD\_year}}{V_{cont} * \frac{3.79L}{gal} * RHO}$$

Where:

$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (container/site-year)
$Q_{1,3\text{-}BD\_year}$	=	Facility annual throughput of 1,3-butadiene (Appendix D.2.4) (kg/site-yr)
RHO	=	1,3-Butadiene density (kg/L)
V_{cont}	=	Container volume (Appendix D.2.11) (gal/container)

D.2.7 Operating Hours

EPA estimated operating hours or hours of release duration using data provided from the ESD on Use of Adhesives (OECD, 2015b), ChemSTEER User Guid*e* (U.S. EPA, 2013), and/or through calculation from other parameters.

For container unloading (release point 3), the operating hours are calculated based on the number of containers unloaded at the site and the unloading rate using the following equation:

Equation_Apx D-9.

$$OH_{RP3} = \frac{N_{cont\_unload\_yr}}{RATE_{fill} * OD}$$

Where:

OH_{RP3}	=	Operating time for release point 3 (h/site-day)
$N_{cont\_unload\_yr}$	=	Annual number of containers unloaded (Appendix D.2.6) (container/site-year)
$RATE_{fill}$	=	Container fill rate (Appendix D.2.13) (containers/h)
OD	=	Operating days (Appendix D.2.9) (days/site-year)

D.2.8 Adhesive and Sealant 1,3-Butadiene Concentration

EPA determined 1,3-butadiene concentrations in adhesive/sealant products ($F_{1,3\text{-}BD}$) using compiled SDS information. EPA did not have information on the prevalence or market share of different adhesive/sealant products in commerce; therefore, EPA developed a uniform distribution of 1,3-butadiene concentrations using a lower bound of 0.1 percent and an upper bound of 24 percent.

D.2.9 Operating Days

EPA modeled the operating days per year using a triangular distribution with a lower bound of 50 days/year, an upper bound of 365 days/year, and a mode of 260 days/year. To ensure that only integer values of this parameter were selected, EPA nested the triangular distribution probability formula within a discrete distribution that listed each integer between (and including) 50 to 365 days/year. This is based on the ESD on Use of Adhesives (OECD, 2013). The ESD provides operating days for several end-use categories, as listed in Appendix D.2.4. The range of operating days for the end-use categories is 50 to 365 days/year. The mode of the distribution is based on the ESDs default of 260 days/year for unknown or general use cases.

D.2.10 Saturation Factor

The CEB Manual indicates that during splash filling, the saturation concentration was reached or exceeded by misting with a maximum saturation factor of 1.45 (CEB, 1991). The CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 (CEB, 1991). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization (CEB, 1991). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model (U.S. EPA, 2013).

D.2.11 Container Size

Due to a lack of readily available 1,3-butadiene adhesive and sealant product volumes, EPA assumed default container size ranges for drums identified in the ChemSTEER User Guide (U.S. EPA, 2013). Drums were chosen as the product size to represent the possibility of commercial use sites that use large volume of adhesive and sealant products, and to prevent an unreasonable estimated number of containers unloaded per day. Specifically, EPA used a lower bound of 20 gallons, an upper bound of 100 gallons based on the upper bound, and a mode of 55 gallons defined by the ChemSTEER User Guide.

D.2.12 Container Loss Fractions

For drums, EPA paired the data from the PEI Associates Inc. study (PEI Associates, 1988) such that the residuals data for emptying drums by pouring was aligned with the default central tendency and high-end values from the EPA/OPPT Drum Residual Model. For unloading drums by pouring in the PEI

Associates Inc. study (PEI Associates, 1988), EPA found that the average percent residual from the pilot-scale experiments showed a range of 0.03 to 0.79 percent and an average of 0.32 percent. The EPA/OPPT Drum Residual Model from the ChemSTEER User Guide (U.S. EPA, 2013) recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent.

The underlying distribution of the loss fraction parameter for drums is not known; therefore, EPA assigned a triangular distribution, since triangular distributions require least assumptions and are completely defined by range and mode of a parameter. The Agency 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, 2013). The Agency assigned the minimum value for the triangular distribution using the minimum average percent residual measured in the PEI Associates, Inc. study (PEI Associates, 1988) for emptying drums by pouring.

D.2.13 Container Fill Rate

The ChemSTEER User Guide (U.S. EPA, 2013) provides a typical fill rate of 20 containers per hour for containers ranging from 20 to 1,000 gallons of liquid.

D.2.14 Diameter 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, 2013).

Appendix E CONSIDERATION OF ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT

OSHA and NIOSH recommend 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 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 (*e.g.*, source enclosure, local exhaust ventilation systems), followed by administrative controls (*e.g.*, do not open machine doors when running), or changes in work practices (*e.g.*, maintenance plan to check equipment to ensure no leaks) to reduce exposure potential. Administrative controls are policies and procedures instituted and overseen by the employer to limit worker exposures. Under 29 CFR 1910.1000, OSHA requires the use of engineering or administrative controls to bring exposures to the levels permitted under the air contaminants standard. The respirators do not replace engineering controls, and they are implemented in addition to feasible engineering controls (29 CFR 1910.134(a)(1). The PPE (*e.g.*, respirators, gloves) could be used as the last means of control when the other control measures cannot reduce workplace exposure to an acceptable level.

The remainder of this section discusses respiratory protection, including protection factors for various respirators. EPA's estimates of occupational exposure presented in this document do not assume the use of engineering controls or PPE; however, the effect of respiratory protection factors on the Agency's occupational exposure estimates can be explored in *Risk Calculator for Occupational Exposures for 1,3-Butadiene (*U.S. EPA, 2025k*)*.

E.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. Engineering and administrative controls must be implemented whenever employees are exposed above the PEL. If engineering and administrative controls do not reduce exposures to below the PEL, respirators must be worn. Respirator selection provisions are provided in 29 CFR 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 29 CFR 1910.134(d)(3)(i)(A) (see below in Table_Apx E-1) and refer to the level of respiratory protection that a respirator or class of respirators could provide to employees when the employer implements a continuing, effective respiratory protection program. Implementation of a full respiratory protection program requires employers to provide training, appropriate selection, fit testing, cleaning, and change-out schedules in order to have confidence in the efficacy of the respiratory protection.

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 (SARs) with the appropriate APF. Respirators that meet these criteria may include air-purifying respirators with organic vapor cartridges. Respirators must meet or exceed the required level of protection listed in Table_Apx E-1. Based on the APF, inhalation exposures may be reduced by a factor of 5 to 10,000 if respirators are properly worn and fitted.

For atmospheres that are immediately dangerous to life and health, workers must use a full facepiece pressure demand self-contained breathing apparatus (SCBA) certified by NIOSH for a minimum service life of 30 minutes or a combination full facepiece pressure demand SAR with auxiliary self-contained air supply. Respirators that are provided only for escape from an atmosphere that is immediately dangerous to life and health must be NIOSH-certified for escape from the atmosphere in which they will be used.

Table_Apx E-1. Assigned Protection Factors for Respirators in OSHA Standard 29 CFR 1910.134

Type of Respirator	Quarter Mask	Half Mask	Full Facepiece	Helmet/ Hood	Loose-Fitting Facepiece
1. Air-Purifying Respirator	5	10	50		
2. Power Air-Purifying Respirator (PAPR)		50	1,000	25/1,000	25
3. 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. 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)					

E.2 Exposure Controls for Industrial Job Groups and Tasks

The table below summarizes information on exposure controls, including PPE usage, from industrial hygiene information submitted to EPA (Docket: EPA-HQ-OPPT-2024-0425-0052). Bolded tasks indicate specific tasks indicated in the respirator usage summary table (Table ES-3) of the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076).

Table_Apx E-2. Exposure Control Crosswalk for Job Group/SEGs and Tasks

Job Group	Tasks/Activities	Exposure Controls
Infrastructure/ Distribution/ Transportation Operations	**Unloading and Loading materials** to and from storage containers to process vessels	Vapor recovery systems
	Opening process equipment (*e.g.*, storage vessels)	Chemical protective gloves
	Sample collection	Suits and boots (to prevent dermal contact)
	Cleaning filters	Respirators: supp air, full/half face APR
	Handling hoses (*e.g.*, connections to truck tankers)	
	Loading/unloading tanks/trucks (*e.g.*, rail cars or cargo vessels and pumping material)	
	Handling utilities and waste streams	
	Handling of waste (transporting and disposing)	Chemical protective gloves
		Suits and boots (to prevent dermal contact)
		Respirators: full/half face APR
Instrument and Electrical	**Performing other work activities**	Chemical protective gloves
	Set up and maintenance of electrical equipment (analyzers and instruments across the facility)	Suits and boots (to prevent dermal contact)
	Opening the lines (like calibration and equipment maintenance)	Respirators: supp air, full/half face APR, no respirator
Laboratory Technician	**Collecting and analyzing samples**	Chemical protective gloves
		Suits and boots (to prevent dermal contact)
		Enclosed sample boxes
		Pressurized sample containers

Job Group	Tasks/Activities	Exposure Controls
		Laboratory ventilation cabinets
		Respirators: supp air, full/half face APR, no respirator
Machinery & Specialists Mechanical Group	**Performing other work activities**	Chemical protective gloves
	Opening process equipment prior to maintenance activities	Suits and boots (to prevent dermal contact)
		Respirators: supp air, full/half face APR, no respirator
Maintenance	**Cleaning and maintaining equipment**	Chemical protective gloves
	Connecting and disconnecting lines	Suits and boots (to prevent dermal contact)
	Draining, clearing and venting equipment	Respirators: supp air, full/half face APR, no respirator
Operations Onsite	**Cleaning and maintaining equipment**	Chemical protective gloves
	Monitor chemical feeds, process temperatures, vessel pressure, etc.	Suits and boots (to prevent dermal contact)
		Respirators: supp air, full/half face APR, no respirator
	Collecting and analyzing samples	Chemical protective gloves
	Drain/vent/clear process equipment and prepare it for maintenance	Suits and boots (to prevent dermal contact)
	Prepare process equipment for maintenance	Enclosed sample boxes
		Pressurized sample containers
		Laboratory ventilation cabinets
		Respirators: supp air, full/half face APR, no respirator
SHE	**Performing other work activities**	Chemical protective gloves
	Conduct exposure assessments of workers	Suits and boots (to prevent dermal contact)
	Monitor other workers or processes	Respirators: supp air, full/half face APR, no respirator
ONUs	**Performing other work activities**	Chemical protective gloves
	Supervisory personnel associated with all of the worker job groups	Suits and boots (to prevent dermal contact)
		Respirators: supp air, full/half face APR, no respirator
Source: *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076)		

Appendix F MAPPING FACILITIES FROM STANDARD ENGINEERING SOURCES TO OESs AND COUs

F.1 COUS and OESs

COU

TSCA section 3(4) defines COUs as "the circumstances, as determined by the Administrator, under which a chemical substance is intended, known, or reasonably foreseen to be manufactured, processed, distributed in commerce, used, or disposed of." COUs included in the scope of EPA's risk evaluations are typically tabulated in scope documents and risk evaluation documents as summaries of life cycle stages, categories, and subcategories of use, as shown in Table_Apx F-1. Therefore, a COU is defined as a combination of life cycle stage, category, and subcategory. EPA identifies COUs for chemicals during the scoping phase; this process is not discussed in this document.

OES

Thus far, EPA has not adopted a standardized definition for OES. The purpose of an OES is to group or segment COUs for assessment of releases and exposures based on similarity of the operations, exposure sources, worker activities, and use patterns. Data availability for each COU also contributes to the assignment of an OES. For example, EPA may assess a group of multiple COUs together as one OES due to similarities in release and exposure potential (*e.g.*, the COUs for formulation of paints, formulation of cleaning solutions, and formulation of other products may be assessed together as a single OES). Alternatively, the Agency may assess multiple OES for one COU because there are different release and exposure potentials for a given COU (*e.g.*, the COU for batch vapor degreasing may be assessed as separate OES for open-top vapor degreasing and closed-loop vapor degreasing). OES determinations are also largely driven by the availability of data and modeling approaches to assess occupational releases and exposures. For example, even if there are similarities between multiple COUs, if there is sufficient data to separately assess releases and exposures for each COU, EPA would not group them into the same OES. This is depicted in Figure_Apx F-1.

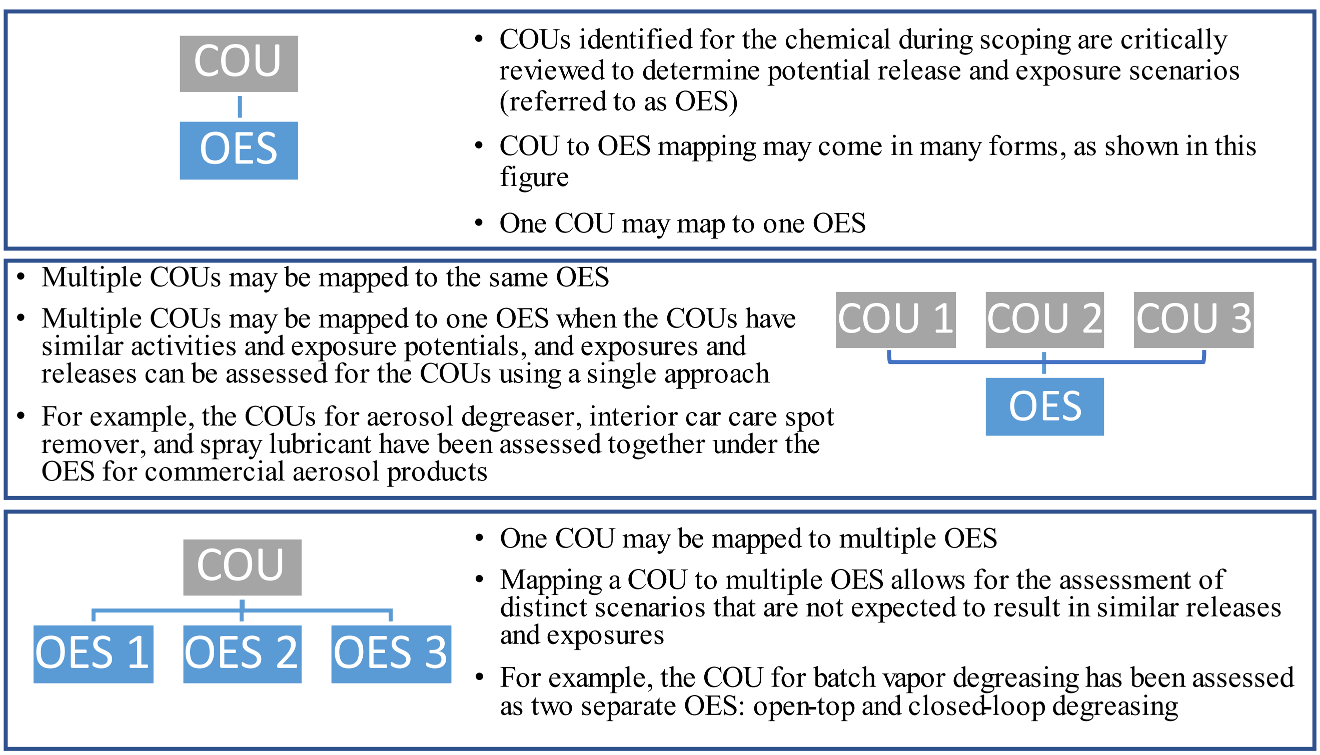
For chemicals undergoing risk evaluation, EPA maps each industrial and commercial COU to one or more OES based on reasonably available data and information (*e.g.*, CDR, use reports, process information, public and stakeholder comments), assumptions, and inferences that describe how release and exposure take place within a COU. The Agency identify OESs for COUs, not vice-versa (*i.e.*, COUs are not altered during OES mapping). The mapping of COUs to OESs is separate from and occurs after the identification of COUs. Both the identification of COUs and subsequent mapping of COUs to OESs occur early in the risk evaluation process and are not in scope of this document. This section is intended to just provide background context on COUs and OESs.

Table_Apx F-1. Example Conditions of Use Table with Mapped Occupational Exposure Scenarios

Condition of Use (COU)			Occupational Exposure Scenario (OES)
Life Cycle Stage	**Category**[a]	**Subcategory**[b]	
Manufacturing	Domestic manufacturing	Domestic manufacturing	Manufacturing
	Import	Import	Repackaging
Processing	As a reactant	Intermediate in all other basic organic	Processing as a reactant

Condition of Use (COU)			Occupational Exposure Scenario (OES)
Life Cycle Stage	Category[a]	Subcategory[b]	
		chemical manufacturing	
	Processing—incorporation into formulation, mixture, or reaction product	Solvents (for cleaning or degreasing)	Formulation
		Adhesives and sealant chemicals	
	Repackaging	Solvents (for cleaning or degreasing)	Repackaging
	Etc.		

[a] Categories reflect CDR codes and broadly represent the industrial and/or commercial settings of the COU.
[b] The subcategories reflect more specific COUs.



Figure_Apx F-1. Condition of Use to Occupational Exposure Scenario Mapping Options

F.2 Standard Sources Requiring Facility Mapping

The Agency utilizes release data from EPA programmatic databases and exposure data from standard sources to complete occupational exposure and environmental release assessments, which are described below:

- CDR (accessed December 1, 2025), to which import and manufacturing sites producing the chemical at or above a specified threshold must report. EPA uses CDR to identify COUs, OESs, sites that import or manufacture the chemical, and for information on physical form and concentration of the chemical. In addition, the Agency is currently developing the Tiered Data Reporting (TDR) rule, which will establish reporting requirements, including changes to CDR to collect information that better meets data needs for the TSCA existing chemical program. The rule will have reporting requirements tiered to specific stages of existing chemical assessments (*e.g.*, prioritization, risk evaluation) and harmonized to the OECD risk assessment framework, which will help to better inform uses of chemicals and improve upon the OES mapping procedures in this TSD.

- TRI (accessed December 1, 2025), to which facilities handling a chemical covered by the TRI program at or above a specified threshold must report. EPA uses TRI data to quantify air, water, and land releases of the chemical undergoing risk evaluation.

- NEI (accessed December 1, 2025), a compilation of air emissions of criteria pollutants, criteria precursors and HAPs from point and nonpoint source air emissions. EPA uses NEI data to quantify air emissions of the chemical undergoing risk evaluation.

- DMR (accessed December 1, 2025), a periodic report required of National Pollutant Discharge Elimination System (NPDES) permitted facilities discharging to surface waters. EPA uses DMR data to quantify surface water discharges of the chemical undergoing risk evaluation.

- OSHA: CEHD (accessed December 1, 2025), a compilation of industrial hygiene samples taken when OSHA monitors worker exposures to chemical hazards. EPA uses OSHA CEHD to quantify occupational inhalation exposures to the chemical undergoing risk evaluation.

- NIOSH: Health Hazard Evaluations (HHEs; accessed December 1, 2025), a compilation of voluntary employee, union, or employer requested evaluations of health hazards present at given workplace. EPA uses NIOSH HHE data to quantify occupational inhalation exposures to the chemical undergoing risk evaluation.

To utilize the data from these sources, the facilities that report to each must first be mapped to an OES. There may be other sources of data for specific facilities that require mapping the facilities to an OES; however, this TSD covers the most common data sources. Additionally, EPA often uses data from sources such as public and stakeholder comments, GSs, and process data that are usually not specific to an individual site; therefore, unlike the above list of sources, they do not involve the mapping of specific sites to an OES. Therefore, they are not discussed further in this document.

Mapping procedures for the above sources are discussed in detail in the subsequent sections; however, Table_Apx F-2 includes a summary of the type of information reported by companies in each database that helps to inform OES and COU mapping. This includes industrial classification codes such as those associated with the NAICS (accessed December 1, 2025) and SIC (accessed December 1, 2025) system. Note that the U.S. government replaced SIC codes with NAICS codes in 1997; however, SIC codes are still used in DMR and are applicable for data from all listed sources for years prior to 1997. Additionally, some of the sources in Table_Apx F-2 have specific reporting requirements that include flags for the type of processes that occur at the site.

Assessors should be sure that a facility that reports to multiple databases/sources is consistently mapped to the same OES, as applicable. This is not applicable if the facility reports separately for different areas/processes of their facility (*e.g.*, a large chemical plant may report 1 block of unit operations separate from another such that they have different OESs).

Table_Apx F-2. EPA Programmatic Database Information That Aids OES/COU Mapping

Source	Reported Information Useful for Mapping OES/COU	Reporting Frequency	Notes
CDR	- Indication if the chemical is imported or domestically manufactured - Indication if the chemical is imported but never at the site, used on-site, or exported	- Facilities must report to CDR every 4 years - New datasets take years to become publicly available - Latest reporting year with available data: 2020	- While CDR also includes information on downstream processing and use, it does not include site identities for these operations; thus, it does not inform reporting site OES/COU mapping. - Claims of CBI can limit data utility in risk evaluations.
TRI	- NAICS codes - Flags for uses and sub-uses of the chemical - Release media information	- Facilities must report to TRI annually - New datasets become publicly available in October for the previous year - Latest reporting year with available data: 2021	- Reporters must select from specific uses (*e.g.*, manufacture, import, processing) and sub-uses (*e.g.*, formulation additive, degreaser, lubricant). - Sub-use information is only available in datasets starting in 2018. - Facilities may report with a Form A under certain circumstances; [a] Form A's do not require use/sub-use reporting.
NEI	- Source Classification Code (SCCs), which classify different types of activities that generate air emissions - EIS Sectors, which classify industry sectors - NAICS codes - Process description free-text field (used for additional information about the process related to the emission unit) - Emission unit description free-text field	- Facilities must report to TRI every 3 years - New datasets take years to become publicly available. - Latest reporting year with available date: 2020	- NEI contains specific SCC codes and industry sectors from which reporters select. - Free-text fields are not mandatory for the reporter to fill out.
DMR	- SIC codes - NPDES) permit numbers	- Facilities must report to DMR at the frequency specified in their NPDES permit, which is typically monthly - Data typically flows through the State DMR reporting platform to EPA's	- Sites that only report non-detection of the chemical for the year are generally excluded from mapping. - NPDES permit numbers can sometimes indicate the type of general permit, which can inform mapping (*e.g.*, remediation general permit).

Source	Reported Information Useful for Mapping OES/COU	Reporting Frequency	Notes
		Enforcement and Compliance History Online (ECHO) database continuously	
OSHA	- NAICS or SIC codes	- OSHA conducts monitoring as-needed for site investigations - Monitoring data are available in CEHD when the investigation and any subsequent litigation cases are closed - Latest year in CEHD with data: 2021	- CEHD includes data from 1984 and forward.
NIOSH HHE	- Facility process information - Worker activities	- NIOSH conducts HHEs upon request - HHEs are published online when NIOSH is completed with the evaluation - Latest year with a published HHE: 2023	- NIOSH HHEs generally include narrative descriptions of facility processes and worker activities, with specific information on how the chemical being monitored for is used.
[a] Facilities may report using a Form A if the annual reportable release amount of the chemical did not exceed 500 lb for the reporting year, and the amounts manufactured, or processed, or otherwise used did not exceed 1 million lb for that year.			

F.3 OES Mapping Procedures

This section contains procedures for mapping facilities to OESs for each source discussed in Section F.2.

F.3.1 CDR

The only facilities required to report to CDR are those that manufacture or import specific chemicals at or above a specified threshold.[9] Therefore, sites that report for the chemical of interest in CDR will generally be mapped to either the Manufacturing or Import – repackaging OES. These sites must also report the processing and uses of the chemical; however, these procedures are specific to mapping of the reporting site and not downstream processing or use sites.

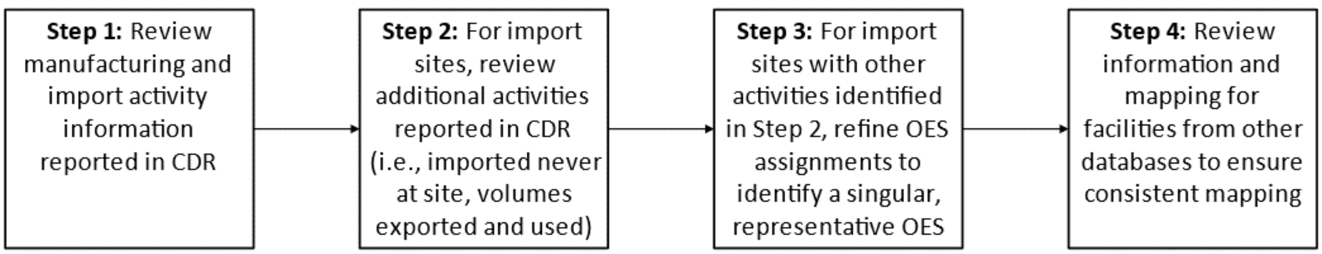
CDR, under TSCA, requires manufacturers (including importers) to provide EPA with information on the production and use of chemicals in commerce. These facilities must report to CDR every 4 years. For risk evaluations conducted under the amended TSCA, EPA has primarily used 2016 and 2020 CDR. The procedures in this document are appliable to both 2016 and 2020 CDR data; however, there are some data elements that are only applicable to 2020 CDR, which are called out in the procedures where

[9] The 2020 CDR reporting instructions, including descriptions on the information required to be reported, can be found at: https://www.epa.gov/chemical-data-reporting/instructions-reporting-2020-tsca-chemical-data-reporting (accessed December 1, 2025).

appliable. These procedures should be applicable to future CDR, depending on changes to reporting requirements. When the TDR rule is implemented, these procedures will be updated accordingly.

Chemical data reported under CDR is classified using Industrial Function Category (IFC) codes and/or commercial/consumer use product categories (PCs). CDR IFC codes describe the "intended physical or chemical characteristics for which a chemical substance or mixture is consumed as a reactant; incorporated into a formulation, mixture, reaction product, or article, repackaged; or used." Alternatively, PCs describe the consumer and commercial products in which each reportable chemical is used. EPA typically uses these CDR codes to identify the COUs for the chemical in the published scope documents.

Figure_Apx F-2 depicts the steps that should be followed to map CDR reporting sites to OESs. Each step is explained in the text below the figure. Additionally, Appendix F.5.1 shows step-by-step examples for using the mapping procedures to determine the OES for three example CDR reporting facilities.



Figure_Apx F-2. OES Mapping Procedures for CDR

To map sites reporting to CDR, the following procedures should be used with the non-CBI CDR:

1. ***Review Manufacturing and Import Activity Information:*** The first step in the process is to review the reported activity information to identify if the facility imports or manufactures the chemical.
    a. If the facility reports domestic manufacturing, the Manufacturing OES should be assigned, even if the facility also reports importation or the facility may conduct other operations with the chemical. This is because manufacturing of the chemical is expected to be the primary operation, with any other processing or uses being ancillary operations.
    b. If the chemical is being manufactured as a byproduct (this is a voluntary reporting element starting in 2020 CDR), this may need to be considered separately from non-byproduct manufacturing depending on assessment needs for the chemical.
    c. If the facility does not manufacture the chemical and only imports the chemical, check if additional processes occur at the site as described in the subsequent steps.
2. ***For Importation Sites, Review Fields for "Imported Never at Site," "Volume Exported," and "Volume Used":*** The next step is to review these additional fields to determine if the reporting facility conducts more than just importation activities.
    a. If the facility imports the chemical, it must report if it is imported but never physically at the reporting site. If the facility indicates the chemical is imported and never at site, the facility does not handle the chemical and the only applicable OES is importation. In such cases, the assessor should proceed to Step 4. If the facility does not indicate the chemical is imported and never at site, proceed to Step 2.b.

b. If the facility reports a quantity for "volume exported" and this quantity is the same as that imported, no additional OES occurs at the site beyond importation. In such cases, the assessor should proceed to Step 4. If the exported quantity is not equal to volume imported, assessors should check if any of the chemical is used at the reporting site per Step 2.c.

c. If the facility reports a quantity for "volume used", additional OESs may be applicable to the facility beyond manufacturing or importation. Proceed to Step 3 to identify and refine additional OESs.

3. ***Refine OES Assignments:*** If multiple OESs were identified from the previous steps, a single primary OES must be selected using additional facility information. OES determinations should be made with the following considerations:

   a. Six-digit NAICS code reported by the facility in CDR. Note that this is only a requirement starting in 2020 CDR (*e.g.*, for a facility that reported NAICS code was 325520, Adhesive manufacturing, the Incorporation into a formulation, mixture, or reaction product OESs may be appropriate; for a facility reporting a NAICS code starting in 424690, Other Chemical and Allied Products Merchant Wholesalers, only the Repackaging OES is likely applicable).

   b. Downstream processing and use information reported in CDR. The reporting site must provide information on downstream processing and use of the chemical for all sites, meaning it cannot be distinguished which processing and use information includes the reporting site operations vs. downstream site operations. However, this information may still help inform the operations at the reporting site and should be reviewed. Specifically, for a given processing/use activity, if the submitter reports "fewer than 10 sites" for the "number of sites" field (which is the lowest number of sites that can be reported), there is a likelihood that the facility's operations may be included in this processing/use activity. In such cases, review the corresponding fields for "type of processing or use operation," "industrial sector," and "function category" to help identify the OES. The greater number of sites that are reported, the more likely that the associated processing and use information includes information from downstream sites and the less reliable the information is for mapping OESs to the reporting site.

   c. Internet research of the types of products made at the facility (*e.g.,* if a facility's website indicates the facility manufactures plastic products, the chemical may be used as a processing aid or component in the plastic products—depending on the known uses of the chemical within the plastics industry).

   d. Information from other reporting databases as described in Step 3.

   e. An evaluation of the OES that is most likely to result in a release (*e.g.*, for facilities that reported importation and may also conduct formulation per the reported NAICS code, the Formulation OES may be assigned, because, in most cases, importation would have a lower likelihood of a release).

   f. Grouped OESs for similar uses (*e.g.*, multiple facilities that may conduct formulation operations based on the reported NAICS code may be assigned a grouped formulation OESs that covers all types of formulation [*e.g.*, adhesives, paints, cleaning products]).

4. ***Review Information from Other Databases:*** Other databases/sources (such as TRI, NEI, and DMR) should be checked to see if the facility has reported to one or more of these. If so, the OES determined from the mapping procedures for those databases (discussed in other sections of

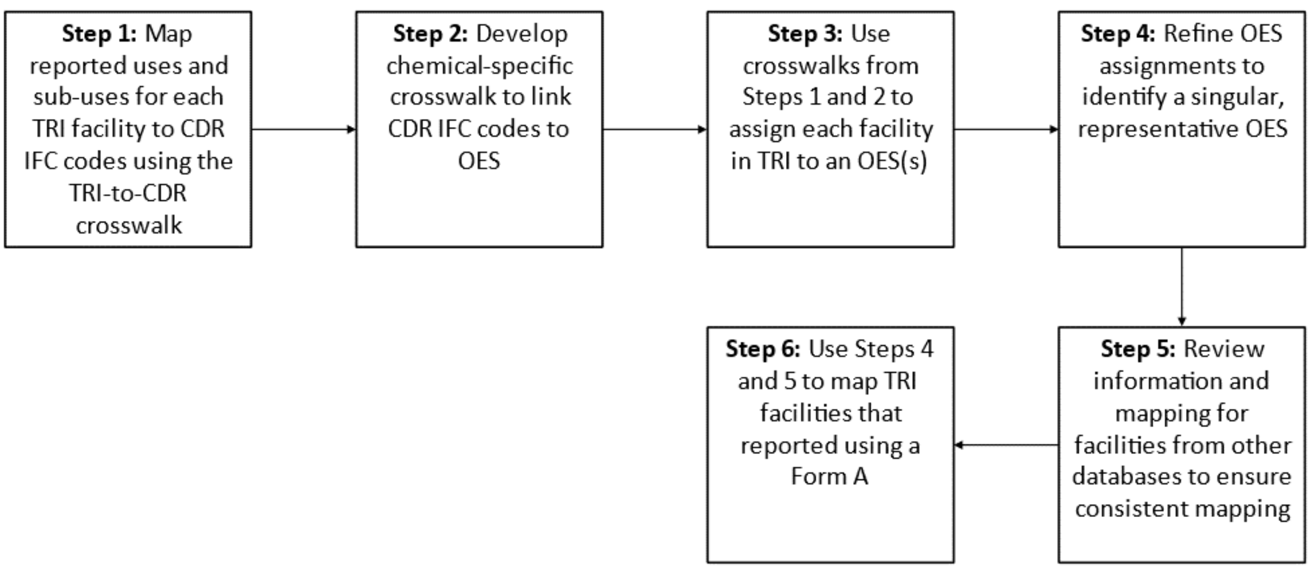
this document) should also be used. It is important that the same facility is mapped consistently across multiple databases/sources. The facility's TRI identification number (TRFID) and Facility Registry Services identification number (FRS ID) can be used to identify sites that report to TRI, DMR, and NEI. If the facility does not report to these databases, but additional OESs are possible per Step 2, the assessor should search available facility information on the internet.

Given the information available in CDR, EPA expects that, for most chemicals, 100 percent of the sites reporting to CDR can feasibly be mapped to an OES.

F.3.2 Toxics Release Inventory (TRI)

TRI reporting is required for facilities that manufacture (including import), process, or otherwise use any TRI-listed chemical in quantities greater than the established threshold in the calendar year AND have 10 or more full-time employee equivalents (*i.e.,* a total of ≥20,000 hours) and are included in a covered NAICS code. Therefore, unlike CDR reporters that are primarily manufacturers and importers, TRI reporters can be mapped to a variety of different OESs.

Figure_Apx F-3 depicts the steps that should be followed to map TRI reporting sites to OES. Each step is explained in the text below the figure. Additionally, Appendix F.5.2 shows step-by-step examples for using the mapping procedures to determine the OES for three example TRI reporting facilities.



Figure_Apx F-3. OES Mapping Procedures for TRI

To map sites reporting to TRI, the following procedures should be used:

1. ***Assign CDR Codes Using TRI-to-CDR Crosswalk:*** The first step in the TRI mapping process is to map the uses and sub-uses reported by each facility to one or more 2016 CDR IFC codes. To do this, first compile all TRI uses/sub-uses for the reporting facility into a single column, then map each to CDR IFC codes using the TRI-to-CDR Use Mapping crosswalk (see Appendix B). This is a universal crosswalk that applies to all chemicals.
2. ***Develop Chemical-Specific Crosswalk to Link CDR Codes to OESs:*** The next step is to develop a separate CDR IFC code-to-OES crosswalk that links CDR IFC codes to OESs for the chemical. To create this crosswalk, match the COU categories and subcategories from the COU table in the

published scope documents (see the example provided in Table 1-1) to the list of 2016 CDR IFC codes in the CDR reporting instructions.[10] The categories and subcategories of COUs typically match the IFC code category. Recent examples of already completed CDR IFC code-to-OES crosswalk can be found for the fenceline chemicals (1-bromopropane, methylene chloride, n-methylpyrrolidone, carbon tetrachloride, perchloroethylene, trichloroethylene, and 1,4-dioxane).

3. ***Assign OES:*** Each TRI facility is then mapped to one or more OES using the CDR IFC codes assigned to each facility in Step 1 and the CDR IFC code-to-OES crosswalk developed in Step 2.
4. ***Refine OES Assignments:*** If a facility maps to more than one OES in Step 3, a single primary OES must be selected using additional facility information. OES determinations should be made with the following considerations:
    a. Six-digit NAICS codes reported by the facility in TRI (*e.g.*, for a facility that reported TRI uses for both formulation and use as cleaner, EPA assigned the Formulation OES if the NAICS code was 325199, All Other Basic Organic Chemical Manufacturing; another example is NAICS codes 562211, Hazardous Waste Treatment and Disposal, and 327310, Cement Manufacturing, almost always corresponded to the Disposal OES, regardless of the reported TRI uses and sub-uses).
    b. Internet research of the types of products made at the facility (*e.g.*, if a facility's website indicates the facility manufactures metal parts, the facility is likely to use chemicals for degreasing or in a metalworking fluid) and information from sources cited in the COU table and scoping document, such as public and stakeholder comments (*i.e.*, EPA will review sources cited in the COU table and scoping document to see if there is any information specific to the reporting site that can be used to inform the mapping).
    c. Information from other reporting databases as described in Step 5.
    d. An evaluation of the OES that is most likely to result in a release (*e.g.*, facilities that reported both importation and formulation may be assigned a Formulation OES, because in most cases, importation would have a lower likelihood of a release).
    e. Grouped OES for similar uses/sub-uses (*e.g.*, facilities that reported cleaner and degreaser sub-uses may be assigned a grouped OES that covers both cleaning and degreasing because the specific cleaning/degreasing operation cannot be determined from the TRI data).
5. ***Review Information from Other Databases:*** Other databases/sources (including CDR, NEI, and DMR) should be checked to see if the facility has reported to these. If so, the OES determined from the mapping procedures for those databases (discussed in other sections of this document) should also be used. It is important that the same facility is mapped consistently across multiple databases/sources. The facility's TRFID and FRS ID can be used to identify sites that report to TRI, DMR, and NEI.
6. Note that facilities that submit using a TRI Form A do not report TRI uses/sub-uses. To determine the OES for these facilities, EPA will use information from Steps 4 and 5.

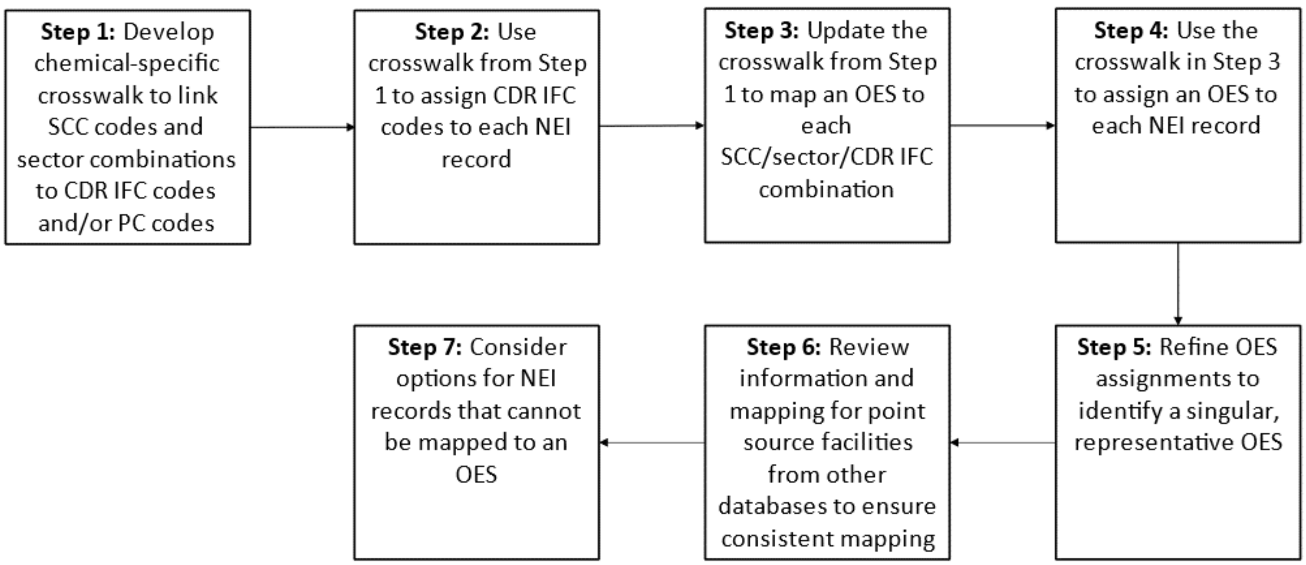
Given the information available in TRI, EPA expects that, for most chemicals, 100 percent of the sites reporting to TRI can feasibly be mapped to an OES.

[10] IFC codes and their definitions can be found in Table 4-11 of the CDR reporting instructions: https://www.epa.gov/chemical-data-reporting/instructions-reporting-2016-tsca-chemical-data-reporting (accessed December 1, 2025).

F.3.3 NEI

The NEI is a compilation of air emissions of criteria pollutants, criteria precursors, and HAPs from point and nonpoint source air emissions. Air emissions data for the NEI are collected at the SLT level. The Air Emissions Reporting Requirement rule requires SLT air agencies to collect, compile, and submit criteria pollutant air emissions data to EPA. Many SLT air agencies also voluntarily submit data for pollutants on EPA's list of HAPs. Major sources are required to report point source emissions data to their SLT air agency. Each SLT entity must in turn report point source emissions data to EPA every 1 to 3 years, depending upon the size of the source. Nonpoint estimates are typically developed by state personnel.

Figure_Apx F-4 depicts the steps that should be followed to map NEI reporting sites/records to OESs. Each step is explained in the text below the figure. Additionally, Section F.5.3 shows step-by-step examples for using the mapping procedures to determine the OES for one point source example and one nonpoint source example.



Figure_Apx F-4. OES Mapping Procedures for NEI

To map sites reporting point source emissions and nonpoint emissions records for the chemical of interest to NEI, the following procedures should be used:

1. ***Develop Crosswalks to Link NEI-Reported SCC and Sector Combinations to CDR Codes:*** The first step in mapping NEI data to potentially relevant OESs is to develop a crosswalk to map each unique combination of NEI-reported Source Classification Code (SCC) (levels 1–4) and industry sectors to one or more CDR codes. This crosswalk is developed on a chemical-by-chemical basis rather than an overall crosswalk for all chemicals because SCCs correspond to emission sources rather than chemical uses such that the crosswalk to CDR codes may differ from chemical to chemical. In some cases, it may not be possible to assign all SCC sector combinations to CDR codes, in which case information from Step 5 can be used to help make OES assignments. Separate crosswalks are needed for point and nonpoint source records, as discussed below.
    a. For the point source NEI data, the crosswalk should map each unique combination of NEI-reported SCC and industry sectors to one or more *CDR IFC codes*.
    b. For nonpoint source NEI data, the crosswalk should link the SCC codes and sectors to

both CDR IFC codes and/or commercial/consumer use PCs. This is because the nonpoint source data may include commercial operations for which CDR PCs may be more appropriate.

2. ***Use CDR Crosswalks to Assign CDR Codes:*** Next, the chemical-specific CDR crosswalk developed in Step 1 should be used to assign CDR IFC codes to each point source NEI record and CDR IFC codes and/or commercial/consumer use PCs to each nonpoint source NEI record.
3. ***Update CDR Crosswalks to Link CDR Codes to OES:*** The chemical-specific crosswalk developed in Step 1 is then used to link the SCCs, sectors, and CDR codes in the crosswalk to an OES. The OES will be assigned based on the chemical-specific COU categories and subcategories and the OES mapped to them as discussed in Appendix F.1.
4. ***Use CDR Crosswalks to Assign OES:*** The chemical-specific CDR crosswalks developed in Steps 1-3 are then used to assign OESs to each point source and nonpoint source NEI data record (*i.e.*, each combination of facility-SCC-sector). Note that the individual facilities in the point source dataset may have multiple emission sources, described by different SCC and sector combinations within NEI, such that multiple OESs map to these NEI records. In such cases, a single, representative OES must be selected for each NEI record using the additional information described in Step 5. Similarly, the sectors reported by nonpoint sources may map to multiple CDR IFC or PC codes, such that multiple OES are applicable and must be refined to a single OES for each NEI record.
5. ***Refine OES Assignments:*** The initial OES assignments may need to be confirmed and/or refined to identify a single primary OES using the following information described below for point source and nonpoint source records.
   a. For point source records in NEI, use the following information to refine OES assignments:
      - Additional information available in NEI:
        - Facility name.
        - Primary NAICS code and description, populated from the EIS lookup tables.
        - Facility site description, which, when populated, is intended to describe the type of industry the facility operates (similar to a NAICS description).
        - Process description, which is a free-text field where reporters can provide additional information about the process related to their emission unit.
        - Emission unit description, which is a free-text field where reporters can provide additional information about their emission units.
      - Internet research of the types of products made at the facility (*e.g.*, if a facility's website indicates the facility manufactures metal parts, the facility is likely to use chemicals for degreasing or in a metalworking fluid) and information from sources cited in the COU table and scoping document, such as public and stakeholder comments (*i.e.*, EPA will review sources cited in the COU table and scoping document to see if there is any information specific to the reporting site that can be used to inform the mapping).
      - Information from other reporting databases as described in Step 5.b.
      - An evaluation of the OES that is most likely to result in a release (*e.g.*, facilities that map to both lubricant use and vapor degreasing may be assigned a vapor

degreasing OES, because, in most cases, vapor degreasing results in higher air emissions).

- Grouped OES for similar uses/sub-uses (*e.g.*, facilities that map to both general cleaning and vapor degreasing may be assigned a grouped OES that covers both cleaning and degreasing because the specific cleaning/degreasing operation cannot be determined from the NEI data).

b. For nonpoint source records in NEI, use the following information to refine OES assignments (there is no additional data reported to NEI by nonpoint sources that can help refine the OES mapping):

- General knowledge about the use of the chemical in the reported sector, such as from scope documents, public or stakeholder comments, process descriptions, professional judgment, or already-identified sources from systematic review.
- Internet research of the uses of the chemical in the reported sector, if insufficient information is not already available per the previous bullet.
- An evaluation of the OES that is most likely to result in a release (*e.g.*, sectors that map to both lubricant use and vapor degreasing may be assigned a vapor degreasing OES, because, in most cases, vapor degreasing results in higher air emissions).
- Grouped OES for similar uses/sub-uses (*e.g.*, sectors that map to both general cleaning and vapor degreasing may be assigned a grouped OES that covers both cleaning and degreasing because the specific cleaning/degreasing operation cannot be determined from the NEI data).

6. ***Review Information from Other Databases for Point Source Facilities:*** Other databases/sources (including CDR, TRI, and DMR) should be checked to see whether the point source facilities have reported to these databases. If so, the OES determined from the mapping procedures for those databases (discussed in other sections of this TSD) should also be used. It is important that the same facility is mapped consistently across multiple databases/sources. The facility’s TRFID and FRS ID can be used to identify sites that report to TRI, DMR, and NEI.
7. ***Consider Options for NEI Records that Cannot be Mapped to an OES:*** Given the number of records in NEI and the information available, it may not always be feasible to achieve mapping of 100 percent of the sites reporting to NEI to an OES. For example, there may be NEI records for restaurants or the commercial cooking sector that do not map to an in-scope COU or OES. Additionally, NEI records may include emissions from combustion byproducts for the chemical, which does not correspond to a COU or OES. In such cases, multiple options may be appropriate depending on assessment needs, such as:

   a. Assigning the sites as having an unknown OES with 250 release days/year. This allows for subsequent exposure modeling and the assessment of risk. For sites with identified risk, the OES can then be mapped using the below resources.

   b. Contacting the facility for clarification on the use of the chemical. Information Collection Request (ICR) requirements also apply when contacting 10 or more facilities. Note that information requests such as these may require an ICR if 10 or more entities are contacted.[11]

[11] More on Information Collection Requests can be found at: https://www.epa.gov/icr/icr-basics (accessed December 1, 2025)

F.3.4 DMR

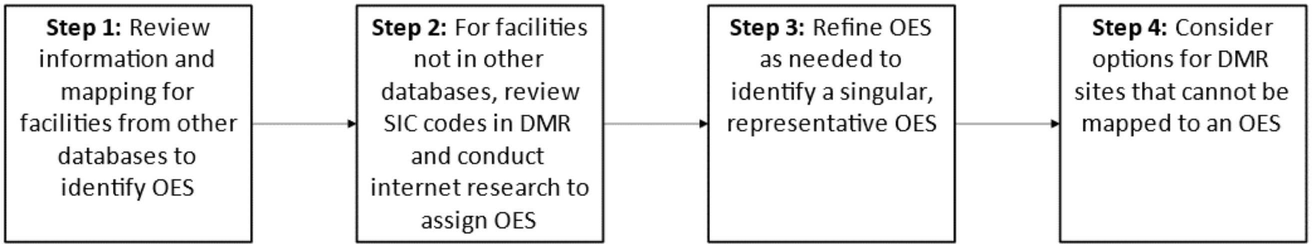
Facilities must submit DMRs for chemicals when the following two conditions are met: (1) the facility has an NPDES permit for direct discharges to surface water, and (2) the NPDES permit contains monitoring requirements for the chemical of interest. Indirect discharges (*e.g.*, those sent to off-site WWTs or POTWs) are not covered under the NPDES program.

If a facility has discharge monitoring requirements for the chemical of interest, these requirements are either technology-based or water-quality based. Typically, a facility has NPDES monitoring requirements for a chemical because the facility somehow manufactures, processes, or uses the chemical. However, it is possible for a facility to have monitoring requirements for a chemical they do not handle if the facility falls within a guideline containing requirements for that chemical, as described below.

- ***Technology-Based Guidelines:*** If the facility falls within a certain industrial sector, it may be covered by a national effluent guideline. Effluent guidelines are industry-specific and contain treatment technology-based guidelines for discharges of specified pollutants (chemicals) commonly found within that industry.[12] A common effluent guideline containing requirements for chemicals that have or are currently undergoing risk evaluation is the Organic Chemicals, Plastics & Synthetic Fibers (OCPSF) effluent guideline. Alternatively, if there is no applicable effluent guideline for the facility, the permitting authority may establish technology-based guidelines using best professional judgment. If a facility falls within an existing effluent guideline, the permitting authority will generally include monitoring requirements in the facility's NPDES permit that are consistent with the effluent guideline—even if the facility does not handle all the chemicals for which there are monitoring requirements. Therefore, under this reasoning, it is possible that a facility reporting for the chemical of interest in DMRs does not actually handle the chemical.[13]
- ***Water Quality-Based Guidelines:*** The receiving water for the facility's discharges is impaired such that the permitting authority sets general water-quality based effluent limits and monitoring requirements for chemicals that may further impair the water quality. It is possible that the permitting authority uses these same general water-quality based requirements for all facilities that discharge to the water body. Therefore, under this reasoning, it is possible that a facility reporting for the chemical of interest in DMRs does not actually handle the chemical.

Figure_Apx F-5 depicts the steps that should be followed to map DMR reporting sites to OESs. Each step is explained in the text below the figure. Additionally, Appendix F.5.4 shows step-by-step examples for using the mapping procedures to determine the OES for two example DMR reporting facilities.

[12] A list of the industries for which EPA has promulgated effluent guidelines is available at: https://www.epa.gov/eg/industrial-effluent-guidelines#existing (accessed December 1, 2025)
[13] Note that a facility may request to have monitoring requirements reduced or removed from the permit where historical sampling demonstrates that these chemicals are consistently measured below the effluent limits. Thus, it is possible for a facility to cease monitoring for the chemical of interest upon approval by the permitting authority.



Figure_Apx F-5. OES Mapping Procedures for DMR

To map sites reporting to DMR, the following procedures should be used:

1. ***Review Information from Other Databases:*** Given the limited facility information reported in DMRs, the first step for mapping facilities reporting to DMR should be to check other databases/sources (including CDR, TRI, and NEI). If so, the OES determined from the mapping procedures for those databases (discussed in other sections of this document) should be used. It is important that the same facility is mapped consistently across multiple databases/sources. The facility's TRFID and FRS ID can be used to identify sites that report to TRI, DMR, and NEI.
2. ***Assign OES:*** If the facility does not report to other databases, the following information should be used to assign an OES.
    a. Four-digit SIC codes reported by the facility in DMR (*e.g.*, a facility that reported SIC code 2891, Adhesives and Sealants, likely formulates these products; a facility that reported SIC code 4952, Sewerage Systems, likely treats wastewater). Note that SIC codes can be crosswalked to NAICS codes, which are often more useful for mapping OES because they are more descriptive than SIC codes.
    b. Internet research of the types of products made at the facility (*e.g.*, if a facility's website indicates the facility manufactures metal parts, the facility is likely to use chemicals for degreasing or in a metalworking fluid) and information from sources cited in the COU table and scoping document, such as public and stakeholder comments (*i.e.*, EPA will review sources cited in the COU table and scoping document to see if there is any information specific to the reporting site that can be used to inform the mapping).
3. ***Refine OES:*** If the specific OES still cannot be determined using the information in Step 2, the following should be considered.
    a. NPDES permit numbers reported in DMR. The permit number generally indicates if the permit is an individual permit or a general permit.[14] If the permit is a general permit, the permit number can often indicate the type of general permit, which can provide information on the operations at the facility.
        - Individual NPDES permits are numbered in the format of the state abbreviation followed by a seven-digit number (*e.g.*, VA0123456). General permits are usually numbered in the format of state abbreviation followed by one letter then a six-digit number (*e.g.*, VAG112345 or MAG912345).
        - Because each state is slightly different in their general permit numbering, the general permit number should be searched on the internet to determine the type of general permit. For the general permit number examples provided above, a

[14] Information on individual and general NPDES permits can be found at: https://www.epa.gov/npdes/npdes-permit-basics (accessed December 1, 2025)

permit number beginning in "VAG11" signifies Virginia's general permit for concrete products facilities and a permit number beginning with "MAG91" signifies Massachusetts' general permit for groundwater remediation. Other common general permit types include those for construction sites, mining operations, sites that only discharge non-contact cooling water, and vehicle washes

b. Searching for the permit online. If the specific NPDES permit for the facility can be found online, it may contain some general process information for the facility that can help inform the OES mapping. However, NPDES permits may be difficult to find online and do not generally contain much information on process operations.

c. An evaluation of the OES that is most likely to result in a water release (*e.g.*, for facilities that report an SIC code for the production of metal products, both Vapor degreasing and Metalworking fluid OESs are applicable; in such cases, the Metalworking fluid OES may be assigned because it is more likely to result in water releases than vapor degreasing).

d. Grouped OES for similar uses (*e.g.*, multiple facilities that may conduct formulation operations based on the reported SIC code may be assigned a grouped formulation OES that covers all types of formulation [*e.g.*, adhesives, paints, cleaning products]).

4. ***Consider Options for DMR Sites That Cannot be Mapped to an OES:*** Given the limited information available in DMR, it may not always be feasible to achieve mapping of 100 percent of the sites reporting to DMR to an OES. In such cases, multiple options may be appropriate depending on assessment needs, such as the following:

   a. Assigning the sites as having an unknown OES with 250 release days/year. This allows for subsequent exposure modeling and the assessment of risk. For sites with identified risk, the OES can then be mapped using the below resources.

   b. Contacting the state government for the NPDES permit, permit applications, past inspection reports, and any available information on facility operations. Note that information requests such as these may require an ICR if 10 or more entities are contacted.

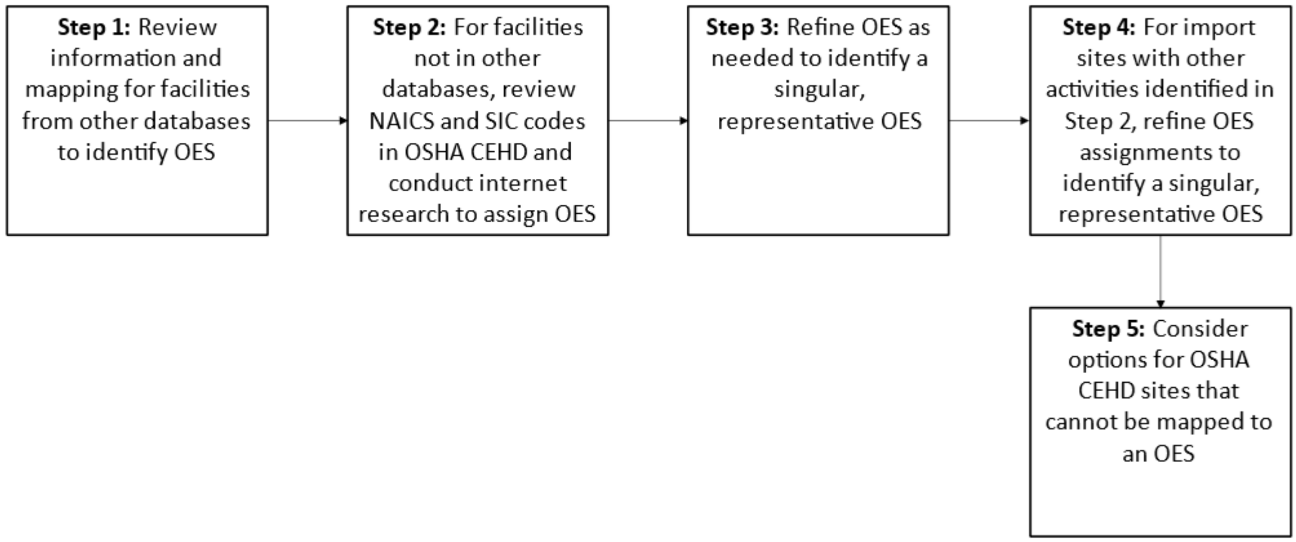
   c. Contacting the facility for clarification on the use of the chemical. ICR requirements also apply when contacting 10 or more facilities.

F.3.5 OSHA CEHD

OSHA CEHD is a compilation of industrial hygiene samples (*i.e.*, occupational exposure data) taken when OSHA monitors worker exposures to chemical hazards. OSHA will conduct monitoring at facilities that fall within targeted industries based on national and regional emphasis programs.[15] OSHA conducts monitoring to compare against occupational health standards. Therefore, unlike CDR, TRI, NEI, and DMR, facilities are not required to report data to OSHA CEHD. Also, OSHA only visits selected facilities so the amount of OSHA data available for each OES is often limited.

Figure_Apx F-6 depicts the steps that should be followed to map OSHA CEHD sites to OES. Each step is explained in the text below the figure. Additionally, Appendix F.5.5 shows step-by-step examples for using the mapping procedures to determine the OES for two example OSHA CEHD facilities.

[15] More information on OSHA CEHD can be found at: https://www.osha.gov/opengov/health-samples (accessed December 1, 2025)



Figure_Apx F-6. OES Mapping Procedures for OSHA CEHD

Within the OSHA CEHD data, there may be sites for which all air sampling data are non-detect (below the LOD) for the chemical. In these cases, if there is also no bulk sampling data indicating the presence of the chemical, there is no evidence that the chemical is present at the site. OSHA may have sampled for the chemical based on a suspicion or pre-determined sampling plan, and not because the chemical was actually present at the site. Therefore, these sites do not need to be mapped to an OES. To map sites for which there is OSHA CEHD data that are not all non-detect for the chemical, the following procedures should be used:

1. ***Review Information from Other Databases:*** Given the limited facility information reported in OSHA CEHD, the first step for mapping facilities should be to check other databases/sources (including CDR, TRI, NEI, and TRI). If so, the OES determined from the mapping procedures for those databases (discussed in other sections of this document) should be used. It is important that the same facility is mapped consistently across multiple databases/sources. Because facility identifiers such as TRFID and FRS ID are not available in the CEHD, the name of the facility in the CEHD will need to be compared to the facility names in other databases to identify if the facility is present in multiple databases/sources.
2. ***Assign an OES:*** If the facility does not report to other databases, the following information should be used to assign an OES.
    a. Four-digit SIC and 6-digit NAICS codes reported in the CEHD (*e.g.*, a facility that reported SIC code 2891, Adhesives and Sealants, likely formulates these products; a facility that reported NAICS code 313320, Fabric Coating Mills, likely uses the chemical in fabric coating).
    b. Internet research of the types of products made at the facility (*e.g.*, if a facility's website indicates the facility manufactures metal parts, the facility is likely to use chemicals for degreasing or in a metalworking fluid) and information from sources cited in the COU table and scoping document, such as public and stakeholder comments (*i.e.*, EPA will review sources cited in the COU table and scoping document to see if there is any information specific to the reporting site that can be used to inform the mapping).
3. ***Refine OES:*** If the specific OES still cannot be determined using the information in Step 2, the following should be considered.

   a. An evaluation of the OES that is most likely to result in occupational exposures (*e.g.*, for facilities that report an SIC code for janitorial services, multiple OESs may be applicable, such as cleaning, painting (*e.g.*, touch-ups), other maintenance activities; in such cases, the cleaning OES may be assigned for volatile chemicals because it has the highest exposure potential).
   b. Grouped OES for similar uses (*e.g.*, multiple facilities that may conduct formulation operations based on the reported NAICS or SIC code may be assigned a grouped formulation OES that covers all types of formulation [*e.g.*, adhesives, paints, cleaning products]).

4. ***Consider Options for OSHA CEHD Sites That Cannot be Mapped to an OES:*** Given the limited information available in OSHA CEHD, it may not always be feasible to achieve mapping of 100 percent of the sites in the database to an OES. In such cases, multiple options may be appropriate depending on assessment needs, such as:
   a. Assigning the sites as having an unknown OES with 250 exposure days/year. This allows for subsequent health modeling and the assessment of risk. For workers with identified risk, the OES can then be mapped using the below resources.
   b. Contacting OSHA for additional information on the facility from the OSHA inspection/monitoring.
   c. Contacting the facility for clarification on the use of the chemical. Note that information requests such as these may require an ICR if 10 or more entities are contacted.
   d. As discussed previously, sites for which all air monitoring data are non-detect for the chemical and for which there is no bulk data indicating the presence of the chemical do not need to be mapped to an OES. This is because the data do not provide evidence that the chemical is present at the site.

F.3.6 National Institute of Occupational Safety and Health (NIOSH) Health Hazard Evaluation (HHE)

NIOSH conducts HHEs at facilities to evaluate current workplace conditions and to make recommendations to reduce or eliminate the identified hazards.[16] NIOSH conducts HHEs at the request of employers, unions, or employees in workplaces where employee health and wellbeing are affected by the workplace. Therefore, unlike CDR, TRI, NEI, and DMR, facilities are not required to report data to NIOSH under the HHE program. Also, NIOSH only visits selected facilities where an HHE was requested, so the number of NIOSH HHEs available for each OES is often limited.

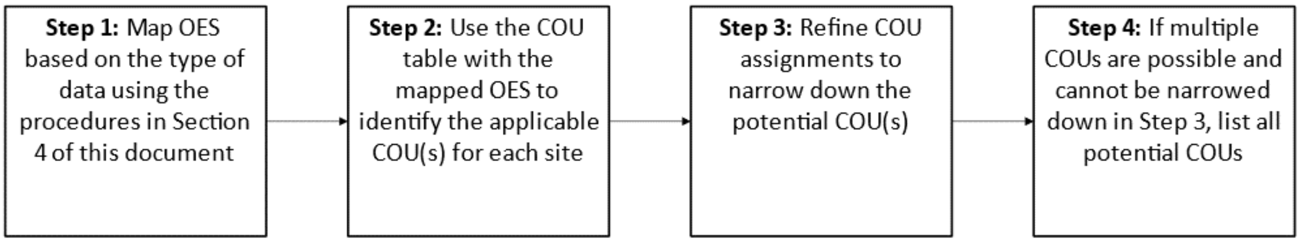
To map a facility that is the subject of a NIOSH HHE, the information in the HHE report should be used. Specifically, the HHE report typically includes general process information for the facility, information on how the chemical is used, worker activities, and the facility's SIC code. This information should be sufficient to map the facility to a single representative OES. Additionally, given the extent of information available about the subject facilities in NIOSH HHE reports, 100 percent of these facilities can be mapped to an OES. Additionally, Appendix F.5.6 shows two examples of how to map NIOSH HHE facilities to OES.

F.4 COU Mapping Procedures

As discussed in Appendix F.1, there is not always a one-to-one mapping between COUs and OES.

[16] More information about NIOSH HHEs is available at: https://www.cdc.gov/niosh/hhe/about.html (accessed December 1, 2025)

Figure_Apx F-7 depicts the steps that should be followed to map sites from the standard sources discussed in this document to COUs, using the OES mapping completed in Appendix F.3. Each step is explained in the text below the figure. Additionally, Appendix F.5.7 shows step-by-step examples for using the mapping procedures to determine the COU for three example facilities.



Figure_Apx F-7. COU Mapping Procedures for Standard Sources Already Mapped to OES

To map facilities from standard sources (*i.e.,* CDR, TRI, NEI, DMR, OSHA CEHD, NIOSH HHE) to COUs, the following procedures should be used:

1. ***Map the Facility to an OES:*** To map a facility from a standard source to a COU, the facility should first be mapped to an OES following the procedures for the specific source of data (discussed in Appendix F.3).
2. ***Use the COU Table with Mapped OES to Assign COUs:*** At the point of the risk evaluation process where EPA is mapping data from standard sources to OES and COU, EPA has already mapped OES to each of the COUs from the scope document, as shown in Table 1-1. This crosswalk between COUs and OES should be used to identify the COU(s) for the facility using the OES mapped per Appendix F.3.
3. ***Refine the COU Assignment:*** In some instances, more than one COU may map to the facility. In such cases, the following information should be used to try to narrow down the list of potentially applicable COUs:
    a. Information from the standard sources (*e.g.*, if EPA assigned a grouped OES like "Industrial processing aid" and the facility's NAICS code in TRI or NEI is related to battery manufacturing, the COU can be identified as the "Processing aid" category and "Process solvent used in battery manufacture" subcategory).
    b. Internet research of the types of products made at the facility (*e.g.,* if a facility's website indicates the facility makes adhesives, the COU category of "Processing – incorporation into formulation, mixture or reaction product" and subcategory of "Adhesives and sealant chemicals" can be assigned and the remaining subcategories [*e.g.,* Solvents for cleaning or degreasing, solvents which become part of the product formulation or mixture] are not applicable) and information from sources cited in the COU table and scoping document, such as public and stakeholder comments (*i.e.,* EPA will review sources cited in the COU table and scoping document to see if there is any information specific to the reporting site that can be used to inform the mapping).
4. ***List All Potential COUs:*** Where the above information does not narrow down the list of potentially applicable COUs, EPA will list all the potential COUs and will not attempt to select just one from the list where there is insufficient information to do so.

F.5 Example Case Studies

This section contains step-by-step examples of how to implement the OES and COU mapping procedures listed in the preceding Appendix Sections F.3 and F.4 to determine OES for facilities that report to standard engineering sources.

F.5.1 CDR Mapping Examples

This section includes examples of how to implement the OES mapping procedures for sites reporting to CDR, as listed in Appendix F.3.1. Specifically, this section includes examples for three example sites that reported to 2020 CDR for the tranche 2 chemical di-isononyl phthalate (DINP). These example sites are referred to as Facility A, Facility B, and Facility C.

To map Facilities A, B, and C to an OES, the following procedures are used with the non-CBI 2020 CDR database.

1. ***Review Manufacturing and Import Activity Information:*** The first step in the process is to review the reported activity information to identify if the facility imports or manufactures the chemical. Table_Apx F-3 summarizes the information gathered from 2020 CDR for the three example sites for this step.

Table_Apx F-3. Step 1 for CDR Mapping Facilities

Facility Name	Step 1a: Reported Activity	Step 1b: Byproduct Information	Step 1c: Check Other Activities?	OES Determination
Facility A	Domestically Manufactured/Imported	Not known or reasonably ascertainable	Not needed.	Per Step 1a, this site maps to the *Manufacturing OES*.
Facility B	Imported	CBI	Yes	Cannot be determined in Step 1—Proceed with Step 2.
Facility C	Imported	Not known or reasonably ascertainable	Yes	Cannot be determined in Step 1—Proceed with Step 2.

2. ***For Importation Sites, Review Fields for "Imported Never at Site," "Volume Exported," and "Volume Used":*** The next step is to review these additional fields to determine if the reporting facility conducts more than just importation activities. Table_Apx F-4 summarizes the information gathered from 2020 CDR for the three example sites for this step.

Table_Apx F-4. Step 2 for CDR Mapping Example Facilities

Facility Name	Step 2a: Imported Never at Site	Step 2b: Volume Exported	Step 2c: Volume Used	OES Determination
Facility A	N/A: OES determined in Step 1			
Facility B	CBI	CBI	CBI	Cannot be determined in Step 2: Proceed with Step 3.
Facility C	Yes	0	0	Since the facility only imports and does not use DINP, this site maps to the Import/Repackaging OES.

3. ***Refine OES Assignments:*** If multiple OES were identified from the previous steps, a single primary OES must be selected using additional facility information as discussed in Steps 3a to 3f. Table_Apx F-5 summarizes the information gathered from 2020 CDR for the three example sites for this step.

Table_Apx F-5. Step 3 for CDR Mapping Example Facilities

Facility Name	Step 3a: NAICS	Step3b: Processing/Use Information	Step 3c: Internet Research	Step 3d–e: Other Databases and OES Grouping	OES Determination
Facility A	N/A: OES determined in Step 1				
Facility B	325110, Petrochemical Manufacturing	CBI	Research indicates the facility is a petrochemical plant and does not indicate how DINP is used.	Check other databases per Step 4.	Cannot be determined in Step 2: Proceed with Step 4.
Facility C	N/A: OES determined in Step 2				

4. ***Review Information from Other Databases:*** Lastly, other databases/sources (such as TRI, NEI, and DMR) should be checked to see if the facility has reported to these. If the facility does not report to these databases, but additional OESs are possible per Step 2, search available facility information on the internet. Table_Apx F-6 summarizes the information gathered from 2020 CDR for the three example sites for this step.

Table_Apx F-6. Step 4 for CDR Mapping Example Facilities

Facility Name	Step 4: Other Databases	OES Determination
Facility A	N/A: OES determined in Step 1	
Facility B	Using the FRS ID reported in CDR, this facility does not report to TRI, NEI, or DMR. EPA searched the facility in EPA's ECHO database and found that the facility does not have any listed NAICS codes, SIC codes, or permits, and appears to be a warehouse from aerial imagery. Therefore, this facility is likely just an importer.	Using the information from Step 4, this site maps to the Import/Repackaging OES.
Facility C	N/A: OES determined in Step 2	

F.5.2 TRI Mapping Examples

This appendix includes examples of how to implement the OES mapping procedures for sites reporting to TRI, as listed in Appendix F.3.2. Specifically, this appendix includes examples for three example sites that reported to TRI for the tranche 2 chemical 1,2-dichloroethane (1,2-dichloroethane). These example sites are referred to as Facility D, Facility E, and Facility F.

To map Facilities D, E, and F to an OES, the following procedures are used with information from TRI.

1. ***Assign CDR Codes Using TRI-to-CDR Crosswalk:*** The first step in the TRI mapping process is to map the uses and sub-uses reported by each facility to one or more 2016 CDR IFC codes. The uses and sub-uses reported to TRI by each example site are compiled in Table_Apx F-7, along with the 2016 CDR IFC codes mapped using Appendix A.

Table_Apx F-7. Step 1 for TRI Mapping Example Facilities

Facility Name	TRI Form Type	TRI Uses (Sub-Uses)	2016 CDR IFC Codes
Facility D	R	Manufacture: produce, import, for onsite use/processing, for sale/distribution, as a byproduct Processing: as a reactant, as a formulation component (P299 Other) Otherwise Used: ancillary or other use (Z399 Other)	PK, U001, U003, U016, U013, U014, U018, U019, U020, U023, U027, U028, or U999
Facility E	R	Otherwise Used: ancillary or other use (Z399 Other)	U001, U013, U014, U018, U020, or U023
Facility F	A	None—not reported in Form A submissions	

2. ***Develop Chemical-Specific Crosswalk to Link CDR Codes to OES:*** The next step is to develop a separate CDR IFC code-to-OES crosswalk that links CDR IFC codes to OES for the chemical. To create this crosswalk, match the COU and OES from the COU table in the published scope documents to the list of 2016 CDR IFC codes. The categories and subcategories of COUs typically match the IFC code category. See Table_Apx F-8 for the completed crosswalk for 1,2-dichloroethane.

Table_Apx F-8. Step 2 for TRI Mapping Example Facilities

COU and OES from Published Scope Document				Mapping		
Life Cycle Stage	**Category**	**Subcategory**	**OES**	**2016 CDR IFC Code**	**2016 CDR IFC Code Name**	**Rationale**
Manufacturing	Domestic manufacturing	Domestic manufacturing	Manufacturing	None	None	Per Section F.5.1, there is no corresponding CDR code for this COU/OES
Repackaging	Repackaging	Repackaging	Repackaging	PK	Processing-repackaging	Category matches CDR code
Processing	Processing—As a reactant	Intermediate in petrochemical manufacturing	Processing as a reactant	U015; U016; U019; U024	Processing as a reactant	Category matches CDR code
		Plastic material and resin manufacturing				
		All other basic organic chemical manufacturing				
Processing	Processing—incorporation into formulation, mixture, or reaction product	Fuels and fuel additives: all other petroleum and coal products manufacturing	Incorporated into formulation, mixture, or reaction product	U012	Fuel and fuel additives	Category matches CDR code
		Formulation of adhesives and sealants		U002	Adhesives and sealant chemicals	Category matches CDR code
		Processing aids: specific to petroleum production		U025	Processing aids: specific to petroleum production	Category matches CDR code
Distribution in Commerce	Distribution in commerce	Distribution in commerce	Distribution in commerce	None	None	Per Section F.5.1, there is no corresponding CDR code for this COU/OES

COU and OES from Published Scope Document				Mapping		
Industrial Use	Adhesives and sealants	Adhesives and sealants	Adhesives and sealants	U002	Adhesives and sealant chemicals	Category matches CDR code
	Functional fluids (closed systems)	Engine coolant additive	Functional fluids (closed systems)	U013	Functional Fluids (closed systems)	Category matches CDR code
	Lubricants and greases	Paste lubricants and greases	Lubricants and greases	U017	Lubricants and Lubricant additives	Category matches CDR code
	Oxidizing/reducing agents	Oxidation inhibitor in controlled oxidative chemical reactions	Oxidizing/reducing agents	U019	Oxidizing/reducing agents	Category matches CDR code
	Cleaning and degreasing	Industrial and commercial non-aerosol cleaning/degreasing	Solvents (for cleaning and degreasing)	U029	Solvents (for cleaning or degreasing)	Category matches CDR code
		Vapor degreasing (TBD)				
Commercial Use	Cleaning and degreasing	Commercial aerosol products (aerosol degreasing, aerosol lubricants, automotive care products)				
	Plastic and rubber products	Products such as: plastic and rubber products	Plastics and rubber products	None	None	Per Section F.5.1, there is no corresponding CDR code for this COU/OES
	Fuels and related products	Fuels and related products	Fuels and related products	U012	Fuels and fuel additives	Category matches CDR code
	Other use	Laboratory chemical	Other use	None		This use does not match any other

COU and OES from Published Scope Document				Mapping		
		Embalming agent			Use-non-incorporative activities	CDR codes and is non-incorporative
Waste Handling, Disposal, Treatment, and Recycling	Waste handling, disposal, treatment, and recycling	Waste handling, disposal, treatment, and recycling	Waste handling, disposal, treatment, and recycling	None	None	Per Section F.5.1, there is no corresponding CDR code for this COU/OES

3. ***Assign OES:*** Each TRI facility is then mapped to one or more OES using the CDR IFC codes assigned to each facility in Step 1 and the CDR IFC code-to-OES crosswalk developed in Step 2. Table_Apx F-9 includes the potential OES for each example facility per this step.

Table_Apx F-9. Step 3 for TRI Mapping Example Facilities

Facility Name	TRI Form Type	2016 CDR IFC Codes	Crosswalked OES	OES Determination
Facility D	R	PK, U001, U003, U016, U013, U014, U018, U019, U020, U023, U027, U028, or U999	Repackaging, Processing as a reactant, Functional fluids (closed systems), or Oxidizing/reducing agents	Cannot be determined in Step 3: proceed to Step 4
Facility E	R	U001, U013, U014, U018, U020, or U023	Functional fluids (closed systems)	Since the facility maps to only one OES, the OES is *Functional fluids (closed systems)*
Facility F	A	None; not reported in Form A submissions		Cannot be determined in Step 3: proceed to Step 4

4. ***Refine OES Assignments:*** If a facility maps to more than one OES in Step 3, a single primary OES must be selected using additional facility information per Steps 4a-e. Table_Apx F-10 summarizes the information gathered for the three example sites for this step.

Table_Apx F-10. Step 4 for TRI Mapping Example Facilities

Facility Name	Step 4a: NAICS Code	Step 4b: Internet Research	Step 4c: Other Databases	Step 4d-e: Most Likely OES or OES Grouping	OES Determination
Facility D	486990, All Other Pipeline Transportation	The facility is a large chemical manufacturing plant	Check databases per Step 5	Based on the type of facility, the Processing as a reactant OES seems the most likely OES from Step 3	Most likely Processing as a reactant OES. Check other databases in Step 5 to verify
Facility E		N/A; OES determined in Step 3			
Facility F	325199, All Other Basic Organic Chemical Manufacturing	The facility is a chemical supplier that does not appear to produce chemicals	Check databases per Step 5.	Based on the NAICS code and type of facility, the Repackaging OES seems the most likely	Most likely Repackaging OES. Check other databases in Step 5 to verify

5. ***Review Information from Other Databases:*** Other databases/sources (including CDR, NEI, and DMR) should be checked to see if the facility has reported to these. If so, the OES determined from the mapping procedures for those databases (discussed in other sections of this document) should also be used. It is important that the same facility is mapped consistently across multiple databases/sources. The facility's TRFID and FRS ID can be used to identify sites that report to TRI, DMR, and NEI. Table_Apx F-11 summarizes the information gathered from other databases for the three example sites for this step.

Table_Apx F-11. Step 5 for TRI Mapping Example Facilities

Facility Name	Step 4: Other Databases	OES Determination
Facility D	The facility did not report to 2016 or 2020 CDR. The facility reported to 2020 NEI, reporting emissions of 1,2-dichloroethane from storage tanks and process equipment from chemical manufacturing processes and storage/transfer operations. The facility reported DMRs for the past few years but reported no releases of 1,2-dichloroethane to DMR.	The NEI information corroborates the most likely OES determined in Step 4d. Therefore, this site maps to the Processing as a reactant OES.
Facility E	N/A; OES determined in Step 3	

Facility Name	Step 4: Other Databases	OES Determination
Facility F	The facility did not report to 2016 or 2020 CDR, 2020 NEI, nor the past few years of DMR.	Since no additional information was determined in Step 5, the site maps to the Repackaging OES per Step 4d.

F.5.3 NEI Mapping Examples

This section includes examples of how to implement the OES mapping procedures for sites reporting to NEI, as listed in Appendix F.3.3. Specifically, this section includes two examples for 1,2-dichloroethane from 2017 NEI: (1) Facility G, which is an industrial site that reported point source emissions under multiple NEI records; and (2) Example H, which is a county that reported nonpoint source emissions under multiple NEI records.

To map Facility G (point source) and Example H (nonpoint source) NEI records to OES, the following procedures should be used:

1. ***Develop Crosswalks to Link NEI-Reported SCC and Sector Combinations to CDR Codes:*** The first step in mapping NEI data to potentially relevant OES is to develop a crosswalk to map each unique combination of NEI-reported SCC (levels 1–4) and industry sectors to one or more CDR codes. This crosswalk is developed on a chemical-by-chemical basis rather than an overall crosswalk for all chemicals because SCCs correspond to emission sources rather than chemical uses such that the crosswalk to CDR codes may differ from chemical to chemical. In some cases, it may not be possible to assign all SCC sector combinations to CDR codes, in which case information from Step 5 can be used to help make OES assignments. Separate crosswalks are needed for point and nonpoint source records, as shown in Table_Apx F-12 and Table_Apx F-13. Note that these tables only present the crosswalk for the SCC and sector codes relevant to Facility G (point source) and Example H (nonpoint source) examples; there are many more SCC and sector codes reported for 1,2-dichloroethane in 2017 NEI.

Table_Apx F-12. Step 1a for NEI Mapping Example Facilities

SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Sector	Assigned CDR Code	Rationale
Chemical Evaporation	Organic Solvent Evaporation	Air Stripping Tower	Solvent	Solvent—Industrial Surface Coating & Solvent Use	U029: Solvents (for Cleaning and Degreasing)	Based on sector
Chemical Evaporation	Organic Solvent Evaporation	Cold Solvent Cleaning/Stripping	Other Not Classified	Solvent—Degreasing	U029: Solvents (for Cleaning and Degreasing)	Based on sector
Chemical Evaporation	Organic Solvent Evaporation	Dry Cleaning	Other Not Classified	Solvent—Dry Cleaning	U029: Solvents (for Cleaning and Degreasing)	Based on sector
Chemical Evaporation	Organic Solvent Evaporation	Fugitive Emissions	General	Solvent—Degreasing	U029: Solvents (for Cleaning and Degreasing)	Based on sector
Chemical Evaporation	Organic Solvent Evaporation	Miscellaneous Volatile Organic Compound Evaporation	Miscellaneous	Solvent—Industrial Surface Coating & Solvent Use	U029: Solvents (for Cleaning and Degreasing)	Based on sector
Chemical Evaporation	Organic Solvent Evaporation	Solvent Storage	General Processes: Drum Storage—Pure Organic Chemicals	Industrial Processes—Storage and Transfer	N/A: no matching CDR IFC, likely Distribution in Commerce	Matched SCC and Sector code
Chemical Evaporation	Organic Solvent Evaporation	Solvent Storage	General Processes: Spent Solvent Storage	Industrial Processes—Storage and Transfer	N/A: no matching CDR IFC, likely Distribution in Commerce	Matched SCC and Sector code

SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Sector	Assigned CDR Code	Rationale
Chemical Evaporation	Organic Solvent Evaporation	Waste Solvent Recovery Operations	Other Not Classified	Solvent—Industrial Surface Coating & Solvent Use	N/A: no matching CDR IFC, likely Waste Handling, Disposal and Treatment	Matched to SCC level 3 code
Chemical Evaporation	Organic Solvent Evaporation	Waste Solvent Recovery Operations	Solvent Loading	Industrial Processes—Storage and Transfer	N/A: no matching CDR IFC, likely Waste Handling, Disposal and Treatment	Matched to SCC level 3 code
Industrial Processes	Photo Equip/Health Care/Labs/Air Condit/SwimPools	Health Care—Crematoriums	Cremation—Animal	Industrial Processes—NEC	U999: Other	Does not fit other CDR code
Industrial Processes	Photo Equip/Health Care/Labs/Air Condit/SwimPools	Health Care—Crematoriums	Cremation—Human	Industrial Processes—NEC	U999: Other	Does not fit other CDR code
Industrial Processes	Photo Equip/Health Care/Labs/Air Condit/SwimPools	Health Care—Crematoriums	Crematory Stack—Human and Animal Crematories	Industrial Processes—NEC	U999: Other	Does not fit other CDR code
Industrial Processes	Photo Equip/Health Care/Labs/Air Condit/SwimPools	Health Care	Miscellaneous Fugitive Emissions	Industrial Processes—NEC	U999: Other	Assume use as a laboratory chemical in the healthcare industry
Industrial Processes	Photo Equip/Health	Laboratories	Bench Scale Reagents: Research	Industrial Processes—NEC	U999: Other	SCC for laboratories

SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Sector	Assigned CDR Code	Rationale
	Care/Labs/Air Condit/SwimPools					
Industrial Processes	Photo Equip/Health Care/Labs/Air Condit/SwimPools	Laboratories	Bench Scale Reagents: Testing	Industrial Processes—NEC	U999: Other	SCC for laboratories

Table_Apx F-13. Step 1b for NEI Mapping Example Facilities

Sector	Assigned CDR Code	Rationale
Commercial Cooking	N/A; no matching CDR IFC	Unknown
Fuel Comb—Comm/Institutional—Biomass	U012: Fuels and fuel additives	Consistent with sector code
Fuel Comb—Comm/Institutional—Coal	U012: Fuels and fuel additives	Consistent with sector code
Fuel Comb—Industrial Boilers, ICEs—Biomass	U012: Fuels and fuel additives	Consistent with sector code
Fuel Comb—Industrial Boilers, ICEs—Coal	U012: Fuels and fuel additives	Consistent with sector code
Fuel Comb—Residential—Other	U012: Fuels and fuel additives	Consistent with sector code
Gas Stations	U012: Fuels and fuel additives	Consistent with sector code
Solvent—Consumer & Commercial Solvent Use	U029: Solvents (for cleaning or degreasing)	Consistent with sector code
Waste Disposal	N/A: no matching CDR IFC, likely Waste handling, disposal and treatment	Consistent with sector code

2. ***Use CDR Crosswalks to Assign CDR Codes:*** Next, the chemical-specific CDR crosswalk developed in Step 1 should be used to assign CDR IFC codes to each point source NEI record and CDR IFC codes and/or commercial/consumer use PCs to each nonpoint source NEI record. This is shown in Table_Apx F-14 for Facility G (point source) and Example H (nonpoint source).

Table_Apx F-14. Step 2 for NEI Mapping Example Facilities

Facility Name	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Sector	Assigned CDR IFC Code
Facility G	Chemical Evaporation	Organic Solvent Evaporation	Air Stripping Tower	Solvent	Solvent—Industrial Surface Coating & Solvent Use	U029: Solvents (for Cleaning and Degreasing)
	Industrial Processes	Photo Equip/Health Care/Labs/Air Condit/SwimPools	Laboratories	Bench Scale Reagents: Testing	Industrial Processes—NEC	U999: Other
Example H	N/A: not applicable to nonpoint source				Commercial Cooking	N/A: no matching CDR IFC
	N/A: not applicable to nonpoint source				Fuel Comb—Residential—Other	U012: Fuels and fuel additives
	N/A: not applicable to nonpoint source				Gas Stations	U012: Fuels and fuel additives

3. ***Update CDR Crosswalks to Link CDR Codes to OES:*** The chemical-specific crosswalk developed in Step 1 is then used to link the SCCs, sectors, and CDR codes in the crosswalk to an OES. The OES will be assigned based on the chemical specific COU categories and subcategories and the OES mapped to them. The same crosswalk developed in Table_Apx F-8 (TRI Step 2) links CDR codes to COUs and OES and is used in this example.

4. ***Use CDR Crosswalks to Assign OES:*** The chemical-specific CDR crosswalks developed in Steps 1 to 3 are then used to assign an OES to each point source and nonpoint source NEI data record (*i.e.*, each combination of facility-SCC-sector). Note that the individual facilities in the point source dataset may have multiple emission sources, described by different SCC and sector combinations within NEI, such that multiple OES map to each NEI record. In such cases, a single, representative OES must be selected for each NEI record using the additional information described in Step 5. Similarly, the sectors reported by nonpoint sources may map to multiple CDR IFC or PC codes, such that multiple OES are applicable and must be refined to a single OES. See Table_Apx F-15 for completed Step 4 for the example facilities.

Table_Apx F-15. Step 4 for NEI Mapping Example Facilities

Facility Name	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Sector	Assigned CDR IFC Code	Mapped OES	OES Determination
Facility G	Chemical Evaporation	Organic Solvent Evaporation	Air Stripping Tower	Solvent	Solvent—Industrial Surface Coating & Solvent Use	U029: Solvents (for Cleaning and Degreasing)	Solvents (for cleaning and degreasing)	Since only one OES maps to this NEI record, the OES is *Solvents (for cleaning and degreasing)*
	Industrial Processes	Photo Equip/Health Care/Labs/Air Condit/Swim Pools	Laboratories	Bench Scale Reagents: Testing	Industrial Processes—NEC	U999: Other	Laboratory chemical embalming agent	Cannot be determined in Step 4: Proceed with Step 5
Example H	N/A: not applicable to nonpoint source				Commercial Cooking	N/A: no matching CDR IFC	None	Cannot be determined in Step 4: Proceed with Step 5
	N/A: not applicable to nonpoint source				Fuel Comb—Residential—Other	U012: Fuels and fuel additives	Incorporated into formulation, mixture, or reaction product fuels and related products	Cannot be determined in Step 4: Proceed with Step 5

Facility Name	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four	Sector	Assigned CDR IFC Code	Mapped OES		OES Determination
	N/A: not applicable to nonpoint source				Gas Stations		U012: Fuels and fuel additives	Incorporated into formulation, mixture, or reaction product fuels and related products	Cannot be determined in Step 4: Proceed with Step 5

5. ***Refine OES Assignments:*** The initial OES assignments may need to be confirmed and/or refined to identify a single primary OES using the following information described in Steps 5a to 5b. See Table_Apx F-16 for Facility G (point source) and Example H (nonpoint source).

Table_Apx F-16. Step 5 for NEI Mapping Example Facilities

Facility Name	Sector	Step 5a: Additional Point Source Information	Step 5b: Additional Nonpoint Source Information	OES Determination
Facility G	Solvent—Industrial Surface Coating & Solvent Use	N/A: mapped to OES in Step 4		
	Industrial Processes—NEC	NAICS is 336415, Guided Missile and Space Vehicle Propulsion Unit and Propulsion Unit Parts Manufacturing. Emitting process is analytical lab operations.	N/A	Information from Step 4 and 5a affirm the OES is Laboratory chemical
Example H	Commercial Cooking	N/A	No knowledge is available on the use of 1,2-dichloroethane in commercial cooking	Cannot be determined in Step 5: Proceed to Step 7
	Fuel Comb—Residential—Other	N/A	1,2-dichloroethane may be used in fuel additives.	Information from Step 4 and 5a affirm the OES is Fuels and related products

Facility Name	Sector	Step 5a: Additional Point Source Information	Step 5b: Additional Nonpoint Source Information	OES Determination
	Gas Stations	N/A	1,2-dichloroethane may be used in fuel additives.	Information from Step 4 and 5a affirm the OES is *Fuels and related products*

6. ***Review Information from Other Databases for Point Source Facilities:*** Other databases/sources (including CDR, TRI, and DMR) should be checked to see if the point source facilities have reported to these. Facility G does not report to other databases. This step is not applicable to nonpoint source Example H.
7. ***Consider Options for NEI Records that Cannot be Mapped to an OES:*** Given the number of records in NEI and the information available, it may not always be feasible to achieve mapping of 100 percent of the sites reporting to NEI to an OES. This is the case for the NEI record Example H—Commercial Cooking. In this case, the OES will be assessed, per Step 7a, as "Unknown OES" with 250 release days/year. This allows for subsequent exposure modeling and the assessment of risk.

F.5.4 DMR Mapping Examples

This section includes examples of how to implement the OES mapping procedures for sites reporting to DMR, as listed in Appendix F.3.4. Specifically, this appendix includes examples for two example sites that reported to DMR for 1,2-dichloroethane. These example sites are referred to as Facility I and J.

To map Facilities I and J to an OES, the following procedures are used with information from DMR:

1. ***Review Information from Other Databases:*** Given the limited facility information reported in DMRs, the first step for mapping facilities reporting to DMR should be to check other databases/sources (including CDR, TRI, and NEI). For these examples, neither Facility I nor J reported to other databases.
2. ***Assign OES:*** If the facility does not report to other databases, the reported SIC code from DMR and internet research should be used to map the facility to an OES, per Steps 2a and 2b. See Table_Apx F-17 for completed Step 2 for the example facilities.

Table_Apx F-17. Step 2 for DMR Mapping Example Facilities

Facility Name	Step 2a: SIC Code	Step 2b: Internet Research	OES Determination
Facility I	4613, Refined Petroleum Pipeline	Internet research indicates that the facility is a fuel terminal	Cannot be determined in Step 2: Proceed with Step 3
Facility J	2821, Plastics Materials and Resins	Internet research indicates the facility makes poly vinyl chloride. 1,2-dichloroethane is known to be used as a reactant in this process	This facility maps to the Processing as a reactant OES, based on the SIC code (which matches the subcategory of use in the COU table, Table_Apx F-8) and internet research

3. ***Refine OES:*** If the specific OES still cannot be determined using the information in Step 2, information in Steps 3a-d should be considered. This includes searching for the facility NPDES permit and trying to determine which OES (or group of OES) is the most likely. See Table_Apx F-18 for completed Step 3 for the example facilities.

Table_Apx F-18. Step 3 for DMR Mapping Example Facilities

Facility Name	Step 3a: NPDES Permit Number	Step 3b: Finding the NPDES Permit	Step 3c-d: Most Likely OES or Grouped OED	OES Determination
Facility I	VAG83#### → A search of VA NPDES permits indicates that permit numbers starting in "VAG0083" are remediation general permits.	The facility's NPDES permit could not be found online	None of COUs or OES for 1,2-dichloroethane in Table_Apx F-8 cover remediation.	Since the facility's permit is for remediation, the facility most likely does not use 1,2-dichloroethane but the chemical is present as a contaminant at the site. This does not correspond to an in-scope OES. However, the OES should be designated as Remediation for EPA to determine how/if to present the release data.
Facility J	N/A: This facility was mapped to an OES in Step 2.			

F.5.5 OSHA CEHD Mapping Examples

This section includes examples of how to implement the OES mapping procedures for sites in the OSHA CEHD dataset, as listed in Appendix F.3.5. Specifically, this section includes examples for two example sites in the OSHA CEHD dataset for 1,4-dioxane. These example sites are referred to as Facility K and L.

To map Facilities K and L to an OES, the following procedures are used with information from OSHA CEHD:

1. ***Review Information from Other Databases:*** Given the limited facility information reported in OSHA CEHD, the first step for mapping facilities should be to check other databases/sources (including CDR, TRI, NEI, and TRI). For these examples, neither Facility K nor L reported to other databases.
2. ***Assign OES:*** If the facility does not report to other databases, the reported SIC code from OSHA CEHD and internet research should be used to map the facility to an OES, per Steps 2a and 2b. See Table_Apx F-19 for completed Step 2 for the example facilities.

Table_Apx F-19. Step 2 for OSHA CEHD Mapping Example Facilities

Facility Name	Step 2a: SIC or NAICS Code	Step 2b: Internet Research	OES Determination
Facility K	339112, Surgical and Medical Instrument Manufacturing	Internet research indicates that the facility produces medical equipment for cardiovascular procedures.	Based on the OES in Table_Apx F-8, the most applicable OES are likely Processing as a reactant (for the production of plastics used in equipment), Solvents (for cleaning or degreasing), Plastics and rubber products, or Other use. The specific OES cannot be determined in Step 2: Proceed with Step 3.
Facility L	5169, Chemicals and Allied Products, Not Elsewhere Classified	Internet research indicates the facility is a waste management company.	This facility maps to the Waste handling, disposal, treatment, and recycling, based on information from internet research.

3. ***Refine OES:*** If the specific OES still cannot be determined using the information in Step 2, an evaluation of the OES that is most likely or a group of OES should be considered per Steps 3a and 3b. See Table_Apx F-20 for completed Step 3 for the example facilities.

Table_Apx F-20. Step 3 for OSHA CEHD Mapping Example Facilities

Facility Name	Step 3a: Mostly Likely OES	Step 3b: Grouped OED	OES Determination
Facility K	The scope document for 1,2-dichloroethane indicates that the chemical is used to make polyvinyl chloride that is then used in medical devices. The use of 1,2-dichloroethane to produce polyvinyl chloride falls under the Processing as a reactant OES (as an intermediate for plastics).	Not needed: the OES was determined as Processing as a reactant in Step 3a.	Per Step 3a, this facility maps to the Processing as a reactant OES. To further support this determination, EPA may contact OSHA for additional information on the visit to this facility, per Step 4b.
Facility L	N/A: This facility was mapped to an OES in Step 2.		

F.5.6 NIOSH HHE Mapping Examples

This section includes examples of how to implement the OES mapping procedures listed in Appendix F.3.6 for two example NIOSH HHEs for 1,2-dichloroethane. To map facilities that are the subject of a NIOSH HHE, the process information and other narrative descriptions in the NIOSH HHE should be used.

1. The first example is for the following NIOSH HHE: https://www.cdc.gov/niosh/hhe/reports/pdfs/80-186-1149.pdf (accessed December 1, 2025). The following information is found in the NIOSH HHE:
    a. The facility produces plastic products, primarily plastic tubes for packaging.
    b. 1,2-dichloroethane was used as a bonding agent for sealing packaging.

    OES determination: Based on the OES for 1,2-dichloroethane (listed in Table_Apx F-8), the use of 1,2-dichloroethane for sealants falls under the Adhesives and sealants OES.
2. The second example is for the following NIOSH HHE: https://www.cdc.gov/niosh/hhe/reports/pdfs/77-73-610.pdf (accessed December 1, 2025). The following information is found in the NIOSH HHE:
    a. The facility is a chemical manufacturer.
    b. The facility uses 1,2-dichloroethane as a solvent in a reaction to produce another chemical.

    OES determination: Based on the OES for 1,2-dichloroethane (listed in Table_Apx F-8), the use of 1,2-dichloroethane as a reactant falls under the Processing as a reactant OES.

As discussed in Appendix F.3.6, NIOSH HHEs typically contain detailed process information and description of how the chemical is used at the facility. Therefore, the mapping of NIOSH HHE facilities to OES is straightforward.

F.5.7 COU Mapping Examples

This appendix includes examples of how to implement the COU mapping procedures for sites from standard sources (*i.e.*, CDR, TRI, NEI, DMR, OSHA CEHD, NIOSH HHE, as listed in Appendix F.4. Specifically, this appendix uses the same example facilities (Facility D, Facility E, and Facility F) for the TRI examples in Appendix F.5.2.

To map Facilities D, E, and F to an COUs, the following procedures should be used:

1. ***Map the Facility to an OES:*** To map a facility from a standard source to a COU, the facility should first be mapped to an OES following the procedures for the specific source of data (discussed in Appendix F.3). This mapping was completed in completed in Appendix F.5.2 and is summarized in Table_Apx F-21.

Table_Apx F-21. Step 1 for COU Mapping Example Facilities

Facility Name	Step 1: OES Determination from Appendix A.2
Facility D	Processing as a reactant
Facility E	Functional fluids (closed systems)
Facility F	Repackaging

2. ***Use the COU Table with Mapped OES to Assign COUs:*** At the point of the risk evaluation process where EPA is mapping data from standard sources to OES and COU, EPA has have already mapped OES to each of the COUs from the scope document. This crosswalk between COUs and OES, which is in Table_Apx F-8, for the example facilities should be used to identify the COU(s). See Table_Apx F-22 for completed Step 2 for the example facilities.

Table_Apx F-22. Step 2 for COU Mapping Example Facilities

<table>
<tr><th>Facility Name</th><th>OES Determination from Appendix A.2</th><th>Step 2: Mapped COUs</th></tr>
<tr><td>Facility D</td><td>Processing as a Reactant</td><td>Using the COU to OES crosswalk previously developed (Table_Apx F-8), the COUs that map to this OES are:
<table>
<tr><th>Life Cycle Stage</th><th>Category</th><th>Subcategory</th></tr>
<tr><td rowspan="3">Processing</td><td rowspan="3">Processing—as a reactant</td><td>Intermediate in petrochemical manufacturing</td></tr>
<tr><td>Plastic material and resin manufacturing</td></tr>
<tr><td>All other basic organic chemical manufacturing</td></tr>
</table></td></tr>
<tr><td>Facility E</td><td>Functional Fluids (Closed Systems)</td><td>Using the COU to OES crosswalk previously developed (Table_Apx F-8), only one COU maps to this OES:
<table>
<tr><th>Life Cycle Stage</th><th>Category</th><th>Subcategory</th></tr>
<tr><td>Industrial Use</td><td>Functional fluids (closed systems)</td><td>Engine coolant additive</td></tr>
</table></td></tr>
<tr><td>Facility F</td><td>Repackaging</td><td>Using the COU to OES crosswalk previously developed (Table_Apx F-8), only one COU maps to this OES:
<table>
<tr><th>Life Cycle Stage</th><th>Category</th><th>Subcategory</th></tr>
<tr><td>Repackaging</td><td>Repackaging</td><td>Repackaging</td></tr>
</table></td></tr>
</table>

3. ***Refine the COU Assignment:*** In some instances, more than one COU may map to the facility. In such cases, the reported NAICS code and internet research should be used to try to narrow down the list of potentially applicable COUs, per Steps 3a to b. See Table_Apx F-23 for completed Step 3 for the example facilities.

Table_Apx F-23. Step 3 for COU Mapping Example Facilities

Facility Name	Step 3a: NAICS Code	Step 3b: Internet Research	COU Determination
Facility D	486990, All Other Pipeline Transportation	The facility is a large chemical manufacturing plant.	The COU subcategory for "Plastic material and resin manufacturing" can be eliminated. However, the COU cannot be narrowed down between the remaining two subcategories of use. Proceed to Step 4.
Facility E	N/A: COU determined in Step 2		
Facility F	N/A: COU determined in Step 2		

4. ***List all Potential COUs:*** Where the above information does not narrow down the list of potentially applicable COUs, EPA will list all the potential COUs and will not attempt to select just one from the list where there is insufficient information to do so. Since a singular OES was identified for Facility D and F, this step is not applicable to those facilities. For Facility F, there are two possible COUs that are listed in Table_Apx F-24. Because a COU consists of a life cycle stage, category, and subcategory, all three should be presented in this step.

Table_Apx F-24. Step 4 for COU Mapping Example Facilities

<table>
<tr><th>Facility Name</th><th>Step 4: All Potential COUs</th></tr>
<tr><td>Facility D</td><td>All potential COUs for this facility are as follows:
<table>
<tr><th>Life Cycle Stage</th><th>Category</th><th>Subcategory</th></tr>
<tr><td rowspan="2">Processing</td><td rowspan="2">Processing—as a reactant</td><td>Intermediate in petrochemical manufacturing</td></tr>
<tr><td>All other basic organic chemical manufacturing</td></tr>
</table></td></tr>
</table>

F.6 TRI to CDR Use Mapping Crosswalk

Table_Apx F-25 presents the TRI-CDR Crosswalk used to map facilities to the OES for each chemical. "N/A" in the 2016 CDR code column indicates there is no corresponding CDR code that matches the TRI code. 2020 CDR introduced new codes for chemicals designated as high priority for risk evaluation; however, reporters may still use the same 2016 CDR codes listed in Table_Apx F-25 for all other chemicals. For 2020 CDR reporting facilities using the new codes, the crosswalk between 2016 CDR codes and 2020 CDR codes in Table 4-15 of the 2020 CDR reporting instructions (accessed December 1, 2025) should be used with Table_Apx F-25.

Table_Apx F-25. TRI-CDR Use Code Crosswalk

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
3.1.a	Manufacture: Produce	N/A	N/A	N/A	N/A	N/A
3.1.b	Manufacture: Import	N/A	N/A	N/A	N/A	N/A
3.1.c	Manufacture: For on-site use/ processing	N/A	N/A	N/A	N/A	N/A
3.1.d	Manufacture: For sale/distribution	N/A	N/A	N/A	N/A	N/A
3.1.e	Manufacture: As a byproduct	N/A	N/A	N/A	N/A	N/A
3.1.f	Manufacture: As an impurity	N/A	N/A	N/A	N/A	N/A
3.2.a	Processing: As a reactant	N/A	N/A	PC	Processing as a reactant	Chemical substance is used in chemical reactions for the manufacturing of another chemical substance or product.
3.2.a	Processing: As a reactant	P101	Feedstocks	N/A	N/A	N/A
3.2.a	Processing: As a reactant	P102	Raw Materials	N/A	N/A	N/A
3.2.a	Processing: As a reactant	P103	Intermediates	U015	Intermediates	Chemical substances consumed in a reaction to produce other chemical substances for commercial advantage. A residual of the intermediate chemical substance which has no separate function may remain in the reaction product.
3.2.a	Processing: As a reactant	P104	Initiators	U024	Process regulators	Chemical substances used to change the rate of a chemical reaction, start or stop the reaction, or otherwise influence the course of the reaction. Process regulators may be consumed or become part of the reaction product.
3.2.a	Processing: As a reactant	P199	Other	U016	Ion exchange agents	Chemical substances, usually in the form of a solid matrix, are used to selectively remove targeted ions from a solution. Examples generally consist of an inert hydrophobic matrix such as styrene divinylbenzene or phenol-formaldehyde, cross-linking polymer such as divinylbenzene, and ionic functional groups including sulfonic, carboxylic or phosphonic acids. This code also includes aluminosilicate zeolites.

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
3.2.a	Processing: As a reactant	P199	Other	U019	Oxidizing/ reducing agent	Chemical substances used to alter the valence state of another substance by donating or accepting electrons or by the addition or removal of hydrogen to a substance. Examples of oxidizing agents include nitric acid, perchlorates, hexavalent chromium compounds, and peroxydisulfuric acid salts. Examples of reducing agents include hydrazine, sodium thiosulfate, and coke produced from coal.
3.2.a	Processing: As a reactant	P199	Other	U999	Other (specify)	Chemical substances used in a way other than those described by other codes.
3.2.b	Processing: As a formulation component	N/A	N/A	PF	Processing-incorporation into formulation, mixture, or reaction product	Chemical substance is added to a product (or product mixture) prior to further distribution of the product.
3.2.b	Processing: As a formulation component	P201	Additives	U007	Corrosion inhibitors and antiscaling agents	Chemical substances used to prevent or retard corrosion or the formation of scale. Examples include phenylenediamine, chromates, nitrates, phosphates, and hydrazine.
3.2.b	Processing: As a formulation component	P201	Additives	U009	Fillers	Chemical substances used to provide bulk, increase strength, increase hardness, or improve resistance to impact. Fillers incorporated in a matrix reduce production costs by minimizing the amount of more expensive substances used in the production of articles. Examples include calcium carbonate, barium sulfate, silicates, clays, zinc oxide and aluminum oxide.
3.2.b	Processing: As a formulation component	P201	Additives	U010	Finishing agents	Chemical substances used to impart such functions as softening, static proofing, wrinkle resistance, and water repellence. Substances may be applied to textiles, paper, and leather. Examples include quaternary ammonium compounds, ethoxylated amines, and silicone compounds.
3.2.b	Processing: As a formulation component	P201	Additives	U017	Lubricants and lubricant additives	Chemical substances used to reduce friction, heat, or wear between moving parts or adjacent solid surfaces, or that enhance the lubricity of other substances. Examples of

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						lubricants include mineral oils, silicate and phosphate esters, silicone oil, greases, and solid film lubricants such as graphite and PTFE. Examples of lubricant additives include molybdenum disulphide and tungsten disulphide.
3.2.b	Processing: As a formulation component	P201	Additives	U034	Paint additives and coating additives not described by other codes	Chemical substances used in a paint or coating formulation to enhance properties such as water repellence, increased gloss, improved fade resistance, ease of application, foam prevention, etc. Examples of paint additives and coating additives include polyols, amines, vinyl acetate ethylene emulsions, and aliphatic polyisocyanates.
3.2.b	Processing: As a formulation component	P202	Dyes	U008	Dyes	Chemical substances used to impart color to other materials or mixtures (*i.e.*, substrates) by penetrating the surface of the substrate. Example types include azo, anthraquinone, amino azo, aniline, eosin, stilbene, acid, basic or cationic, reactive, dispersive, and natural dyes.
3.2.b	Processing: As a formulation component	P202	Dyes	U021	Pigments	Chemical substances used to impart color to other materials or mixtures (*i.e.*, substrates) by attaching themselves to the surface of the substrate through binding or adhesion. This code includes fluorescent agents, luminescent agents, whitening agents, pearlizing agents, and opacifiers. Examples include metallic oxides of iron, titanium, zinc, cobalt, and chromium; metal powder suspensions; lead chromates; vegetable and animal products; and synthetic organic pigments.
3.2.b	Processing: As a formulation component	P203	Reaction Diluents	U030	Solvents (which become part of product formulation or mixture)	Chemical substances used to dissolve another substance (solute) to form a uniformly dispersed mixture (solution) at the molecular level. Examples include diluents used to reduce the concentration of an active material to achieve a specified effect and low gravity materials added to reduce cost.

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
3.2.b	Processing: As a formulation component	P203	Reaction Diluents	U032	Viscosity adjustors	Chemical substances used to alter the viscosity of another substance. Examples include viscosity index (VI) improvers, pour point depressants, and thickeners.
3.2.b	Processing: As a formulation component	P204	Initiators	U024	Process regulators	Chemical substances used to change the rate of a chemical reaction, start, or stop the reaction, or otherwise influence the course of the reaction. Process regulators may be consumed or become part of the reaction product.
3.2.b	Processing: As a formulation component	P205	Solvents	U030	Solvents (which become part of product formulation or mixture)	Chemical substances used to dissolve another substance (solute) to form a uniformly dispersed mixture (solution) at the molecular level. Examples include diluents used to reduce the concentration of an active material to achieve a specified effect and low gravity materials added to reduce cost.
3.2.b	Processing: As a formulation component	P206	Inhibitors	U024	Process regulators	Chemical substances used to change the rate of a chemical reaction, start, or stop the reaction, or otherwise influence the course of the reaction. Process regulators may be consumed or become part of the reaction product.
3.2.b	Processing: As a formulation component	P207	Emulsifiers	U003	Adsorbents and absorbents	Chemical substances used to retain other substances by accumulation on their surface or by assimilation. Examples of adsorbents include silica gel, activated alumina, and activated carbon. Examples of absorbents include straw oil, alkaline solutions, and kerosene.
3.2.b	Processing: As a formulation component	P208	Surfactants	U002	Adhesives and sealant chemicals	Chemical substances used to promote bonding between other substances, promote adhesion of surfaces, or prevent seepage of moisture or air. Examples include epoxides, isocyanates, acrylamides, phenol, urea, melamine, and formaldehyde.
3.2.b	Processing: As a formulation component	P208	Surfactants	U023	Plating agents and surface treating agents	Chemical substances applied to metal, plastic, or other surfaces to alter physical or chemical properties of the surface. Examples include metal surface treating agents, strippers, etchants, rust and tarnish removers, and descaling agents.

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
3.2.b	Processing: As a formulation component	P208	Surfactants	U031	Surface active agents	Chemical substances used to modify surface tension when dissolved in water or water solutions or reduce interfacial tension between two liquids or between a liquid and a solid or between liquid and air. Examples include carboxylates, sulfonates, phosphates, carboxylic acid, esters, and quaternary ammonium salts.
3.2.b	Processing: As a formulation component	P209	Lubricants	U017	Lubricants and lubricant additives	Chemical substances used to reduce friction, heat, or wear between moving parts or adjacent solid surfaces, or that enhance the lubricity of other substances. Examples of lubricants include mineral oils, silicate and phosphate esters, silicone oil, greases, and solid film lubricants such as graphite and PTFE. Examples of lubricant additives include molybdenum disulphide and tungsten disulphide.
3.2.b	Processing: As a formulation component	P210	Flame Retardants	U011	Flame retardants	Chemical substances used on the surface of or incorporated into combustible materials to reduce or eliminate their tendency to ignite when exposed to heat or a flame for a short period of time. Examples include inorganic salts, chlorinated, or brominated organic compounds, and organic phosphates/phosphonates.
3.2.b	Processing: As a formulation component	P211	Rheological Modifiers	U022	Plasticizers	Chemical substances used in plastics, cement, concrete, wallboard, clay bodies, or other materials to increase their plasticity or fluidity. Examples include phthalates, trimellitates, adipates, maleates, and lignosulphonates.
3.2.b	Processing: As a formulation component	P211	Rheological Modifiers	U032	Viscosity adjustors	Chemical substances used to alter the viscosity of another substance. Examples include VI improvers, pour point depressants, and thickeners.
3.2.b	Processing: As a formulation component	P299	Other	U003	Adsorbents and absorbents	Chemical substances used to retain other substances by accumulation on their surface or by assimilation. Examples of adsorbents include silica gel, activated alumina, and activated carbon. Examples of

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						absorbents include straw oil, alkaline solutions, and kerosene.
3.2.b	Processing: As a formulation component	P299	Other	U016	Ion exchange agents	Chemical substances, usually in the form of a solid matrix, are used to selectively remove targeted ions from a solution. Examples generally consist of an inert hydrophobic matrix such as styrene divinylbenzene or phenol-formaldehyde, cross-linking polymer such as divinylbenzene, and ionic functional groups including sulfonic, carboxylic or phosphonic acids. This code also includes aluminosilicate zeolites.
3.2.b	Processing: As a formulation component	P299	Other	U018	Odor agents	Chemical substances used to control odors, remove odors, mask odors, or impart odors. Examples include benzenoids, terpenes and terpenoids, musk chemicals, aliphatic aldehydes, aliphatic cyanides, and mercaptans.
3.2.b	Processing: As a formulation component	P299	Other	U019	Oxidizing/ reducing agent	Chemical substances used to alter the valence state of another substance by donating or accepting electrons or by the addition or removal of hydrogen to a substance. Examples of oxidizing agents include nitric acid, perchlorates, hexavalent chromium compounds, and peroxydisulfuric acid salts. Examples of reducing agents include hydrazine, sodium thiosulfate, and coke produced from coal.
3.2.b	Processing: As a formulation component	P299	Other	U020	Photosensitive chemicals	Chemical substances used for their ability to alter their physical or chemical structure through absorption of light, resulting in the emission of light, dissociation, discoloration, or other chemical reactions. Examples include sensitizers, fluorescents, photovoltaic agents, ultraviolet absorbers, and ultraviolet stabilizers.
3.2.b	Processing: As a formulation component	P299	Other	U027	Propellants and blowing agents	Chemical substances used to dissolve or suspend other substances and either to expel those substances from a container in the form of an aerosol or to impart a cellular structure to plastics, rubber, or 242hermos set resins. Examples include compressed gasses and liquids and substances

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						which release ammonia, carbon dioxide, or nitrogen.
3.2.b	Processing: As a formulation component	P299	Other	U028	Solid separation agents	Chemical substances used to promote the separation of suspended solids from a liquid. Examples include flotation aids, flocculants, coagulants, dewatering aids, and drainage aids.
3.2.b	Processing: As a formulation component	P299	Other	U999	Other (specify)	Chemical substances used in a way other than those described by other codes.
3.2.c	Processing: As an article component	N/A	N/A	PA	Processing-incorporation into article	Chemical substance becomes an integral component of an article distributed for industrial, trade, or consumer use.
3.2.c	Processing: As an article component	N/A	N/A	U008	Dyes	Chemical substances used to impart color to other materials or mixtures (*i.e.*, substrates) by penetrating the surface of the substrate. Example types include azo, anthraquinone, amino azo, aniline, eosin, stilbene, acid, basic or cationic, reactive, dispersive, and natural dyes.
3.2.c	Processing: As an article component	N/A	N/A	U009	Fillers	Chemical substances used to provide bulk, increase strength, increase hardness, or improve resistance to impact. Fillers incorporated in a matrix reduce production costs by minimizing the amount of more expensive substances used in the production of articles. Examples include calcium carbonate, barium sulfate, silicates, clays, zinc oxide and aluminum oxide.
3.2.c	Processing: As an article component	N/A	N/A	U021	Pigments	Chemical substances used to impart color to other materials or mixtures (*i.e.*, substrates) by attaching themselves to the surface of the substrate through binding or adhesion. This code includes fluorescent agents, luminescent agents, whitening agents, pearlizing agents, and opacifiers. Examples include metallic oxides of iron, titanium, zinc, cobalt, and chromium; metal powder suspensions; lead chromates; vegetable and animal products; and synthetic organic pigments.
3.2.c	Processing: As an article component	N/A	N/A	U034	Paint additives and coating	Chemical substances used in a paint or coating formulation to enhance

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
					additives not described by other codes	properties such as water repellence, increased gloss, improved fade resistance, ease of application, foam prevention, etc. Examples of paint additives and coating additives include polyols, amines, vinyl acetate ethylene emulsions, and aliphatic polyisocyanates.
3.2.c	Processing: As an article component	N/A	N/A	U999	Other (specify)	Chemical substances used in a way other than those described by other codes.
3.2.d	Processing: Repackaging	N/A	N/A	PK	Processing-repackaging	Preparation of a chemical substance for distribution in commerce in a different form, state, or quantity. This includes transferring the chemical substance from a bulk container into smaller containers. This definition does not apply to sites that only relabel or redistribute the reportable chemical substance without removing the chemical substance from the container in which it is received or purchased.
3.2.e	Processing: As an impurity	N/A	N/A	N/A	N/A	N/A
3.2.f	Processing: Recycling	N/A	N/A	N/A	N/A	N/A
3.3.a	Otherwise Use: As a chemical processing aid	N/A	N/A	U	Use-non incorporative Activities	Chemical substance is otherwise used (*e.g.*, as a chemical processing or manufacturing aid).
3.3.a	Otherwise Use: As a chemical processing aid	Z101	Process Solvents	U029	Solvents (for cleaning or degreasing)	Chemical substances used to dissolve oils, greases, and similar materials from textiles, glassware, metal surfaces, and other articles. Examples include trichloroethylene, perchloroethylene, methylene chloride, liquid carbon dioxide, and n-propyl bromide.
3.3.a	Otherwise Use: As a chemical processing aid	Z102	Catalysts	U020	Photosensitive chemicals	Chemical substances used for their ability to alter their physical or chemical structure through absorption of light, resulting in the emission of light, dissociation, discoloration, or other chemical reactions. Examples include sensitizers, fluorescents, photovoltaic agents, ultraviolet absorbers, and ultraviolet stabilizers.

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
3.3.a	Otherwise Use: As a chemical processing aid	Z102	Catalysts	U025	Processing aids, specific to petroleum production	Chemical substances added to water-, oil-, or synthetic drilling muds or other petroleum production fluids to control viscosity, foaming, corrosion, alkalinity and pH, microbiological growth, hydrate formation, etc., during the production of oil, gas, and other products from beneath the earth's surface.
3.3.a	Otherwise Use: As a chemical processing aid	Z102	Catalysts	U026	Processing aids, not otherwise listed	Chemical substances used to improve the processing characteristics or the operation of process equipment or to alter or buffer the pH of the substance or mixture, when added to a process or to a substance or mixture to be processed. Processing agents do not become a part of the reaction product and are not intended to affect the function of a substance or article created. Examples include buffers, dehumidifiers, dehydrating agents, sequestering agents, and chelators.
3.3.a	Otherwise Use: As a chemical processing aid	Z103	Inhibitors	U024	Process regulators	Chemical substances used to change the rate of a chemical reaction, start or stop the reaction, or otherwise influence the course of the reaction. Process regulators may be consumed or become part of the reaction product.
3.3.a	Otherwise Use: As a chemical processing aid	Z103	Inhibitors	U025	Processing aids, specific to petroleum production	Chemical substances added to water-, oil-, or synthetic drilling muds or other petroleum production fluids to control viscosity, foaming, corrosion, alkalinity and pH, microbiological growth, hydrate formation, etc., during the production of oil, gas, and other products from beneath the earth's surface.
3.3.a	Otherwise Use: As a chemical processing aid	Z103	Inhibitors	U026	Processing aids, not otherwise listed	Chemical substances used to improve the processing characteristics or the operation of process equipment or to alter or buffer the pH of the substance or mixture, when added to a process or to a substance or mixture to be processed. Processing agents do not become a part of the reaction product and are not intended to affect the function of a substance or article created. Examples include buffers,

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						dehumidifiers, dehydrating agents, sequestering agents, and chelators.
3.3.a	Otherwise Use: As a chemical processing aid	Z104	Initiators	U024	Process regulators	Chemical substances used to change the rate of a chemical reaction, start, or stop the reaction, or otherwise influence the course of the reaction. Process regulators may be consumed or become part of the reaction product.
3.3.a	Otherwise Use: As a chemical processing aid	Z104	Initiators	U025	Processing aids, specific to petroleum production	Chemical substances added to water-, oil-, or synthetic drilling muds or other petroleum production fluids to control viscosity, foaming, corrosion, alkalinity and pH, microbiological growth, hydrate formation, etc., during the production of oil, gas, and other products from beneath the earth's surface.
3.3.a	Otherwise Use: As a chemical processing aid	Z104	Initiators	U026	Processing aids, not otherwise listed	Chemical substances used to improve the processing characteristics or the operation of process equipment or to alter or buffer the pH of the substance or mixture, when added to a process or to a substance or mixture to be processed. Processing agents do not become a part of the reaction product and are not intended to affect the function of a substance or article created. Examples include buffers, dehumidifiers, dehydrating agents, sequestering agents, and chelators.
3.3.a	Otherwise Use: As a chemical processing aid	Z105	Reaction Terminators	U024	Process regulators	Chemical substances used to change the rate of a chemical reaction, start, or stop the reaction, or otherwise influence the course of the reaction. Process regulators may be consumed or become part of the reaction product.
3.3.a	Otherwise Use: As a chemical processing aid	Z105	Reaction Terminators	U025	Processing aids, specific to petroleum production	Chemical substances added to water-, oil-, or synthetic drilling muds or other petroleum production fluids to control viscosity, foaming, corrosion, alkalinity and pH, microbiological growth, hydrate formation, etc., during the production of oil, gas, and other products from beneath the earth's surface.
3.3.a	Otherwise Use: As a chemical processing aid	Z105	Reaction Terminators	U026	Processing aids, not	Chemical substances used to improve the processing characteristics or the operation of

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
					otherwise listed	process equipment or to alter or buffer the pH of the substance or mixture, when added to a process or to a substance or mixture to be processed. Processing agents do not become a part of the reaction product and are not intended to affect the function of a substance or article created. Examples include buffers, dehumidifiers, dehydrating agents, sequestering agents, and chelators.
3.3.a	Otherwise Use: As a chemical processing aid	Z106	Solution Buffers	U026	Processing aids, not otherwise listed	Chemical substances used to improve the processing characteristics or the operation of process equipment or to alter or buffer the pH of the substance or mixture, when added to a process or to a substance or mixture to be processed. Processing agents do not become a part of the reaction product and are not intended to affect the function of a substance or article created. Examples include buffers, dehumidifiers, dehydrating agents, sequestering agents, and chelators.
3.3.a	Otherwise Use: As a chemical processing aid	Z199	Other	U002	Adhesives and sealant chemicals	Chemical substances used to promote bonding between other substances, promote adhesion of surfaces, or prevent seepage of moisture or air. Examples include epoxides, isocyanates, acrylamides, phenol, urea, melamine, and formaldehyde.
3.3.a	Otherwise Use: As a chemical processing aid	Z199	Other	U006	Bleaching agents	Chemical substances used to lighten or whiten a substrate through chemical reaction, usually an oxidative process which degrades the color system. Examples generally fall into one of two groups: chlorine containing bleaching agents (*e.g.*, chlorine, hypochlorite, N-chloro compounds and chlorine dioxide); and, peroxygen bleaching agents (*e.g.*, hydrogen peroxide, potassium permanganate, and sodium perborate).
3.3.a	Otherwise Use: As a chemical processing aid	Z199	Other	U018	Odor agents	Chemical substances used to control odors, remove odors, mask odors, or impart odors. Examples include benzenoids, terpenes and terpenoids,

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						musk chemicals, aliphatic aldehydes, aliphatic cyanides, and mercaptans.
3.3.a	Otherwise Use: As a chemical processing aid	Z199	Other	U023	Plating agents and surface treating agents	Chemical substances applied to metal, plastic, or other surfaces to alter physical or chemical properties of the surface. Examples include metal surface treating agents, strippers, etchants, rust and tarnish removers, and descaling agents.
3.3.a	Otherwise Use: As a chemical processing aid	Z199	Other	U025	Processing aids, specific to petroleum production	Chemical substances added to water-, oil-, or synthetic drilling muds or other petroleum production fluids to control viscosity, foaming, corrosion, alkalinity and pH, microbiological growth, hydrate formation, etc., during the production of oil, gas, and other products from beneath the earth's surface.
3.3.a	Otherwise Use: As a chemical processing aid	Z199	Other	U026	Processing aids, not otherwise listed	Chemical substances used to improve the processing characteristics or the operation of process equipment or to alter or buffer the pH of the substance or mixture, when added to a process or to a substance or mixture to be processed. Processing agents do not become a part of the reaction product and are not intended to affect the function of a substance or article created. Examples include buffers, dehumidifiers, dehydrating agents, sequestering agents, and chelators.
3.3.a	Otherwise Use: As a chemical processing aid	Z199	Other	U028	Solid separation agents	Chemical substances used to promote the separation of suspended solids from a liquid. Examples include flotation aids, flocculants, coagulants, dewatering aids, and drainage aids.
3.3.b	Otherwise Use: As a manufacturing aid	N/A	N/A	U	Use − non incorporative activities	Chemical substance is otherwise used (*e.g.*, as a chemical processing or manufacturing aid).
3.3.b	Otherwise Use: As a manufacturing aid	Z201	Process Lubricants	U017	Lubricants and lubricant additives	Chemical substances used to reduce friction, heat, or wear between moving parts or adjacent solid surfaces, or that enhance the lubricity of other substances. Examples of lubricants include mineral oils, silicate and phosphate esters, silicone oil, greases, and solid film lubricants such as graphite and PTFE.

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						Examples of lubricant additives include molybdenum disulphide and tungsten disulphide.
3.3.b	Otherwise Use: As a manufacturing aid	Z202	Metalworking Fluids	U007	Corrosion inhibitors and antiscaling agents	Chemical substances used to prevent or retard corrosion or the formation of scale. Examples include phenylenediamine, chromates, nitrates, phosphates, and hydrazine.
3.3.b	Otherwise Use: As a manufacturing aid	Z202	Metalworking Fluids	U014	Functional fluids (open systems)	Liquid or gaseous chemical substances used for one or more operational properties in an open system. Examples include antifreezes and de‑icing fluids such as ethylene and propylene glycol, sodium formate, potassium acetate, and sodium acetate. This code also includes substances incorporated into metal working fluids.
3.3.b	Otherwise Use: As a manufacturing aid	Z203	Coolants	U013	Functional fluids (closed systems)	Liquid or gaseous chemical substances used for one or more operational properties in a closed system. Examples include heat transfer agents (*e.g.*, coolants and refrigerants) such as polyalkylene glycols, silicone oils, liquified propane, and carbon dioxide; hydraulic/transmission fluids such as mineral oils, organophosphate esters, silicone, and propylene glycol; and dielectric fluids such as mineral insulating oil and high flash point kerosene. This code does not include fluids used as lubricants.
3.3.b	Otherwise Use: As a manufacturing aid	Z204	Refrigerants	U013	Functional fluids (closed systems)	Liquid or gaseous chemical substances used for one or more operational properties in a closed system. Examples include heat transfer agents (*e.g.*, coolants and refrigerants) such as polyalkylene glycols, silicone oils, liquified propane, and carbon dioxide; hydraulic/transmission fluids such as mineral oils, organophosphate esters, silicone, and propylene glycol; and dielectric fluids such as mineral insulating oil and high flash point kerosene. This code does not include fluids used as lubricants.
3.3.b	Otherwise Use: As a	Z205	Hydraulic Fluids	U013	Functional fluids (closed systems)	Liquid or gaseous chemical substances used for one or more operational properties in a closed

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
	manufacturing aid					system. Examples include heat transfer agents (*e.g.*, coolants and refrigerants) such as polyalkylene glycols, silicone oils, liquified propane, and carbon dioxide; hydraulic/transmission fluids such as mineral oils, organophosphate esters, silicone, and propylene glycol; and dielectric fluids such as mineral insulating oil and high flash point kerosene. This code does not include fluids used as lubricants.
3.3.b	Otherwise Use: As a manufacturing aid	Z299	Other	U013	Functional fluids (closed systems)	Liquid or gaseous chemical substances used for one or more operational properties in a closed system. Examples include heat transfer agents (*e.g.*, coolants and refrigerants) such as polyalkylene glycols, silicone oils, liquified propane, and carbon dioxide; hydraulic/transmission fluids such as mineral oils, organophosphate esters, silicone, and propylene glycol; and dielectric fluids such as mineral insulating oil and high flash point kerosene. This code does not include fluids used as lubricants.
3.3.b	Otherwise Use: As a manufacturing aid	Z299	Other	U023	Plating agents and surface treating agents	Chemical substances applied to metal, plastic, or other surfaces to alter physical or chemical properties of the surface. Examples include metal surface treating agents, strippers, etchants, rust and tarnish removers, and descaling agents.
3.3.c	Otherwise Use: Ancillary or other use	N/A	N/A	U	Use─non incorporative Activities	Chemical substance is otherwise used (*e.g.*, as a chemical processing or manufacturing aid).
3.3.c	Otherwise Use: Ancillary or other use	Z301	Cleaner	U007	Corrosion inhibitors and antiscaling agents	Chemical substances used to prevent or retard corrosion or the formation of scale. Examples include phenylenediamine, chromates, nitrates, phosphates, and hydrazine.
3.3.c	Otherwise Use: Ancillary or other use	Z301	Cleaner	U029	Solvents (for cleaning or degreasing)	Chemical substances used to dissolve oils, greases, and similar materials from textiles, glassware, metal surfaces, and other articles. Examples include trichloroethylene, perchloroethylene, methylene chloride, liquid carbon dioxide, and n-propyl bromide.

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
3.3.c	Otherwise Use: Ancillary or other use	Z302	Degreaser	U003	Adsorbents and Absorbents	Chemical substances used to retain other substances by accumulation on their surface or by assimilation. Examples of adsorbents include silica gel, activated alumina, and activated carbon. Examples of absorbents include straw oil, alkaline solutions, and kerosene.
3.3.c	Otherwise Use: Ancillary or other use	Z302	Degreaser	U029	Solvents (for cleaning or degreasing)	Chemical substances used to dissolve oils, greases, and similar materials from textiles, glassware, metal surfaces, and other articles. Examples include trichloroethylene, perchloroethylene, methylene chloride, liquid carbon dioxide, and n-propyl bromide.
3.3.c	Otherwise Use: Ancillary or other use	Z303	Lubricant	U017	Lubricants and lubricant additives	Chemical substances used to reduce friction, heat, or wear between moving parts or adjacent solid surfaces, or that enhance the lubricity of other substances. Examples of lubricants include mineral oils, silicate and phosphate esters, silicone oil, greases, and solid film lubricants such as graphite and PTFE. Examples of lubricant additives include molybdenum disulphide and tungsten disulphide.
3.3.c	Otherwise Use: Ancillary or other use	Z304	Fuel	U012	Fuels and fuel additives	Chemical substances used to create mechanical or thermal energy through chemical reactions, or which are added to a fuel for the purpose of controlling the rate of reaction or limiting the production of undesirable combustion products, or which provide other benefits such as corrosion inhibition, lubrication, or detergency. Examples of fuels include coal, oil, gasoline, and various grades of diesel fuel. Examples of fuel additives include oxygenated compound such as ethers and alcohols, antioxidants such as phenylenediamines and hindered phenols, corrosion inhibitors such as carboxylic acids, amines, and amine salts, and blending agents such as ethanol.
3.3.c	Otherwise Use: Ancillary or other use	Z305	Flame Retardant	U011	Flame retardants	Chemical substances used on the surface of or incorporated into combustible materials to reduce or

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						eliminate their tendency to ignite when exposed to heat or a flame for a short period of time. Examples include inorganic salts, chlorinated, or brominated organic compounds, and organic phosphates/phosphonates.
3.3.c	Otherwise Use: Ancillary or other use	Z306	Waste Treatment	U006	Bleaching agents	Chemical substances used to lighten or whiten a substrate through chemical reaction, usually an oxidative process which degrades the color system. Examples generally fall into one of two groups: chlorine containing bleaching agents (*e.g.*, chlorine, hypochlorites, N-chloro compounds and chlorine dioxide); and peroxygen bleaching agents (*e.g.*, hydrogen peroxide, potassium permanganate, and sodium perborate).
3.3.c	Otherwise Use: Ancillary or other use	Z306	Waste Treatment	U018	Odor agents	Chemical substances used to control odors, remove odors, mask odors, or impart odors. Examples include benzenoids, terpenes and terpenoids, musk chemicals, aliphatic aldehydes, aliphatic cyanides, and mercaptans.
3.3.c	Otherwise Use: Ancillary or other use	Z306	Waste Treatment	U019	Oxidizing/reducing agent	Chemical substances used to alter the valence state of another substance by donating or accepting electrons or by the addition or removal of hydrogen to a substance. Examples of oxidizing agents include nitric acid, perchlorates, hexavalent chromium compounds, and peroxydisulfuric acid salts. Examples of reducing agents include hydrazine, sodium thiosulfate, and coke produced from coal.
3.3.c	Otherwise Use: Ancillary or other use	Z306	Waste Treatment	U028	Solid separation agents	Chemical substances used to promote the separation of suspended solids from a liquid. Examples include flotation aids, flocculants, coagulants, dewatering aids, and drainage aids.
3.3.c	Otherwise Use: Ancillary or other use	Z307	Water Treatment	U006	Bleaching agents	Chemical substances used to lighten or whiten a substrate through chemical reaction, usually an oxidative process which degrades the color system. Examples generally fall into one of two groups: chlorine containing bleaching agents (*e.g.*,

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						chlorine, hypochlorites, N-chloro compounds and chlorine dioxide); and peroxygen bleaching agents (*e.g.*, hydrogen peroxide, potassium permanganate, and sodium perborate).
3.3.c	Otherwise Use: Ancillary or other use	Z307	Water Treatment	U018	Odor agents	Chemical substances used to control odors, remove odors, mask odors, or impart odors. Examples include benzenoids, terpenes and terpenoids, musk chemicals, aliphatic aldehydes, aliphatic cyanides, and mercaptans.
3.3.c	Otherwise Use: Ancillary or other use	Z307	Water Treatment	U019	Oxidizing/reducing agent	Chemical substances used to alter the valence state of another substance by donating or accepting electrons or by the addition or removal of hydrogen to a substance. Examples of oxidizing agents include nitric acid, perchlorates, hexavalent chromium compounds, and peroxydisulfuric acid salts. Examples of reducing agents include hydrazine, sodium thiosulfate, and coke produced from coal.
3.3.c	Otherwise Use: Ancillary or other use	Z307	Water Treatment	U028	Solid separation agents	Chemical substances used to promote the separation of suspended solids from a liquid. Examples include flotation aids, flocculants, coagulants, dewatering aids, and drainage aids.
3.3.c	Otherwise Use: Ancillary or other use	Z308	Construction Materials	N/A	N/A	N/A
3.3.c	Otherwise Use: Ancillary or other use	Z399	Other	U001	Abrasives	Chemical substances used to wear down or polish surfaces by rubbing against the surface. Examples include sandstones, pumice, silex, quartz, silicates, aluminum oxides, and glass.
3.3.c	Otherwise Use: Ancillary or other use	Z399	Other	U013	Functional fluids (closed systems)	Liquid or gaseous chemical substances used for one or more operational properties in a closed system. Examples include heat transfer agents (*e.g.*, coolants and refrigerants) such as polyalkylene glycols, silicone oils, liquified propane, and carbon dioxide; hydraulic/transmission fluids such as mineral oils, organophosphate esters, silicone, and propylene glycol; and dielectric fluids such as mineral

TRI Section	TRI Description	TRI Sub-Use Code	TRI Sub-Use Code Name	2016 CDR Code	2016 CDR Code Name	2016 CDR Functional Use Definition
						insulating oil and high flash point kerosene. This code does not include fluids used as lubricants.
3.3.c	Otherwise Use: Ancillary or other use	Z399	Other	U014	Functional fluids (open systems)	Liquid or gaseous chemical substances used for one or more operational properties in an open system. Examples include antifreezes and de-icing fluids such as ethylene and propylene glycol, sodium formate, potassium acetate, and sodium acetate. This code also includes substances incorporated into metal working fluids.
3.3.c	Otherwise Use: Ancillary or other use	Z399	Other	U018	Odor agents	Chemical substances used to control odors, remove odors, mask odors, or impart odors. Examples include benzenoids, terpenes and terpenoids, musk chemicals, aliphatic aldehydes, aliphatic cyanides, and mercaptans.
3.3.c	Otherwise Use: Ancillary or other use	Z399	Other	U020	Photosensitive chemicals	Chemical substances used for their ability to alter their physical or chemical structure through absorption of light, resulting in the emission of light, dissociation, discoloration, or other chemical reactions. Examples include sensitizers, fluorescents, photovoltaic agents, ultraviolet absorbers, and ultraviolet stabilizers.
3.3.c	Otherwise Use: Ancillary or other use	Z399	Other	U023	Plating agents and surface treating agents	Chemical substances applied to metal, plastic, or other surfaces to alter physical or chemical properties of the surface. Examples include metal surface treating agents, strippers, etchants, rust and tarnish removers, and descaling agents.

Appendix G GUIDANCE FOR USING THE NEI AND TOXIC RELEASE INVENTORY FOR ESTIMATING AIR RELEASES

This appendix provides guidance for using EPA's NEI and TRI data to estimate air releases for certain chemicals undergoing risk evaluation under TSCA. These estimates will be used as inputs to air modeling for the purposes of estimating ambient air concentrations.

G.1 Background

EPA's NEI and TRI programs require individual facilities, as well as SLT Air Agencies, to report information on airborne chemical releases to the Agency. Although the chemicals reported under each program differ, both inventories include data for some of the chemicals undergoing TSCA risk evaluation. When available, the NEI and TRI data include information on the sources, magnitude, and nature (*e.g.*, stack vs. fugitive, stack height, stack gas velocity/temperature) of airborne releases from industrial/commercial facilities and other smaller emissions sources. Thus, these databases may provide useful information for estimating air releases of TRI- and/or NEI-covered chemicals, for certain OESs.

As the NEI and TRI programs operate under separate regulatory frameworks, the data reported under these programs do not always overlap. For example, in 2017, approximately 745,000 lb of perchloroethylene (also referred to as "PERC":) air emissions were reported to TRI, whereas approximately 16.6 million lb of PERC air emissions were reported to NEI. This document provides an approach for using NEI data in combination with TRI data to estimate air emissions.

G.2 Obtaining Air Emissions Data

G.2.1 Obtaining NEI Data

NEI emissions data are categorized into (1) point source data, (2) area or nonpoint source data, (3) onroad mobile source data, and (4) nonroad mobile source data. EPA included only point source data categories in the assessment of environmental releases in this risk evaluation. Point sources are stationary sources of air emissions from facilities with operating permits under Title V of the CAA, also called "major sources." Major sources are defined as having actual or potential emissions at or above the major source thresholds. Although thresholds can vary for certain chemicals in NAAQS non-attainment areas, the default threshold is 100 tons/year for non-HAPs, 10 tons per year for a single HAP, or 25 tons per year for any combination of HAPs. Point source facilities include large energy and industrial sites and are reported at the emission unit- and release point-level.

Area or nonpoint sources are stationary sources that do not qualify as major sources. The nonpoint data are aggregated and reported at the county-level and include emissions from smaller facilities as well as agricultural emissions, construction dust, and open burning. Industrial and commercial/institutional fuel combustion, gasoline distribution, oil and gas production and extraction, POTWs, and solvent emissions may be reported in the point or nonpoint source categories depending upon source size. EPA targeted its review of environmental releases to point sources, and did not review road, nonroad, and other automotive exhaust information identified.

Onroad mobile sources include emissions from onroad vehicles that combust liquid fuels during operation, including passenger cars, motorcycles, trucks, and buses. The nonroad mobiles sources data include emissions from other mobile sources that are not typically operated on public roadways, such as locomotives, aircraft, commercial marine vessels, recreational equipment, and landscaping equipment.

Onroad and nonroad mobile data are reported in the same format as nonpoint data; however, it is not available for every chemical. EPA did not include area or nonpoint sources in the assessment of environmental releases in this risk evaluation. Further details on the Agency's approach to using NEI data for estimating releases are described in Section 2.3.3.2, Appendix F, and F.1.

The first step in using NEI data to estimate air releases is to obtain the NEI data in a workable format that provides the requisite data for release estimation and modeling. NEI data are available on EPA's NEI public website (accessed December 1, 2025) as downloadable zip files, divided into onroad, nonroad, nonpoint, and point source data files. The zipped point source data files are extremely large and require specialized database experience to query and manipulate. As an alternative, EPA's EIS Gateway allows registered EPA users, registered SLT users, and approved contractors to query and download NEI data and associated reporting code descriptions. As a result, this methodology uses the EIS Gateway to query point source data. Following download, the point and nonpoint emissions data for the chemical of interest will be imported into an MS Excel spreadsheet (or using an alternative tool, if the data exceeds Excel's size threshold), to be filtered and manipulated. At this point, EPA will use the EIS lookup tables to populate field descriptions for data fields reported as numerical codes (*e.g.*, NAICS code).

G.2.2 Obtaining TRI Data

TRI data may be downloaded from EPA's public TRI Program and TRI Data and Tools website (accessed December 1, 2025). Once the csv file(s) has (have) been downloaded, the data are filtered by the chemical of interest using the CAS number and/or chemical name. Relevant NEI data fields include reporting year, facility identifying information (*e.g.*, name, address, FRS ID, and TRIFID), chemical information (chemical name, CASRN), primary NAICS codes, fugitive air releases, and stack air releases.

G.3 Mapping NEI and TRI DATA to Occupational Exposure Scenarios

Once TRI and NEI data are obtained, the next step is to map the data to OESs. For procedures for mapping facilities from TRI and NEI to OESs, refer to Appendix F.

G.4 Estimating Air Releases Using NEI and TRI Data

EPA used the mapped NEI and TRI data to develop facility- and/or release-point-specific emissions estimates for chemicals undergoing TSCA risk evaluation. The data summary includes pertinent information for risk evaluation and emission modeling, such as facility location, annual releases, daily releases, operating information, release type (*i.e.*, stack vs. fugitive), and stack parameters.

G.4.1 Linking NEI and TRI Data

Although NEI and TRI have different reporting requirements, some major sources are expected to report to both databases. The most reliable way to link the datasets is with a common identifier. NEI reports EIS Facility Identifier and Facility Registry Identifier (FRSID), though the latter is not reliably populated for all NEI records. TRI reports TRI Facility ID (TRIFID) and FRSID. EPA uses its database of EIS Alternate Facility Identifiers ("EISAltFacilityIdentifiers_20211221.accdb") to link TRIFIDs to an EIS Facility Identifier. Linkages may have been confirmed and/or refined using facility names and addresses, if necessary.

Following linkage, EPA reviews the linked NEI/TRI data to ensure that facilities with records in both databases are assigned to a consistent OES. When discrepancies arise, the Agency resolves these using the dataset with the greatest level of detail. In general, NEI provides more detailed air emissions data than TRI. For example, NEI reports SCC levels 1 to 4, which provide insight into the specific operations and/or process units associated with NEI-reported air emissions. For example, "Chemical Evaporation Organic Solvent Evaporation Degreasing Entire Unit: Open-top Vapor Degreasing" is a SCC description used in the NEI. This SCC description identifies the emission unit, not only as a degreaser, but as a specific type of degreaser. NEI also includes free text fields where reporters can include additional information about a particular facility and/or emission unit. TRI does not provide this level of detail.

Following a review of OES assignments, the TRI and NEI data is divided into separate tables by OES code, which may be linked using the EIS Facility Identifier.

G.4.2 Evaluation of Sub-annual Emissions

As air emissions data in TRI and NEI are reported as annual values, sub-annual (*e.g.,* daily) emissions must be calculated from information on release duration, release days, and release pattern. Although TRI does not report information on release duration or pattern, this information may be estimated from operating data reported to the NEI.[17] Other sources of release duration and pattern information include GSs and ESDs, literature sources, process information, and standard engineering methodology for estimating number of release days. These sources are described in further detail below, in order of preference.

Sources for Estimating Release Duration

1. *NEI Data* – The NEI dataset includes facility-specific air emissions estimates for major sources and often includes data on the number of hours of operation per day for these facilities. The number of operating hours from NEI can be used to inform release duration for the specific facilities being assessed. Hours of operation for one facility in NEI are typically not used for a different facility; however, engineers may consider conducting an analysis of operating hours for multiple facilities in NEI that are a part of the same OES to develop a broader estimate of release duration at the OES-level. EPA has previously used this approach to inform development of GS/ESDs, but it is dependent on the amount of data and time available and should be discussed on a chemical-specific basis.
2. *Models* – Models used to estimate air emissions and associated inhalation exposures (*e.g.,* Tank Truck and Railcar Loading and Unloading Release and Inhalation Exposure Model, Open-Top Vapor Degreasing Near-Field/Far-Field Inhalation Exposure Model, Spot Cleaning Near-Field/Far-Field Inhalation Exposure Model, models from GS/ESDs) sometimes include data on release duration, which are usually either cited from literature or based on generic assumptions about the activity being modeled. Release duration information from models may be presented with non-modeled air emission data from NEI or TRI, if the model is applicable and expected to represent the primary release source for the OES (*e.g.,* release duration from the Tank Truck and Railcar Loading and Unloading Release and Inhalation Exposure Model may be used with estimates of air emissions for a facility in the Repackaging OES). For models that calculate release duration as a distribution, such as from Monte Carlo simulations, the mean and range of release durations from the model should be presented with the air emission estimate.
3. *Literature* – Literature sources from systematic review, including GS/ESDs, are another source of information for release duration. Often, release duration information from literature sources may be broad, such as a range of durations for a given operation. Alternatively, literature sources may describe release duration qualitatively, such as "on and off throughout the day" or "over half the day". Therefore, literature sources may inform release duration at the OES-level, as opposed to at the facility-level. All details from literature sources on release duration, including

[17] Note that the NEI operating hours fields are not populated for all, or in the case of ethylene dibromide, most, NEI entries.

qualitative descriptions, should be presented with air emission estimates if they are available and there is no other source of this data.

4. *List as "Unknown"* – Often, no information on release duration is available at either the facility or OES-level from the above sources. In such cases, engineers list that the release duration is unknown.

Sources for Estimating Release Pattern

1. *NEI Data* – The NEI dataset includes facility-specific air emissions estimates for major sources and often includes data on the number of days of operation per week and number of weeks of operation per year for these facilities. NEI does not indicate if the number of days per week or weeks per year of operation are consecutive or intermittent throughout the week/year; however, these data are still useful and should be provided by engineers with air emission estimates to help inform release patterns. Data on operational days per week and weeks per year for one facility in NEI is typically not used for a different facility; however, engineers may consider conducting an analysis of these data for multiple facilities in NEI that are a part of the same OES to develop a broader estimate of release pattern at the OES-level. EPA has previously used this approach to inform development of GS/ESDs, but it is dependent on the amount of data and time available and should be discussed on a chemical-specific basis.
2. *Models* – Models used to estimate air emissions (*e.g.,* Tank Truck and Railcar Loading and Unloading Release and Inhalation Exposure Model, Open-Top Vapor Degreasing Near-Field/Far-Field Inhalation Exposure Model, Spot Cleaning Near-Field/Far-Field Inhalation Exposure Model, models from GS/ESDs) sometimes (but rarely) include data on release pattern from the underlying data sources. Release pattern information from models may be presented with non-modeled air emission data (*e.g.,* NEI, TRI) if the model is applicable and expected to represent the primary release source for the OES (*e.g.,* release pattern from the Tank Truck and Railcar Loading and Unloading Release and Inhalation Exposure Model may be used with estimates of air emissions for a facility in the Repackaging OES).
3. *Literature* – Literature sources from systematic review, including GS/ESDs, are another source of information for release pattern. Often, literature sources provide general release pattern information for a given operation. Therefore, literature sources may inform release pattern at the OES-level, as opposed to at the facility-level. All details from literature sources on release pattern, even if general and/or limited, should be presented with air emission estimates, if they are available and there is no other source of this information.
4. *List as "Unknown" and Provide Operating Days* – Often, no information on release pattern is available at either the facility or OES-level from the above sources. In these cases, engineers should do the following:
   a. List that the release pattern is unknown.
   b. Provide the number of operating days for the facility based on project-level engineering methodology (which is summarized below).
   c. Provide any information based on process knowledge (*e.g.,* commercial aerosol degreasing using cans may occur on/off throughout a day and year).

Estimating Number of Operating Days for Point Sources

For major sources that report operating data to NEI, EPA uses these data to calculate operating hours on a days per year basis. For major sources that do not report operating data in NEI (including facilities that only report to TRI), EPA estimates operating hours using the other data sources described above. A hierarchical approach for estimating the number of facility operating days per year is described below.

1. *Facility-Specific Data* – Use facility-specific data, if available. NEI reports operating data as hours per year, hours per day, days per week, and weeks per year.
    a. If possible, calculate operating days per years (days/yr = hours per year ÷ hours per day).
    b. If hours per year and/or hours per day are not reported, calculate days per year (days/yr = days per week × weeks per year).
2. *Facility-Specific Use Rates* – If information on facility-specific use rates is available, estimate days/year using one of the following approaches:
    a. If facilities have known or estimated average daily use rates, calculate the days/year (days/yr = estimated annual use rate for the site [kg/yr] ÷ average daily use rate from sites with available data [kg/day].
    b. If sites without days/year data do not have known or estimated average daily use rates, use the average number of days/year from the sites with such data.
3. *Industry-Specific Data* – Industry-specific data may be available in the form of GSs, ESDs, trade publications, or other relevant literature. In such cases, these estimates should take precedent over other approaches, unless facility-specific data are available.
4. *Manufacture of Large-PV Commodity Chemicals* – For the manufacture of the large-PV commodity chemicals, a value of 350 days/year should be used. This assumes that both the plant runs 7 days/week and 50 weeks/year (with 2 weeks down for turnaround) and that the plant is always producing the chemical.
5. *Manufacture of Lower-PV Specialty Chemicals* – For the manufacture of lower-PV specialty chemicals, it is unlikely the chemical is being manufactured continuously throughout the year. Therefore, a value of 250 days/year should be used. This assumes the plant manufactures the chemical 5 days/week and 50 weeks/year (with 2 weeks down for turnaround).
6. *Processing as Reactant (Intermediate Use) in the Manufacture of Commodity Chemicals* – As noted above, the manufacture of commodity chemicals is assumed to occur 350 days/year such that the use of a chemical as a reactant to manufacture a commodity chemical will also occur 350 days/year.
7. *Processing as Reactant (Intermediate Use) in the Manufacture of Specialty Chemicals* – As noted above, the manufacture of specialty chemicals is not likely to occur continuously throughout the year. Therefore, a value of 250 days/year can be used.
8. *Other Chemical Plant OESs (e.g., Processing into formulation; Use of industrial processing aids)* – For these OESs, it is reasonable to assume that the chemical of interest is not always in use at the facility, even if the facility operates 24 hours per day/7 days per week. Therefore, a value of 300 days/year can be used, based on the European Solvent Industry Group's "SpERC fact sheet – Formulation & (re)packing of substances and mixtures – Industrial (Solvent-borne)" default of 300 days/year for the chemical industry. However, in instances where the OES uses a low volume of the chemical of interest, 250 days/year can be used as a lower estimate for the days/year.
9. *All Other OESs* – Regardless of facility operating schedule, other OESs are unlikely to use the chemical of interest every day. Therefore, a value of 250 days/year should be used for these OESs.

Estimating Number of Operating Days for Area Sources

For area sources, EPA also estimates operating days per year using information such as NEI operating data for major source facilities within the same OES, general information about the OES, and values from literature. Facility operating days per year will be used to calculate daily emissions from the NEI and TRI annual emissions data, as follows:

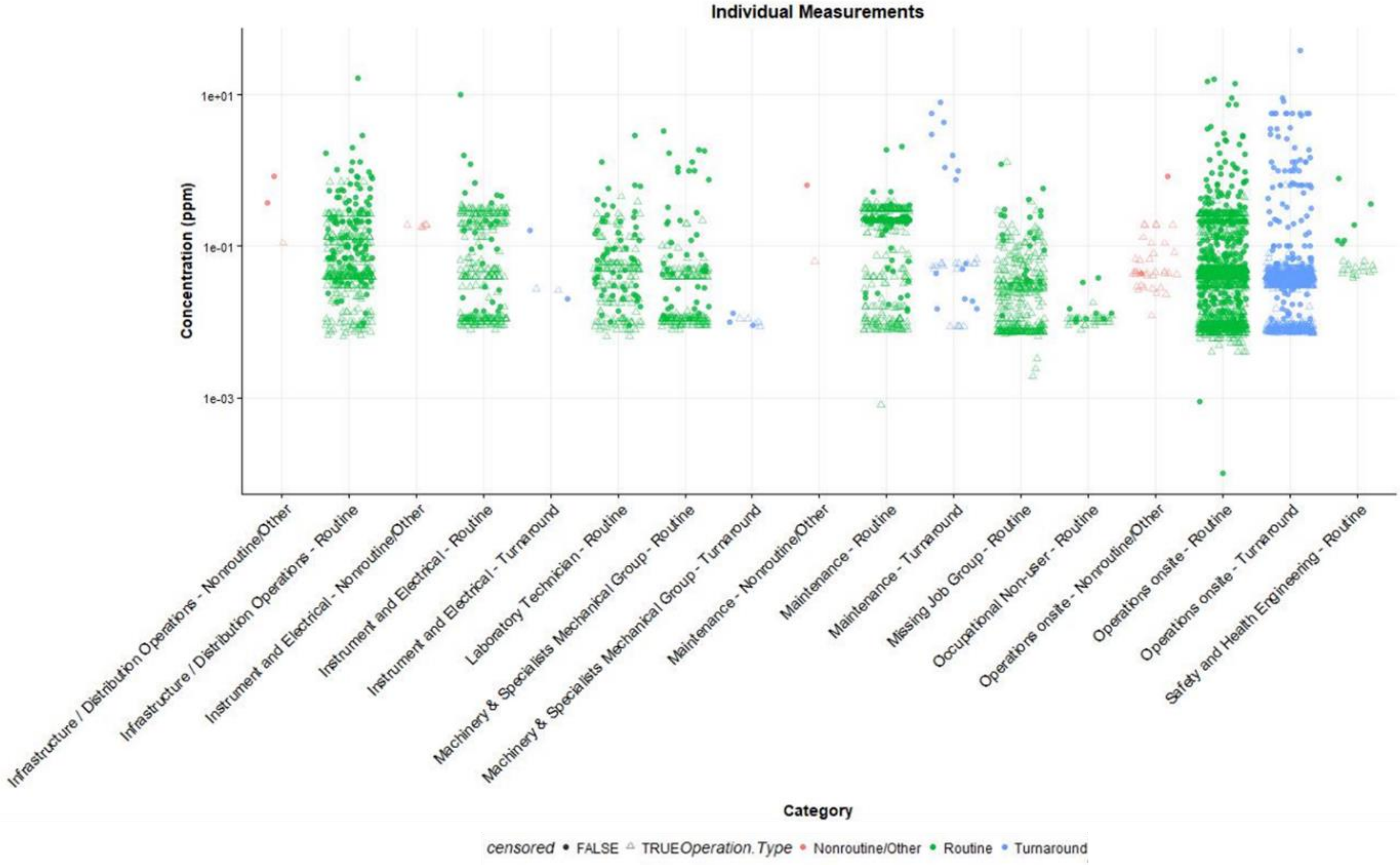
Daily emissions (kg/day) = Annual emissions (kg/yr) ÷ Operating days per year (days/year)

Appendix H ANALYZING HIGHLY CENSORED 1,3-BUTADIENE OCCUPATIONAL EXPOSURE MEASUREMENTS

This appendix provides the method of how EPA analyzed highly censored 1,3-butadiene occupational exposure measurements, in this example using the discrete dataset obtained from the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076) directly relevant to the Manufacturing and Processing as a reactant OESs. Several methods of estimating the dataset were conducted and compared to determine which would be best for the datasets relevant to 1,3-butadiene.

H.1 Analysis of 1,3-Butadiene Occupational Inhalation Exposure Data

An overall view of the data by Job Group and Operation Type is shown in Figure_Apx H-1. There are very few data points above the LOD for many categories, making it difficult to compare concentrations among Operation Types for some Job Groups. The range of values seen in Turnaround and Nonroutine operations are within those seen in Routine operations, with the exception of the "Maintenance" and "Operations onsite" Turnaround groups.



Figure_Apx H-1. Scatterplot of Individual 1,3-Butadiene Measurements by Category

H.2 Methods

Full shift data for air concentration ("Measured Concentration [ppm]") were analyzed. All analyses were completed in R v. 2022.07.0 using the *EnvStats* package v. 3.1.0, which contains functions for estimating distribution parameters for environmental monitoring data, including approaches for handling censored data. Percentile and mean estimates (with confidence intervals, where appropriate) were generated for each job-operation group using the methods described below.

Approaches for Treating Censored Data

- Maximum likelihood estimation (MLE) assuming a lognormal distribution of concentration, as follows:
  - The distribution means were estimated using both the MLE of the arithmetic mean and a MVUE (minimum variance unbiased estimation) approach that corrects for bias in the mean estimate. Such MVUE approaches have been shown to be important for small sample sizes.
  - Confidence intervals for the mean estimates were derived using bootstrap approaches when there were enough detected samples (>14) for successful completion of the *EnvStats* function (*i.e.*, small sample sizes resulted in failure of the method). In the case of small sample size with small number of detects, the delta method was used, which estimates bounds by assuming the estimators are asymptotically-normally distributed.
  - Confidence intervals for the percentiles were estimated using the exact method ("exact.for.complete"; the EnvStats default), which is consistent with the assumption of lognormality of the concentrations and does not require an additional assumption that the quantiles are normally distributed.
- The substitution approach as described in the *Analysis of 1,3-Butadiene Industrial Hygiene Data* (ToxStrategies, 2021, EPA-HQ-OPPT-2024-0425-0076), which used different substitution values based on the dispersion (geometric standard deviation) of the data.
- The Kaplan-Meier approach described in the *Analysis of 1,3-Butadiene Industrial Hygiene* Data and as follows:
  - Confidence intervals for the mean were estimated using the "normal approximation" method, which reproduced the limits in the *Analysis of 1,3-Butadiene Industrial Hygiene*.

Estimates could be generated only for categories with at least three uncensored values (detects). Several of the Nonroutine and Turnaround Operation Type categories contained very few measurements. Due to these small sample sizes, parameters were also estimated for three aggregated data categories: "All Routine," "All Nonroutine," and "All Turnaround" measurements. These distributions could be used for certain groups, if needed, in the absence of more complete information.

Diagnostic visualizations were performed to explore the assumption of a lognormal distribution for all groups. These included quantile-quantile (Q-Q) plots and cumulative distribution function (CDF) plots that compare the shape of the empirical distributions of the data with the theoretical best-fit lognormal distributions (estimated using standard functions of the distribution parameters).

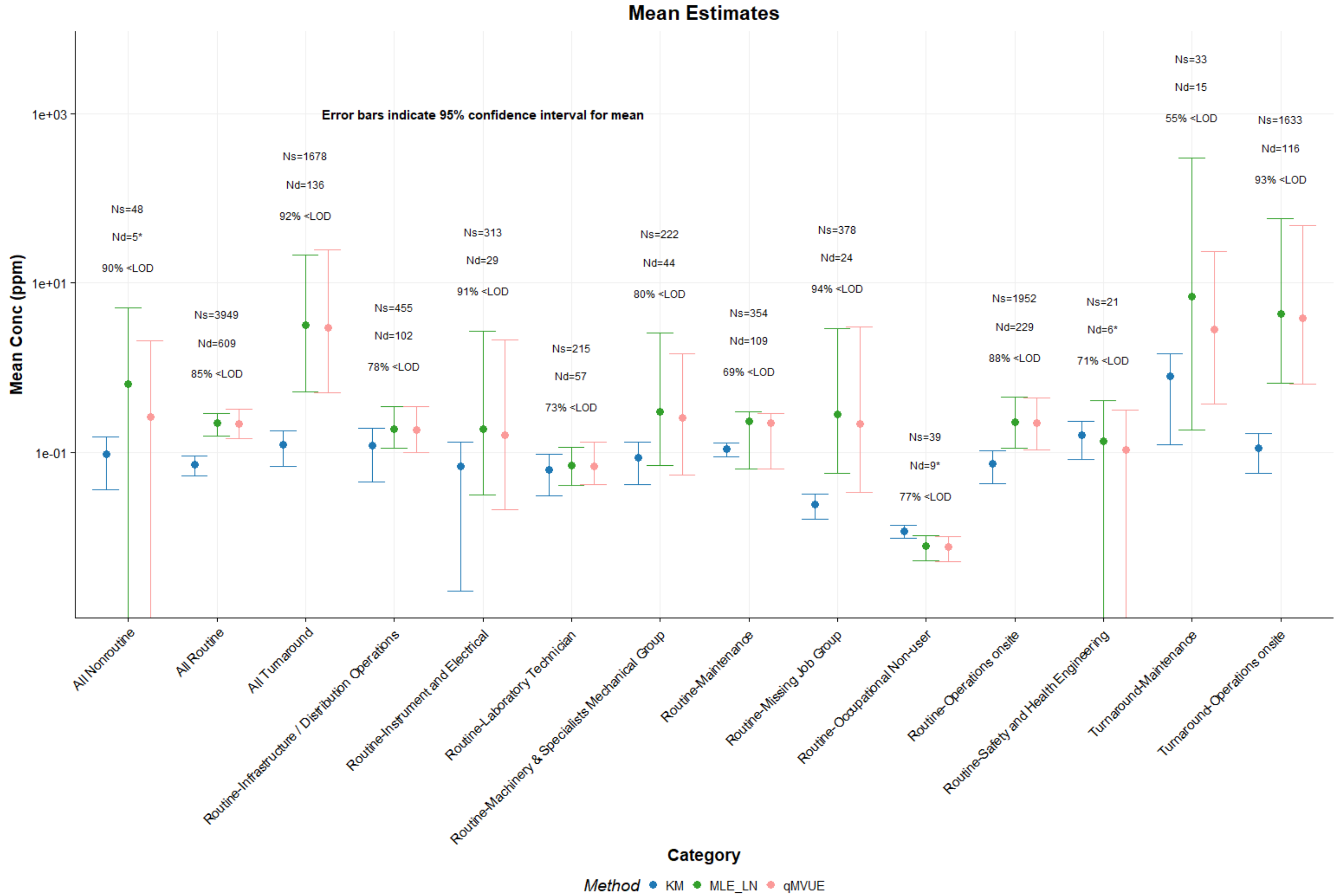
H.3 Results

The estimated distribution parameter, quantile, and mean estimates are provided in *Appendix H*

Attachment of 1,3-Butadiene Occupational Exposure Assessment (U.S. EPA, 2025f). A data dictionary for the estimated parameters included in the dataset is also provided in that file.

A summary of the results for estimation of the mean for each category is shown in

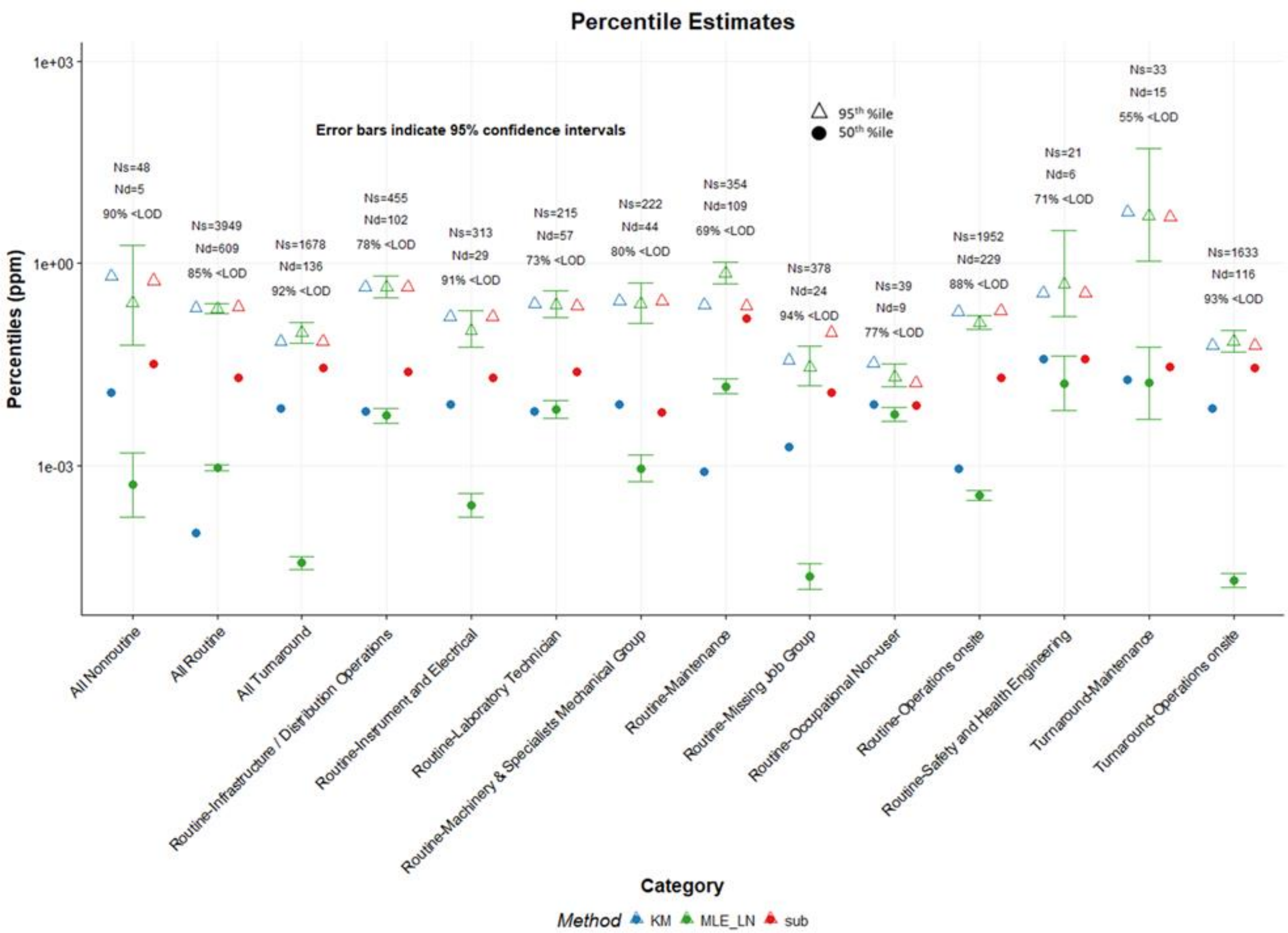
Figure_Apx H-2. Note that when the number of detected concentration measurements is small and the distribution is highly skewed, the uncertainty in the mean can be very large.



Figure_Apx H-2. Mean Concentration Estimates (with Confidence Intervals) of 1,3-Butadiene by Category

Note that "Ns" is the number of samples and "Nd" the number of detects. Confidence intervals were estimated using a bootstrap approach except where Nd is marked with an asterisk (*), indicating that the delta method was used. Two categories with a small number of detections (Nd = 5) lacked sufficient information to estimate a true lower confidence bound with the delta method, resulting in negative estimates that are truncated.

Estimates (with uncertainty represented by confidence intervals) of 50th and 95th percentile values are shown in Figure_Apx H-3. As with the mean (Figure_Apx H-2), the confidence intervals for the estimates of the quantiles are larger for those categories with a small number of detections. However, the intervals are not as large as those for the mean because they are less impacted by extreme values.



Figure_Apx H-3. Estimates of 50th and 95th Percentiles (with Confidence Intervals When Available) of 1,3-Butadiene by Category

H.4 Confidence in the Assumption of a Lognormal Distribution

Diagnostic Q-Q and CDF plots are given in Appendix H.6 of this TSD. For most categories, the assumption of a lognormal distribution seems reasonable (with a caveat that making any assumption about distributions with low sample sizes and small number of detections warrants caution) as the points on the Q-Q plot roughly fall along a straight, diagonal line. However, the "Maintenance – Routine" category did demonstrate a departure from lognormal (with evidence of a bimodal distribution of values; see also Figure_Apx H-1). This may reflect varying conditions encountered by workers during maintenance operations (a mix of conditions where the chemical source may be absent due to shutdown or elevated due to a leak or spill incident). Any selection of estimates for "Maintenance" categories should take this into consideration, as discussed below.

H.5 Recommended Methods for Estimating Central Tendencies and Upper Bounds for Highly Censored 1,3-Butadiene Occupational Inhalation Exposure Data

EPA has carefully reviewed the full shift exposure data for 1,3-butadiene and evaluated expected method performance based on simulation studies in the literature (Huynh et al., 2014; Hewett and Ganser, 2007). The Agency considered each job-operation group's sample size, censoring percentage, estimated geometric standard deviation (GSD), number of LODs, and conformity to a lognormal distribution in evaluating expected method performance for each group based on these studies. EPA focused on MLE with a lognormal distribution assumption and the non-parametric Kaplan-Meier method as leading candidates for analysis based on recommendations from SACC and within the *Analysis of 1,3-Butadiene Industrial Hygiene* and available implementations.[18]

For the particular characteristics of the 1,3-butadiene data, EPA's findings for estimating exposure medians, arithmetic means (AMs), and 95th percentiles are summarized below:

- For all full shift routine groups and two turnaround groups ("maintenance" and "operations onsite" with N > 20 and at least 5 detected values): MLE is preferred with a lognormal distribution assumption, with the minimum variance unbiased estimator (MVUE) (Finney, 1941) used to estimate the AM.[19]
    - For "maintenance-routine," the lognormal assumption appears to be violated, with an apparent bimodal distribution on the log-scale. However, MLE outperforms the Kaplan-method for simulated mixed lognormal data most similar to maintenance-routine data (N = 354 and 69% censoring) (Huynh et al., 2014; Hewett and Ganser, 2007), and generally it is not preferable to use the Kaplan-Meier method when using greater than 50 percent censoring. Thus, MLE is the preference for this group, but the Kaplan-Meier method is a reasonable alternative.
- For the remaining job-operation groups (all non-routine and two turnaround ["instrument and electrical" and "machinery and specialists"] groups): estimating parameters for these remaining

[18] Robust regression on order statistics (ROS) is another estimation method that is expected to perform well for highly censored data (Hewett and Ganser, 2007), but it requires a lognormal distribution assumption similar to ML, and it was not evaluated in Huynh et al., (2014) in which detailed results are provided for particular combinations of N, censoring percentage, GSD, number of LODs, and distributional shape. Additionally, β-substitution (Ganser and Hewett, 2010) is expected to perform well for these data (Huynh et al., 2014), but the method does not appear to be widely implemented with readily available software.

[19] The MVUE has superior performance for estimating the AM compared to the MLE at smaller sample sizes (N < 40) (Huynh et al., 2014).

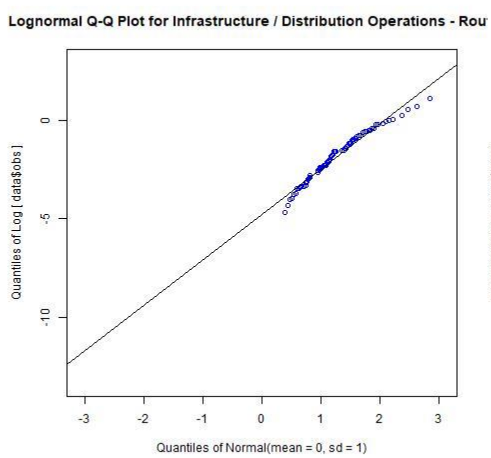
groups separately is a challenge given the small sample sizes and/or number of detections. These groups all have a sample size less than 20 and censoring exceeds 50 percent (in which case neither MLE nor the Kaplan-Meier method is expected to perform well) and/or have 0 to 2 detected values (in which case confidence in estimates is low and assessment of fit is difficult). For these groups, the following was considered:

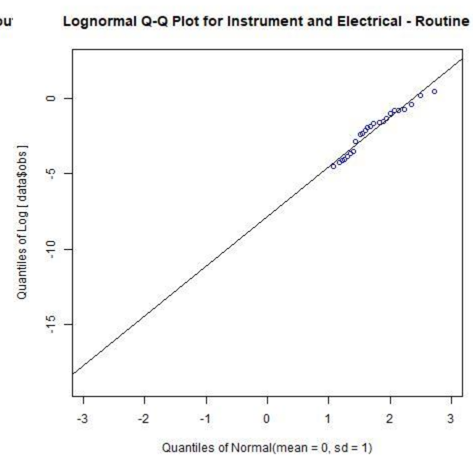
- Aggregating data to increase sample size and number of detections. For example, if data are aggregated by operation type, aggregated non-routine data would have equaled 48 with 5 detections (90% censoring), which is sufficient for parameter estimation with MLE. Furthermore, visual inspection indicated that observations in each non-routine job-operation group were approximately in the same range (Figure_Apx H-1). Data could also be aggregated by job group or other groupings that are useful for the risk evaluation.
- Alternatively, the range of values for each job-operation group could simply be reported, or an exceedance fraction relative to an occupational exposure limit could be calculated, if appropriate.

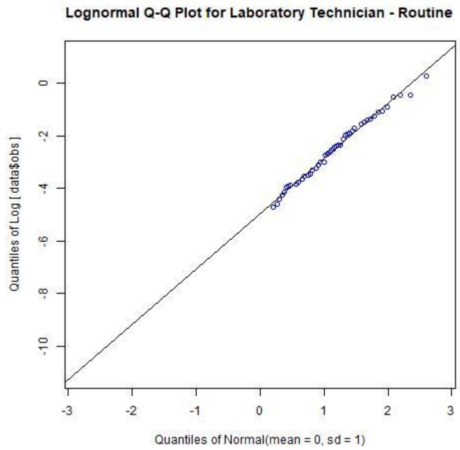
It is difficult to determine the ideal method of handling censored data because method performance depends on level of censoring in combination with sample size, variance, and underlying distribution; for example, the Kaplan-Meier method can outperform MLE when censoring is less than 50 percent—particularly when the lognormal assumption is violated, and it is preferred to reference simulation studies such as the ones cited here when choosing an appropriate method. Although simulation studies provided only an approximation of the data at hand, they still provide the best available basis for comparison of method performance. Additional research is likely needed to more thoroughly evaluate method performance in the context of non-lognormally distributed data.

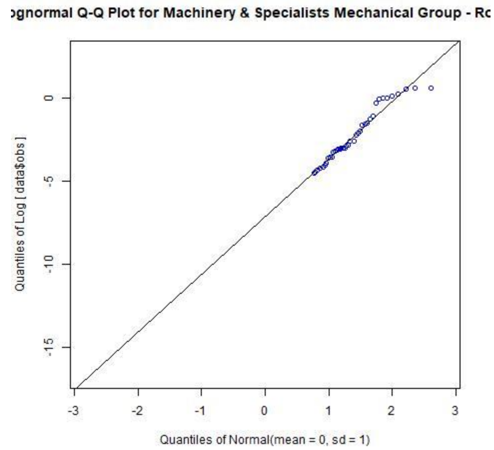
H.6 Quantile-Quantile and Cumulative Distribution Function Plots for Categories

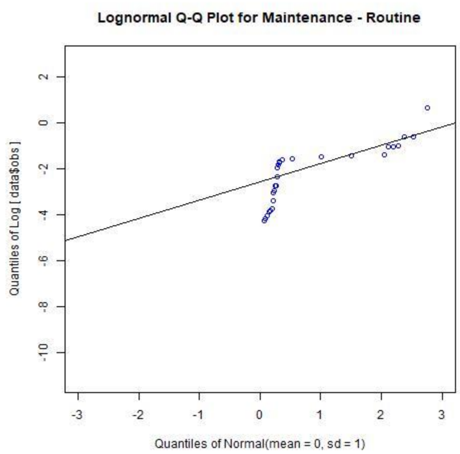
H.6.1 Quantile–Quantile Plots

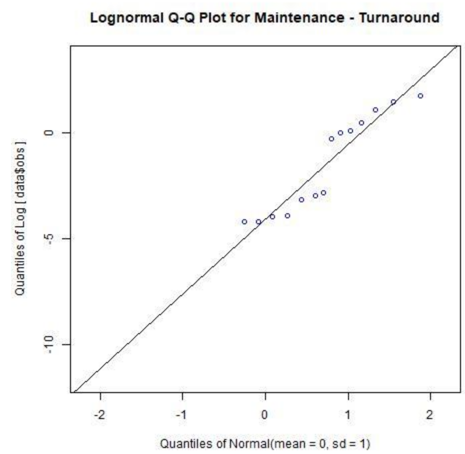


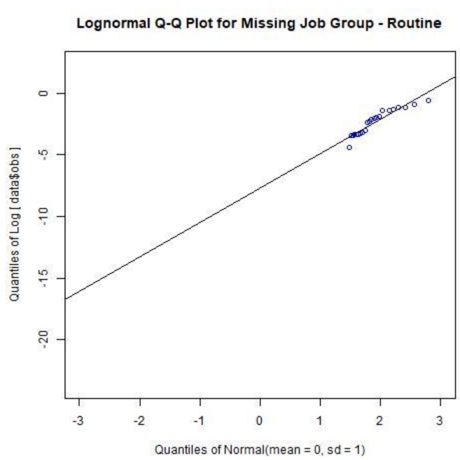


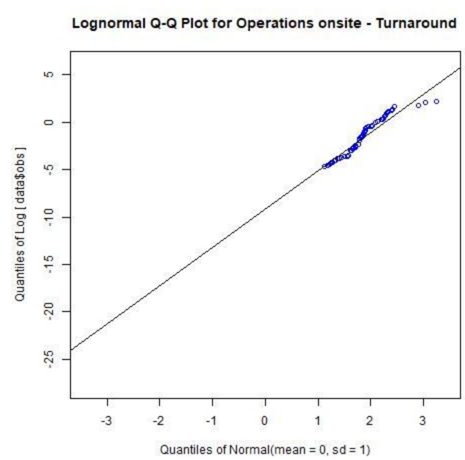

Lognormal Q-Q Plot for Laboratory Technician - Routine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

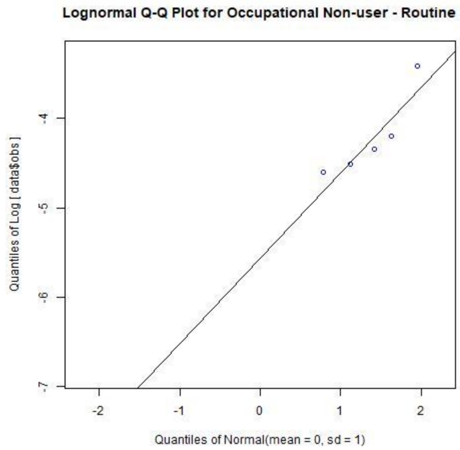

ognormal Q-Q Plot for Machinery & Specialists Mechanical Group - Ro
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

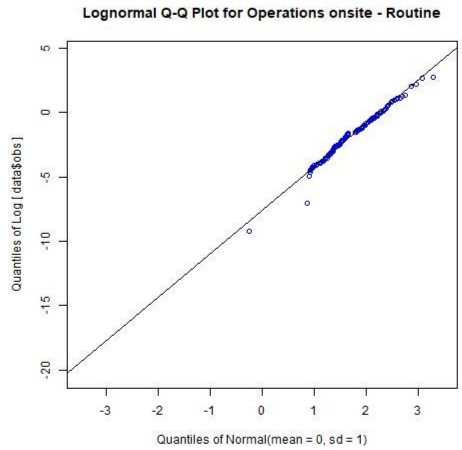

Lognormal Q-Q Plot for Maintenance - Routine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

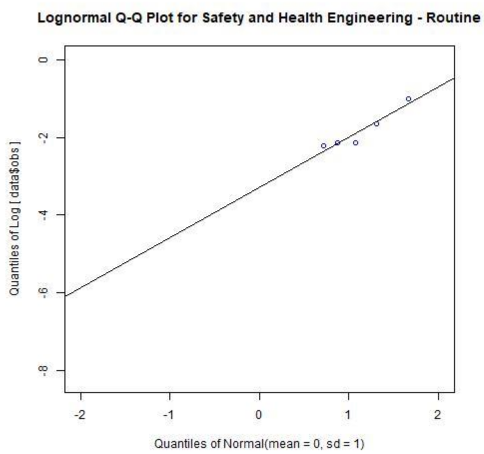

Lognormal Q-Q Plot for Maintenance - Turnaround
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

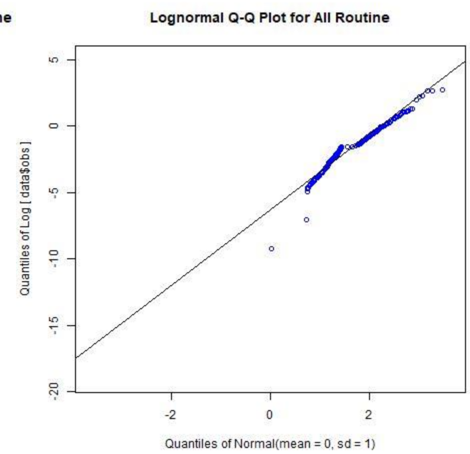

Lognormal Q-Q Plot for Missing Job Group - Routine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

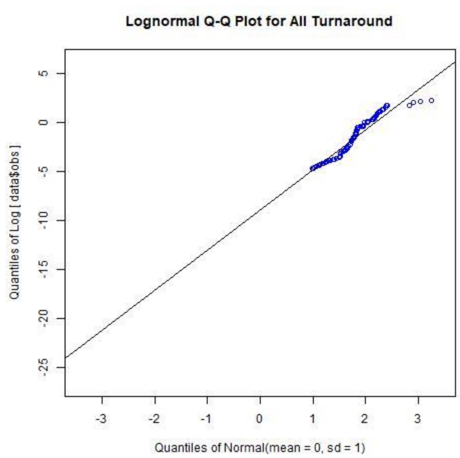

Lognormal Q-Q Plot for Operations onsite - Turnaround
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

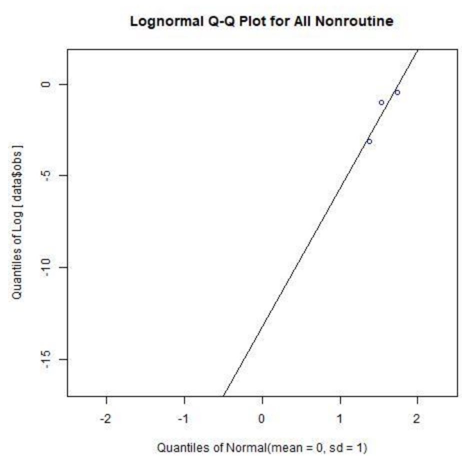

Lognormal Q-Q Plot for Occupational Non-user - Routine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)


Lognormal Q-Q Plot for Operations onsite - Routine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

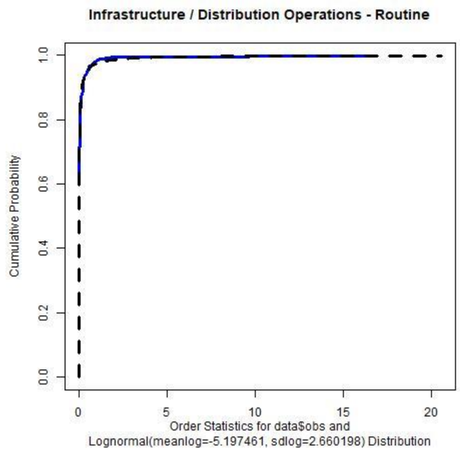

Lognormal Q-Q Plot for Safety and Health Engineering - Routine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

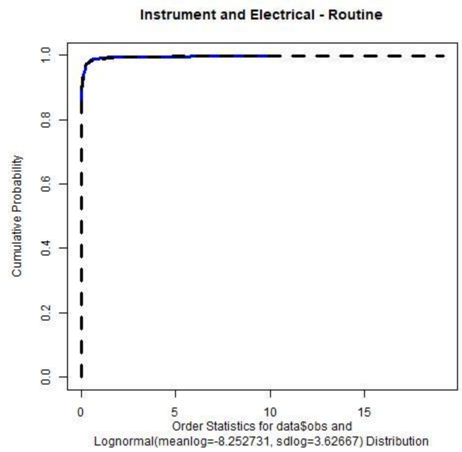

Lognormal Q-Q Plot for All Routine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

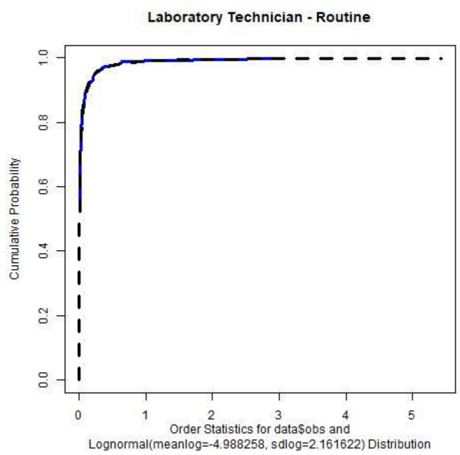

Lognormal Q-Q Plot for All Turnaround
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

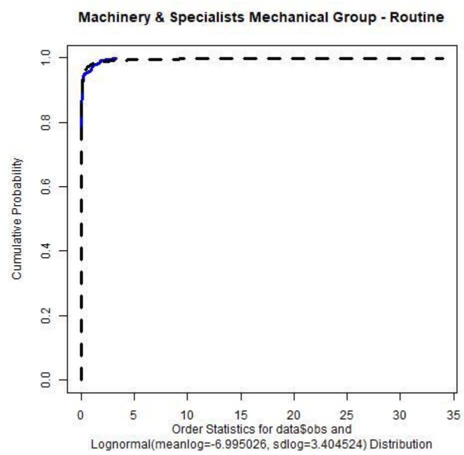

Lognormal Q-Q Plot for All Nonroutine
Quantiles of Log [data$obs]
Quantiles of Normal(mean = 0, sd = 1)

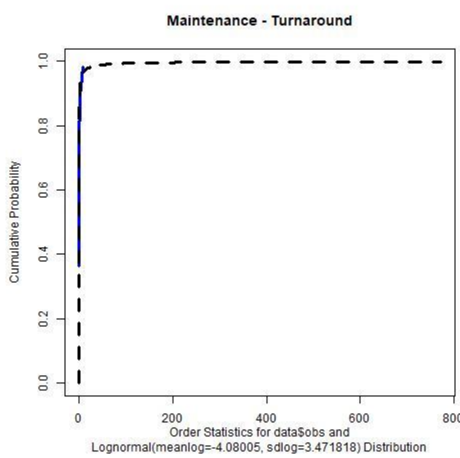
H.6.2 Cumulative Distribution Plots

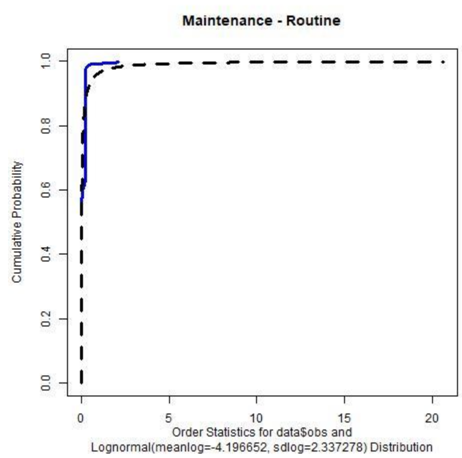


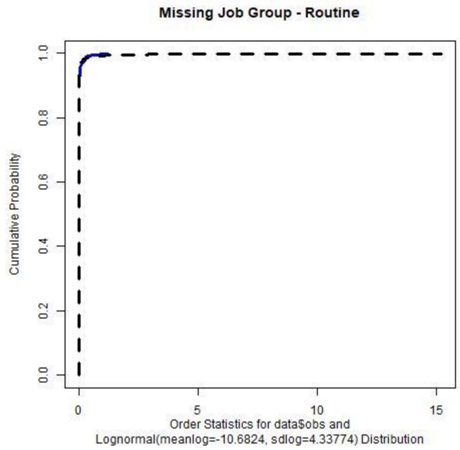


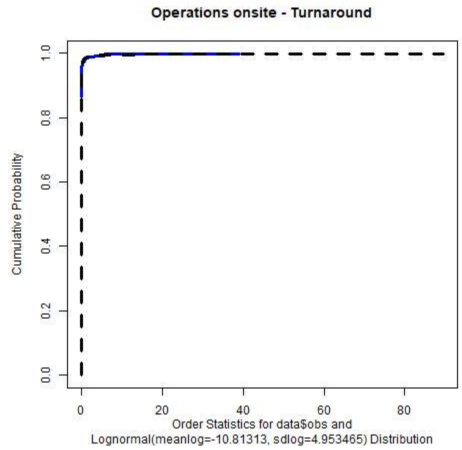


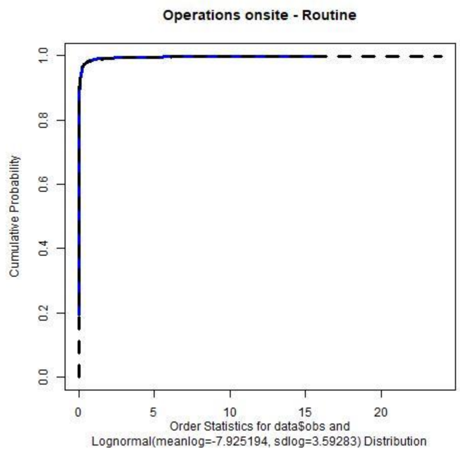


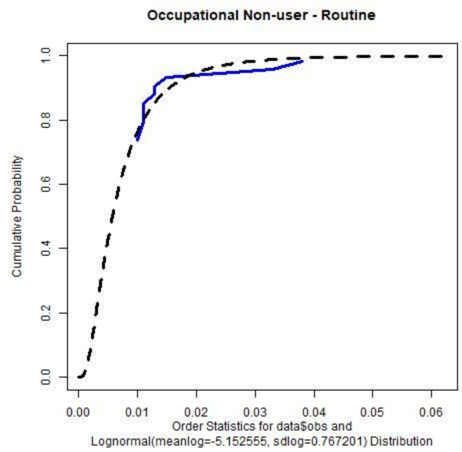


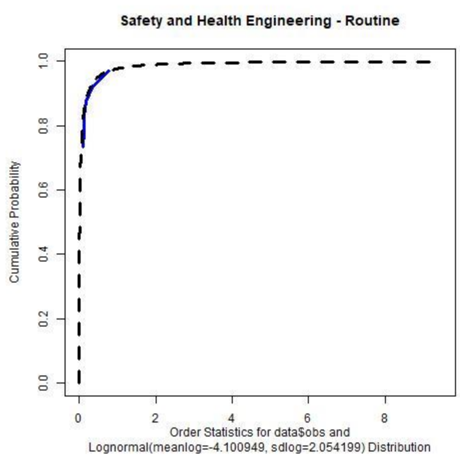


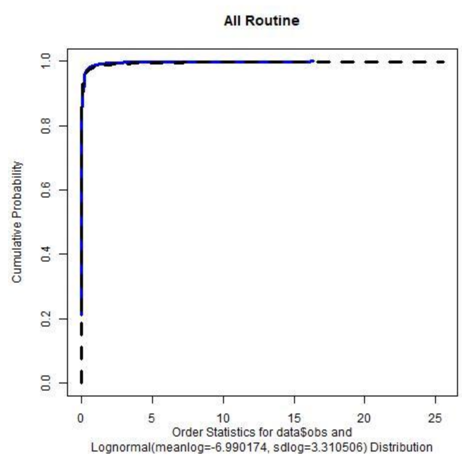

Missing Job Group - Routine
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
Order Statistics for data$obs and
Lognormal(meanlog=-10.6824, sdlog=4.33774) Distribution

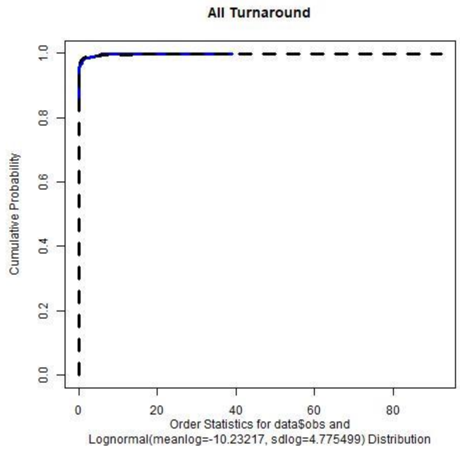

Operations onsite - Turnaround
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
Order Statistics for data$obs and
Lognormal(meanlog=-10.81313, sdlog=4.953465) Distribution

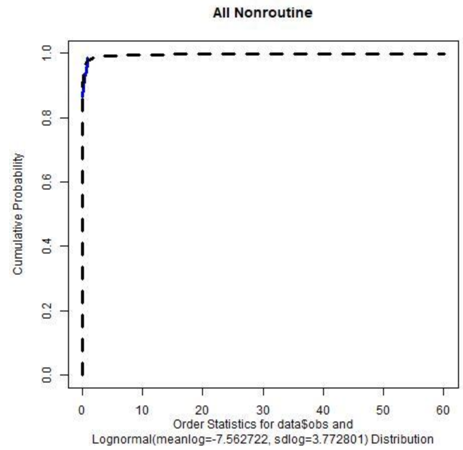

Operations onsite - Routine
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
Order Statistics for data$obs and
Lognormal(meanlog=-7.925194, sdlog=3.59283) Distribution


Occupational Non-user - Routine
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Order Statistics for data$obs and
Lognormal(meanlog=-5.152555, sdlog=0.767201) Distribution


Safety and Health Engineering - Routine
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
Order Statistics for data$obs and
Lognormal(meanlog=-4.100949, sdlog=2.054199) Distribution


All Routine
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
Order Statistics for data$obs and
Lognormal(meanlog=-6.990174, sdlog=3.310506) Distribution


All Turnaround
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
Order Statistics for data$obs and
Lognormal(meanlog=-10.23217, sdlog=4.775499) Distribution


All Nonroutine
Cumulative Probability
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50
60
Order Statistics for data$obs and
Lognormal(meanlog=-7.562722, sdlog=3.772801) Distribution