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Draft Environmental Release and Occupational Exposure Assessment for Octamethylcyclotetrasiloxane (D4)

Technical Support Document for the Draft Risk Evaluation

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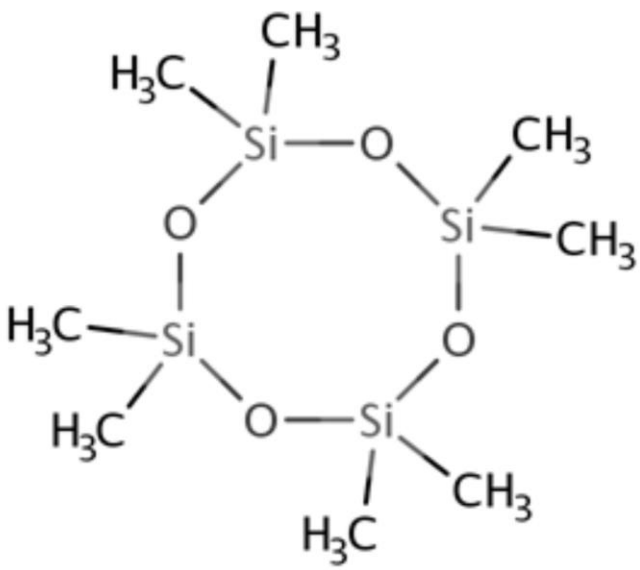

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ABBREVIATIONS AND ACRONYMS

AC	Acute concentration
AC_{CT}	Acute concentration (central tendency)
ACGIH	American Conference of Governmental Industrial Hygienists
AC_{HE}	Acute concentration (high-end)
AD	Acute retained dose
ADC	Average daily concentration
ADC_{CT}	Average daily concentration (central tendency)
ADC_{HE}	Average daily concentration (high-end)
AIHA	American Industrial Hygiene Association
APDR	Acute potential dose rate
APF	Assigned protection factor
AT_{acute}	Acute averaging time
AT_{Int}	Averaging time for intermediate exposure
AWD	Annual working days
BLS	Bureau of Labor Statistics (U.S.)
BR	Breathing rate ratio
BW	Body weight
CBI	Confidential business information
CDR	Chemical Data Reporting (rule)
CEB	Chemical Engineering Branch
CEHD	Chemical Exposure Health Database
CEPE	European Council of the Paint, Printing Ink, and Artist's Colours Industry
CFR	Code of Federal Regulations
CPS	Current Population Survey
CSM	Conceptual site model
CT	Central tendency
$Cv_{activity}$	Exposure activity volumetric concentration
DMR	Discharge Monitoring Report
ECETOC TRA	European Centre for Ecotoxicology and Toxicology of Chemicals Targeted Risk Assessment (model)
ED	Exposure duration
EF	Exposure frequency
EF_{Int}	Intermediate exposure frequency
EF_{yearly}	Number of exposure days
EPA	Environmental Protection Agency (U.S.)
ESD	Emission Scenario Document
ETIMEOFF	Months when not working (CPS data)
f	Fractional number of working days per year a worker works
$F_{activity\_loss}$	Loss fraction for activity
$F_{correction\_factor}$	Vapor pressure correction factor
$F_{exposure}$	Fraction of operating days with worker exposure
F_{loss_can}	Loss fraction for cans/small containers
F_{loss_cont}	Container loss fraction
$F_{loss\_cont\text{-}residue}$	Loss fraction for containers
F_{loss_drum}	Loss fraction for drum containers
$F_{loss\_equipment}$	Loss fraction for equipment cleaning
F_{loss_filter}	Loss fraction for filter changeout
$F_{loss\_off\text{-}spec}$	Loss fraction for off-specification wastes

$F_{loss\_smallcont}$	Loss fraction for small containers
$F_{saturation\_loading}$	Saturation factor loading
$F_{saturation\_unloading}$	Saturation factor unloading
F_{D4_import}	Import concentration
F_{D4_prod}	Product concentration
G	Vapor generation rate
$G_{activity}$	Vapor generation rate for an activity
GS	Generic Scenario
HAP	Hazardous Air Pollutant
HE	High-end
IADC	Intermediate average daily concentration
$IADC_{CT}$	Intermediate average daily concentration (central tendency)
$IADC_{HE}$	Intermediate average daily concentration (high-end)
LADC	Lifetime average daily concentration
$LADC_{CT}$	Lifetime average daily concentration (central tendency)
$LADC_{HE}$	Lifetime average daily concentration (high-end)
LOD	Limit of detection
LT	Lifetime years for cancer risk
M_{batch}	Batch size
MMRE	Manufacturer-requested risk evaluation
MRD	Methodology review draft
MW_{D4}	Molecular weight of D4
NAICS	North American Industry Classification System
N_{batch_yr}	Annual number of batches
N_{cont_yr}	Annual number of import containers
NEI	National Emissions Inventory
NESHAP	National Emissions Standards of Hazardous Air Pollutants
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NIOSH	National Institute of Occupational Safety and Health
$N_{prodcont\_yr}$	Annual number of product containers
N_s	Number of sites
OD	Operating days
OECD	Organisation for Economic Co-Operation and Development
OEL	Occupational exposure limit
OES	Occupational exposure scenario
ONU	Occupational non-user
OPPT	Office of Pollution Prevention and Toxics
OSHA	Occupational Safety and Health Administration
$P_{\_atm}$	Pressure (atm)
$P_{\_torr}$	Pressure (torr)
PAPR	Power air-purifying respirator
PBZ	Personal breathing zone
PDMS	Polydimethylsiloxane
PEI	PEI Associates, Inc.
PEL	Permissible exposure limit
PF	Protection factor
POTW	Publicly owned treatment work
PPE	Personal protective equipment
PV	Production volume

PV_{site}	Facility production rate
Q	Ventilation rate
$Q_{product}$	Facility production rate
R	Universal gas constant
$RATE_{air\_speed}$	Air speed
$RATE_{fill}$	Fill rate of container
$RATE_{fill\_drum}$	Fill rate of drum
$RATE_{fill\_smallcont}$	Fill rate of small container
RD	Release days
REL	Recommended exposure limit
$\rho_{product}$	Product density
ρ_{D4}	D4 density
RQ	Reportable quantity
SAR	Supplied-air respirator
SCBA	Self-contained breathing apparatus
SDS	Safety Data Sheet
SEG	Similar Exposure Group
SEHSC	Silicones Environmental, Health, and Safety Center
SIC	Standard Industrial Classification
SIPP	Survey of Income and Program Participation
SOC	Standard Occupational Classification (SOC)
SpERC	Specific Emission Release Category
SUSB	Statistics of U.S. Businesses
T	Temperature
TDS	Technical data sheet
TE	Transfer efficiency
$Time_{activity}$	Operating time for activity
$TIME_{operating\_days}$	Operating days
TJBIND1	Employed individual works (SIPP Data)
TLV	Threshold limit value
TMAKMNYR	First year worked (SIPP data)
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TWA	Time-weighted average
V_{batch}	Batch volume
V_{fill_cont}	Small container volume
V_{import_cont}	Import container volume
Vm_{D4}	Molar volume of D4
VOC	Volatile organic compound
VP	Vapor pressure
V_{prod_cont}	Small container volume
W	Workers
WEEL	Workplace Environmental Exposure Level
WWT	Wastewater treatment
WWTP	Wastewater treatment plant
WY	Working years per lifetime

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Docket

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Disclaimer

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SUMMARY

This technical support document (TSD) for octamethylcyclotetrasiloxane (D4) summarizes the environmental releases and occupational exposures that are reasonably expected to occur during the manufacture (including import), processing, and industrial and commercial uses of D4. This TSD supports the Toxic Substances Control Act (TSCA) *Draft Risk Evaluation for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025c) in response to a request through the American Chemistry Council's Silicones Environmental, Health, and Safety Center (SEHSC). (U.S. EPA, 2025c)

D4, also known as "Cyclotetrasiloxane, 2,2,4,4,6,6,8,8-octamethyl-" or "Octamethylcyclotetrasiloxane", is a colorless volatile liquid primarily used as an intermediate in the production of polymers used for products such as silicone rubber, sealants, paint and coating manufacturing, and a wide variety of silicone fluids such as anti-foaming agents; it is also used as a laboratory chemical, as an ingredient in cleaning products, and in personal care products like shampoos, conditioners and stick deodorants.

Focus of the Supplemental Report on Environmental Release and Occupational Exposure Assessment

During scoping, EPA considered all known TSCA conditions of use for D4. TSCA section 3(4) defines the conditions of use 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". At the time of this draft, the most recently available data was from the 2020 Chemical Data Reporting (CDR), which indicated between 250,000,000 to 500,000,000 pounds were either manufactured or imported in the U.S. in 2019 (U.S. EPA, 2020a). The previous, 2016 CDR, cycle provided a national aggregate production volume (PV) of between 750,000,000 and 1,000,000,000 pounds per year (U.S. EPA, 2016) and the 2012 National Aggregate PV was between 500,000,000 and 750,000,000 pounds (U.S. EPA, 2012). The largest use of D4 is as a reactant or monomer to produce silicone-based products.

Exposures to workers, consumers, general populations, and ecological species may occur from industrial, commercial, and consumer uses of D4 and releases to air, water, or land. Workers and occupational non-users (ONUs) may be exposed to D4 during conditions of use. Exposure to the general population and ecological species may occur from industrial releases related to the manufacture, import, processing, distribution, and use of D4. This supplemental report provides the details of the assessment of the environmental releases and occupational exposures from each condition of use of D4.

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

EPA evaluated environmental releases of D4 to air, water, and land from identified conditions of use. EPA used release data from the American Chemistry Council's Silicones Environmental, Health, and Safety Center (SEHSC, also described here as the D4 Consortium) (ERM, 2012) and reasonably available literature sources where available and used modeled estimates of release where release data were not available.

EPA evaluated acute, intermediate, and chronic exposures to workers and occupational non-users in association with D4 conditions of use. EPA used inhalation monitoring data from SEHSC (SEHSC, 2019) and reasonably available literature sources and used exposure models where monitoring data were not available for the condition of use. EPA also used modeling approaches to estimate dermal exposures to workers as no monitoring data on dermal exposure was available.

Results for Environmental Releases and Occupational Exposures: EPA evaluated environmental releases of D4 to air, water, and/or land for 17 occupational exposure scenarios (OESs) assessed in the draft risk evaluation. The Agency did not separately quantify environmental releases for the Recycling, Disposal, or Distribution in Commerce as a distinct OESs because disposal related to each OES were assumed to be captured in release assessments for those OESs. The highest central tendency and high-end daily water releases were estimated from the Formulation of Adhesives and Sealants (Neat D4) OES, followed by the Repackaging OES.

EPA also evaluated inhalation and dermal exposures to worker populations, including ONUs, for each OES. Inhalation exposures are expected to occur predominantly to vapor. However, exposures to mist are possible during the spray application of paint products. Inhalation exposures during manufacturing and processing OESs were estimated using personal breathing zone (PBZ) data that was submitted by the D4 Consortium. Inhalation exposures during end use OESs were modelled using appropriate OPPT models. Dermal exposures to liquids are expected to occur during most OES's, these were modelled using appropriate OPPT models. Detailed results for exposures can be found throughout Section 2.7.

Uncertainties of this Risk Evaluation: There are uncertainties associated with the monitoring and modeling approaches used to assess D4 environmental releases and occupational exposures. For example, the lack of facility-specific production volume data and amount of D4 handled based on the upper bound of the CDR national aggregate PV reporting may not be representative of the total production volume of D4 used in each OES. EPA also used generic EPA models and default input parameter values when site-specific data were not available. In addition, site-specific differences in material handling practices and engineering controls exist but are largely unknown, representing a source of variability that EPA could not quantify.

Environmental Release and Exposure Pathways Considered in this Risk Evaluation: EPA assessed environmental releases to air, water, and land to estimate exposures to the general population and ecological species for D4 conditions of use outlined in the *Final Scope of the Risk Evaluation for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2022d). Environmental release estimates developed by EPA were used to estimate the presence of D4 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 D4) and occupational non-users (workers not directly involved with the use of D4) for D4 conditions of use outlined in the *Final Scope of the Risk Evaluation for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2022d). EPA assumed that workers and occupational non-users would be individuals of both sexes (age 16 years and older, including pregnant workers) based upon occupational work permits, although exposures to younger workers (*i.e.,* age 16 years and older) in occupational settings cannot be ruled out. An objective of the monitored and modeled inhalation data was to provide separate exposure level estimates for workers and occupational non-users. Dermal exposures were considered for workers and most ONUs.

1 INTRODUCTION

1.1 Overview

Toxic Substances Control Act (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 non-risk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator under the conditions of use*."

This manufacturer-requested risk evaluation (MRRE) for D4 has been conducted in response to a request through the American Chemistry Council's Silicones Environmental, Health, and Safety Center (SEHSC) in 2020. The *Final Scope of the Risk Evaluation for Octamethylcyclotetrasiloxane (Cyclotetrasiloxane, 2,2,4,4,6,6,8,8-octamethyl-) (D4); CASRN 556-67-2* (U.S. EPA, 2022d) (hereinafter referred to as the "final scope document") was published in March 2022.

D4 is a common chemical name for a chemical substance that includes the following names: cyclotetrasiloxane, 2,2,4,4,6,6,8,8-octamethyl- or octamethylcyclotetrasiloxane. D4 is a colorless volatile liquid that is used primarily in the production of polymers in various applications, such as coatings, resins, and plastic articles, and occasionally as a laboratory chemical. All uses are subject to federal and state regulations and reporting requirements (summarized in Appendix B of the *Draft Risk Evaluation for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025c)). D4 is not a Toxics Release Inventory (TRI)-reportable substance. It is on the TSCA Inventory and reported under the Chemical Data Reporting (CDR) rule.

1.2 Scope

EPA assessed environmental releases and occupational exposures for conditions of use (COUs) across all life cycle stages of D4 as described in Table 2-2 of the final scope document (U.S. EPA, 2022d). To estimate environmental releases and occupational exposures, EPA first developed occupational exposure scenarios (OESs) related to the conditions of use of D4. An OES is based on a set of facts, assumptions, and inferences that describe how releases and exposures take place within an occupational COU. Some release and exposure scenarios are common to multiple COUs, and some COUs are associated with multiple release/exposure scenarios. Table 1-1 shows mapping of OESs assessed in this technical support document to the COUs assessed in the *Draft Risk Evaluation for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025c)(U.S. EPA, 2025c). The table is organized by COU lifecycle stage and subcategory and identifies the section of this document relevant to the assessment of each OES.

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

1. Manufacture
2. Import – repackaging
3. Processing as a reactant

4. Formulation of adhesives
5. Rubber compounding
6. Rubber converting
7. Formulation of paints and coatings
8. Formulation of products containing greater than residual D4
9. Formulation of products containing residual D4
10. Use of adhesives and sealants
11. Use of paints and coatings
12. Use of solvents
13. Use of automotive care products
14. Use of fabric finishing products
15. Use of animal grooming products
16. Use of D4 as a laboratory chemical
17. Use of residual D4-containing products

EPA also considered Recycling, Waste handling, disposal, and treatment and Distribution in commerce. Recycling of D4 does occur as a process step during the processing as a reactant OES. Waste handling (incineration or landfill) is covered under each respective OES, end of service life disposal of D4-containing products and distribution in commerce are discussed qualitatively because no data or suitable surrogate release data or models were available to estimate releases for these OESs.

Table 1-1. Crosswalk of Subcategories of Use Listed in the Final Scope Document (U.S. EPA, 2022d) to OESs Assessed in the Risk Evaluation

<table>
<tr><th>Life Cycle Stage[a]</th><th>Category[b]</th><th>Subcategory[c]</th><th>OES[d]; Relevant Section</th></tr>
<tr><td rowspan="2">Manufacturing</td><td>Domestic manufacturing</td><td>Domestic manufacturing</td><td>Manufacture of D4; Section 3.1</td></tr>
<tr><td>Import</td><td>Import</td><td rowspan="2">Repackaging D4; Section 3.2</td></tr>
<tr><td rowspan="2">Processing</td><td>Repackaging</td><td>Intermediate (all other basic inorganic chemical manufacturing)

Solvent (all other chemical product and preparation manufacturing)</td></tr>
<tr><td>Processing as a reactant</td><td>Adhesives and sealant chemicals (adhesive and sealant manufacturing)

Intermediate (All other basic organic chemical manufacturing; all other basic inorganic chemical manufacturing; all other chemical product and preparation manufacturing; plastic material and resin manufacturing; synthetic rubber manufacturing)</td><td>Processing as a reactant; Section 3.3</td></tr>
</table>

Life Cycle Stage[a]	Category[b]	Subcategory[c]	OES[d]; Relevant Section
		Monomer (all other chemical product and preparation manufacturing) Processing aid (plastic material and resin manufacturing; rubber product manufacturing)	
	Incorporation into formulation, mixture, or reaction product	Adhesive and sealant chemicals (computer and electronic product manufacturing; electrical equipment, appliance, and component manufacturing; construction)	Formulation of adhesives; Section 3.4
		Intermediate (polyurethane foam manufacturing) Intermediate (All other basic inorganic chemical manufacturing; all other chemical product and preparation manufacturing; cyclic crude and intermediate manufacturing; paint and coating manufacturing; synthetic rubber manufacturing.)	Rubber compounding; Section 3.5 Rubber converting; Section 3.6
		Corrosion inhibitors and anti-scaling agents (paint and coating manufacturing) Paint additives and coatings not described by other categories (Rubber product manufacturing)	Formulation of paints and coatings; Section 3.7
		Solvent (for cleaning or degreasing (aerospace manufacturing) Solvent (which become part of product formulation or mixture) (all other chemical and product preparation manufacturing; soap, cleaning compound, and toilet preparation manufacturing)	Formulation of products containing greater than residual D4; Section 3.8
		Other (miscellaneous manufacturing; working fluid manufacturing, lubricating oil and grease manufacturing) Processing aid (*e.g.,* component in an antifoaming agent) (miscellaneous manufacturing, asphalt paving, roofing, and coating materials manufacturing,	Formulation of products containing residual D4; Section 3.9 Products this could be applicable to: • Printing inks • Anti foam • Metal cutting fluids

Life Cycle Stage[a]	Category[b]	Subcategory[c]	OES[d]; Relevant Section
		fabricated metal product manufacturing; oil and gas industry products (*e.g.,* fuel additive)) Surface active agent (plastics product manufacturing; paint and coating manufacturing; surfactant manufacturing (pesticides))	• Release agents • Cleaning/polishing formulations • Laundry • Working fluids • Lubricants • Other uncertain residual level products
Industrial and/or commercial uses	Adhesives and sealants	Adhesives and sealants (*e.g.,* electronic equipment)	Use of adhesives; Section 3.10
	Paints and coatings	Paints and coatings (*e.g.,* construction and electronic equipment)	Use of paints and coatings – spray application; Section 3.11
	Solvent (for cleaning or degreasing)	Solvent for cleaning of degreasing (*e.g.,* aerospace manufacturing)	Use of solvents; Section 3.12
	Automotive care products	Automotive care products	Use of automotive Care products; Section 3.13
	Animal grooming products	Animal grooming products	Use of animal grooming product; Section 3.14
	Laboratory chemicals	Laboratory chemicals	Use of D4 as a laboratory chemical; Section 3.15
	Furnishing, cleaning, treatment/care products	Cleaning and furnishing care products	Use of residual D4-containing products; Section 3.16 Environmental releases represented by: • Use of fabric finishing products • Use of cleaning products • Commercial/institutional laundry Occupational exposures represented by: • Use of cleaning products • Commercial/institutional laundry
		Fabric, textile, and leather products not covered elsewhere	
		Laundry and dishwashing products	
	Lubricant and greases	Lubricants and greases	
	Working Fluids	Working fluids (*e.g.,* hydraulic, heat transfer, and other fluids used in gauges, pumps, and other equipment)	
	Release agents	Release agents (*e.g.,* in wood product manufacturing)	
	Polyurethane foam (additive)	Polyurethane foam (*e.g.,* construction)	
	Oil and gas products	Oil and gas products	
	Ink, toner, and colorant products	Ink, toner, and colorant products	
	Plastic and rubber products not	Plastic and rubber products not covered elsewhere	

Life Cycle Stage[a]	Category[b]	Subcategory[c]	OES[d]; Relevant Section
	covered elsewhere		
Waste handling, disposal, and treatment			Waste handling, disposal, and treatment; Section 3.17
Distribution in commerce			Distribution in Commerce; Section 3.18

[a] Life Cycle Stage Use Definitions (40 CFR 711.3)

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

[b] These categories of conditions of use appear in the Life Cycle Diagram (Figure 1-3 in the D4 Risk Evaluation (U.S. EPA, 2025c)), reflect CDR codes, and broadly represent conditions of use of *Octamethylcyclotetrasiloxane* in industrial and/or commercial settings.

[c] These subcategories represent more specific activities within the life cycle stage and category of the conditions of use of D4.

[d] An OES is based on a set of facts, assumptions, and inferences that describe how releases and exposures take place within an occupational condition of use. The occurrence of releases/exposures may be similar across multiple conditions of use (multiple COUs mapped to single OES), or there may be several ways in which releases/exposures take place for a given condition of use (single COU mapped to multiple OESs).

EPA's assessment of releases includes quantifying annual and daily releases of D4 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 to surface water (including on-site and off-site treatment) (ERM, 2012) and indirect discharges to publicly owned treatment works (POTW) or non-POTW wastewater treatment (WWT). It should be noted that for purposes of risk evaluation, discharges to POTW, and non-POTW WWT are not evaluated the same as discharges to surface water. EPA considers removal efficiencies of POTWs and wastewater treatment plants (WWTPs) and environmental fate and transport properties when evaluating risks from indirect discharges. Releases to land include any disposal of liquid or solids wastes containing D4 into landfills, land treatment, surface impoundments, or other land applications. The purpose of this supplemental report is only to quantify releases; therefore, downstream environmental fate and transport factors used to estimate exposures to the general population and ecological species are not discussed. The details on how these factors were considered when determining risk are described in the D4 Risk Evaluation (U.S. EPA, 2025c).

For workplace exposures, EPA considered exposures to both workers who directly handle D4 and occupational non-users (ONUs). Workers work in close proximity to D4 and may handle D4 while ONUs do not directly handle D4 but may be indirectly exposed to it as part of their employment. EPA evaluated inhalation and dermal exposures to both workers and ONUs. EPA has performed a quantitative estimation of the effect of personal protective equipment (PPE) on worker exposure.

Specifically, the effect of PPE on occupational risk estimates is discussed in Section 5 the *Draft Risk Evaluation for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025c) and the calculations can be found in the *Draft Risk Calculator for Occupational Exposures for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025b).

2 COMPONENTS OF AN OCCUPATIONAL EXPOSURE AND RELEASE ASSESSMENT

The occupational exposure and environmental release assessment of each OES comprises the following components:

- **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 production volume associated with the OES; per site throughputs/use rates of the chemical; operating schedules; and process vessels, equipment, and tools used during the condition of use.
- **Estimates of Number of Facilities:** An estimate of the number of sites that use D4 for the given OES.
- **Environmental Release Sources:** A description of each of the potential sources of environmental releases in the process and their expected media of release 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 each type of 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 ONUs:** An estimate of the number of workers and occupational non-users 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 occupational non-users. See Section 2.4.2 for a discussion of EPA's statistical analysis approach for assessing inhalation exposure.
- **Occupational Dermal Exposure Results:** Central tendency and high-end estimates of dermal exposure to workers. See Section 2.4.3 for a discussion of EPA's approach for assessing dermal exposure.

2.1 Approach and Methodology for Process Descriptions

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

- Total production volume associated with the OES;
- Name and location of sites 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 D4-specific process descriptions were unclear or not available, EPA referenced generic process descriptions from literature, including relevant Emission Scenario Documents (ESD) or Generic Scenarios (GS). Process descriptions for each OES can be found in Section 2.7.

2.2 Approach and Methodology for Estimating Number of Facilities

To estimate the number of facilities within each OES, EPA used a combination of bottom-up analyses of EPA reporting programs and top-down analyses of U.S. economic data and industry-specific data.

Generally, EPA used the following steps to develop facility estimates:

1. Identify or "map" each facility reporting for D4 in the 2016 and 2020 CDR (2020a, 2019) to an OES. 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 is expected to cover most or all of 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.
3. Supplement the available reporting data with U.S. economic and market data using the following method:
    a. Identify the NAICS codes for the industry sectors associated with the OES.
    b. Estimate total number of facilities using the U.S. Census' Statistics of U.S. Businesses (SUSB) data on total establishments by 6-digit NAICS.
    c. Use market penetration data to estimate the percentage of establishments likely to be using D4 instead of other chemicals.
    d. Combine the data generated in Steps 3a through 3c to produce an estimate of the number of facilities using D4 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 for the analysis of each OES.
4. If market penetration data required for Step 3c. are not available, use generic industry data from GSs, ESDs, and other literature sources, such as The UK RE (Brooke et al., 2009) which indicates the use profile of D4 in the U.S. and EU is similar , on typical throughputs/use rates, operating schedules, and the D4 production volume used within the OES to estimate the number of facilities. In cases where EPA identified a range of operating data in the literature for an OES, EPA used stochastic modeling to provide a range of estimates for the number of facilities within an OES. EPA provided the details of the approaches, equations, and input parameters used in stochastic modeling in Appendix E and the Supplemental Files listed in Appendix G.

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 attempted to provide annual releases, high-end and central tendency daily releases, and the number of release days per year for each media of release (air, water, and land).

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

1. Monitoring and measured data:
    a. Releases calculated from site-specific concentration in medium and flow rate data
    b. Releases calculated from mass balances or emission factor methods using site-specific measured data
2. Modeling approaches:
    a. Surrogate release data

b. Fundamental modeling approaches
c. Statistical regression modeling approaches

3. Release limits:
   a. Company-specific limits
   b. Regulatory limits (*e.g.*, National Emission Standards for Hazardous Air Pollutants [NESHAPs] or effluent limitations/requirements

EPA's preference was to rely on facility-specific release data reported in TRI, Discharge Monitoring Report (DMR), and the National Emissions Inventory (NEI), where available, however, D4 is not reportable in these databases. Therefore, EPA primarily relied on data from literature, relevant ESDs or GSs, existing EPA models, and/or relevant regulatory limits to estimate releases. Specific details related to the use of release data or models for each OES can be found in Section 2.7

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:

1. **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. EPA 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 2.7.
2. **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.
3. **Combination of deterministic and probabilistic calculations**: EPA had full distributions for some parameters but point estimates of the remaining parameters. For example, EPA used Monte Carlo modeling to estimate annual throughputs and emission factors, but only had point estimate of production volume. EPA used the upper bound of the 2020 CDR Production volume based on the historical use profile of D4 indicated in past CDR reporting (*e.g.*, 2012 and 2016). 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 2.7 and a more thorough explanation of the PV calculations can be found in Section 2.3.1

2.3.1 Production Volume Estimation

In previous risk evaluations, when much of the CDR PV data are claimed as confidential business information (CBI), EPA has typically utilized an aggregate approach and provided estimates based on both the lower and upper bounds of the National Aggregate PV reported in the CDR. For this risk evaluation, EPA deviated from the typical process from based on factors that are specific to D4. For D4, the 2020 CDR National Aggregate PV was 250,000,000 to 500,000,000 lb per year (U.S. EPA, 2020a). In this assessment, EPA primarily relied on the upper-bound of the national aggregate PV of 500,000,000 lb per year. EPA also used additional PVs within the national aggregate production volume bounds as needed for refinement of environmental releases.

Historical production volumes of D4 informed the selection of 500,000,000 lb per year as an upper bound of exposure. Specifically, the 2016 CDR National Aggregate PV was 750,000,000 to 1,000,000,000 lb per year (U.S. EPA, 2016) and the 2012 CDR aggregate PV was between 500,000,000 and 750,000,000 lb per year (U.S. EPA, 2012), which represents a significantly larger historical PV than the range provided in the 2020 CDR. The significant change in the National Aggregate PV, which exhibited a shift in two aggregate ranges from the 2016 to 2020 CDR serves as notable as rationale for the selection of the PV of 500,000,000 lb per year within the current risk assessment for D4. The methodology used to estimate the PVs for the COUs/OESs included in the risk evaluation are further explained below. For some OESs lower PV values were included to better represent the CDR PV range in refined analyses. These OESs were Manufacturing, Repackaging, Processing as a reactant, Rubber compounding (neat D4), and Rubber converting.

Based on data found during systematic review, and further explained in Section 3.3.2, EPA assumes that 80 percent of the D4 PV is processed as a reactant to create various polymer mixtures. These polymer mixtures are then used to create downstream products and or formulations throughout the D4 lifecycle. In many of the evaluated OESs there are multiple scenarios that provide estimates based on both neat and residual processing scenarios.

D4 is used across many industrial and commercial sectors, in many cases the same products, such as rubber articles and silicone fluids, are used simultaneously in multiple industrial and commercial sectors for differing uses. For example, polydimethylsiloxane (PDMS) can be used as a grease, polish, heat transfer fluid, anti-foaming agent, mold release agent, etc. (Momentive, 2022). This creates a challenge when trying to map the uses of D4 to a given COU or OES. The throughput estimation approach that EPA used relies on data from the United Kingdom Environmental Agency's risk evaluation (Brooke et al., 2009), CDR, industry submissions, and other available sources to sort the use profile of D4 into major use categories. Brooke et al. (2009) provides a breakdown into six major use categories; these are sealants (32%), elastomers (21%), specialties (14%), silanes (9%), and resins (3%). A further breakdown of the elastomers and silicone fluids category was also provided, this further breakdown was calculated into an overall PV use percentage, see Table 2-1.

The first major use category is sealants (Brooke et al., 2009) denotes that 32 percent of D4 PV is used for this. The second major use category is elastomers (which would be considered rubber product manufacturing). Brooke et al. (2009) denotes that 21 percent of D4 PV is used for this, however, the overall PV percentage for the subcategories of textile coatings (1.47%) and paints and coatings (1.47%) were removed from this category for inclusion in other categories. This leaves approximately 18.1 percent of the D4 PV being used for the elastomers category. The next major use category is paints and coatings (12.6%); this includes the subcategories of paints and coatings (1.47%), silicone fluids (2.1%), and silanes (9%) The rationale for including silanes is further explained in Section 3.7.2. The next major use category is formulations containing greater than residual levels of D4, this major use category accounts for approximately 17.4 percent of the D4 PV, the rationale for this is in Section 3.8.2. The final major use category is for the formulation containing residual levels of D4 (*e.g.,* less than 3% D4 remaining in the final product). This major use category is the remainder of the D4 PV not used in other major use categories. Table 2-1 below provides EPA's breakdown of the major use categories and Table 2-2 provides the categories and subcategories provided by Brooke et al. (2009).

Table 2-1. D4 PV Breakdown into Major Use Categories Provided in Brooke et al. (2009)

Category	PV (%)
Adhesives and sealants	32.0
Paints and coatings	12.6
Rubber compounding and converting	18.1
Greater than residual (remainder or neat minus paints and coatings and lab chemical)	17.4
Less than residual (remainder left from all above)	19.9
Total	100

Table 2-2. Categories and Subcategories from Brooke et al. (2009)

Life Cycle			
Category (Percent)	**Subcategory**	**Subcategory Percent (%)**	**Overall Percent (%)**
Sealants (32%)	N/A	N/A	32.00
Elastomers (21%)	Automotive	20	4.20
	Electrical fittings	15	3.15
	Medical/healthcare	14	2.94
	Appliances	9	1.89
	Consumer goods (articles)	9	1.89
	Textile coatings	7	1.47
	Paints and coatings	7	1.47
	Mould making	7	1.47
	Business machines	5	1.05
	Other	7	1.47
Silicone fluids (21%)	Processing aids	26	5.46
	Personal care products	18	3.78
	Paper coatings	15	3.15
	Paints and coatings	10	2.10
	Mechanical fluids	7	1.47
	Textile applications	5	1.05
	Other	24	5.04
Specialities (14%)	N/A	N/A	14.00
Silanes (9%)	N/A	N/A	9.00
Resins (3%)	N/A	N/A	3.00

2.3.2 Identifying Release Sources

The D4 Consortium submitted conceptual site models (CSMs) that contained data regarding release points and media of release for manufacturing and processing OESs. In addition to this, EPA performed a literature search to identify process operations that could potentially result in releases of D4 to air, water, or land from each OES. For each OES, EPA identified the release sources and the associated media of release. Where D4-specific 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 2.7.

2.3.3 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, EPA used the following hierarchy:

1. **Facility-specific data:** EPA used facility-specific operating days per year data if available. If facility-specific data was 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 (or release) rates, EPA calculated the days per year as:

$$Days\ per\ year = \frac{Estimated\ annual\ use\ (or\ release)\ rate\ for\ facility\ (kg/yr)}{Average\ daily\ use\ (or\ release)\ rate\ from\ facilities\ with\ available\ data\ (kg/day)}$$

    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:** For the manufacture of the large-PV commodity chemicals, EPA used a value of 350 days per year. This assumes the plant runs seven days per week and 50 weeks per year (with two weeks down for turnaround) and assumes that the plant is always producing the chemical.
4. **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, 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 two 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 chemicals 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 OES (*e.g.*, processing into formulation and use of industrial processing aids):** For these OES, EPA assumed that the chemical of interest is not always in use at the facility, even if the facility operates 24 hours, 7 days a week. Therefore, in general, EPA used a value of 300 days per year based on the "SpERC fact sheet – Formulation & (re)packing of substances and mixtures – Industrial (Solvent-borne)" which uses a default of 300 days per 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 OES) 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 OES:** Regardless of what the facility operating schedule is, other OES are unlikely to use the chemical of interest every day. Therefore, EPA used a value of 250 days per year for these OES.

2.3.4 Estimating Releases from Models

EPA 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.
    a. Chemical-specific information on release sources were provided for certain OESs (*e.g.*, Processing as a reactant) from the D4 consortium. If chemical-specific information was not available, release sources were identified from generic scenarios or emission scenario documents that detail common release sources for the industry.
2. Identify or develop model equations for estimating releases from each release source.
    a. For each release source, EPA determined the best model to estimate the release. For many OESs, EPA used standard models for air emissions and emission factors of residual amounts remaining after container unloading, cleaning or equipment cleaning.
3. Identify model input parameter values from relevant literature sources.
    a. Key model input parameters in the release models used include, but are not limited to, the weight concentrations and site-specific throughputs (production volume per site and the number of operating days).
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[1] with 100,000 iterations and the Latin Hypercube sampling method. Detailed descriptions of the model approaches used for each OES, model equations, input parameter values and associated distributions are provided in Section 2.7 and Appendix E.

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

[1] @Risk; Palisade; https://www.palisade.com/risk/

2.3.5 Estimating Releases Using Literature Data

Where available, EPA used data identified from literature sources to estimate releases. Literature data may include directly measured release data or information useful for release modeling. Therefore, EPA's approach to literature data differs depending on the type of literature data available. For example, if facility-specific release data are available, EPA may use that data directly to estimate releases for that facility. If facility-specific data are available for only a subset of the facilities within an OES, EPA may also build a distribution of the available data and estimate releases from facilities within the OES using central tendency and high-end values from the distribution. If facility-specific data are not available, but industry- or chemical-specific emission factors are available, EPA may use those directly to calculate releases for an OES or incorporate the emission factors into release models to develop a distribution of potential releases for the OES. Detailed descriptions of how various literature data was incorporated into release estimates for each OES are described in Section 2.7.

2.4 Occupational Exposure Approach and Methodology

For workplace exposures, EPA considered exposures to both workers who directly handle D4 and ONUs who do not directly handle D4 but may be exposed to D4 while handling formulations that contain D4 or during mist generating activities that may be present during most conditions of use (COUs).. EPA evaluated inhalation exposures to both workers and ONUs and dermal exposures to workers and, for some OES's, ONUs..

EPA evaluated occupational inhalation and dermal exposures representative of *central tendency* conditions and *high-end* conditions. A central tendency is assumed to be representative of occupational exposures in the center of the distribution for a given condition of use. For risk evaluations, EPA uses 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 provide the 50th percentile of the distribution. However, if the full distribution is not known, EPA 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, 1992a). For risk evaluations, EPA presents high-end results at the 95th percentile. If the 95th percentile is not available, EPA uses 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 will estimate a maximum or bounding estimate in lieu of the high-end.

For each OES, EPA provided high-end and central tendency full-shift time-weighted averages (TWAs) (typically as 8-hr TWAs) inhalation exposure concentrations and high-end and central tendency acute potential dermal dose rates (APDR). EPA uses 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 monitoring data
   b. Fundamental modeling approaches
   c. Statistical regression modeling approaches
3. Occupational exposure limits:
   a. Company-specific occupational exposure limits (OELs) (for site-specific exposure assessments, *e.g.*, there is only one manufacturer who provides 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 American Industrial Hygiene Association (AIHA)])

For occupational exposures, EPA used measured and estimated air concentrations to calculate exposure concentration metrics required for risk assessment. Exposure metrics for inhalation exposures include acute concentration (AC), intermediate average daily concentration (IADC), average daily concentration (ADC), and lifetime average daily concentration (LADC). The approach for estimating each exposure metric is described in Appendix B.

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, EPA referenced relevant ESDs or GSs. Worker activities for each OES can be found in Section 2.7.

2.4.2 Estimating Inhalation Exposures

2.4.2.1 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 by the D4 Consortium via public comments. No data was available through governmental agencies such as OSHA and NIOSH. Studies were evaluated using the evaluation strategies laid out in the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021a) (hereinafter referred to as the "2021 Draft Systematic Review Protocol").

Exposures are calculated from the monitoring datasets provided in the sources depending on the size of the dataset. For datasets with six or more data points, central tendency and high-end exposures were estimated using the 50th percentile and 95th percentile. For datasets with three to five data points, central tendency exposure was calculated using the 50th percentile and the maximum was presented as the high-end exposure estimate. For datasets with two data points, the midpoint was presented as a midpoint value and the higher of the two values was presented as a higher value. Finally, data sets with only one data point presented the single exposure value. For datasets including exposure data that were reported as below the limit of detection (LOD), EPA estimated the exposure concentrations for these data, following EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. 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. The dataset provided by SEHSC had a low number of non-detect data points within the PBZ monitoring data. This is likely due to the PBZ data targeting specific activities where D4 is being used and where exposure was likely.

A key source of monitoring data are samples provided by the D4 Consortium. They provided 138 monitoring data points that were either PBZ or area samples taken during various activities that occurred during manufacturing and/or processing of D4 (SEHSC, 2019). These data points were ultimately grouped into several similar exposure group (SEG) categories based on the position title and the duration of the activity. These categories are; Administrative (ONU), Chemical Operator, Laboratory Technician, Logistic Technician, Material Handler, and Production Operator (8-, 10-, and 12-hour shifts). In addition, monitoring data for the polymer plant operator was obtained from systematic review (1998; 1989, 1977). While these monitoring data can be linked to specific tasks involving directly handling D4, there is limited information about the exact type of facility (manufacture, processing, and/or formulating of D4), specific OES, or industry sectors that each data point came from. Many of the OES-specific estimates identified in this analysis are based on the same aggregated dataset and do not reflect OES-specific monitoring, but rather these estimates reflect the handling of D4 across all manufacturing, processing and formulating OES's during different activities.

2.4.2.2 Inhalation Exposure Modeling

Where inhalation exposures are expected for an OES but monitoring data were not available or where EPA determined monitoring data did not sufficiently capture the exposures for an OES, EPA attempted to utilize models to estimate inhalation exposures. 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 inhalation exposures, EPA followed these steps to estimate exposures:

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

For exposure models that utilize stochastic calculations, EPA performed a Monte Carlo simulation using the Palisade @Risk software with 100,000 iterations and the Latin Hypercube sampling method. Detailed descriptions of the model approaches used for each OES, model equations, input parameter values and associated distributions are provided in Section 2.7 under the respective OES and in Appendix E.

2.4.3 Estimating Dermal Exposures

Dermal exposure data was not reasonably available for the COUs in the assessment. Because D4 is a volatile liquid that readily evaporates from the skin, EPA estimated dermal exposures using a variation of Dermal Exposure to Volatile Liquids Model and the EPA 2-Hand Contact with Container Surfaces Model. The model was used to calculate the applied dose of D4 to the skin (*i.e.*, the amount available for absorption rather than the amount absorbed).

Evaporation and absorption were not included in the dermal exposure model because parameters related to D4's evaporation from and absorption through skin were included in the PBPK model used to estimate dermal hazard values (*i.e.*, acute and intermediate/chronic human equivalent doses). The dermal parameters included in the model are based on a human *in vivo* dermal absorption study and an *in vitro* evaporation experiment. The resulting HEDs used to calculate occupational risks are specific for unoccluded scenarios (where D4 is not trapped at the skin surface). A more detailed explanation of this can be found in Section 4.2.2 of the *Draft Human Health Hazard Assessment for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025a).

The deterministic dermal exposure model calculates an acute potential dose rate (mg/day) based on an assumed amount of liquid or solid on skin during one contact event per day. Specific details of the dermal exposure assessment for each OES and equations for estimating dermal exposures can be found in Appendix B and Appendix D.

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

For each COU, the estimated exposures were used to calculate acute (up to 24 hours), intermediate (22 days in a 30 day period), and chronic (non-cancer; workday exposure between 31 and 40 working years) inhalation exposures and dermal doses. These calculations require additional parameter inputs, such as years of exposure, exposure duration and frequency, and lifetime years.

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

1. **Deterministic calculations:** EPA used combinations of point estimates of each parameter to estimate a central tendency and high-end for each final exposure metric result. EPA documented the method and rationale for selecting parametric combinations to be representative of central tendency and high-end.
2. **Probabilistic (stochastic) calculations:** EPA used Monte Carlo simulations using the full distribution of each parameter to calculate a full distribution of the final exposure metric results and selecting the 50th and 95th percentiles of this resulting distribution as the central tendency and high-end, respectively.
3. **Combination of deterministic and probabilistic calculations:** EPA had full distributions for some parameters but point estimates of the remaining parameters. For example, EPA used Monte Carlo modeling to estimate exposure concentrations, but only had point estimates of exposure duration and frequency, and lifetime years. In this case, EPA documented the approach and rationale for combining point estimates with distribution results for estimating central tendency and high-end results.

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

2.5 Consideration of Engineering Controls and Personal Protective Equipment

This section contains general information on engineering controls and personal protective equipment. EPA has performed a quantitative estimation of the effect of PPE on worker exposure. The effect of PPE on occupational risk estimates is discussed in the D4 Risk Evaluation (U.S. EPA, 2025c) and the calculations can be found in the *Draft Risk Calculator for Occupational Exposures for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025b).

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 Section 1910.1000, OSHA requires the use of engineering or administrative controls to bring exposures to the levels permitted under the air contaminants standard (29 Code of Federal Regulations [CFR] 1910.1000). 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.

2.5.1 Respiratory Protection

OSHA's Respiratory Protection Standard (29 CFR 1910.134) requires employers in certain industries to address workplace hazards by implementing engineering control measures and, if these are not feasible, provide respirators that are applicable and suitable for the purpose intended. 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 Section 1910.134(d) and require that appropriate respirators are selected based on the respiratory hazard(s) to which the worker will be exposed and workplace and user factors that affect respirator performance and reliability. Assigned protection factors (APFs) are provided in Table 1 under Section 1910.134(d)(3)(i)(A) (see below in Table 2-3) 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 2-3. 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 2-3. Assigned PFs for Respirators in OSHA Standard 29 CFR 1910.134

Type of Respirator	Quarter Mask	Half Mask	Full Facepiece	Helmet/ Hood	Loose-Fitting Facepiece
1. Air-purifying respirator	5	10	50	—	—
2. Power air-purifying respirator (PAPR)	—	50	1,000	25/1,000	25
3. Supplied-air respirator (SAR) or airline respirator					
• Demand mode	—	10	50	—	—
• Continuous flow mode	—	50	1,000	25/1,000	25
• Pressure-demand or other positive-pressure mode	—	50	1,000	—	—
4. Self-contained breathing apparatus (SCBA)					
• Demand mode	—	10	50	50	—
• Pressure-demand or other positive-pressure mode (*e.g.*, open/closed circuit)	—	—	10,000	10,000	—
Source: 29 CFR 1910.134(d)(3)(i)(A)					

2.5.2 Glove Protection

OSHA's hand protection standard (29 CFR 1910.138) requires employers select and require employees to use appropriate hand protection when expected to be exposed to hazards such as those from skin absorption of harmful substances; severe cuts or lacerations; severe abrasions; punctures; chemical burns; thermal burns; and harmful temperature extremes. Dermal protection selection provisions are provided in Section 1910.138(b) and require that appropriate hand protection is selected based on the performance characteristics of the hand protection relative to the task(s) to be performed, conditions present, duration of use, and the hazards to which employees will be exposed.

Unlike respiratory protection, OSHA standards do not provide protection factors (PFs) associated with various hand protection PPE, such as gloves, and data about the frequency of effective glove use – that is, the proper use of effective gloves – is very limited in industrial settings. Initial literature review suggests that there is unlikely to be sufficient data to justify a specific probability distribution for effective glove use for a chemical or industry. Instead, the impact of effective glove use is explored by considering different percentages of effectiveness.

EPA made assumptions about glove use and associated PF. Where workers wear gloves, workers are exposed to D4-based products that may penetrate the gloves, such as seepage through the cuff from improper donning of the gloves, and if the gloves occlude the evaporation of D4 from the skin. Where workers do not wear gloves, workers are exposed through direct contact with D4.

Gloves only offer barrier protection until the chemical breaks through the glove material, which are a partial basis for PF ratings. Using a conceptual model, Cherrie et al. (2004) proposed a glove workplace PF – the ratio of estimated uptake through the hands without gloves to the estimated uptake though the hands while wearing gloves: this protection factor is driven by flux, and thus varies with time. The European Centre For Ecotoxicology and Toxicology of Chemicals Targeted Risk Assessment (ECETOC TRA) model represents the protection factor of gloves as a fixed, APF equal to 5, 10, or 20 (Marquart et al., 2017) where, similar to the APF for respiratory protection, the inverse of the protection factor is the fraction of the chemical that penetrates the glove. It should be noted that the described PFs are not based on experimental values or field investigations of PPE effectiveness, but rather professional judgements used in the development of the ECETOC TRA model. EPA did not identify reasonably available information on PPE usage to corroborate the PFs used in this model.

As indicated in Table 2-4, use of PFs above 1 is recommended only for glove materials that have been tested for permeation against the D4-containing liquids associated with the condition of use. EPA has not found information that would indicate specific activity training (*e.g.*, procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur in a majority of sites in industrial only OESs, so the PF of 20 would usually not be expected to be achieved. Protection factors are incorporated into the risk characterization section of the main body of the Risk Evaluation document.

Table 2-4. Glove PFs for Different Dermal Protection Strategies from ECETOC TRA v3

Dermal Protection Characteristics	Affected User Group	Indicated Efficiency (%)	PF
Any glove/gauntlet without permeation data and without employee training	Both industrial and professional users	0	1
Gloves with available permeation data indicating that the material of construction offers good protection for the substance		80	5
Chemically resistant gloves (*i.e.*, as *b* above) with "basic" employee training		90	10
Chemically resistant gloves in combination with specific activity training (*e.g.*, procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur	Industrial users only	95	20

2.6 Evidence Integration for Environmental Releases and Occupational Exposures

Evidence integration for the environmental release and occupational exposure assessment includes analysis, synthesis and integration of information and data to produce estimates of environmental releases and occupational inhalation and dermal 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 EPA 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 data set 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 data quality and data hierarchy equally when determining evidence integration strategies. For example, EPA 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.

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

2.7 Estimating Number of Workers and Occupational Non-users

This section provides a summary of the estimates for the total exposed workers and ONUs for each OES. To prepare these estimates, EPA first identified relevant North American Industrial Classification (NAICS) codes and Standard Occupational Classification (SOC) codes from the Bureau of Labor Statistics (BLS) (U.S. BLS, 2023). The estimation process for the total number of workers and ONUs is described in Section 2.7.1 below. EPA also estimated the total number facilities associated with the relevant NAICS codes based on data from the U.S. Census Bureau (U.S. Census Bureau, 2015). To estimate the average number of potentially exposed workers and ONUs per site, the total number of workers and ONUs were divided by the total number of facilities. The following sections provide additional details on the approach and methodology for estimating the number of facilities using D4 and the number of potentially exposed workers and ONUs.

2.7.1 Number of Workers and Occupational Non-users Estimation Methodology

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

1. Identify the NAICS codes for the industry sectors associated with these uses (Table 2-5 below).
2. Estimate total employment by industry/occupation combination using the Bureau of Labor Statistics' Occupational Employment Statistics data (BLS Data).
3. Refine the Occupational Employment Statistics estimates where they are not sufficiently granular by using the U.S. Census' SUSB data on total employment by 6-digit NAICS.
4. Use market penetration data to estimate the percentage of employees likely to be using D4 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 D4 in each industry/occupation combination and sum these to arrive at a total estimate of the number of employees with potential exposure within the OES.

Table 2-5 below contains the relevant NAICS codes and the calculated average number of workers and ONUs identified per site for each OES.

Table 2-5. NAICS Code Crosswalk and Number of Workers and ONUs for Each OES

OES	Relevant NAICS Codes	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
Manufacturing	325199 All Other Basic Organic Chemical Manufacturing 325180 Other Basic Inorganic Chemical Manufacturing	31	15
Import and Repackaging	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)	0.4	0.8
Processing as a reactant	325998 All Other Miscellaneous Chemical Product and Preparation Manufacturing 325199 All Other Basic Organic Chemical Manufacturing 325180 Other Basic Inorganic Chemical Manufacturing 325211 Plastics Material and Resin Manufacturing	23	13
Formulation of adhesives	325520 Adhesive Manufacturing	4	9
Rubber compounding	326211 Tire Manufacturing (except Retreading) 326212 Tire Retreading 326220 Rubber and Plastics Hoses and Belting Manufacturing 326291 Rubber Product Manufacturing for Mechanical Use 326299 All Other Rubber Product Manufacturing	41	13
Rubber converting	326211 Tire Manufacturing (except Retreading) 326212 Tire Retreading 326220 Rubber and Plastics Hoses and Belting Manufacturing 326291 Rubber Product Manufacturing for Mechanical Use 326299 All Other Rubber Product Manufacturing	41	13
Formulation of paints and coatings	325510 Paint and Coating Manufacturing 325520 Adhesive Manufacturing	9	8
Formulation of products containing greater than residual D4	325199 All Other Basic Organic Chemical Manufacturing 325180 Other Basic Inorganic Chemical Manufacturing 325998 All Other Miscellaneous Chemical Product and Preparation Manufacturing	25	12

OES	Relevant NAICS Codes	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
Formulation of products containing residual D4	325199 All Other Basic Organic Chemical Manufacturing 325180 Other Basic Inorganic Chemical Manufacturing 325998 All Other Miscellaneous Chemical Product and Preparation Manufacturing	25	12
Use of adhesives	334111 Electronic Computer Manufacturing 334112 Computer Storage Device Manufacturing 334118 Computer Terminal and Other Computer Peripheral Equipment Manufacturing 334210 Telephone Apparatus Manufacturing 334220 Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing 334290 Other Communications Equipment Manufacturing 334310 Audio and Video Equipment Manufacturing 334412 Bare Printed Circuit Board Manufacturing 334413 Semiconductor and Related Device Manufacturing 334416 Capacitor, Resistor, Coil, Transformer, and Other Inductor Manufacturing 334417 Electronic Connector Manufacturing 334418 Printed Circuit Assembly (Electronic Assembly) Manufacturing 334419 Other Electronic Component Manufacturing 334510 Navigational, Measuring, Electromedical, and Control Instruments Manufacturing 334511 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing 334512 Automatic Environmental Control Manufacturing for Residential, Commercial, and Appliance Use 334513 Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables 334514 Totalizing Fluid Meter and Counting Device Manufacturing 334515 Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals 334516 Analytical Laboratory Instrument Manufacturing 334517 Irradiation Apparatus Manufacturing 334519 Other Measuring and Controlling Device Manufacturing 334610 Manufacturing and Reproducing Magnetic and Optical Media	14	17

OES	Relevant NAICS Codes	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
	335131 Residential Electric Lighting Fixture Manufacturing 335132 Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing 335139 Electric Lamp Bulb and Other Lighting Equipment Manufacturing 335210 Small Electrical Appliance Manufacturing 335220 Major Household Appliance Manufacturing 335311 Power, Distribution, and Specialty Transformer Manufacturing 335312 Motor and Generator Manufacturing 335313 Switchgear and Switchboard Apparatus Manufacturing 335314 Relay and Industrial Control Manufacturing 335910 Battery Manufacturing 335921 Fiber Optic Cable Manufacturing 335929 Other Communication and Energy Wire Manufacturing 335931 Current-Carrying Wiring Device Manufacturing 335932 Noncurrent-Carrying Wiring Device Manufacturing 335991 Carbon and Graphite Product Manufacturing 335999 All Other Miscellaneous Electrical Equipment and Component Manufacturing 336991 Motorcycle, Bicycle, and Parts Manufacturing	14	17
Use of paints and coatings	238320 Painting and Wall Covering Contractors 238330 Flooring Contractors 238160 Roofing Contractors	1	1
Use of solvents	336411 Aircraft Manufacturing 336412 Aircraft Engine and Engine Parts Manufacturing 488190 Other Support Activities for Air Transportation	189	37
Use of automotive care products	811111 General Automotive Repair 811121 Automotive Body, Paint, and Interior Repair and Maintenance 811191 Automotive Oil Change and Lubrication Shops 811192 Car Washes 811198 All Other Automotive Repair and Maintenance	2	0.5
Use of animal grooming product	812910 Pet Care (except Veterinary) Services	0.03	0.2
Use of D4 as a laboratory chemical	541380 Testing Laboratories and Services 541714 Research and Development in Biotechnology (except Nanobiotechnology)	0.5	2

OES		Relevant NAICS Codes	Exposed Workers per Site[a]	Exposed ONUs per Site[a]
Use of residual D4-containing products	Fabric finishing	313210 Broadwoven Fabric Mills 313220 Narrow Fabric Mills and Schiffli Machine Embroidery 313230 Nonwoven Fabric Mills 313240 Knit Fabric Mills 313310 Textile and Fabric Finishing Mills 313320 Fabric Coating Mills 314910 Textile Bag and Canvas Mills 314994 Rope, Cordage, Twine, Tire Cord, and Tire Fabric Mills 314999 All Other Miscellaneous Textile Product Mills	20	5
	Cleaning products	561720 Janitorial Services 561790 Other Services to Buildings and Dwellings 811310 Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance 811412 Appliance Repair and Maintenance	2	0
	Laundry products – industrial	812331 Linen Supply 812332 Industrial Launderers	3	0
	Laundry products – institutional	622110 General Medical and Surgical Hospitals 622210 Psychiatric and Substance Abuse Hospitals 622310 Specialty (except Psychiatric and Substance Abuse) Hospitals 721110 Hotels (except Casino Hotels) and Motels 721120 Casino Hotels	42	2

2.7.2 Summary of Number of Workers and ONUs

Table 2-6 summarizes the number of facilities and total number of exposed workers for all OESs. For scenarios in which the results are expressed as a range, the low end of the range is based on the 50th percentile estimate of the number of sites and the upper end of the range is based on the 95th percentile estimate of the number of sites. For some OESs, the estimated number of facilities is based on the number of reporting sites to the 2020 CDR (U.S. EPA, 2020b), NEI (U.S. EPA, 2023a), DMR (U.S. EPA, 2024a), and TRI databases (U.S. EPA, 2024b).

Table 2-6. Summary of Total Number of Workers and ONUs Potentially Exposed to D4 for Each OES

OES	Total Exposed Workers	Total Exposed ONUs	Number of Facilities	Notes
Manufacturing	92	46	3	NAICS codes correspond to those stated in 2020 CDR with reporters for manufacturing D4. Total of three sites assessed per the OES release assessment.
Import and repackaging	2–4	4–7	5–9	NAICS codes correspond to those presented in the Repackaging GS. Number of sites distribution comes from the OES release assessment.
Processing as a reactant	580–719	319–396	25–31	NAICS codes correspond to those represented in 2020 CDR expected to fall under this OES. Number of sites distribution comes from the OES release assessment.
Formulation of adhesives	94–136	199–290	22–32	NAICS code corresponds to the one stated in the Adhesive Formulation ESD. Number of sites distribution comes from the OES release assessment.
Rubber compounding	1,441–2,511	449–782	35–61	NAICS codes correspond to those stated in 2020 CDR. Number of sites distribution comes from the OES release assessment.
Rubber converting	117,922–342,652	36,737–106,748	2,865–8,325	NAICS codes correspond to those stated in 2020 CDR. Number of sites distribution comes from the OES release assessment.
Formulation of paints and coatings	321–1,530	278–1,327	35–167	NAICS codes corresponds to the ones stated in 2020 CDR expected to fall under this OES, the Formulation of Adhesives ESD, and Formulation of Waterborne Coatings GS. Number of sites distribution comes from the OES release assessment.
Formulation of products containing greater than residual D4	1,085–2,096	542–1,046	1,085–2,096	NAICS codes corresponds to the ones stated in 2020 CDR expected to fall under this OES. Number of sites distribution comes from the OES release assessment.
Formulation of products containing residual D4	24,462–17,582	8,777–12,211	17,582–24,462	NAICS codes corresponds to the ones stated in 2020 CDR expected to fall under this OES. Number of sites distribution comes from the OES release assessment.
Use of adhesives	13,720–41,023	17,379–51,963	997–2,981	Adhesive end-use products are intended for industries in the 334, 335, and 336 series of NAICS codes

OES		Total Exposed Workers	Total Exposed ONUs	Number of Facilities	Notes
					that corresponds to computer/electronic products and motor/non-motor vehicle products based on product technical data sheets and Use of Adhesives ESD. Number of sites distribution comes from the OES release assessment.
Use of paints and coatings		13,818–136,524	7,730–76,373	11,373–112,371	NAICS codes correspond to those that align with information from available product information. Number of sites distribution comes from the OES release assessment.
Use of solvents		5,050,973–9,863,376	998,411–1,949,664	26,541–52,217	NAICS codes correspond to those that align with information from available product information. Number of sites distribution comes from the OES release assessment.
Use of automotive care products		233,477	75,353	147,152	NAICS codes correspond to the ones stated in the Auto Detailing MRD. The number of sites ranged from 1,558–147,152 sites with the central tendency at 147,152 sites based on the corresponding release assessment.
Use of animal grooming product		869	6,152	28,932	NAICS code correspond to the one assessed in the corresponding release assessment. A static number of sites was assessed at 28,932 sites.
Use of D4 as a laboratory chemical		148 - 471	770 - 2,453	312–994	NAICS codes correspond to those stated in the Laboratory Chemicals GS. The number of sites distribution comes from the corresponding release assessment.
Use of residual D4-containing products	Fabric finishing	222,421–807,487	59,761–216,959	10,886–39,521	NAICS codes correspond to those stated in the release assessment that were assessed for the maximum number of sites for this OES.
	Cleaning products	60,984–164,411	184–497	39,223–105,745	NAICS codes correspond to those stated in the release assessment that were assessed for the maximum number of sites for this OES.
	Laundry products – industrial	38,984	41	11,749	NAICS codes correspond to those stated in the release assessment that were assessed for the maximum number of sites for this OES. The number of sites ranged from 252–11,749 sites with the central tendency at 11,749 sites based on the corresponding release assessment.
	Laundry products – institutional	14,719,752–17,243,234	530,235–621,136	347,86–407,479	NAICS codes correspond to those stated in the release assessment that were assessed for the maximum number of sites for this OES.

<table>
<tr><th>OES</th><th>Total Exposed Workers</th><th>Total Exposed ONUs</th><th>Number of Facilities</th><th>Notes</th></tr>
<tr><td colspan="5">When the number of facilities was estimated from Monte Carlo simulation, the 50th percentile was the CT and 95th percentile was the HE. The number of workers and ONUs were obtained by multiplying the workers and ONUs for relevant NAICS codes with the number of facilities estimates (CT and HE for ranges).</td></tr>
</table>

3 ENVIRONMENTAL RELEASE AND OCCUPATIONAL EXPOSURE ASSESSMENTS BY OCCUPATIONAL EXPOSURE SCENARIO

3.1 Manufacturing

3.1.1 Process Description

The overall process of manufacturing D4 starts with the reduction of quartz to silicon, followed by the reaction of silicon metal with methyl chloride to produce chlorosilanes. The hydrolysis of chlorosilanes, and the condensation of siloxanes to produce oligomers and polymers summarize the process route for producing siloxane compounds. The silanol condensate is further processed, split, or distilled into linear or cyclic siloxanes, such as D4 (SEHSC, 2020). Figure 3-1 provides an illustration of the process.

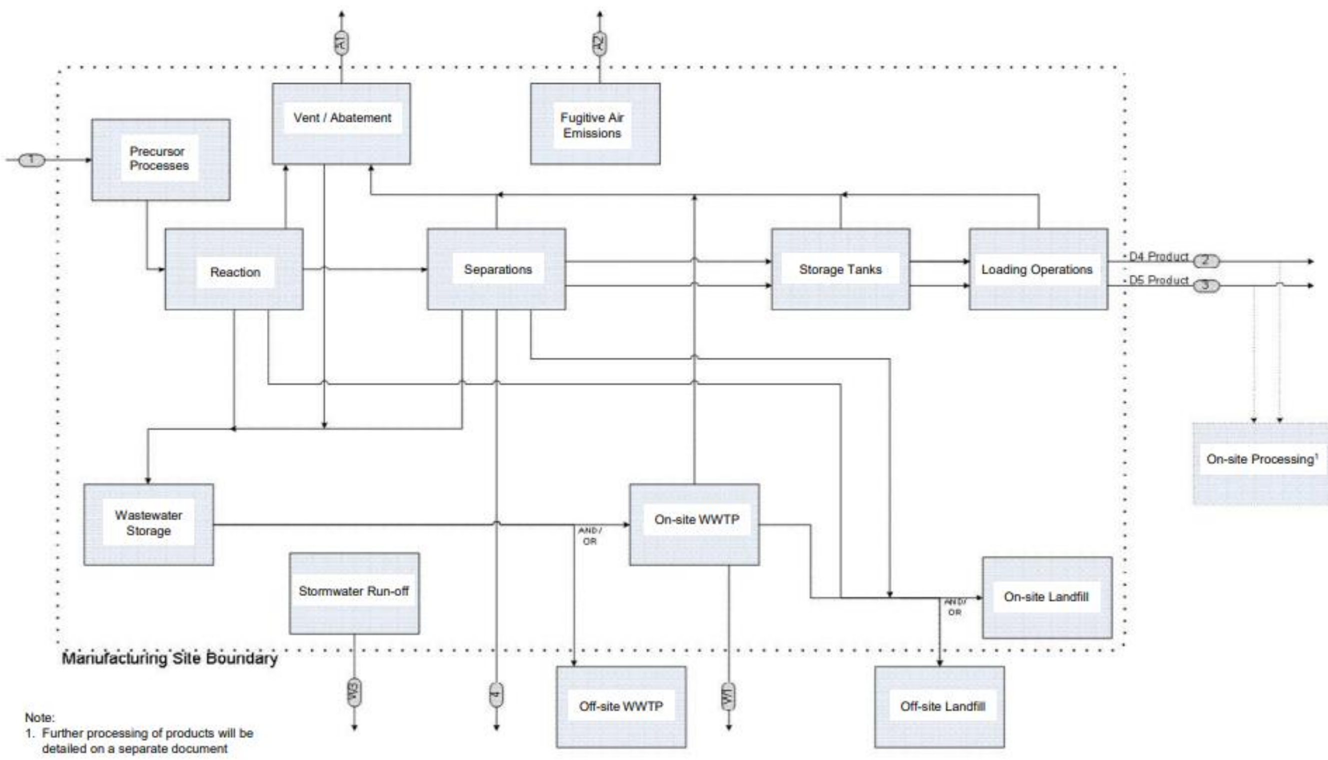

Figure 3-1. D4 Manufacturing Flow Diagram from SEHSC (ERM, 2012)

3.1.2 Facility Estimates

In the 2020 CDR, the reported national aggregate production volume is listed as 250,000,000 to 500,000,000 lb per year. There are assumed to be five domestic manufacturers of D4 (three companies reported manufacture and two reported CBI as activity). Of these five sites, two provided PV information. These two sites are both operated by Momentive Performance Materials; one site located in West Virginia reported a 2019 PV of 6,330 lb and the other site in New York provided a 2019 PV of 100,872,580 lb (U.S. EPA, 2020a). An estimate of PV for the other sites are calculated by taking the difference of the upper bound of the total non-CBI CDR PV range (500,000,000 lb) by the sum of the known PVs reported for manufacture and import (121,806,598 lb). This difference is divided by the number of sites whose actual PVs are claimed CBI to produce a high-end estimate of average PV per site as is further explained below.

2019 CDR reported import volumes:

- BRB North America, Inc.: 513,199 lb
- Shin Etsu Silicones of America: 16,000,000 lb
- Momentive Performance Materials: 4,414,489 lb
- Total: 20,927,688 lb

2019 CDR reported manufacturing volumes:

- BRB North America, Inc.: 0 lb
- Shin Etsu Silicones of America: 0 lb
- Momentive Performance Materials: 100,878,910 lb

Based on the 2019 CDR, up to an additional two sites were listed as CBI for site activity. These sites are Elkem Silicones USA Corporation and Wacker Chemical Corporation, both of which are listed as formulator or processor in the D4 Conceptual Site Model published by ERM in 2012 (ERM, 2012). In the consortium provided data, however, both Elkem Silicones and Wacker Chemical Corporation stated that they manufacture D4. It is assumed that these two companies likely manufactured D4 themselves and processed it (as a reactant or incorporate into formulation) for their downstream products. An additional reporter, Dow Chemical, states that they manufacture D4 but listed their PV as CBI.

This gives a total CDR reported import and manufacture of D4 of 121,806,598 lb for 2019. Subtracting that from the upper bound of 500,000,000 lb yields 378,193,402 lb that could be either imported or manufactured at eight sites. This ultimately yields 47,274,402 lb that could be manufactured or imported per site. Based on this, EPA modeled two PV scenarios for the manufacture of D4:

1. One site using the Momentive 2019 CDR reported a PV of 100,878,910 lb
2. One generic/unknown site using a PV of 47,274,402 lb

EPA did not identify any data on site-specific throughputs. The D4 Consortium provided data on the manufacturing process but did not include more specific data due to privacy concerns (ERM, 2012). EPA assumes the manufacturing plants run for 350 days per year.

3.1.3 Release Assessment

3.1.3.1 Environmental Release Points

EPA used the SEHSC CSM submission in conjunction with EPA models to identify and estimate the release points for this OES (ERM, 2012). The expected process steps, media of release, and methodology of assessment are listed below.

1. Vented losses to air during reaction/separations/other process operations – Stack air – ESD on the Chemical Industry Emission Factors
2. Product sampling wastes – Wastewater to on-site treatment or discharge to POTW (with or without pretreatment); waste disposal – EPA's 2023 Methodology for Estimating Environmental Releases from Sampling Waste
3. Open surface losses to air during product sampling – Fugitive air – Combination of EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
4. Equipment cleaning releases – Wastewater to on-site treatment or discharge to POTW (with or without pretreatment); waste disposal – EPA/OPPT Multiple Process Vessel Residual Model
5. Open surface losses to air during equipment cleaning – Fugitive air – Combination of EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model

6. Transfer operation losses to air from packaging manufactured D4 into transport containers – Fugitive air – EPA/OAQPS AP-42 Loading Model

3.1.3.2 Environmental Release Assessment Results

Table 3-1 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Manufacturing OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-1. Summary of Modeled Environmental Releases for the Manufacturing of D4

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days[d]		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
PV of 100,878,910 lb (Momentive site, CDR value)	Fugitive air	7.1E01	7.7E02	189	345	3.8E−01	2.2
	Stack air	1.0E05	1.0E05	350	350	2.9E02	2.9E02
	Wastewater to on-site treatment or discharge to POTW[c]	1.0E04	1.0E04	350	350	3.0E01	3.0E01
	Waste disposal (incineration or landfill)[a]	8.8E03	2.0E04	350	350	2.5E01	5.7E01
PV of 47,274,402 lb (Unknown site)	Fugitive air	7.4E01	1.6E02	179	237	4.1E−01	6.8E−01
	Stack air	4.7E04	4.7E04	350	350	1.3E02	1.3E02
	Wastewater to on-site treatment or discharge to POTW[c]	4.9E03	4.9E03	350	350	1.4E01	1.4E01
	Waste disposal (incineration or landfill)[a]	4.1E03	9.4E03	350	350	1.2E01	2.7E01

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days[d]		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End

[a] When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.
[b] The Monte Carlo simulation calculated the total D4 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.
[c] Water release days may not be the same number of days that waste is generated (*e.g.*, quarterly equipment cleaning).
[d] The number of release days presented here is the division of annual releases by daily releases. The number of release days may fall outside of the distribution because waste generation activities may not all occur daily (*e.g.*, quarterly equipment cleaning) or may only occur during certain process activities (*e.g.*, fugitive air releases during container loading). In some cases, release activities are expected to occur continuously throughout the year and use a static number of release days for both the high-end and central tendency, in other cases the lower number of release days corresponds to a larger daily release.

3.1.4 Occupational Exposure Assessment

3.1.4.1 Worker Activities

During manufacturing, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES. The available data does not provide sufficient information about PPE use to determine what degree of PPE is typical for each OES.

SEHSC submitted monitoring data that provided information from D4 manufacturing and processing facilities. Included in this data were “Administrative (ONU)” employees; it was further stated that this group of employees could be exposed to D4 by both the inhalation and dermal routes during activities such as “inspecting/observing” (SEHSC, 2019). EPA generally defines ONUs to include employees (*e.g.*, supervisors, managers) who work at the facility but do not directly handle the chemical of interest. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly

3.1.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites. Specifically, 17 PBZ monitoring datapoints for “chemical operators” as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for “Administrative” as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-2 below are the inhalation exposure estimates for the manufacture of D4. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor. The central tendency and high-end exposures use 250 days per year as the exposure frequency, which is the expected maximum for working days.

Table 3-2. Summary of Estimated Inhalation Exposures for Manufacture of D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-hr TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Manufacturing	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		1.4E−01	
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	1.4	4.5
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	1.1E−01	2.2E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	2.3E−01	2.4
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	7.3E−02	7.3E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	2.4E−01	3.8
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	5.3E−01	1.2
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	1.3E−01	1.3

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.1.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-3 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-3. Summary of Estimated Dermal Exposures for the Manufacturing of D4

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Manufacturing	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	6.4	1.9E01
	ONU	7.5E02		9.4		6.9		6.4	

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2)(U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.2 Processing – Repackaging

3.2.1 Process Description

In the 2020 CDR, Dow Chemical Corporation reported Processing – repackaging of D4 (U.S. EPA, 2020a). A typical repackaging site first stores the imported chemical in warehouses until orders for the chemical are received, then the chemical product is loaded into smaller containers. Quality control sampling of the D4 product may also occur at the repackaging site. After repackaging, empty containers will be cleaned, disposed of, or reconditioned for reuse and the smaller containers containing the chemical product will be shipped offsite for downstream processing or use. No changes to chemical composition are expected to occur during repackaging (U.S. EPA, 2022a). Figure 3-2 provides an illustration of the repackaging process.

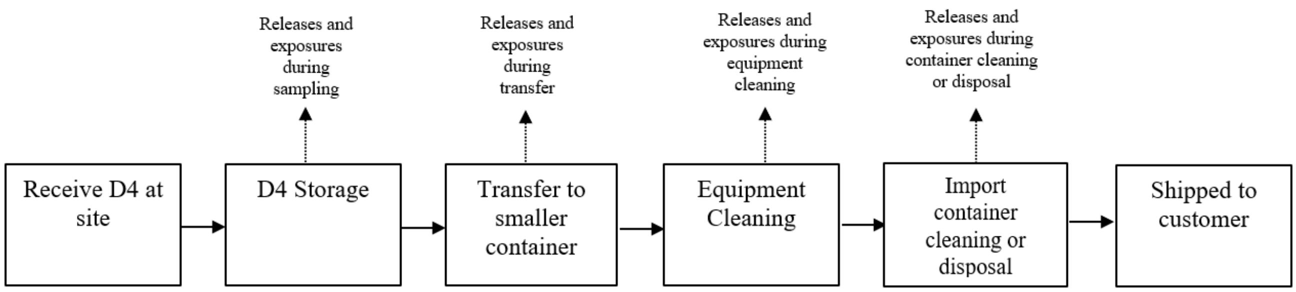

Figure 3-2. D4 Repackaging Flow Diagram

3.2.2 Facility Estimates

The 2020 CDR data included two reporters, the Dow Chemical Corporation in Carrollton, KY and Midland, MI, that reported Processing – repackaging (U.S. EPA, 2020a). The Midland, MI site reported the industrial sector of all other basic inorganic chemical manufacturing with the industrial function of intermediate and the industrial sector of other as a solvent in personal care product manufacturing, and further reports up to 9 sites. The Carrolton, KY site reported the industrial sector of all other chemical product and preparation manufacturing as a solvent. Because the Carrolton, KY site lists its activity as import but also states that the chemical is never present there, EPA assumes that this activity could occur at up to nine sites as listed on the 2020 CDR (U.S. EPA, 2020a). Based on the throughput calculations in Section 3.12, the assumed throughput for this OES is 47,274,402 lb.

EPA did not identify site-specific data regarding the repackaging D4. Based on the high production volume, EPA expects that D4 will be imported in larger bulk containers rather than drums or smaller containers. EPA assumes that D4 arrives to the repackaging facility in either rail cars (10,000–20,000 gallons) or tanker trucks (1,000–10,000 gallons) and is repackaged into totes (100–1,000 gallons). The Agency further assumes that this process will occur over 250 days a year.

EPA modeled environmental releases and occupational exposures for this scenario as a conservative estimate. The results of the Monte Carlo simulation provide a high-end estimate of 21,443,205 kg per site being repackaged at one site and a central tendency of 4,288,641 kg per site being repackaged at five sites.

3.2.3 Release Assessment

3.2.3.1 Environmental Release Points

EPA used input parameters using data from literature and the GS on Chemical Repackaging (U.S. EPA, 2022a) to identify and estimate the release points for this OES. The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operation losses to air from unloading D4 – Fugitive air – Chemical Loading Exposure Model
2. Sampling wastes – Incineration or landfill – EPA's 2023 Methodology for Estimating Environmental Releases from Sampling Waste
3. Open surface losses to air during product sampling – Fugitive air – Combination of EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
4. Import container residue – Wastewater to on-site treatment or discharge to POTW (with or without pretreatment) – EPA/OPPT Bulk Transport Residual Model
5. Open surface losses to air during container cleaning – Fugitive air – Combination of EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
6. Equipment cleaning releases – Wastewater to on-site treatment or discharge to POTW (with or without pretreatment) – EPA/OPPT Multiple Process Vessel Residual Model
7. Open surface losses to air during equipment cleaning – Fugitive air – Combination of EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
8. Transfer operation losses to air during loading of D4 – Fugitive air – EPA/OAQPS AP-42 Loading Model

3.2.3.2 Environmental Release Assessment Results

Table 3-4 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Repackaging OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-4. Summary of Modeled Environmental Releases for the Repackaging of D4

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
PV of 21,443,205 kg/yr	Fugitive air	7.7E01	3.8E02	208	190	5.7E−01	2.0
	Wastewater to on-site treatment or discharge to POTW[c]	5.8E03	2.9E04	250	250	2.3E01	1.2E02

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day) [b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	Waste disposal (incineration or landfill)[a]	8.8E02	4.8E03	208	208	4.2	2.3E01

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

[b] The Monte Carlo simulation calculated the total D4 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.

[c] Water release days may not be the same number of days that waste is generated (*e.g.*, quarterly equipment cleaning).

3.2.4 Occupational Exposure Assessment

3.2.4.1 Worker Activities

During repackaging, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES. The available data does not provide sufficient information about PPE use to determine what degree of PPE is typical for each OES. ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly.

3.2.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites (SEHSC, 2019). Specifically, 17 PBZ monitoring datapoints for “chemical operators” as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for “Administrative” as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-5 below are the inhalation exposure estimates for the repackaging of D4. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor. The central tendency and high-end exposures use 235 and 250 days per year, respectively, as the exposure frequency, which is the expected maximum for working days

Table 3-5. Summary of Estimated Inhalation Exposures for Repackaging of D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-hr TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Repackaging	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		1.3E−01	
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	1.3	4.5
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	1.1E−01	2.2E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	2.2E−01	2.4
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	6.9E−02	7.3E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	2.2E−01	3.8
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	5.0E−01	1.2
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	1.2E−01	1.3

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.2.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-6 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-6. Summary of Estimated Dermal Exposures for the Repackaging of D4

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Repackaging	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	6.0	1.9E01
	ONU	7.5E02		9.4		6.9		6.0	

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.3 Processing – As a Reactant

3.3.1 Process Description

The primary use of D4 is as a monomer and/or intermediate in the production of silicone polymers. One of the most prominent of these is PDMS, however, these polymers can also contain a wide range of reactive functional groups such as amines, silane, or vinyl depending on the anticipated end use. This process occurs by feeding raw material, including D4 into a reactor in the presence of a catalyst where an equilibrium reaction occurs thus producing the desired product along with excess D4. The next stage involves separating the D4 from the desired product, the excess D4 from the separation stage is typically recycled back into the raw material stream and fed back into the reactor (SEHSC, 2020). Figure 3-3 and Figure 3-4 below illustrate a typical processing facility with or without on-site WWTP treatment, respectively.

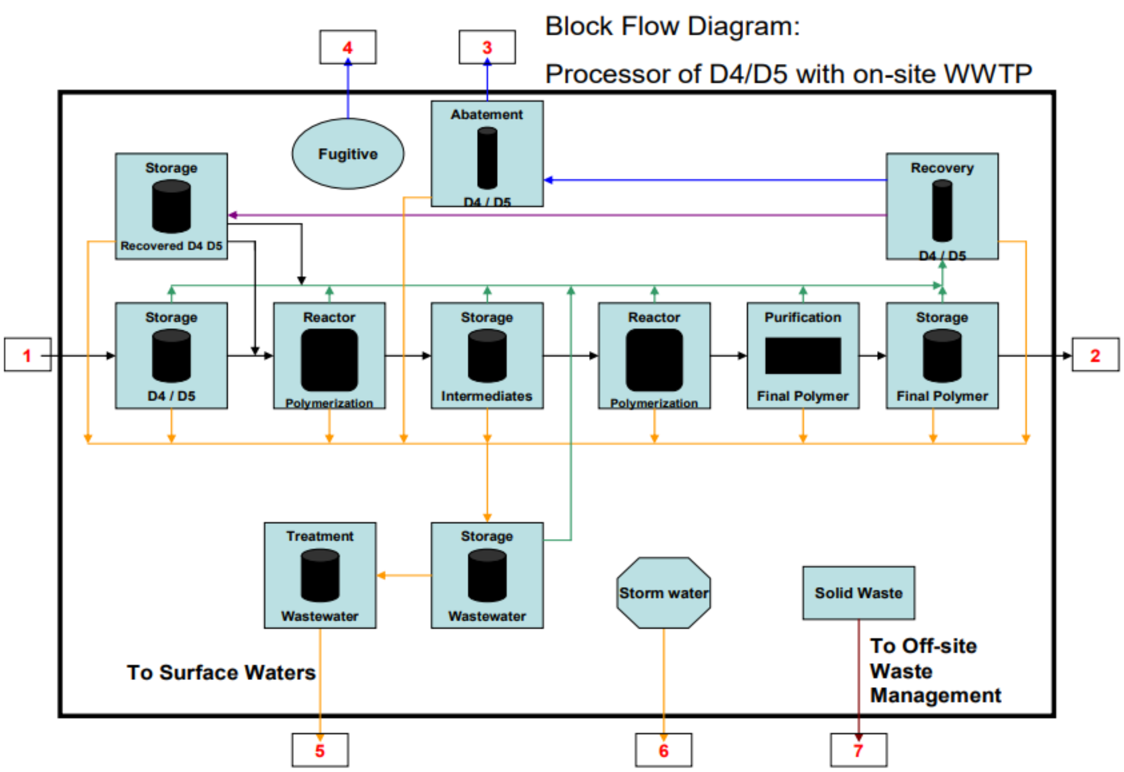

Figure 3-3. D4 Processing as a Reactant Flow Diagram (With On-Site WWTP) (ERM, 2012)

The numbers correspond to release points listed in Section 3.3.3.1.

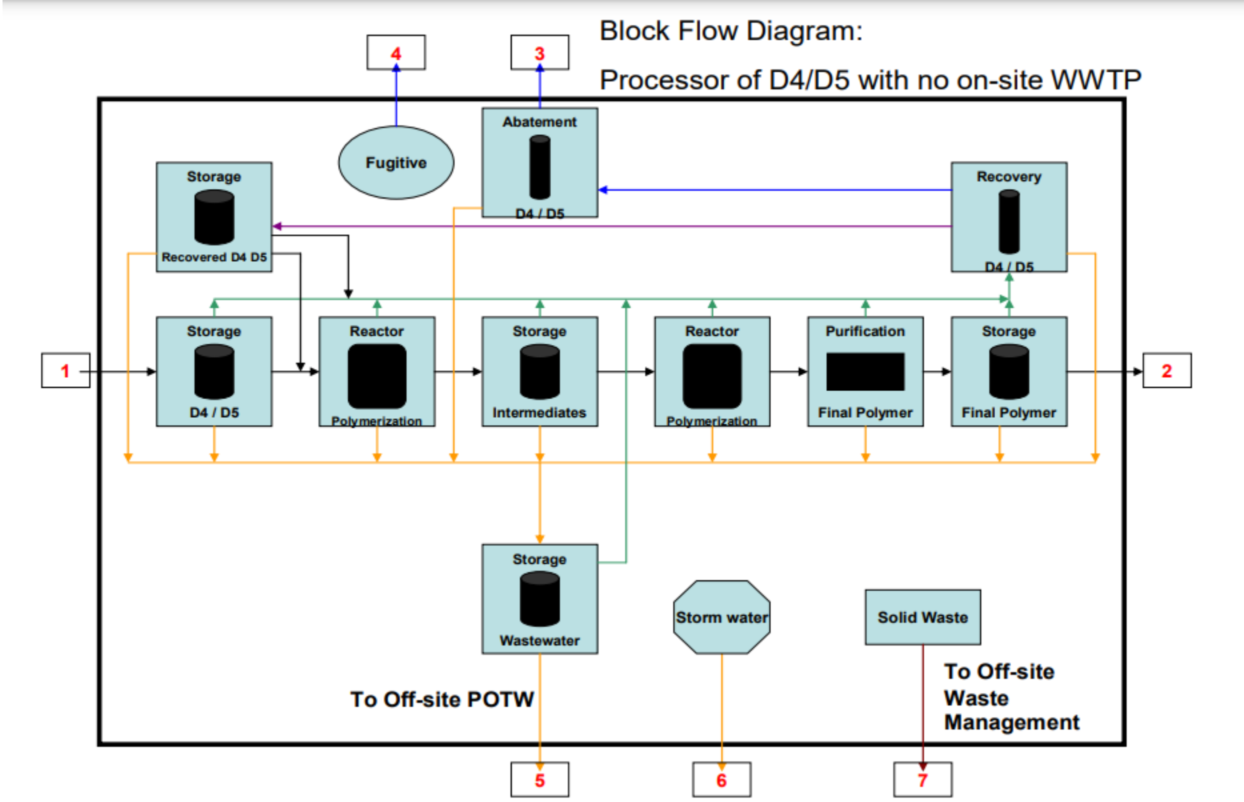

Figure 3-4. D4 Processing as a Reactant Flow Diagram (Without On-Site WWTP) (ERM, 2012)
The numbers correspond to release points listed in Section 3.3.3.1.

3.3.2 Facility Estimates

The 2020 CDR reported that there could be 80 or more sites that processes D4 as a reactant, while the CSM states six companies operating nine sites. Based on a deeper look into the CDR data and CSM, EPA used a uniform distribution based on the number of sites ranging from 18 to 32. This assumes that the sites which report to CDR in the less than ten sites range can be characterized by their corresponding number of D4 processing facilities outlined in the CSM:

- Evonik Corporation has between 10 to 24 sites based on CDR reported range;
- Momentive Performance Materials has two sites based on the CDR range (<10 sites) and the two sites listed in Attachment 3 of the CSM;
- Shin-Etsu Silicones of America has one site based on the CDR range (<10 sites) and the one site listed in Attachment 3 of the CSM;
- Dow Corning Corporation has three sites based on the CDR range (<10 sites) and the three sites listed in Attachment 3 of the CSM;
- Bluestar Silicones USA Corporation has one site based on the CDR range (<10 sites) and the one site listed in Attachment 3 of the CSM; and
- Wacker Chemical Corporation has one site based on the CDR range (<10 sites) and the one site listed in Attachment 3 of the CSM.

The CSM provided a PV throughput estimate of 67,268,603 lb per year average throughput per site which processes D4 as a reactant. This site throughput would greatly exceed the upper bound of the national aggregate PV range reported in CDR for D4 of 250,000,000 to 500,000,000 lb per year when multiplied by the number of sites.

To estimate the PV for this site EPA applied an 80/20 split that assumes that 80 percent of the upper bound of the national aggregate PV for D4 is processed as a reactant, or 400,000,000 lb per year (181,436,948 kg/year) (Dow Chemical, 1998; Dow Corning, 1986; Silicones Health Co., 1986). The annual throughput per site was estimated as 9,702,511 kg/site-year (95th percentile) and 7,257,478 kg/site-year (50th percentile) for between 18 to 32 sites. EPA further assumes that the final products from this OES could contain up to 3 percent of unreacted D4, though this could be much lower depending on the anticipated end use of these products (SEHSC, 2020).

3.3.3 Release Assessment

3.3.3.1 Environmental Release Points

The D4 Consortium (SEHSC) provided numerical release results for a generic processing facility based on the data provided from its members in their CSM. This data was based on the media of release and did not provide insight to releases that could occur during activities that could be part of the overall process. Where able, EPA used the loss fractions provided by SEHSC for certain activities (release points 3 and 5 below) and modeled other activities that are reasonably expected to occur. These steps are based on Figure 3-3 and Figure 3-4 presented in Section 3.3.1. The expected process steps, media of release, and methodology of assessment are listed below.

1. Unloading losses to air from feedstock D4 transport containers – Fugitive air – EPA/OAQPS AP-42 Loading Model
2. Transport container cleaning after unloading – Water – EPA/OPPT Bulk Transport Residual Model
3. Vented losses during reaction/separations/other process operations – Stack air – CSM (ERM, 2012)
4. Fugitive air losses during processing – Fugitive air – ESD on the Chemical Industry Emission Factors
5. Process waste from reaction/separations/other process operations to water, incineration, or landfill – Wastewater on- or off-site treatment, and solid waste disposal – CSM (ERM, 2012)
6. Product sampling wastes disposed to water, incineration, or landfill – Solid waste disposal – EPA's 2023 Methodology for Estimating Environmental Releases from Sampling Waste
7. Open surface losses to air during product sampling – Fugitive air – Combination of EPA/OPPT Mass Transfer Coefficient Model and EPA/OPPT Penetration Model
8. Equipment cleaning releases to air, water, incineration, or landfill – Wastewater on- or off-site treatment – EPA/OPPT Multiple Process Vessel Residual Model
9. Open surface losses to air during equipment cleaning – Fugitive air – Combination of EPA/OPPT Mass Transfer Coefficient Model and EPA/OPPT Penetration Model
10. Transfer operation losses to air from packaging manufactured siloxane product into transport containers – Fugitive air – EPA/OAQPS AP-42 Loading Model

3.3.3.2 Environmental Release Assessment Results

Table 3-7 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Processing as a Reactant OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-7. Summary of Modeled Environmental Releases for Processing as a Reactant

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
PV of 9,702,511 kg/site-year (95th percentile) and 7,257,478 kg/site-year (50th percentile)	Fugitive air	2.7E04	3.6E04	319	310	8.4E01	1.2E02
	Stack air	2.3E04	4.7E04	321	317	7.1E01	1.5E02
	Wastewater to on-site treatment or discharge to POTW[c]	9.0E03	1.6E04	350	350	2.6E01	4.5E01
	Surface water	7.1E01	1.5E02	321	316	2.2E−01	4.8E−01
	Waste disposal (incineration or landfill)[a]	4.1E04	8.7E04	320	316	1.3E02	2.8E02

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

[b] The Monte Carlo simulation calculated the total D4 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.

[c] Water release days may not be the same number of days that waste is generated (*e.g.*, quarterly equipment cleaning)

3.3.4 Occupational Exposure Assessment

3.3.4.1 Worker Activities

During processing as a reactant, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES. The available data does not provide sufficient information about PPE use to determine what degree of PPE is typical for each OES. ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 250 days per year as the exposure frequency, which is the expected maximum for working days.

3.3.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites (SEHSC, 2019), as well as literature sources for a polymer plant operator (Dow Chemical, 1998;

Dow Corning, 1989, 1977) and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-8 below are the inhalation exposure estimates for processing D4 as a reactant. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor.

Table 3-8. Summary of Estimated Inhalation Exposures for Processing as a Reactant

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m³)		Acute Concentration (AC; mg/m³)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m³)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m³)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Processing as a reactant	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		1.4E−01	
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	1.4	4.5
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	1.1E−01	2.2E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	2.3E−01	2.4
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	7.3E−02	7.3E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	2.4E−01	3.8
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	5.3E−01	1.2
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	1.3E−01	1.3
	Operators at polymer plants	8-hr	3.24	1.64E01	2.2	11.15	1.6	8.17	1.5	7.63

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.3.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-9 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-9. Summary of Estimated Dermal Exposures for Processing as a Reactant

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Processing as a reactant	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	6.4	1.9E01
	ONU	7.5E02		9.4		6.9		6.4	

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.4 Processing – Formulation of Adhesives and Sealants

3.4.1 Process Description

The formulation of adhesives and sealants OES could refer to several types of products, such as building/construction products (*e.g.*, caulks) and electronic potting agents. Potting agents are identified by SEHSC as a common use of D4, they are used to fill cavities of an electronic substrate and to seal, or encapsulate, electronics to protect them from moisture (SEHSC, 2020). EPA used the ESD on the Formulation of Adhesives and Sealants to model this OES (OECD, 2009a). The identified industrial and commercial adhesive and sealant products for this OES include polymer sealants and industrial and commercial adhesives (see Appendix F for all EPA identified D4-containing products for this OES). Based on the 2009 ESD on the Manufacture of Adhesives (OECD, 2009a), a typical adhesive incorporation site receives and unloads D4, or polymer mixtures containing D4, into industrial mixing vessels as a batch blending or mixing process, no reactions or chemical changes are expected to occur to the D4 or D4-containing polymers during the mixing process (OECD, 2009a). Figure 3-5 provides an illustration of the process.

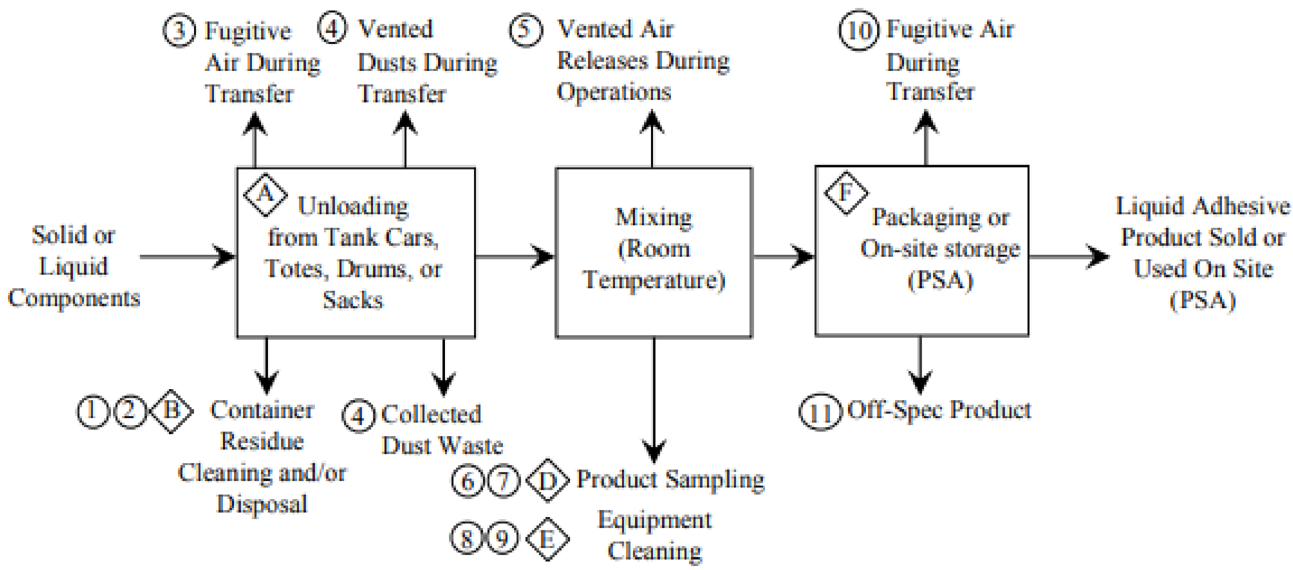

Figure 3-5. Formulation of Adhesives and Sealants Flow Diagram (OECD, 2009a)

3.4.2 Facility Estimates

The 2020 CDR had two reporters for the industrial function category of adhesives and sealants. One was processing as a reactant and the other was incorporation into formulation or reaction products. The 2020 CDR further provided a range of 11 to 33 sites (U.S. EPA, 2020a). BRB North America, Inc. and the Sherwin-Williams Company submitted CDR data for consumer/commercial categories related to caulks or adhesives. For industrial and processing categories, BRB North America, Inc. and Evonik Corporation submitted CDR data. BRB North America, Inc. denoted 14 percent of the PV (513,199 lb in 2019) went to adhesives and sealants, and the Sherwin-Williams Company and Evonik Corporation claimed PV as CBI. The Sherwin-Williams Company had 100 percent going to one-component caulks, and Evonik Corporation had 10 percent going to adhesives and sealant chemicals as the industrial function category. EPA further expects that this scenario could be applicable to industries such as electronic and semiconductor manufacturers that use electronic potting or encapsulating agents, which is a use indicated by the D4 Consortium (SEHSC, 2020). It is not clear how electronic potting or encapsulating agents would be reported to CDR, it is possible they are reported as part of a category separate from caulks or adhesives.

Given the uncertainty of site-specific data available in CDR, EPA used a PV estimate from Brooke et al. (2009) that amounts to 32 percent of the upper bound of the national aggregate D4 PV could be used for this OES. The underlying data used in that assessment consists of U.S. PV data and is therefore expected to be applicable for this risk evaluation. EPA is uncertain what raw materials are received at the processing site (*e.g.*, neat D4 or reacted polymer mixtures) and provides what-if scenarios to cover these possibilities of either neat D4 or polymer mixture(s) containing residual D4 being processed. D4 can be received as either neat (*i.e.* 100% concentration) from the import or repackaging of D4 OESs or residual (*i.e.*, 0.1–3.0% concentration) amounts in polymer mixtures from the Processing as a Reactant OES. The overall PV for the neat scenario is 32,000,000 lb (32% of 100,000,000 lb) and for the residual scenario is 128,000 to 3,840,000 lb of residual D4 left in the polymer mixtures after being processed as a reactant.

3.4.3 Release Assessment

3.4.3.1 Environmental Release Points

EPA used the ESD on the Formulation of Adhesives to estimate the release points for this OES (OECD, 2009a). The expected process steps, media of release, and methodology of assessment are listed below.

1. Container residue from adhesive component transport container – Water, incineration, or landfill – EPA/OPPT Bulk Transport Residual Model
2. Open surface losses of volatile chemicals to air during container cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
3. Transfer operation losses to air of volatile chemicals from unloading the adhesive component – Fugitive air – EPA/OAQPS AP-42 Loading Model
4. Dust losses vented to outside air from the transfer of a solid/powdered adhesive component into the process – Not assessed for liquid components
5. Vented losses of volatile chemicals to air during mixing operations – Stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
6. Product sampling wastes disposed to water, incineration or landfill (not quantified in this ESD) – Water, incineration, or landfill – Methodology review draft (MRD) on sampling waste release estimation
7. Open surface losses of volatile chemicals during product sampling – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
8. Equipment cleaning releases to water, incineration, or landfill – Water, incineration, or landfill – EPA/OPPT Multiple Process Vessel Residual Model
9. Open surface losses of volatile chemicals to air during equipment cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
10. Transfer operation losses of volatile chemicals to air from loading adhesive product into transport containers – Fugitive air – EPA/OAQPS AP-42 Loading Model
11. Off-spec adhesive product – Water, incineration, or landfill – Parameter from the ESD itself

3.4.3.2 Environmental Release Assessment Results

Table 3-10 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Formulation of Adhesives OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-10. Summary of Modeled Environmental Releases for Formulation of Adhesives and Sealants

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of adhesives and sealants (neat D4)	Fugitive air	5.8	1.4E01	47	39	1.3E−01	3.7E−01
	Stack air	1.8	7.0	49	110	3.8E−02	6.3E−02
	Water, incineration, or landfill[a]	2.1E04	3.7E04	44	34	4.7E02	1.1E03
Formulation of adhesives and sealants (residual D4)	Fugitive air	8.4E−01	2.5	5	6	1.6E−01	4.3E−01
	Stack air	3.0E−03	1.7E−02	5	11	6.5E−04	1.5E−03
	Water, incineration, or landfill[a]	1.6E03	3.7E03	5	5	3.6E02	7.9E02

[a] When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.
[b] The Monte Carlo simulation calculated the total D4 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.

3.4.4 Occupational Exposure Assessment

3.4.4.1 Worker Activities

During the formulation of adhesives and sealants, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES.(SEHSC, 2019). The available data does not provide sufficient information about PPE use to determine what degree of PPE is typical for each OES. ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. For neat D4 the central tendency and high-end exposures use 49 and 164 days per year, respectively, as the exposure frequency, which is the expected maximum for working days. For residual D4 the central tendency and high-end exposures use 1 and 15 days per year, respectively, as the exposure frequency, which is the expected maximum for working days.

3.4.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites (SEHSC, 2019). Specifically, 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-11 below are the inhalation exposure estimates for the formulation of D4 into adhesives and sealants. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor.

Table 3-11. Summary of Estimated Inhalation Exposures for Formulation of Adhesives and Sealants of D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m³)		Acute Concentration (AC; mg/m³)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m³)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m³)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of adhesives and sealants (neat D4)	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		2.8E−02	9.3E−02
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	2.7E−01	3.0
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	2.2E−02	1.4E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	4.6E−02	1.6
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	1.4E−02	4.8E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	4.7E−02	2.5
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	1.0E−01	8.2E−01
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	2.5E−02	8.6E−01
Formulation of adhesives and sealants (residual D4)	Administrative (ONU)	8-hr	3.0E−01	3.0E−01	2.1E−01	2.1E−01	6.9E−03	1.0E−01	5.7E−04	8.5E−03
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	6.6E−02	3.3	5.4E−03	2.7E−01
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	5.5E−03	1.6E01	4.5E−04	1.3
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	1.1E−02	1.7	9.3E−04	1.4E−01
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	3.6E−03	5.4E−02	2.9E−04	4.4E−03
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	1.2E−02	2.7	9.5E−04	2.3E−01
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	2.6E−02	9.1E−01	2.1E−03	7.5E−02
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	6.3E−03	9.6E−01	5.2E−04	7.9E−02

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.4.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-12 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-12. Summary of Estimated Dermal Exposures for the Formulation of Adhesives and Sealants

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of adhesives and sealants (neat D4)	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	1.3	1.3E01
	ONU	7.5E02		9.4		6.9		1.3	
Formulation of adhesives and sealants (residual D4)	Worker	2.2E01	6.7E01	2.8E−01	8.4E−01	9.4E−03	4.2E−01	7.7E−04	3.5E−02
	ONU	2.2E01		2.8E−01		9.4E−03		7.7E−04	
Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.									

3.5 Rubber Compounding

3.5.1 Process Description

Synthetic rubber manufacturing was reported to CDR in 2020 (U.S. EPA, 2020a). EPA further identified compounded rubber products that contain D4 at concentrations up to 5 percent (see Appendix F for product data). During the compounding process, D4 or D4-containing polymer mixtures are reacted to create high temperature vulcanizing (HTV) rubber masterbatch. This process is expected to consist of loading the raw materials into a reactor and/or mixer until it reaches the desired parameters. The rubber masterbatch is then packaged and shipped to a rubber converter to create a final product/article.

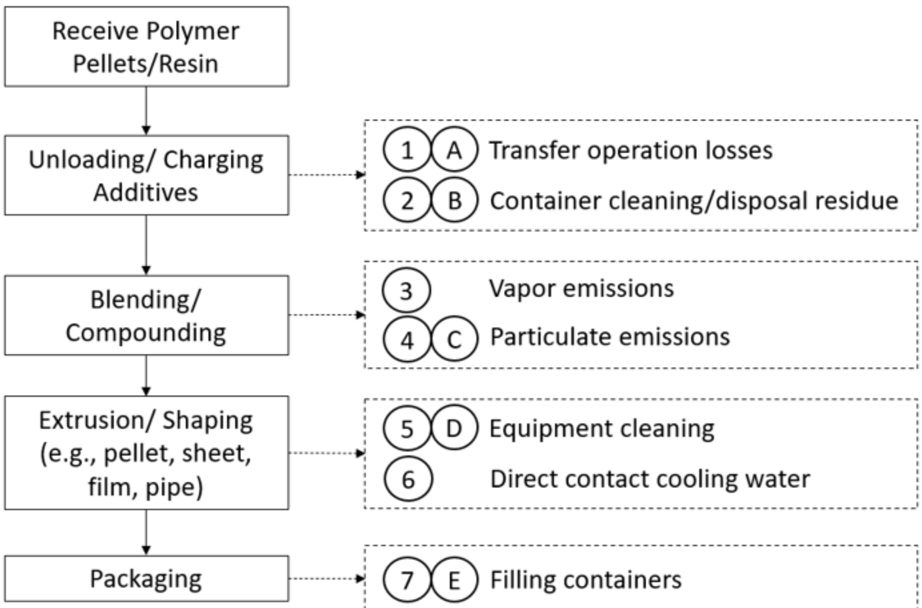

Figure 3-6. Rubber Compounding Flow Diagram (U.S. EPA, 2021b)

3.5.2 Facility Estimates

Brooke et al. (2009) reported that 21 percent of D4 is used for elastomers. This category was further broken down into the subcategories of use. EPA considers that the term “elastomer” is synonymous with rubber product manufacturing. Textile coatings and paints and coatings are included in the breakdown of subcategories of elastomers. These subcategories were removed since they are considered a part of other OESs. This leaves 18.1 percent of D4 national aggregate PV being used for rubber product manufacturing. EPA used neat D4 and residual D4, using a D4-containing polymer mixture from the processing as a reactant OES, scenarios for this OES.

EPA used the CDR reporters for synthetic rubber manufacturing and all other basic inorganic manufacturing to estimate the number of sites for this OES, these CDR reports indicated that D4 is used as an intermediate. BRB North America, Inc. and Shin-Etsu both reported between one to nine sites each for synthetic rubber manufacturing. Dow Chemical reported between 5 and 45 sites for all other basic inorganic chemical manufacturing. This provides a total range for the number of sites of between 7 and 63.

EPA is uncertain what raw materials are received at the processing site (*e.g.*, neat D4 or reacted polymer mixtures) and provides what-if scenarios to cover these possibilities. The results of the Monte Carlo simulation provided throughput values for the residual scenario of 62,973 kg/site-yr at nine sites (95th percentile) and 15,940 kg/site-yr at 35 sites (50th percentile). For the neat scenario the model provides 234,572 kg/site-yr at 35 sites (50th percentile) and 912,225 kg/site-yr at nine sites (95th percentile). EPA further assumes that the D4, or D4-containing polymer mixture arrives at the site in either rail cars, tanker trucks, or totes.

3.5.3 Release Assessment

3.5.3.1 Environmental Release Points

EPA used the Revised Plastic Compounding GS to estimate the release points for this OES (U.S. EPA, 2021b). The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operation losses to air from unloading plastics additive – Fugitive or stack air – EPA/OAQPS AP-42 Loading Model
2. Release source #2:
    a. Container residue losses – Wastewater to on-site treatment or off-site POTW, incineration, or landfill – EPA/OPPT Bulk Container Residual Model
    b. Open surface losses to air during container cleaning – Fugitive or Stack Air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
3. Vapor emissions from blending/compounding – Fugitive or stack air – 2021 Revised Plastics Compounding GS
4. Particulate emissions from blending/compounding – Not assessed for liquids
5. Equipment cleaning losses – Wastewater to on-site treatment or off-site POTW, incineration, or landfill – EPA/OPPT Multiple Process Vessel Residual Model
6. Direct contact cooling water losses – Wastewater (to on-site treatment or off-site POTW) – 2021 Revised Plastics Compounding GS
7. Release source #7:
    a. Release of additives during loading (uncaptured dust) – Fugitive air, wastewater (to on-site treatment or off-site POTW), incineration, or landfill – 2021 Revised Plastics Compounding GS
    b. Release of additives during loading (captured, uncontrolled dust) – Stack air – 2021 Revised Plastics Compounding GS
    c. Release of additives during loading (captured and controlled dust) – Wastewater (to on-site treatment or off-site POTW), incineration, or landfill – 2021 Revised Plastics Compounding GS

3.5.3.2 Environmental Release Assessment Results

Table 3-13 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Rubber Compounding OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-13. Summary of Modeled Environmental Releases for Processing – Rubber Compounding

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Rubber compounding (residual D4, *i.e.*, PDMS)	Fugitive or stack air[a]	8.2	3.2E01	227	225	3.6E−02	1.4E−01
	Stack air	3.7E01	2.5E02	229	225	1.6E−01	1.1
	Water (to on-site treatment or off-site POTW)	1.6E02	6.3E02	227	225	7.0E−01	2.8
	Fugitive air, water (to on-site treatment or off-site POTW), incineration, or landfill[a]	4.7E01	3.3E02	229	226	2.1E−01	1.5
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	4.8E02	1.6E03	214	225	2.2	7.2
Rubber compounding (neat D4)	Fugitive or stack air[a]	1.2E02	4.6E02	225	234	5.2E−01	2.0
	Stack air	5.8E02	3.6E03	229	224	2.5	1.6E01
	Water (to on-site treatment or off-site POTW)	2.3E03	9.1E03	227	236	1.0E01	3.9E01
	Fugitive air, water (to on-site treatment or off-site POTW), incineration, or landfill[a]	7.6E02	4.7E03	230	226	3.3	2.1E01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	6.0E03	2.3E04	97	156	6.3E01	1.5E02

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

[b] The Monte Carlo simulation calculated the total D4 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.

3.5.4 Occupational Exposure Assessment

3.5.4.1 Worker Activities

During rubber compounding, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES.(SEHSC, 2019). ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 234 and 250 days per year, respectively, as the exposure frequency.

3.5.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites. Specifically, 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-14 below are the inhalation exposure estimates for rubber compounding. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor.

Table 3-14. Summary of Estimated Inhalation Exposures for Rubber Compounding

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m³)		Acute Concentration (AC; mg/m³)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m³)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m³)	
			Central Tendency	**High-End**	**Central Tendency**	**High-End**	**Central Tendency**	**High-End**	**Central Tendency**	**High-End**
Rubber compounding	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		1.3E−01	1.4E−01
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	1.3	4.5
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	1.1E−01	2.2E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	2.2E−01	2.4
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	6.9E−02	7.3E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	2.2E−01	3.8
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	5.0E−01	1.2
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	1.2E−01	1.3

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.5.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal application modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-15 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

1917 **Table 3-15. Summary of Estimated Dermal Exposures for Rubber Compounding**

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Rubber compounding	Worker	7.7E02	2.3E03	9.6	2.9E01	7.1	2.1E01	6.2	2.0E01
	ONU	7.7E02		9.6		7.1		6.2	

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2)(U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

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3.6 Rubber Converting

3.6.1 Process Description

Rubber converting is the process of creating articles from a rubber base that is created during the rubber compounding OES. EPA expects that a typical silicone rubber converting site operates similar to a plastic converting site. A typical converting site receives and unloads the rubber base polymer in solid form, as a masterbatch, from compounding sites. The converting sites then transfers the masterbatch to a shaping unit operation such as an extruder, injection molding unit, or blow molding unit to achieve the final product shape. The converting site may trim excess material from the final product after it cools. Figure 3-7 provides an illustration of the converting process. EPA used the revised draft of the Use of Additives in Plastics Converting GS to model this scenario (U.S. EPA, 2021b).

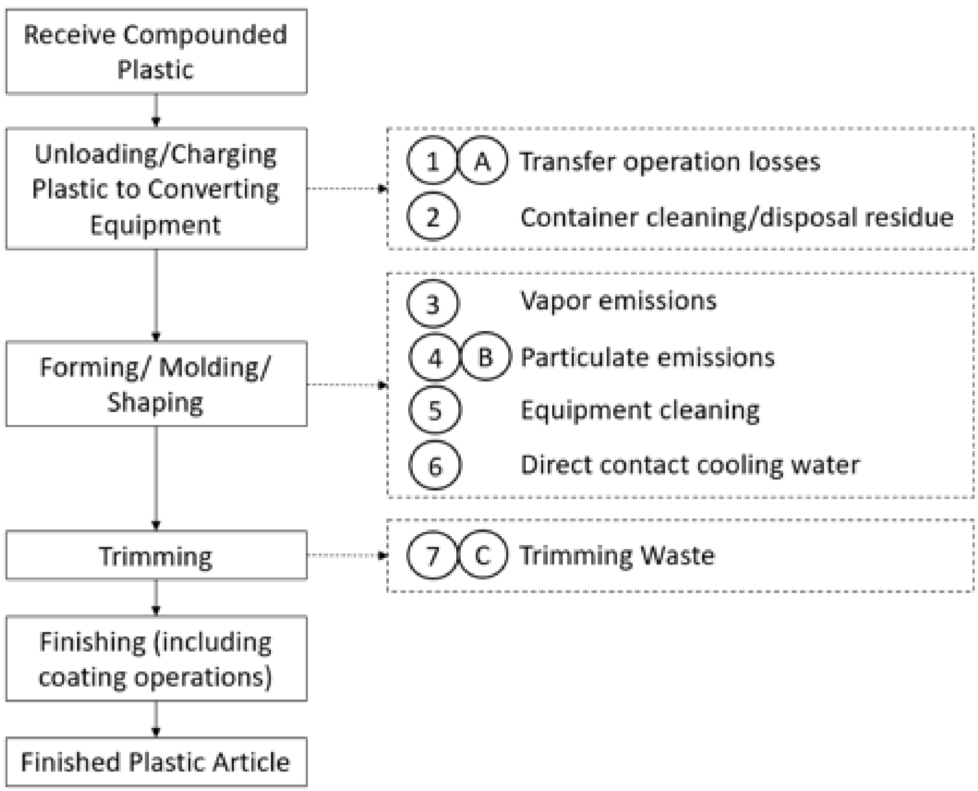

Figure 3-7. Rubber Converting Flow Diagram (U.S. EPA, 2021b)

3.6.2 Facility Estimates

EPA used the following NIACS codes to estimate the maximum number of sites for this OES; 326211: Tire Manufacturing (except retreading) – 584 sites, 326220: Rubber and Plastics Hoses and Belting Manufacturing – 1,443 sites, 326291: Rubber Product Manufacturing for Mechanical Use – 2,241 sites, 326299: All Other Rubber Product Manufacturing – 4,057 sites. This provides an upper bound of 8,325 sites. EPA identified D4-containing rubber masterbatch products that contain up to 5 percent D4 according to Safety Data Sheets (SDS) (see Appendix F for product data). Based on the results of the Monte Carlo release simulation, EPA estimates a high-end scenario of 21,106 kg-D4/site-yr (102 kg-D4/site-day) being processed at 302 sites and a central-tendency of 3,063 kg-D4/site-yr (14 kg-D4/site-day) being processed at 2,132 sites.

3.6.1 Release Assessment

3.6.1.1 Environmental Release Points

EPA used the Revised Plastic Converting GS to estimate the release points for this OES (HERO:). The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operation losses unloading compounded rubber – Stack air, fugitive air, wastewater (to on-site treatment or off-site POTW), incineration, or landfill – 2021 Revised Plastics Converting GS
2. Container residue losses – Wastewater (to on-site treatment or off-site POTW), incineration, or landfill – EPA/OPPT Solid Residuals in Transport Containers Model
3. Vapor emissions during converting to air – Fugitive or stack air – 2021 Revised Plastics Converting GS
4. Particulate emissions during converting – Fugitive or stack air, wastewater (to on-site treatment or off-site POTW), incineration, or landfill – 2021 Revised Plastics Converting GS
5. Equipment cleaning losses – Wastewater (to on-site treatment or off-site POTW), incineration, or landfill – EPA/OPPT Multiple Vessel Residual Model
6. Direct contact cooling water losses – Wastewater (to on-site treatment or off-site POTW) – EPA/OPPT Single Vessel Residual Model
7. Solid waste from trimming operations – Incineration or landfill – 2021 Revised Plastics Converting GS

3.6.1.2 Environmental Release Assessment Results

Table 3-16 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Rubber Converting OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-16. Summary of Modeled Environmental Releases for Processing – Rubber Converting

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Rubber converting	Fugitive or stack air[a]	4.5	4.3E01	213	207	2.1E−02	2.0E−01
	Stack air	7.6	8.6E01			3.6E−02	4.1E−01
	Fugitive air, water (to on-site treatment or off-site POTW), incineration, or landfill[a]	9.7	1.2E02			4.6E−02	5.5E−01

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	Fugitive air, stack air, water (to on-site treatment or off-site POTW), incineration, or landfill[a]	1.8E−01	1.3			8.6E−04	6.5E−03
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	1.1E02	7.4E02			5.0E−01	3.6
	Water (to on-site treatment or off-site POTW)	3.1E01	2.1E02			1.4E−01	1.0
	Incineration or landfill[a]	7.7E01	5.3E02			3.6E−01	2.5

[a] When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.
[b] The Monte Carlo simulation calculated the total D4 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.

3.6.2 Occupational Exposure Assessment

3.6.2.1 Worker Activities

During rubber compounding, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES.(SEHSC, 2019). ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 219 and 250 days per year, respectively, as the exposure frequency.

3.6.2.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites. Specifically, 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-17 below are the inhalation exposure estimates for rubber converting. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor.

Table 3-17. Summary of Estimated Inhalation Exposures for Rubber Converting

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Rubber converting	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		1.2E−01	1.4E−01
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	1.2	4.5
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	9.9E−02	2.2E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	2.0E−01	2.4
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	6.4E−02	7.3E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	2.1E−01	3.8
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	4.7E−01	1.2
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	1.1E−01	1.3

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.6.2.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-18 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-18. Summary of Estimated Dermal Exposures for Rubber Converting

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Rubber converting	Worker	2.3E01	5.5E01	2.8E−01	6.9E−01	2.1E−01	5.0E−01	1.7E−01	4.7E−01
	ONU	2.3E01		2.8E−01		2.1E−01		1.7E−01	

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2)(U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.7 Processing – Formulation of Paints and Coatings

3.7.1 Process Description

EPA used the Formulation of Waterborne Coatings GS to model this OES. A typical incorporation site receives and unloads D4 or D4-containing mixtures into industrial mixing vessels as a batch blending or mixing process, with no reactions or chemical changes occurring to the D4 during the mixing process (U.S. EPA, 2014a). Blending or mixing operations can take up to eight hours a day. Process operations may include quality control sampling. In the case of waterborne coatings, the formulator will transfer the blended formulation through an in-line filter. Sites may dispose of off-specification product when the product does not meet quality or desired standards. Following formulation, incorporation sites will load D4-containing products into bottles, small containers, or drums depending on the product type (U.S. EPA, 2014a). EPA identified paint and coating products consisting of between 0.0006 to 0.25 percent D4, and they are identified in Appendix F. Figure 3-8 provides an illustration of the paint and coating manufacturing process.

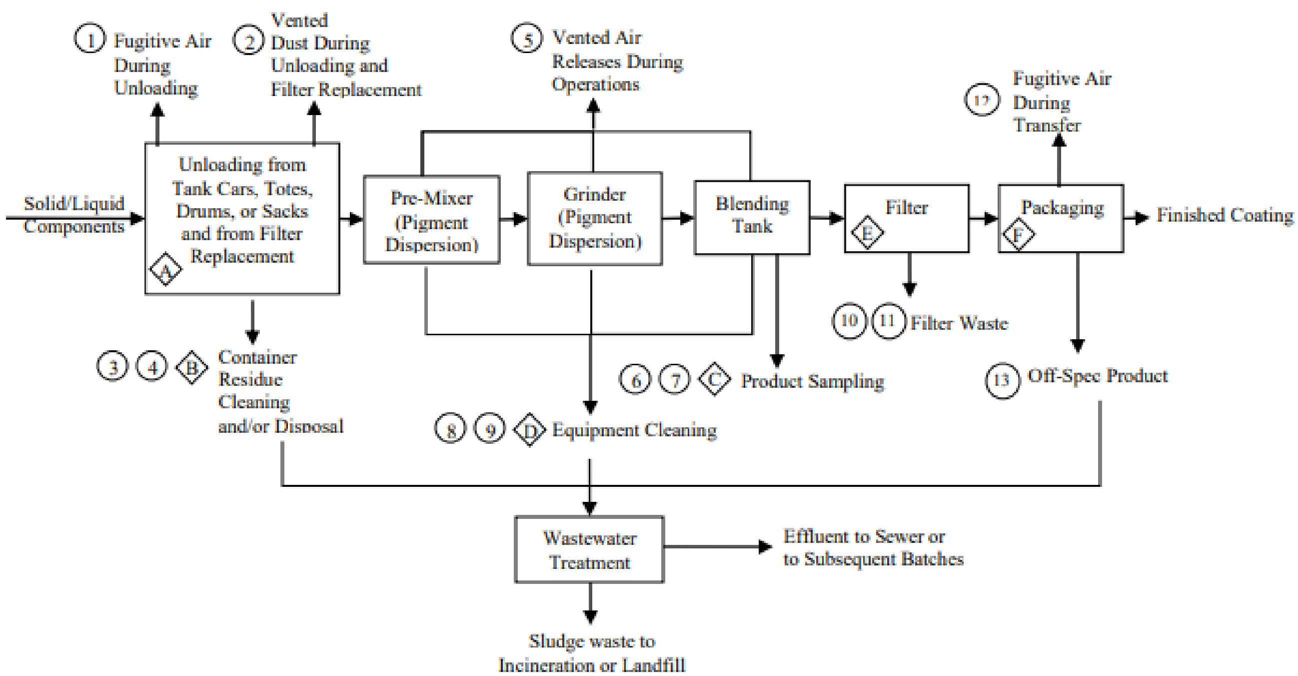

Figure 3-8. Formulation of Paints and Coatings Flow Diagram (U.S. EPA, 2014a)

3.7.2 Facility Estimates

In the 2020 CDR, there are two reporters for Processing – Incorporation into formulation, mixture, or reaction product in the industrial sector of paint and coating manufacturing. These companies are BRB North America, Inc. and Evonik Corporation. BRB North America, Inc. reported importing 513,199 lb in 2019, a D4 concentration of at least 90 percent, and further denotes that 33 percent of their PV goes towards this use at between one to nine sites with the industrial function of intermediate. Evonik Corporation reported both import and manufacture, claimed their PV as CBI, a D4 concentration of between 1 to 30 percent, and further denotes that 10 percent of the PV goes towards this use at between 10 to 24 sites with the industrial function of corrosion inhibitor and anti-scaling agents.

EPA used data from Brooke et al. (2009) to estimate the PV for this OES. The underlying data used in Brooke et al. (2009) consists of U.S. production volume data and is therefore expected to be applicable for this risk evaluation. Paints and coatings appear in both the silicone fluids (2.1%) and elastomers (1.5%) categories. Also appearing in that assessment are the category of silanes (9%); which appear to be used in coatings, adhesives, and inks (BRB, 2025; Dow Chemical, 2025). According to Dow Website, BRB Website, Elkem Website, "they [silanes] are ideal for high-performance paints, inks, and coatings due to their unique properties." This amounts to an overall PV of 12.6 percent of the national aggregate PV being accounted for in this OES.

Brooke et al. (2009) assumes that the raw materials are received at the site in rail cars, tanker trucks and/or totes and that D4 can be received as either neat (*i.e.*, 100% concentration) from the import or repackaging of D4 OESs or residual (*i.e.*, 0.1–3.0% concentration) amounts in polymer mixtures from the Processing as a Reactant OES. EPA is uncertain what raw materials are received are received at the processing site (*e.g.*, neat D4 or reacted polymer mixtures) and provides what-if scenarios to cover these possibilities. The overall PV for the neat scenario is 12,600,000 lb (12.6% of the 100,000,000 lb) and 50,400 to 1,512,000 lb of residual D4 for the residual scenario. EPA calculated the potential number of sites using both the upper bound of the CDR site data (33 sites) and the 2020 County Business Patterns (CBP) U.S. Census Bureau data for NAICS code 32551 (Paint and Coating Manufacturing) which lists 1,131 establishments in the United States (U.S. BLS, 2023). This provides a possible range of between 33 to 1,131 sites. The results from the Monte Carlo simulation done for this OES ultimately provided a 95th percentile of 167 sites and a 50th percentile of 35 sites.

EPA further expects that this scenario could be applicable to industries such as electronic and semiconductor manufacturers that process D4 into conformal coating products, which is a use indicated by the D4 Consortium (SEHSC, 2020).

3.7.3 Release Assessment

3.7.3.1 Environmental Release Points

EPA used the Formulation of Waterborne Coatings GS to estimate the release points for this OES (U.S. EPA, 2014a). The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operation losses of volatile chemicals to air during unloading of the chemical component – Fugitive or stack air – EPA/OAQPS AP-42 Loading Model
2. Dust losses vented of solid/powder chemical components to air during unloading – Not assessed for liquids
3. Container residue losses – Water, incineration, or landfill – EPA/OPPT Bulk Container Residual Model
4. Open surface losses of volatile chemicals to air during container cleaning – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model for Totes; EPA/OPPT Mass Transfer Coefficient Model for Tank Trucks and Rail Cars
5. Vented losses of volatile chemicals to air during pre-mixing, grinding, or blending operations – Stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
6. Product sampling losses to water, incineration, or landfill – Water, incineration, or landfill – MRD on sampling waste release estimation
7. Open surface losses of volatile chemicals to air during product sampling – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model

8. Equipment cleaning losses – Water, incineration, or landfill – EPA/OPPT Multiple Process Vessel Residual Model
9. Open surface losses of volatile chemicals to air during equipment cleaning – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
10. Filter waste losses to incineration or landfill during filter media change out – Incineration or landfill – Formulation of Waterborne Coatings GS
11. Open surface losses of volatile chemicals to air during filter media change out – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model in combination with the Formulation of Waterborne Coatings GS
12. Transfer operation losses of volatile chemicals to air during product loading – Fugitive or stack air – EPA/OAQPS AP-42 Loading Model
13. Off-spec coating released to water, incineration, or landfill – Off-spec coating may be treated on-site before disposal or may be recycled into subsequent batches.

3.7.3.2 Environmental Release Assessment Results

Table 3-19 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Formulations of Paints and Coatings OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-19. Summary of Modeled Environmental Releases for Processing – Formulation of Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of paints and coatings (neat D4)	Fugitive or stack air[a]	1.2E01	2.2E01	250	250	5.0E−02	8.9E−02
	Water, incineration, or landfill[a]	5.3E03	2.5E04	93	170	5.7E01	1.5E02
	Incineration or landfill[a]	3.3E01	1.6E02	250	250	1.3E−01	6.5E−01
Formulation of paints and coatings (residual D4)	Fugitive or stack air[a]	6.7E−01	1.6	250	250	2.7E−03	6.4E−03
	Water, incineration, or landfill[a]	6.9E02	3.5E03	250	250	2.7	1.4E01
	Incineration or landfill[a]	4.3	2.2E01	250	250	1.7E−02	8.7E−02

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End

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

[b] The Monte Carlo simulation calculated the total D4 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.

3.7.4 Occupational Exposure Assessment

3.7.4.1 Worker Activities

During formulation of paints and coatings worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES. ONUs include employees (*e.g.,* supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 250 days per year as the exposure frequency, which is the expected maximum for working days.

3.7.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites. Specifically, 17 PBZ monitoring datapoints for “chemical operators” as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for “Administrative” as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-20 below are the inhalation exposure estimates for the formulation of D4 into paints and coatings. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor.

Table 3-20. Summary of Estimated Inhalation Exposures for Formulation of Paints and Coatings of D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m³)		Acute Concentration (AC; mg/m³)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m³)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m³)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of paints and coatings	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		1.4E−01	
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	1.4	4.5
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	1.1E−01	2.2E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	2.3E−01	2.4
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	7.3E−02	7.3E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	2.4E−01	3.8
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	5.3E−01	1.2
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	1.3E−01	1.3

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.7.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-21 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-21. Summary of Estimated Dermal Exposures for Formulation of Paints and Coatings

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of paints and coatings	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	6.4	1.9E01
	ONU	7.5E02		9.4		6.9		6.4	
Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.									

3.8 Processing – Formulations of Products Containing Greater than Residual D4 Products

3.8.1 Process Description

D4 is used as a solvent component in many products used in many industries (U.S. EPA, 2020a). These types of products could include degreasing solvents (*e.g.*, aircraft maintenance products), automotive care products, animal grooming products, and cleaning or laundry products (see Appendix F for identified products). While some of these end products have residual levels of D4 (<3%), EPA has included them in this OES due to uncertainties regarding the exact manner they are formulated. EPA used the Formulation of Waterborne Coatings GS to model this OES. A typical incorporation site receives and unloads D4 or D4-containing mixtures into industrial mixing vessels as a batch blending or mixing process, with no reactions or chemical changes occurring to the D4 during the mixing process (U.S. EPA, 2014a). Blending or mixing operations can take up to 8 hours a day. Process operations may include quality control sampling. It is likely that formulators will transfer the blended formulation through an in-line filter. Sites may dispose of off-specification product when the product does not meet quality or desired standards. Following formulation, incorporation sites will load D4-containing products into bottles, small containers, drums, or in some cases spray cans depending on the product type (Momentive, 2022). Figure 3-9 provides an illustration of the process.

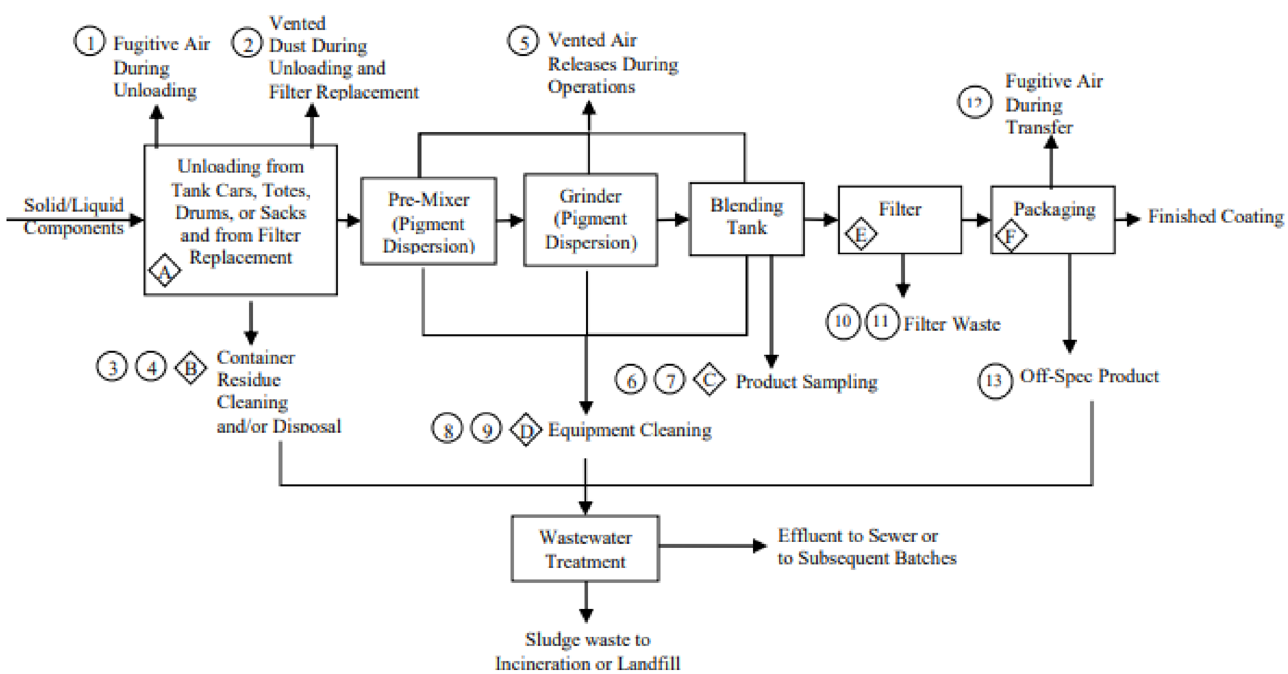

Figure 3-9. Formulations Containing Greater Than Residual D4 Flow Diagram (U.S. EPA, 2014a)

3.8.2 Facility Estimates

The production volume for this OES is not known, therefore the PV assessed using different elements of the overall PV mass balance based on Brooke et al. (2009). Of the 100,000,000 lb per year of unreacted D4, 300,344 lb per year are allocated towards the lab chemicals PV, and 12,600,000 lb per year are allocated towards the paints and coatings PV. The remaining PV amounts to 87,099,656 lb per year. However, since EPA does not know the exact extent to which neat D4 vs residual D4 (from the processing as a reactant OES) 87,099,656 lb was divided by the national aggregate PV of 500,000,000 lb which provides an overall value of 17.4 percent of the national aggregate PV going towards the formulation of these products. The Monte Carlo simulation created for this OES considers, among other parameters, the varying concentration of D4 remaining in the polymer mixtures formed during the processing as a reactant OES (lower bound of 0.001 and upper bound of 0.03) and accounts for this in this OES. Based on this simulation EPA is assessing that the throughput for this OES could have a high end of 1,373,798 kg/site-yr being formulated across six sites and a central tendency of 63,741 kg/site-yr being formulated across 124 sites. Other assumptions that EPA has made for this OES are that D4 or D4-containing mixtures arrive at the formulation sites in rail cars, tanker trucks, and/or totes and that products are packaged into containers ranging between 1 and 100 gallons with a mode of 55-gallon drums.

EPA further expects that this scenario could be applicable to industries such as electronic and semiconductor manufacturers that process D4 into carrier solvent formulations that are used in the production of electronic wafers, which is a use indicated by the D4 Consortium (SEHSC, 2020).

3.8.3 Release Assessment

3.8.3.1 Environmental Release Points

As explained in Section 3.8.1, EPA used the Formulation of Waterborne Coatings GS to estimate the release points for this OES (U.S. EPA, 2014a). The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operation losses of volatile chemicals to air during unloading of the chemical component – Fugitive or Stack Air – EPA/OAQPS AP-42 Loading Model
2. Dust losses vented of solid/powder chemical components to air during unloading – Not assessed for liquids
3. Container residue losses – Water, Incineration, or Landfill – EPA/OPPT Bulk Container Residual Model
4. Open surface losses of volatile chemicals to air during container cleaning – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model for Totes; EPA/OPPT Mass Transfer Coefficient Model for Tank Trucks and Rail Cars
5. Vented losses of volatile chemicals to air during pre-mixing, grinding, or blending operations – Stack Air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
6. Product sampling losses to water, incineration, or landfill – Water, incineration, or landfill – MRD on sampling waste release estimation
7. Open surface losses of volatile chemicals to air during product sampling – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
8. Equipment cleaning losses – Water, incineration, or landfill – EPA/OPPT Multiple Process Vessel Residual Model
9. Open surface losses of volatile chemicals to air during equipment cleaning – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
10. Filter waste losses to incineration or landfill during filter media change out – Incineration or landfill – Formulation of Waterborne Coatings GS
11. Open surface losses of volatile chemicals to air during filter media change out – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model in combination with the Formulation of Waterborne Coatings GS

12. Transfer operation losses of volatile chemicals to air during product loading – Fugitive or stack air – EPA/OAQPS AP-42 Loading Model
13. Off-spec coating released to water, incineration, or landfill – Off-spec coating maybe treated on-site before disposal or may be recycled into subsequent batches.

3.8.3.2 Environmental Release Assessment Results

Table 3-22 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Formulation of Greater then Residual D4 Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-22. Summary of Modeled Environmental Releases for Processing of Formulations Greater than Residual D4 Products

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Processing of formulations containing greater than residual D4	Fugitive air	1.9	4.0E01	245	245	7.8E−03	1.6E−01
	Stack air	9.4	1.6E01	245	245	3.9E−02	6.4E−02
	Water, incineration, or landfill[a]	2.1E03	4.4E04	47	213	4.4E01	2.1E02
	Incineration or landfill[a]	1.3E01	2.7E02	245	245	5.2E−02	1.1

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

[b] The Monte Carlo simulation calculated the total D4 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.

3.8.4 Occupational Exposure Assessment

3.8.4.1 Worker Activities

During the formulation of products containing greater than residual D4 worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES (SEHSC, 2019). ONUs include employees (*e.g.*, supervisors and managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 246 and 250 days per year, respectively, as the exposure frequency.

3.8.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites. Specifically, 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-23 below are the inhalation exposure estimates for the formulation of products containing greater than residual levels of D4. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor.

2238 **Table 3-23. Summary of Estimated Inhalation Exposures for the Processing of Formulations Containing Greater Than Residual D4**
2239

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Processing of formulations containing greater than residual D4	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		1.5E−01		1.4E−01	
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	1.5	4.8	1.3	4.5
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	1.1E−01	2.2E01
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	2.5E−01	2.6	2.3E−01	2.4
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	7.9E−02	7.9E−02	7.2E−02	7.3E−02
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	2.5E−01	4.0	2.3E−01	3.8
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	5.7E−01	1.3	5.2E−01	1.2
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	1.4E−01	1.4	1.3E−01	1.3

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.8.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-24 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-24. Summary of Estimated Worker Dermal Exposures for the Processing of Formulations Containing Greater Than Residual D4

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Processing of formulations containing greater than residual D4	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	6.3	1.9E01
	ONU	7.5E02		9.4		6.9		6.3	

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.9 Processing – Formulations of Products Containing Residual D4

3.9.1 Process Description

EPA used the Formulation of Waterborne Coatings GS to model this OES. A typical incorporation site receives and unloads D4 or D4-containing mixtures into industrial mixing vessels as a batch blending or mixing process, with no reactions or chemical changes occurring to the D4 during the mixing process (U.S. EPA, 2014a). Blending or mixing operations can take up to eight hours a day. Process operations may include quality control sampling. In the case of waterborne coatings, the formulator will transfer the blended formulation through an in-line filter. Sites may dispose of off-specification product when the product does not meet quality or desired standards. Following formulation, incorporation sites will load D4-containing products into bottles, small containers, or drums depending on the product type (U.S. EPA, 2014a). Figure 3-10 provides an illustration of the formulation process.

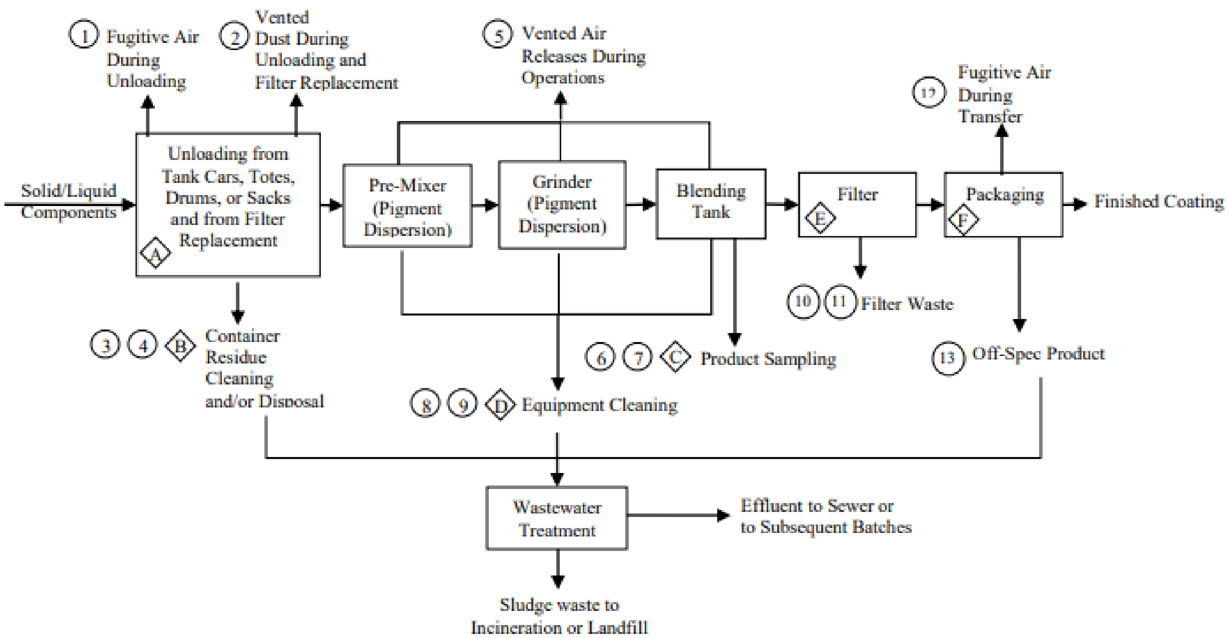

Figure 3-10. Formulations Containing Residual D4 Flow Diagram (U.S. EPA, 2014a)

3.9.2 Facility Estimates

EPA calculated the throughput for this OES by using the remainder after all other processing throughputs, except for processing as a reactant (which is included throughout the OESs), had been calculated. The overall breakdown can be seen in Section 2.3.1.

EPA lacks data regarding if neat D4 is used for the formulation of the products included in the release estimate. The Monte Carlo simulation created for this OES considers, among other parameters, the varying concentration of D4 remaining in the polymer mixtures formed during the Processing as a reactant OES (lower bound of 0.001 and upper bound of 0.03) and accounts for this in this OES. Based on this simulation EPA is assessing that the throughput for this OES could have a 95th percentile of 20, 798kg/site-yr being formulated across 434 sites and a 50th percentile of 12,659kg/site-yr being formulated across 713 sites. Other assumptions that EPA has made for this OES are that D4 or D4-containing mixtures arrive at the formulation sites in rail cars, tanker trucks, and/or totes and that products are packaged into containers ranging between 1 and 100 gallons with a mode of 55-gallon drums.

3.9.3 Release Assessment

3.9.3.1 Environmental Release Points

As explained in Section 3.9.1, EPA used the Formulation of Waterborne Coatings GS to estimate the release points for this OES (U.S. EPA, 2014a). The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operation losses of volatile chemicals to air during unloading of the chemical component – Fugitive or stack air – EPA/OAQPS AP-42 Loading Model
2. Dust losses vented of solid/powder chemical components to air during unloading – Not assessed
3. Container residue losses – Water, Incineration, or Landfill – EPA/OPPT Bulk Container Residual Model
4. Open surface losses of volatile chemicals to air during container cleaning – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model for Totes; EPA/OPPT Mass Transfer Coefficient Model for Tank Trucks and Rail Cars
5. Vented losses of volatile chemicals to air during pre-mixing, grinding, or blending operations – Stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
6. Product sampling losses to water, incineration, or landfill – Water, incineration, or landfill – MRD on sampling waste release estimation
7. Open surface losses of volatile chemicals to air during product sampling – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
8. Equipment cleaning losses – Water, incineration, or landfill – EPA/OPPT Multiple Process Vessel Residual Model
9. Open surface losses of volatile chemicals to air during equipment cleaning – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
10. Filter waste losses to incineration or landfill during filter media change out – Incineration or landfill – Formulation of Waterborne Coatings GS
11. Open surface losses of volatile chemicals to air during filter media change out – Fugitive or stack air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model in combination with the Formulation of Waterborne Coatings GS
12. Transfer operation losses of volatile chemicals to air during product loading – Fugitive or stack air – EPA/OAQPS AP-42 Loading Model.
13. Off-spec coating released to water, incineration, or landfill – Off-spec coating maybe treated on-site before disposal or may be recycled into subsequent batches

3.9.3.2 Environmental Release Assessment Results

Table 3-25 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Formulation of Residual D4 Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-25. Summary of Modeled Environmental Releases for Processing – Formulation of Residual D4 Products

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of residual D4 products	Fugitive air	1.4E−01	3.8E−01	245	245	5.5E−04	1.6E−03
	Stack air	1.6E−01	3.2E−01	245	245	6.3E−04	1.3E−03
	Water, incineration, or landfill[a]	5.6E01	1.1E02	218	228	2.6E−01	4.9E−01
	Incineration or landfill[a]	3.3E−01	6.4E−01	245	245	1.3E−03	2.6E−03

[a] When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.
[b] The Monte Carlo simulation calculated the total D4 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.

3.9.4 Occupational Exposure Assessment

3.9.4.1 Worker Activities

During the formulation of products containing residual levels of D4 worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling raw materials, product sampling, equipment cleaning, and/or loading of D4 into transport containers for shipment. Available information on PPE use in the monitoring dataset provided by the D4 Consortium (SEHSC, 2019) indicates that PPE use is inconsistent within the Chemical Operator SEG used to represent inhalation exposures for this OES (SEHSC, 2019). ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 246 and 250 days per year, respectively, as the exposure frequency.

3.9.4.2 Occupational Inhalation Exposure Results

EPA utilized monitoring data submitted by the D4 Consortium across manufacturing and processing sites. Specifically, 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. These were calculated into high-end and central tendency estimates for each SEG. Presented in Table 3-26 below are the inhalation exposure estimates for the formulation of products containing residual levels of D4. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor.

Table 3-26. Summary of Estimated Inhalation Exposures for the Processing of Formulations Containing Residual D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m³)		Acute Concentration (AC; mg/m³)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m³)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m³)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of residual D4 products	Administrative (ONU)	8-hr	3.0E−01		2.1E−01		6.9E−03	1.0E−01	5.7E−04	8.5E−03
	Chemical operator	8-hr	2.9	9.7	2.0	6.6	6.6E−02	3.3	5.4E−03	2.7E−01
	Laboratory technician	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	5.5E−03	1.6E01	4.5E−04	1.3
	Logistic technician	12-hr	3.3E−01	3.4	3.4E−01	3.5	1.1E−02	1.7	9.3E−04	1.4E−01
	Material handler	8-hr	1.6E−01	1.6E−01	1.1E−01	1.1E−01	3.6E−03	5.4E−02	2.9E−04	4.4E−03
	Production operator	8-hr	5.1E−01	8.0	3.5E−01	5.5	1.2E−02	2.7	9.5E−04	2.3E−01
	Production operator	10-hr	9.1E−01	2.1	7.8E−01	1.8	2.6E−02	9.1E−01	2.1E−03	7.5E−02
	Production operator	12-hr	1.8E−01	1.9	1.9E−01	1.9	6.3E−03	9.6E−01	5.2E−04	7.9E−02

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data contained both PBZ and area measurements. This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2.

3.9.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. The SEHSC worker exposure submission indicates that ONUs could have dermal exposure (SEHSC, 2019). In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-27 summarizes the APDR, AC, IADC, and ADC for average adult workers and ONUs.

Table 3-27. Summary of Estimated Dermal Exposures for the Formulation of Residual D4 Products

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Formulation of residual D4 products	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	6.3	1.9E01
	ONU	7.5E02		9.4		6.9		6.3	

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.10 Use of Adhesives and Sealants

3.10.1 Process Description

The use of adhesives and sealants OES could refer to several COUs included in the risk evaluation, such as building/construction products (*e.g.*, caulks) and electronic potting agents. EPA used the ESD on the Use of Adhesives and Sealants to model this OES (OECD, 2015b). The adhesive or sealant products are expected to arrive at the use site in containers ranging between 1 and 55 gallons with a mode of 20 gallons. They can be applied to the substrate using handheld manual applicators or a larger facility could use other types of equipment intended to apply a higher volume of products or to apply that product in a more precise manner depending on the industry (OECD, 2015b). Once applied to the substrate the adhesive or sealant product will begin to cure, typically by reacting with the ambient moisture in the air which causes a polycondensation reaction (OECD, 2015b). Figure 3-11 provides an illustration of the process.

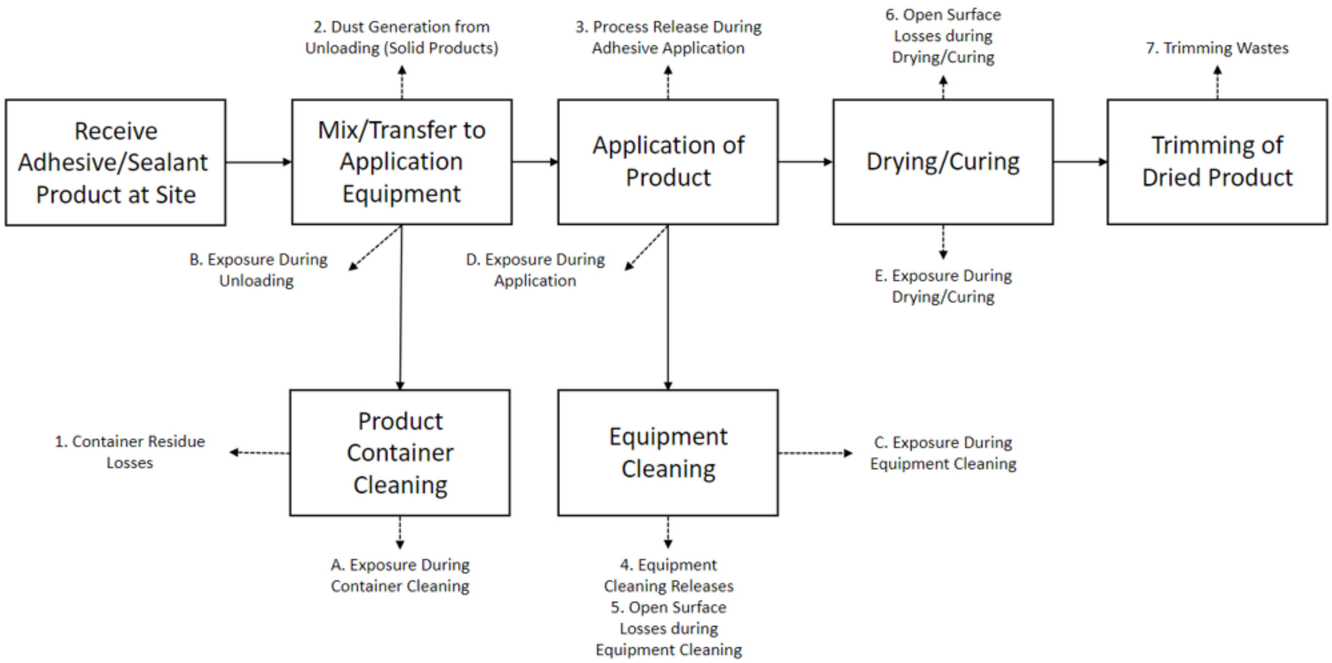

Figure 3-11. Use of Adhesives and Sealants Flow Diagram (OECD, 2015b)

3.10.2 Facility Estimates

There are two reporters to CDR for the commercial use of adhesives and sealants. BRB North America, Inc. reports the product category of adhesives and sealants and Sherwin Williams reports the products category of one-component caulks. EPA has identified several adhesives and sealant products that range in D4 concentration between 0.05 to 5.0 percent according to their SDSs (data for these products can be found in Appendix F). EPA used a Monte Carlo simulation based on the parameters in ESD for the Use of Adhesives, specifically the bead or syringe application method as well as the unreacted D4 remaining from the upstream formulation OES. For the site throughput volume, the ESD provides an annual throughput of between 1,000 and 1,000,000 kg/site-yr. The results of the Monte Carlo simulation provide a 95th percentile of 32,932 kg/site-yr (192 kg/site-day) at 471 sites. The 50th percentile results are 15,539 kg/site-yr (103 kg/site-day) at 997 sites.

3.10.3 Release Assessment

3.10.3.1 Environmental Release Points

As explained in Section 3.10.1, EPA used the ESD on The Use of Adhesives to estimate the release points for this OES (OECD, 2015b). The expected process steps, media of release, and methodology of assessment are listed below.

1. Container residue from adhesive transport container – Waste disposal (incineration or landfill) – EPA/OPPT Small Container Residual Model and EPA/OPPT Drum Residual Model
2. Open surface losses of volatile chemicals during container cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
3. Transfer operations losses to air from unloading the adhesive formulation – Fugitive air – EPA/OAQPS AP-42 Loading Model
4. Equipment cleaning releases - Waste disposal (incineration or landfill) – EPA/OPPT Single Process Vessel Residual Model
5. Open surface losses to air during equipment cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
6. Evaporative losses to air during curing/drying – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
7. Trimming Wastes – Not assessed – Negligible for syringe/bead application

3.10.3.2 Environmental Release Assessment Results

Table 3-28 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Use of Adhesives and Sealants OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-28. Summary of Modeled Environmental Releases for Use of Adhesives and Sealants

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of adhesives and sealants	Fugitive air	6.0E−02	3.3E−01	149	164	4.0E−04	2.0E−03
	Waste disposal (incineration or landfill)[a]	2.0E02	4.4E02	151	170	1.3	2.6

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End

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

[b] The Monte Carlo simulation calculated the total D4 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.

3.10.4 Occupational Exposure Assessment

3.10.4.1 Worker Activities

During the use of adhesives and sealants worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquids. EPA utilized the ESD on the Use of Adhesives (OECD, 2015b) to identify activities that could result in exposure during this OES. Possible exposure points include:

- Inhalation (volatile chemicals only) and dermal exposure to adhesives during container cleaning;
- Inhalation (volatile chemicals only) and dermal exposure during equipment loading/container unloading;
- Inhalation (volatile chemicals only) and dermal exposure during equipment cleaning;
- Inhalation (volatile chemicals only) exposure during adhesive application; and
- Inhalation (volatile chemicals only) exposure during drying/curing.

Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 160 and 222 days per year, respectively, as the exposure frequency.

3.10.4.2 Occupational Inhalation Exposure Results

The EPA/OPPT Mass Balance Inhalation Model was used in conjunction with the potential exposure points and concentration data for product SDSs to provide an 8-hr TWA and to calculate the AC, IADC, and ADC for worker exposures to D4 during this OES. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of Vapor. Table 3-29 summarizes the AC, IADC, and ADC for average adult workers and ONUs. For this OES, ONU-specific estimates were not available, ONU inhalation exposures were assumed to be no greater than central tendency exposures for workers.

Table 3-29. Summary of Estimated Inhalation Exposures for Use of Adhesives and Sealants of D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of adhesives and sealants	Worker	8-hr	1.4E−02	1.0E−01	9.2E−03	6.8E−02	6.7E−03	5.0E−02	3.8E−03	3.0E−02
	ONU	8-hr	1.4E−02		9.2E−03		6.7E−03		3.8E−03	

Note: EPA used a Monte Carlo simulation using the EPA/OPPT Mass Balance Inhalation Model with parameters from the Use Of Adhesives ESD (OECD, 2015b), which has a rating of medium through EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

3.10.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. ONUs are not expected to have dermal exposure during this OES. Table 3-30 summarizes the APDR, AC, IADC, and ADC for workers.

2439 **Table 3-30. Summary of Estimated Dermal Exposures for Use of Adhesives and Sealants of D4**

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of adhesives and sealants	Worker	3.7E01	1.1E02	4.7E−01	1.4	3.4E−01	1.0	2.1E−01	8.5E−01

Note: EPA received monitoring data from SEHSC from manufacturing and processing facilities, this submission indicated that dermal exposure was possible during inspecting and observing activities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

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3.11 Use of Paints and Coatings

3.11.1 Process Description

D4 is a component in coating products for many commercial and industrial uses, it is found in concentrations ranging from 0.0006 to 0.25 percent by weight (see Appendix F for identified products). Upon receiving of the D4-containing coating product, an operator will transfer the coating product from the container to the application equipment. Coating application methods for D4-containing paints and coatings include spray gun, brush, and trowel coating for use on structures or equipment. Spray gun applications may include an air (*e.g.*, low volume/high pressure), air-assisted, or airless spray system (U.S. EPA, 2014b; OECD, 2009b; U.S. EPA, 2004). EPA did not identify the prevalence of these various application methods. EPA assumes that spray application will be the most common method of application, and that this operation could occur at a site over the course of 1 day, 2 days, or 250 days. The one- and two-day scenarios are representative of a job that consists of applying paints at a location such as a construction site, the 250-day scenario represents a location such as a manufacturing facility that is expected to apply paints to products over the course of an entire year. The 250-day scenario could also be applicable to a worker that uses D4-containing paints at different locations over the course of an entire year. Figure 3-12 presents an illustration of the process.

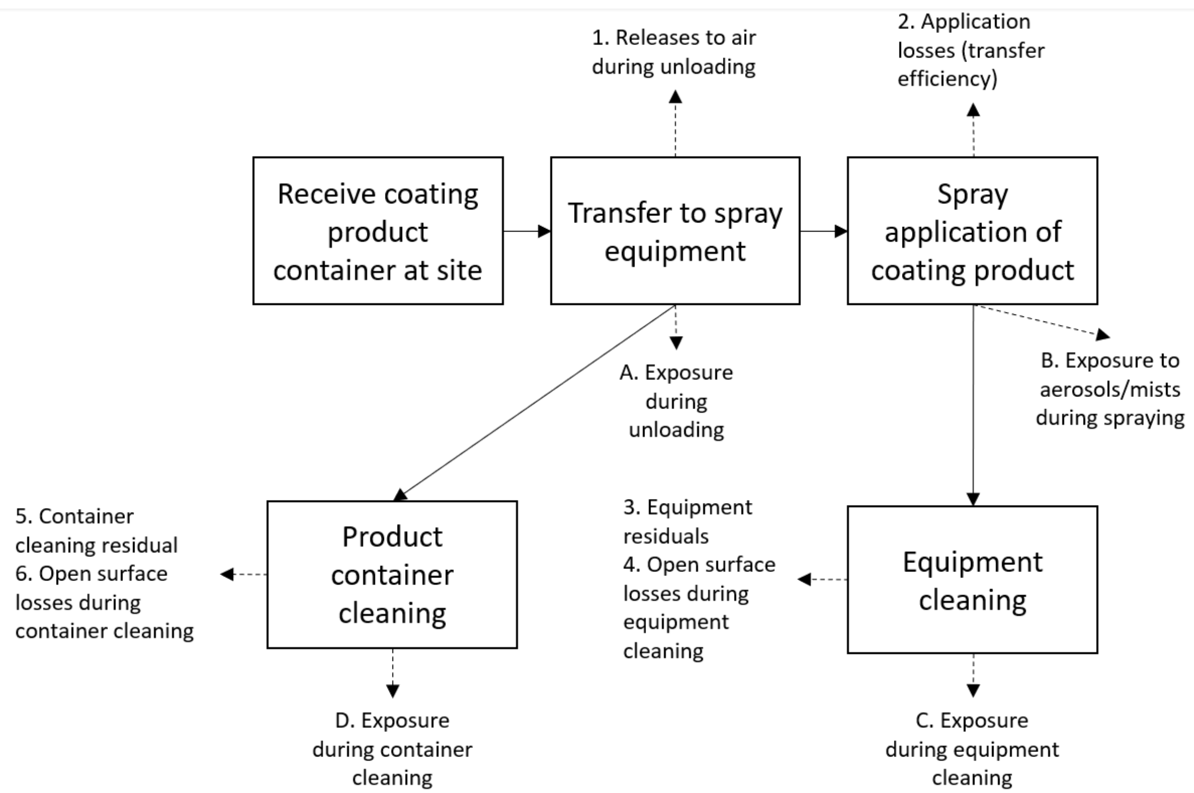

Figure 3-12 Use of Paints and Coatings Flow Diagram

3.11.2 Facility Estimates

EPA did not find information on D4-specific use rates and EPA expects D4-containing paint and coating application rates at commercial and industrial sites to vary depending on the specific needs of the site. The Specific Emission Release Category (SpERC) documents developed by the European Council of the Paint, Printing Ink, and Artist's Colours Industry (CEPE) for industrial application of coatings by spraying and professional application of inks and coatings by spraying estimate coating use rates of

1,000 kg and 100 kg per site, per day, respectively (CEPE, 2020a, b). These scenarios are meant to estimate generic site(s) that apply D4-containing paints and coatings in a commercial or industrial setting.

EPA expects that coatings containing D4 as an additive component arrive at the end-user site in containers ranging from approximately 1 quart up through 100 gallon drums based on the relevant ESD and review of available technical data sheets from D4-containing coating products identified. EPA assesses an overall concentration range of 0.0006 to 25 percent of D4 by mass in paint and coating products based on a review of available safety and technical data sheets from D4-containing coating products identified by EPA. Specific concentrations and products are provided in Appendix F.

EPA expects that coating applications occur over the course of an 8-hour workday for 1, 2, or 250 days at a given site, accounting for multiple coats and typical drying or curing times listed for D4-containing coatings. EPA modeled six scenarios for this OES: a 100 kg/site-day product throughput for 1, 2, and 250-days of application and a 1,000 kg/site-day product throughput for 1, 2, and 250-days of application. This is intended to provide a broad range of release and exposure scenarios.

EPA further expects that this scenario, specifically the 250-day scenario, could be applicable to industries such as electronic and semiconductor manufacturers that use D4-containing conformal coatings, which is a use indicated by the D4 Consortium (SEHSC, 2020).

3.11.3 Release Assessment

3.11.3.1 Environmental Release Points

As discussed in Section 3.11.1, EPA used the Use of Paints and Coatings GS to estimate the release points for this OES (U.S. EPA, 2014b). The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operation losses to air from unloading the coating component – Fugitive air – EPA/OAQPS AP-42 Loading Model
2. Application losses – Fugitive air – Transfer efficiencies adapted from 2011 ESD on Spray-Painting in Automotive Refinishing
3. Equipment residues – Water, incineration, or landfill – EPA/OPPT Multiple Process Vessel Residual Model and Coating Industry ESD estimates
4. Open surface losses to air during equipment cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
5. Can/container residues – Water, incineration, or landfill – EPA/OPPT Drum and Small Container Residual Models
6. Open surface losses to air during can/container cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model

3.11.3.2 Environmental Release Assessment Results

Table 3-31 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Use of Paints and Coatings OES*

Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4) also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-31. Summary of Modeled Environmental Releases for Use of Paints and Coatings

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of paints and coatings (1-day application, 100 kg/day)	Fugitive air	9.3E−01	7.3	1	1	9.3E−01	7.3
	Water, incineration, or landfill[a]	1.9E−01	1.5	1	1	1.9E−01	1.5
Use of paints and coatings (2-day application, 100 kg/day)	Fugitive air	1.9	1.5E01	2	2	9.3E−01	7.3
	Water, incineration, or landfill[a]	3.8E−01	3.1	2	2	2.3E−01	1.5
Use of paints and coatings (250-day application, 100 kg/day)	Fugitive air	2.3E02	1.8E03	250	250	9.2E−01	7.4
	Water, incineration, or landfill[a]	4.7E01	3.8E02	250	250	4.4E−01	1.6
Use of paints and coatings (1-day application, 1000 kg/day)	Fugitive air	9.2	7.4E01	1	1	9.2	7.4E01
	Water, incineration, or landfill[a]	1.9	1.5E01	1	1	1.9	1.5E01
Use of paints and coatings (2-day application, 1000 kg/day)	Fugitive air	1.9E01	1.5E02	2	2	9.3	7.3E01
	Water, incineration, or landfill[a]	3.8	3.1E01	2	2	1.9	1.5E01
Use of paints and coatings (250-day application, 1000 kg/day)	Fugitive air	2.3E03	1.8E04	250	250	9.2	7.3E01
	Water, incineration, or landfill[a]	4.7E02	3.8E03	250	250	1.9	1.5E01

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

[b] The Monte Carlo simulation calculated the total D4 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.

3.11.4 Occupational Exposure Assessment

3.11.4.1 Worker Activities

During the use of paints and coatings worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquids. EPA utilized the ESD on Coating Application via Spray-Painting in the

Automotive Refinishing Industry (OECD, 2011a) to identify activities that could result in exposure during this OES. Possible exposure points include:

- Dermal exposure from unloading/mixing liquid coating product into final coating, as sprayed;
- Dermal exposure to cured/solid or liquid coating product components during container cleaning;
- Dermal exposure to final mixed liquid coating during manual transfer from mixing cup to spray gun;
- Dermal exposure to final mixed liquid coating during equipment cleaning of mixing cup, spray gun, and spray booth floors/walls; and
- Inhalation and dermal exposure to solid/liquid coating particulates (*i.e.,* overspray mist) during spray application.

Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly.

3.11.4.2 Occupational Inhalation Exposure Results

EPA used the Spray Application of Paints & Coatings OES via the All-Data Scenario of the Auto Refinish Sample Data Summary as a surrogate (OECD, 2011a) in conjunction with concentration data for product SDSs to provide an 8-hr TWA and to calculate the AC, IADC, and ADC for worker exposures to D4 during this OES. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor. Table 3-32 summarizes the AC, IADC, and ADC for average adult workers and ONUs. For this OES, ONU-specific estimates were not available, ONU inhalation exposures were assumed to be no greater than central tendency exposures for workers.

Table 3-32. Summary of Estimated Inhalation Exposures for Use of Paints and Coatings

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Spray application of paints and coatings (1-day scenario)	Worker	8-hr	3.0E−01	2.2E01	2.0E−01	1.5E01	6.7E−03	5.0E−01	5.5E−04	4.1E−02
	ONU	8-hr	3.0E−01		2.0E−01		6.7E−03		5.5E−04	
Spray application of paints and coatings (2-day scenario)	Worker	8-hr	3.0E−01	2.2E01	2.0E−01	1.5E01	1.3E−02	1.0	1.1E−03	8.2E−02
	ONU	8-hr	3.0E−01		2.0E−01		1.3E−02		1.1E−03	
Spray application of paints and coatings (250-day scenario)	Worker	8-hr	3.0E−01	2.2E01	2.0E−01	1.5E01	1.5E−01	1.1E01	1.4E−01	1.0E01
	ONU	8-hr	3.0E−01		2.0E−01		1.5E−01		1.4E−01	

Note: EPA used the spray application of paints and coatings OES via the All Data Scenario of the Auto Refinish Sample Data Summary as a surrogate (U.S. EPA, 2014b), which has a rating of medium through EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

3.11.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. Since there may be mists deposited on surfaces from this OES, dermal exposures to ONUs from contact with mists on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-33 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs for 1-, 2-, and 250-day scenarios. The explanations for these scenarios are in Section 3.11.1.

Table 3-33. Summary of Estimated Dermal Exposures for Use of Paints and Coatings

OES	SEG	Exposure Days Per Year	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)		Physical Form
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	
Spray application of paints and coatings (1-, 2-, and 250-day scenarios)	Worker	1	5.1E02	2.7E03	6.4	3.3E01	2.1E−01	1.1	1.7E−02	9.2E−02	Liquid
	ONU		1.9E02		2.3		7.8E−02		6.4E−03		Mist deposited on surfaces
	Worker	2	5.1E02	2.7E03	6.4	3.3E01	4.2E−01	2.2	3.5E−02	1.8E−01	Liquid
	ONU		1.9E02		2.3		1.6E−01		1.3E−02		Mist deposited on surfaces
	Worker	250	5.1E02	2.7E03	6.4	3.3E01	4.7	2.5E01	4.4	2.3E01	Liquid
	ONU		1.9E02		2.3		1.7		1.6		Mist deposited on surfaces

Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.12 Use of Solvents

3.12.1 Process Description

EPA incorporated this OES based on a public comment indicating that Aircraft Maintenance products included D4 as a component (EPA-HQ-OPPT-2018-0443-0032). EPA further identified products that are labelled as degreasers, cleaning solvents, and electrical lubricants that contain between 5 and 50 percent D4, by weight. Technical data sheets for these products indicate they are used as either a spray degreasing or cold cleaning application (United Laboratories, 2019b; Safety-Kleen, 2018; Ecolink, 2012). Specific concentrations and products are provided in Appendix F.

During the use of a spray degreasing product, the surface that is intended to be cleaned will be sprayed with the degreasing formulation which will be left of the surface so that it can penetrate the surface dirt or scale. This is followed by manual cleaning or scraping of the dirt or scale from the surface after which the surface will be recoated with the spray degreaser which will then act as an anticorrosive coating (United Laboratories, 2019b).

In the case of cold cleaning degreaser use, the product will typically utilize an immersion tank to soak the item. After the item has soaked for enough time, the item being cleaned can be manually cleaned with a brush or rag. This process can be repeated until the item is fully cleaned (Ecolink, 2012).

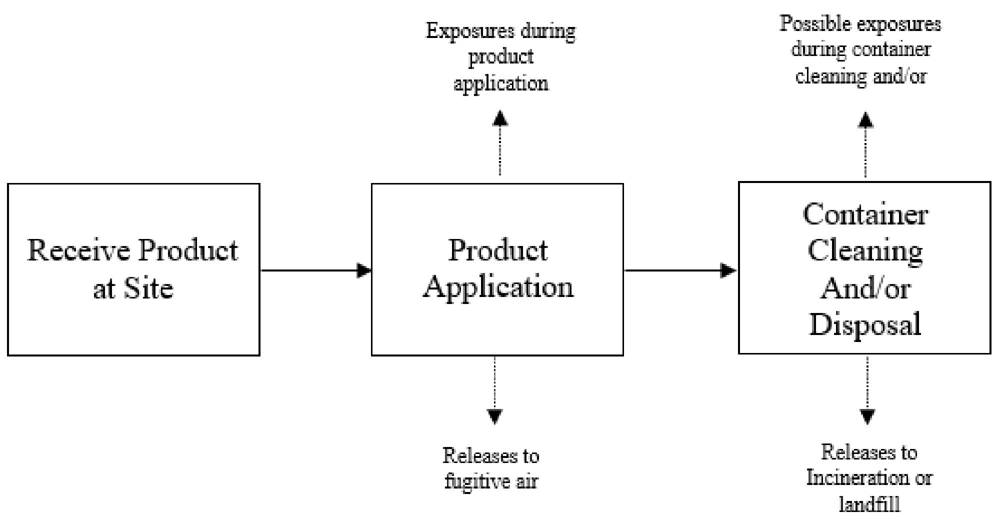

Figure 3-13. Use of Solvents, Lubricants, and Greases Flow Diagram – Spray Application

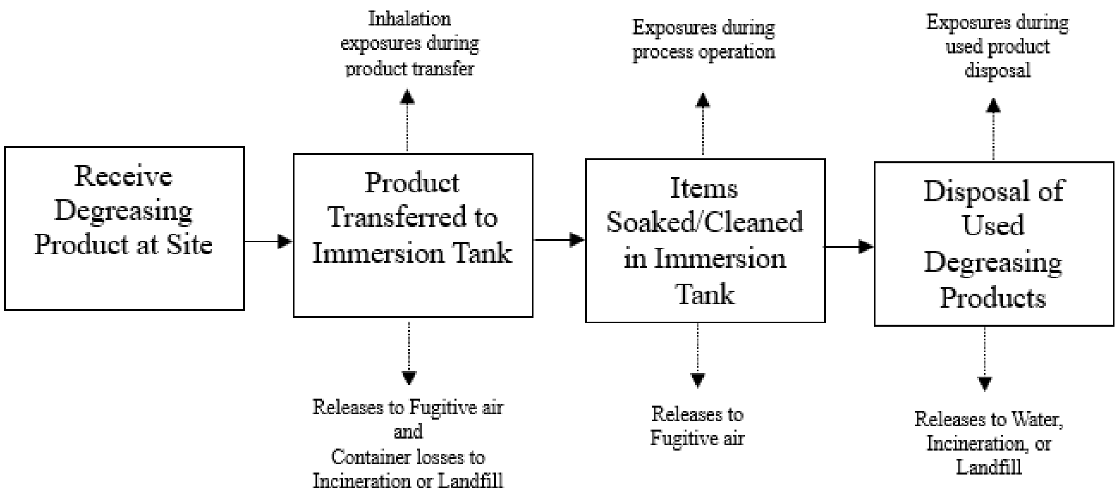

Figure 3-14. Use of Solvents, Lubricants, and Greases Flow Diagram – Cold Cleaning Application

3.12.2 Facility Estimates

EPA did not identify site or chemical specific use operating data (*e.g.*, facility use rates, operating days, overall PV) for this OES. EPA relied on OPPT models and parameters, U.S. Census data, and other sources identified during systematic review for parameters used in this assessment. Product data sheets indicate that the container sizes range from 1 to 55 gallons, given that the product can be received in larger container sizes EPA chose to use a value of 5 percent of the national aggregate PV for this OES. This is also in line with Brooke et al. (2009), which provides an average of approximately 5 percent of the D4 PV is used for any given subcategory of use. Therefore, EPA used a value of 5 percent of the D4 that is not processed as a reactant (*i.e.*, 5% of 100,000,000 lb or 2,267,962 kg). EPA further assumes that this is part of the alloted 14 percent of D4 that is used for "specialty" products.

EPA further expects that this scenario could be applicable to industries such as electronic and semiconductor manufacturers that use D4 carrier solvent formulations that are used in the production of electronic wafers, which is a use indicated by the D4 Consortium (SEHSC, 2020). EPA expects that such uses would have lower potential for releases and exposures and considers this assessment to be protective of those uses. EPA has noted this in Section 4.

EPA did not find data regarding facility use or changeout rates for the application types of penetrant or cold cleaning. EPA created multiple "what-if" scenarios. The penetrant type of application scenario modelled both 100 percent and 50 percent of the OES PV being used for this application. The cold cleaning scenario modeled 50 percent and 100 percent of the OES PV being used and considered varying changeout frequencies being conducted. The results of these modeled releases can be found in Table 3-34.

3.12.3 Release Assessment

3.12.3.1 Environmental Release Points

As explained in Section 3.12.1, EPA used the ESD on the Use Vapor Degreasers and Furnishing Cleaning Revised GS to estimate the release points for this OES (U.S. EPA, 2022b; OECD, 2021). The expected process steps, media of release, and methodology of assessment are listed below.

Spray-applied scenario:

1. Container Residue Losses – Incineration or landfill – EPA/OPPT Small Container Residual Model and/or EPA/OPPT Drum Residual Model
2. Aerosol application of product – Fugitive air, incineration, or landfill – 2022 Furnishing Cleaning Revised GS

Cold cleaning scenario:

1. Container residue losses – Incineration or landfill – EPA/OPPT Small Container Residual Model and/or EPA/OPPT Drum Residual Model
2. Release from transferring degreaser from transport containers – Fugitive air – EPA/OAQPS AP-42 Loading Model
3. Open surface losses to air during container cleaning – Fugitive air – EPA/OPPT Penetration Model and/or EPA/OPPT Mass Transfer Coefficient Model
4. Application of degreaser open air losses – Fugitive air – EPA/OPPT Penetration Model and/or EPA/OPPT Mass Transfer Coefficient Model
5. Disposal of used degreaser – Water, incineration, or landfill – 100% release scenario

3.12.3.2 Environmental Release Assessment Results

Table 3-34 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Use of Solvents OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results; refer to Appendix G for a reference to this supplemental document.

Table 3-34. Summary of Modeled Environmental Releases for the Use of Solvents, Lubricants, and Greases

Modeled Scenario	Release Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Penetrant product; what-if scenario 50% of total PV	Fugitive air	7.1	4.3E01	296	296	2.4E−02	1.4E−01
	Incineration or landfill[a]	3.7E01	4.2E01	296	296	1.2E−01	1.4E−01
Penetrant Product; what-if scenario 100% of total PV	Fugitive air	1.3E01	5.1E01	296	296	4.4E−02	1.7E−01
	Incineration or landfill[a]	7.4E01	7.4E01	296	296	2.5E−01	2.5E−01
Cold cleaning product; what-if scenario 50% of total PV; daily changeout	Fugitive air	1.2E01	9.1E01	296	296	4.2E−02	3.1E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	6.7E01	6.2E02	296	296	2.3E−01	2.1

Modeled Scenario	Release Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	Incineration or landfill[a]	5.3E−01	8.6	296	296	1.8E−03	2.9E−02
Cold cleaning product; what-if scenario 50% of total PV; monthly changeout	Fugitive air	1.2E01	9.1E01	296	296	4.2E−02	3.1E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	6.7E01	6.3E02	12	12	5.6	5.2E01
	Incineration or landfill[a]	2.2E−02	3.4E−01	12	12	1.8E−03	2.9E−02
Cold cleaning product; what-if scenario 50% of total PV; bi-annual changeout	Fugitive air	1.2E01	9.1E01	296	296	4.2E−02	3.1E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	6.8E01	6.2E02	2	2	3.4E01	3.1E02
	Incineration or landfill[a]	3.6E−03	5.8E−02	2	2	1.8E−03	2.9E−02
Cold cleaning product; what-if scenario 100% of total PV; daily changeout	Fugitive air	1.2E01	9.1E01	296	296	4.2E−02	3.1E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	8.4E01	6.2E02	296	296	2.8E−01	2.1
	Incineration or landfill[a]	5.3E−01	8.5	296	296	1.8E−03	2.9E−02
Cold cleaning product; what-if scenario 100% of total PV; monthly changeout	Fugitive air	1.2E01	9.1E01	296	296	4.2E−02	3.1E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	8.5E01	6.2E02	12	12	7.1	5.2E01
	Incineration or landfill[a]	2.2E−02	3.5E−01	12	12	1.8E−03	2.9E−02
Cold cleaning product; what-if scenario 100% of total PV; bi-annual changeout	Fugitive air	1.2E01	9.1E01	296	296	4.2E−02	3.1E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	8.5E01	6.3E02	2	2	4.2E01	3.1E02
	Incineration or landfill[a]	3.5E−03	5.8E−02	2	2	1.8E−03	2.9E−02

Modeled Scenario	Release Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End

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

[b] The Monte Carlo simulation calculated the total D4 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.

3.12.4 Occupational Exposure Assessment

3.12.4.1 Worker Activities

During the use of solvents worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquids. EPA utilized the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model to identify activities that could result in exposure during this OES. This model was chosen due to the product being spray applied. The Cold Cleaning Near-Field/Far-Field Model was used for an immersion tank scenario Possible exposure points include:

Spray-applied scenario:
- Container cleaning/disposal
- Aerosol application of product

Cold cleaning scenario:
- Container cleaning/disposal
- Transferring degreaser from transport containers
- Application of degreaser
- Disposal of used degreaser

The near field/far field models a scenario where the vapor generation source, which is located inside the near field (*e.g.*, immersion tank equipment) diffuses into the surrounding environment. Workers are assumed to be exposed to D4 vapor concentrations in the near-field, while occupational non-users are exposed at concentrations in the far-field. The concentration is directly proportional to the evaporation rate of D4 into the near field, whose volume is considered the immediate area of the activity or equipment. The ventilation rate for the near-field zone determines how quickly D4 dissipates into the far-field, resulting in occupational non-user exposures to D4 at a lower concentration

The central tendency and high-end exposures use 250 days per year as the exposure frequency, which is the expected maximum for working days.

3.12.4.2 Occupational Inhalation Exposure Results

EPA used the Near-Field/Far-Field Inhalation Exposure Model in conjunction with concentration data for product SDSs to provide an 8-hour TWA and to calculate the AC, IADC, and ADC for worker and ONU exposures to D4 during this OES. Worker exposures are represented by the near field modeling results and ONUs are represented by the far field results. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor. Table 3-35 summarizes the AC, IADC, and ADC for average adult workers and ONUs.

Table 3-35. Summary of Estimated Inhalation Exposures for the Use of Solvents, Lubricants, and Greases

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Degreasing (penetrant)	Worker	8-hr	2.9E−02	1.0E−01	2.0E−02	6.9E−02	1.5E−02	5.0E−02	1.4E−02	4.7E−02
	ONU	8-hr	5.4E−04	4.2E−03	3.6E−04	2.9E−03	2.7E−04	2.1E−03	2.5E−04	2.0E−03
Degreasing (cold cleaning)	Worker	8-hr	1.2	8.3	8.5E−01	5.6	6.2E−01	4.1	5.8E−01	3.9
	ONU	8-hr	7.0E−01	6.3	4.8E−01	4.3	3.5E−01	3.1	3.3E−01	2.9

Note: EPA used a Monte Carlo simulation using the Near Field/Far Field Inhalation Model with parameters from relevant EPA models. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

3.12.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. Since there may be mists deposited on surfaces from this OES, dermal exposures to ONUs from contact with mists on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-36 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs for penetrant and cold cleaning scenarios. The explanations for these scenarios are located in Section 3.12.1.

Table 3-36. Summary of Estimated Dermal Exposures for the Use of Solvents, Lubricants, and Greases

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Degreasing (penetrant)	Worker	7.5E01	2.2E02	9.4E−01	2.8	6.9E−01	2.1	6.4E−01	1.9
	ONU	7.5E01		9.4E−01		6.9E−01		6.4E−01	
Degreasing (cold cleaning)	Worker	3.7E02	1.1E03	4.7	1.4E01	3.4	1.0E01	3.2	9.6
	ONU	3.7E02		4.7		3.4		3.2	

Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.13 Use of Automotive Care Products

3.13.1 Process Description

The use of automotive care products is a COU included in the final scope document (U.S. EPA, 2022d) and is also included as a use in the D4 Consortium submission and therefore included as an OES (SEHSC, 2020). EPA has identified several automotive care products that can be used as polishes and fabric treatments for vehicles (3M, 2019; Adam's Polishes, 2017; B&B Blending, 2017). Specific concentrations and products are provided in Appendix F. The process for detailing a vehicle typically consists of first washing the vehicle and then applying the polish or wax to the exterior (Figure 3-15). This process can also include touching up scratches on the exterior of the vehicle by hand or using a buffer. Once the detailing process is complete, it is expected that residual amounts of product will remain on the vehicle surfaces.

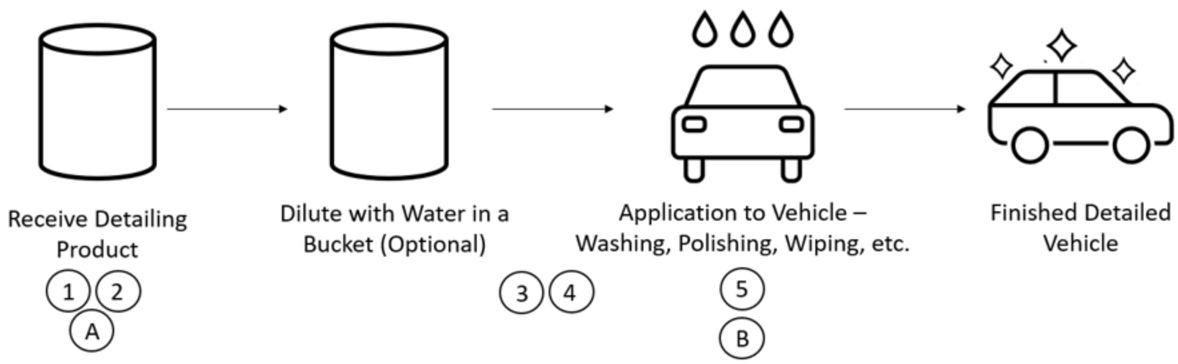

Figure 3-15. Use of Automotive Care Products Flow Diagram (U.S. EPA, 2022c)

3.13.2 Facility Estimates

EPA was not able to find PV data for this OES. EPA considers this to be a part of the "specialty" category in Brooke et al. (2009) which encompasses 14 percent of the overall D4 lifecycle PV. EPA used 1,179,340 kg per year, or 2.6 percent of the overall neat D4 PV for this OES, and it is considered a downstream use of the formulation of greater than residual D4 products based on identified product concentration range, which was between 0.0005 and 0.5 percent D4 by weight. Product data can be found in Appendix F.

EPA used a Monte Carlo simulation for this OES with the following parameters based on the automotive detailing MRD (U.S. EPA, 2022c). The maximum possible number of sites was capped at 147,152 sites. The maximum number of operating days was capped at 260. The amount of product that can be applied to each vehicle ranges between 2 and 16 ounces, the number of vehicles serviced per site/year ranges between 1,610 to 3,212 with a mode of 2,191. Container size for products ranged between 1 and 100 gallons with a mode of 55 gallons. The results from the Monte Carlo simulation for annual throughput per site is estimated to have a high end of 88 kg per year at 13,414 sites and the central tendency of 8 kg per year at 147,152 sites.

3.13.3 Release Assessment

3.13.3.1 Environmental Release Points

As explained in Section 3.13.1, EPA used the Commercial Use of Automotive Detailing Products GS - MRD to estimate the release points for this OES (U.S. EPA, 2022c). The expected process steps, media of release, and methodology of assessment are listed below.

1. Transfer operations losses during unloading volatile chemicals – Fugitive air – EPA/OAQPS AP-42 Loading Model
2. Cleaning or disposal of transport containers – Water or landfill – EPA/OPPT Small Container Residual Model or EPA/OPPT Drum Residual Model
3. Cleaning containers used for volatile chemicals – Fugitive air – EPA/OPPT Penetration Model and/or EPA/OPPT Mass Transfer Coefficient Model
4. Release of the automotive detailing product during application/detailing – Fugitive air, water, or landfill – Industry specific data

3.13.3.2 Environmental Release Assessment Results

Table 3-37 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Use of Automotive Care Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-37. Summary of Modeled Environmental Releases for the Use of Automotive Care Products

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of automotive care products	Fugitive air	2.6E−02	3.6E−01	228	230	1.1E−04	1.6E−03
	Fugitive air, water (to on-site treatment or off-site POTW), or landfill[a]	7.7	8.2E01	219	223	3.5E−02	3.7E−01
	Water (to on-site treatment or off-site POTW) or landfill[a]	2.9E−01	3.5	2	1	1.7E−01	2.6

[a] When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.
[b] The Monte Carlo simulation calculated the total D4 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.

3.13.4 Occupational Exposure Assessment

3.13.4.1 Worker Activities

During the use of automotive care products worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquids. EPA utilized the Commercial Use of Automotive Detailing Products MRD (U.S. EPA, 2022c) to identify activities that could result in exposure during this OES. Possible exposure points include:

- Unloading chemicals from transport containers
- Application and use of automotive detailing product

The central tendency and high-end exposures use 235 and 250 days per year, respectively, as the exposure frequency.

3.13.4.2 Occupational Inhalation Exposure Results

EPA used the exposure methodology outlined in the Commercial Use of Automotive Detailing Products MRD (U.S. EPA, 2022c), which estimates total volatile organic compounds and applies the product weight fraction to calculate an 8-hour TWA, which is used to calculate the AC, IADC, and ADC for worker exposures to D4 during this OES. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor. Table 3-38 summarizes the AC, IADC, and ADC for average adult workers and ONUs. For this OES, ONU-specific estimates were not available, ONU inhalation exposures were assumed to be no greater than central tendency exposures for workers.

Table 3-38. Summary of Estimated Inhalation Exposures for Use of Automotive Care Products

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m³)		Acute Concentration (AC; mg/m³)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m³)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m³)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of automotive care products	Worker	8-hr	6.5E−02	1.2	4.4E−02	8.2E−01	3.2E−02	6.0E−01	2.8E−02	5.6E−01
	ONU	8-hr	6.5E−02		4.4E−02		3.2E−02		2.8E−02	3.0E−02

EPA used the total VOC method in the Use of Automotive Detailing MRD (U.S. EPA, 2022c), which has a rating of medium through EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

3.13.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. Since there may be mists deposited on surfaces from this OES, dermal exposures to ONUs from contact with mists on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-39 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-39. Summary of Estimated Dermal Exposures for the Use of Automotive Care Products

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of automotive care products	Worker	4.1E02	1.2E03	5.1	1.5E01	3.8	1.1E01	3.3	1.1E01
	ONU	4.1E02		5.1		3.8		3.3	3.5

Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.14 Use of Animal Grooming Products

3.14.1 Process Description

The COU of Animal Grooming Products was included in the D4 Scope based on a public comment received for a D4-containing product called "Rockin' Paws ROCKIN' MAT STOPPER Coat De-Matting and Shine Serum" (EPA-HQ-OPPT-2018−0443). According to the product data sheet, it is hand applied during pet grooming and brushed in. Figure 3-16 provides an illustration of the process.

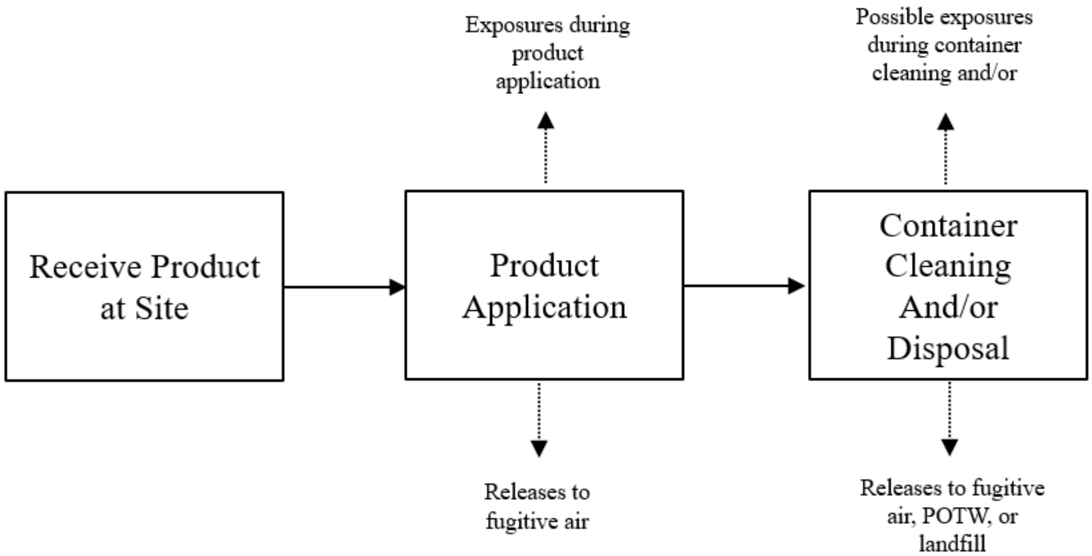

Figure 3-16. Use of Animal Grooming Products Flow Diagram

3.14.2 Facility Estimates

EPA calculated the PV for this OES to be 300,478 lb per year (136,295 kg/yr) of D4 using the methodology in the GS for the Use of Laboratory Chemicals (U.S. EPA, 2023b). This method assumes at least 25,000 lb of D4 or 5 percent of the reporters' total PV goes to this OES. The possible number of sites was calculated by using NAICS Code 812910, which represents Pet Care (except Veterinary) Services. Within that NAICS Code is SIC Code 07529901 for Grooming Services, Pet and Animal Specialties, which has a total number of marketable U.S. businesses of 28,932 (U.S. BLS, 2023). Therefore, this number of businesses is used as the total number of sites for animal grooming services. Container sizes are assumed to range from 4 to 64 fluid ounces which is consistent with the half gallon product size found on the TDS sheet provided to EPA via public comment. EPA did not identify data regarding specific product concentrations, therefore, D4 concentrations are based on Section 4.1.3 of the MRRE that states that D4 is present in most products in the range of 1 to 5 percent (SEHSC, 2020).

3.14.3 Release Assessment

3.14.3.1 Environmental Release Points

EPA used standard OPPT models and parameters to estimate the release points for this OES. This is a total release scenario due to the expectation that all D4 contained within the product will ultimately volatize to fugitive air after product application (*e.g.*, step #2). The expected process steps, media of release, and methodology of assessment are listed below.

1. Releases during container cleaning – Fugitive air – Combination of EPA/OPPT Mass Transfer Coefficient Model and EPA/OPPT Penetration Model
2. Losses from application – Fugitive air – Mass balance of remaining D4 after other releases
3. Container residual losses – POTW or landfill – EPA/OPPT Small Container Residual Model

3.14.3.2 Environmental Release Assessment Results

Table 3-40 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Use of Animal Grooming Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document)

Table 3-40. Summary of Modeled Environmental Releases for the Use of Animal Grooming Products

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of animal grooming products	Fugitive air	7.0E−01	1.5	250	250	2.8E−03	6.1E−03
	POTW or landfill[a]	1.4E−02	2.4E−02	177	96	8.2E−05	2.5E−04
	Unknown[c]	4.0	4.6	250	250	1.6E−02	1.8E−02

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

[b] The Monte Carlo simulation calculated the total D4 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.

[c] All of the identified animal grooming products with D4 are intended to remain on the animal; however, if products were to be washed off or naturally fall off the animal over time, additional release may occur, which is what this release amount represents. This release is anticipated to POTW (if the animal is washed), or other unknown media depending on circumstances of release (*e.g.*, if the product is washed off in the rain, rubbed off on the ground). If this release is to POTW from washing the animal, the presented number of sites and days of release are accurate. If this release is from the product naturally falling off the animal, then the number of sites and release days is unknown.

3.14.4 Occupational Exposure Assessment

3.14.4.1 Worker Activities

During the use of animal grooming products, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling D4-containing products, equipment cleaning, and/or disposing of product containers. EPA did not identify information on engineering controls or worker PPE used at D4 manufacturing facilities. ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. The central tendency and high-end exposures use 250 days per year as the exposure frequency, which is the expected maximum for working days.

3.14.4.2 Occupational Inhalation Exposure Results

EPA used the exposure methodology outlined in the Furnishing Cleaning GS (U.S. EPA, 2022b) as a surrogate for this OES. This model estimates total volatile organic compounds and applies the product weight fraction to calculate an 8-hour TWA, which is used to calculate the AC, IADC, and ADC for worker exposures to D4 during this OES. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor. Table 3-41 summarizes the AC, IADC, and ADC for average adult workers and ONUs. For this OES, ONU-specific estimates were not available, ONU inhalation exposures were assumed to be no greater than central tendency exposures for workers.

2831 **Table 3-41. Summary of Estimated Inhalation Exposures for Use of Animal Grooming Products**

2832

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m³)		Acute Concentration (AC; mg/m³)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m³)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m³)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of animal grooming products	Worker	8-hr	5.4E−03	8.5E−02	3.7E−03	5.8E−02	2.7E−03	4.2E−02	2.5E−03	4.0E−02
	ONU	8-hr	5.4E−03		3.7E−03		2.7E−03		2.5E−03	
Note: EPA used the total VOC method in the Furnishing Cleaning GS (U.S. EPA, 2022b), which has a rating of medium through EPA's systematic review process. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.										

3.14.4.3 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. Since there may be mists deposited on surfaces from this OES, dermal exposures to ONUs from contact with mists on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Table 3-42 summarizes the APDR, AD, IADD, and ADD for average adult workers and ONUs.

Table 3-42. Summary of Estimated Dermal Exposures for the Use of Animal Grooming Products

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of animal grooming products	Worker	3.7E01	1.1E02	4.7E−01	1.4	3.4E−01	1.0	3.2E−01	9.6E−01
	ONU	3.7E01		4.7E−01		3.4E−01		3.2E−01	

Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

3.15 Laboratory Use

3.15.1 Process Description

D4 is expected to be used as a laboratory chemical at commercial and industrial laboratory sites. EPA identified relevant SDS that indicate laboratory chemicals containing liquid D4 at greater than 90 percent and up to 100 percent (Sigma-Aldrich, 2023; TCI America, 2019). It is expected to arrive at the lab site in containers ranging from 0.5 mL to up to 1 gallon (U.S. EPA, 2023b). The end-use site transfers the chemical to labware and lab equipment for analyses. After analysis, laboratory sites clean containers, labware, and lab equipment and dispose of laboratory waste and unreacted D4-containing laboratory chemicals. Figure 3-17 provides an illustration of the use of laboratory chemicals.

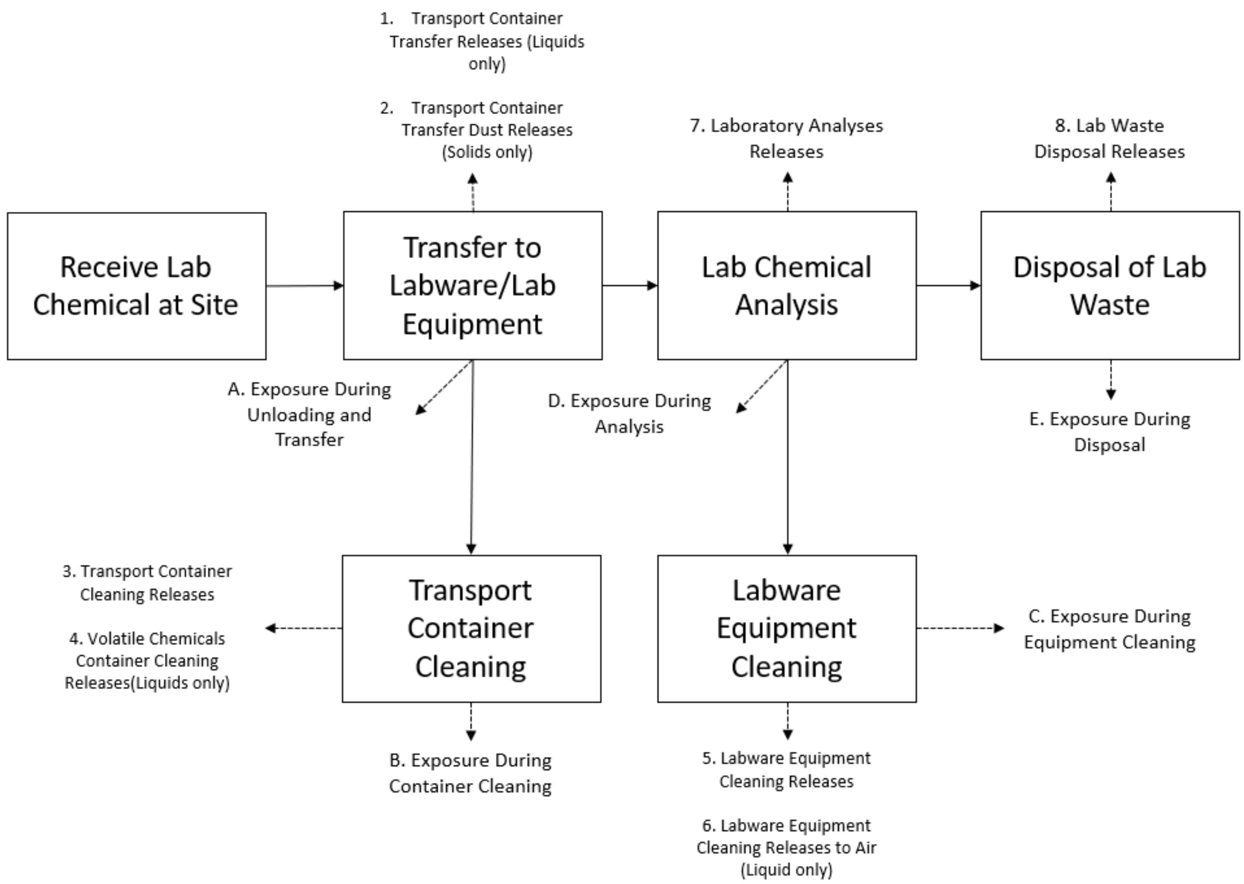

Figure 3-17. Use of Laboratory Chemicals Flow Diagram (U.S. EPA, 2023b)

3.15.2 Facility Estimates

No sites reported the use of D4-containing laboratory chemicals in the 2020 CDR. Instead, EPA assumed that a portion of the D4 production volume from each CDR reporting site may be used in laboratory chemicals. Specifically, EPA estimated the total production volume of D4 in laboratory chemicals using the CDR reporting threshold limits of either 25,000 lb (11,340 kg) or 5 percent of a site's reported production volume, whichever value was smaller. EPA considered every site that reported using D4 to CDR, regardless of assigned OES. EPA assumed that sites that claimed their production volume as CBI used 25,000 lb of D4-containing laboratory chemicals annually. The total production volume for this OES was 300,344 lb per year, or 136,234 kg per year. The number of site and PV throughputs were estimated using a Monte Carlo simulation. The 95th percentile provided a daily throughput of 3.2 kg/site-day, an annual throughput of 752.7 kg/site-yr, and 181 laboratory sites where this operation could be occurring. The 50th percentile provided a daily throughput of 1.9 kg/site-day, an annual throughput of 435.3 kg/site-yr, and 312 laboratory sites where this operation could be occurring.

3.15.3 Release Assessment

3.15.3.1 Environmental Release Points

As explained in Section 3.15.1, EPA used the GS on the Use of Laboratory Chemicals to estimate the release points for this OES (U.S. EPA, 2023b). The expected process steps, media of release, and methodology of assessment are listed below.

1. Release to air from transferring volatile chemicals from transport containers – Fugitive air – EPA/OAQPS AP-42 Loading Model
2. Dust emissions – Not assessed
3. Product container cleaning and/or disposal – Wastewater, incineration or landfill – EPA/OPPT Small Container Residual Model
4. Product container cleaning and/or disposal – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
5. Labware equipment cleaning residuals following use of chemicals – Wastewater, incineration or landfill – EPA/OPPT Multiple Vessel Residual Model
6. Release to air during labware equipment cleaning for volatile chemicals – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
7. Release to air during laboratory analyses – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
8. Laboratory waste disposal – Wastewater, incineration or landfill – Mass balance from other release points

3.15.3.2 Environmental Release Assessment Results

Table 3-43 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Laboratory Use OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-43. Summary of Modeled Environmental Releases for the Use of D4 as a Laboratory Chemical

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
	Fugitive or stack air[a]	1.3E−01	2.3E−01	220	229	6.1E−04	1.0E−03

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Laboratory use of D4	Water, incineration, or landfill[a]	8.7E01	1.5E02	136	44	6.4E−01	3.5

[a] When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.
[b] The Monte Carlo simulation calculated the total D4 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.

3.15.4 Occupational Exposure Assessment

3.15.4.1 Worker Activities

During the use of D4 in a laboratory setting, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling neat D4 or D4-containing products, equipment cleaning, and/or disposing of product containers. EPA did not identify information on engineering controls or worker PPE used at D4 manufacturing facilities. ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. ONU are not expected to have dermal exposures to D4 during this OES. The central tendency and high-end exposures use 235 and 250 days per year, respectively, as the exposure frequency.

3.15.4.2 Occupational Inhalation Exposure Results

EPA used area monitoring data submitted by SEHSC for this OES (SEHSC, 2019). Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor and that exposures occur for 250 days a year. Table 3-44 summarizes the AC, IADC, and ADC for average adult workers and ONUs. For this OES, ONU-specific estimates were not available, ONU inhalation exposures were assumed to be no greater than central tendency exposures for workers.

Table 3-44. Summary of Estimated Inhalation Exposures for Laboratory Use of D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of laboratory chemicals	Worker	8-hr	2.4E−01	4.7E01	1.7E−01	3.2E01	1.2E−01	2.3E01	1.1E−01	2.2E01
	ONU	8-hr	2.4E−01		1.7E−01		1.2E−01		1.1E−01	

Note: EPA received inhalation monitoring data from SEHSC from manufacturing and processing facilities (SEHSC, 2019). This data received a rating of medium from EPA's systematic review process. The distributions (*e.g.*, high-end and central tendency) were created based on the number of data points and used the process described in Section 2.4.2. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

3.15.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. Dermal exposure for ONUs was not assessed for this OES since it is not expected to occur. Table 3-45 summarizes the APDR, AD, IADD, and ADD for workers.

2925 **Table 3-45. Summary of Estimated Dermal Exposures for Laboratory Use of D4**

OES	SEG	Acute Potential Dose Rate (mg/day)		Acute Applied Dose (mg/kg-day)		Intermediate Applied Daily Dose (mg/kg-day)		Chronic Average Applied Daily Dose (mg/kg-day)	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Use of laboratory chemicals	Worker	7.5E02	2.2E03	9.4	2.8E01	6.9	2.1E01	6.0	1.9E01

Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (*i.e.*, 1070 cm^2) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2).

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3.16 Residual Uses

3.16.1 Process Description

This OES is intended to capture what EPA is considering to be industrial and/or commercial uses of products that are expected to contain residual levels of D4. The source of the residual D4 is based on the expectation that a small amount of D4 will remain from the Processing as a reactant OES, it is also possible that the product was formulated using small amounts of neat D4. These types of products are expected to contain less than 5 percent by weight (SEHSC, 2020), and in many cases significantly less. Because silicone polymer mixtures, such as PDMS, are used in such a broad range of products and commercial and/or industrial sectors, it is almost impossible to analyze every single use (Brooke et al., 2009). Based on uses defined in the SEHSC Submission (SEHSC, 2020), EPA analyzed the following scenarios:

Environmental releases from the use of:

- Fabric finishing products
- Cleaning products
- Laundry products

Occupational exposures from the use of:

- Cleaning products
- Laundry products

The SEHSC Submission describes several uses of D4 in textile related categories. These uses include functional fabric finishing agents, textile coatings, and processing aids (defoamers, lubricants, and/or wetting agents). Typically, these types of fabric finishing use(s) involve the fabric being fed through a trough containing the finishing agent by a system of rollers. Other methods can involve application by brushes, rollers, and/or spraying. The SEHSC submission also describes how silicone-based products have numerous uses in washing, cleaning, and polishing applications (SEHSC, 2020). Figure 3-18 below provides an illustration of the fabric finishing process.

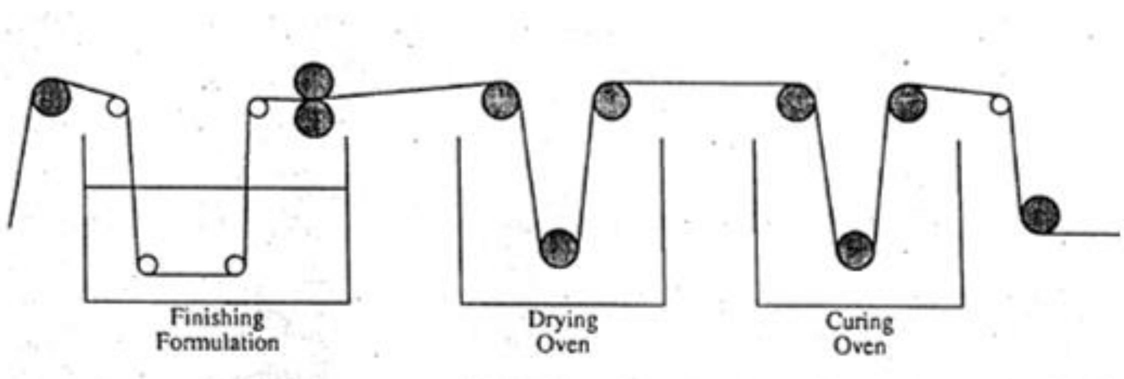

Figure 3-18. Fabric Finishing Process (OECD, 2004)

3.16.2 Facility Estimates

EPA estimated the PV for Fabric finishing OES based on Brooke et al. (2009) which provided approximately 2.6 percent for textile coatings and textile applications in the silicone fluids and elastomers category, respectively. For the OESs of cleaning products and laundry products, EPA assumed a PV of 5 percent for both OESs based on the PV percentage provided for the processing aids and other subcategories (see Section 2.3.1 for PV assumptions).

EPA calculated the maximum number of sites using the following NAICS codes:

Fabric finishing:

- 313210 – Broadwoven Fabric Mills – 1,772 sites
- 313220 – Narrow Fabric Mills and Schiffli Machine Embroidery – 1,090 sites
- 313230 – Nonwoven Fabric Mills – 1,232 sites
- 313240 – Knit Fabric Mills – 742 sites
- 313310 – Textile and Fabric Finishing Mills – 4,585 sites
- 313320 – Fabric Coating Mills – 949 sites
- 314910 – Textile Bag and Canvas Mills – 10,234 sites
- 314994 – Rope, Cordage, Twine, Tire Cord, and Tire Fabric Mills – 752 sites
- 314999 – All other Miscellaneous Textile Product Mills – 18,165 sites

This comes out to a maximum number of sites of 39,521 sites for the fabric finishing OES.

Use of cleaning products:

- 561720 - Janitorial Services
- 561790 - Other Services to Buildings and Dwellings
- 811310 - Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance)
- 811412 - Appliance Repair and Maintenance

This comes out to a maximum number of sites of 105,745 sites for the use of cleaning products OES.

Use of Laundry Products:

- 812331 – Linen Supply: 4,831 sites
- 812332 – Industrial Launderers: 6,918 sites
- 622110 – General Medical and Surgical Hospitals: 25,084 sites
- 622210 – Psychiatric and Substance Abuse Hospitals: 3,276 sites
- 622310 – Specialty (except Psychiatric and Substance Abuse) Hospitals: 3,239 sites
- 721110 – Hotels (except Casino Hotels) and Motels: 373,696 sites
- 721120 – Casino Hotels: 2,184 sites

This comes out to a total of 419,228 sites for the use of laundry products OES.

The results of the Monte Carlo simulations for these OESs provide the following throughput parameters. For the use of fabric finishing products, the high-end value provides 613 kg of residual D4 being used at 1,924 sites and the central tendency value provides 108 kg of residual D4 being used at 10,886 sites. For the use of cleaning products, the high-end value provides 453 kg of residual D4 being used at 5,877 sites and the central tendency value provides 68 kg of residual D4 being used at 39,223 sites. For the use of industrial laundry products, the high-end value provides 167 kg of residual D4 being used at 3,940 sites and the central tendency value provides 57 kg of residual D4 being used at 11,749 sites. For the use of institutional laundry products, the high-end value provides 194 kg of residual D4 being used at 10,274 sites and the central tendency value provides 6 kg of residual D4 being used at 347,846 sites.

3.16.3 Release Assessment

3.16.3.1 Environmental Release Points

Releases from the use of fabric finishing products, cleaning products, and laundry products were assessed due to the importance of the water pathway. EPA expects that the above listed exposure and release scenarios will be sufficiently representative of all other types of residual D4-containing product uses.

As explained in Section 3.16.1, EPA used the following scenarios to assess environmental releases for this OES. The expected process steps, media of release, and methodology of these scenarios are listed below.

Fabric finishing products:

1. Transfer operation losses to air during unloading of volatile chemicals – Fugitive air – EPA/OAQPS AP-42 Loading Model
2. Transfer operation losses to air, water, incineration, or landfill during unloading of solid chemicals (not applicable for liquid formulations)
3. Container residue losses – Water (on-site wastewater treatment and direct discharge or discharge to a POTW), incineration, or landfill – EPA/OPPT Drum Residual Model
9. Open surface losses to air during container cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
4. Equipment cleaning residue losses – Water (on-site wastewater treatment and direct discharge or discharge to a POTW), incineration, or landfill – EPA/OPPT Single Process Vessel Residual Model
10. Open surface losses to air during equipment cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
11. Volatile releases during fabric finishing operations – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
5. Non-volatile releases during fabric finishing operations – Water (on-site wastewater treatment and direct discharge or discharge to a POTW) – Industry specific data
6. Fabric scrap/offcuts disposed - landfill – Landfill – Industry specific data

Cleaning products:

1. Transfer operation losses of liquids – Fugitive air – EPA/OAQPS AP-42 Loading Model
2. Transfer operation losses of solids to fugitive air – Not assessed
3. Container residue released – POTW or landfill – EPA/OPPT Small Container Residual Model and EPA/OPPT Drum Residual Model
4. Open surface losses to air during container cleaning – Fugitive air – Combination of EPA/OPPT Mass Transfer Coefficient Model and EPA/OPPT Penetration Model
4. Release point #5
    a. Furniture cleaning product application and use releases – Fugitive air – Mass balance of other release points
    b. Furniture cleaning product application and use – POTW or landfill – Mass balance of other release points

Laundry products:

1. Container residue – Water, incineration, or landfill – Modified EPA/OPPT Small Container Residual Model
2. Open surface losses to air during container cleaning – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
3. Transfer operation losses to air from loading laundry cleaning product into washers – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
4. Dust generation from transfer operations – Not assessed
5. Releases to air into the worker's breathing zone from water-washing process – Fugitive air – EPA/OPPT Penetration Model and EPA/OPPT Mass Transfer Coefficient Model
6. Release from the water-washing process – Stack air or water – Mass balance of other release points

3.16.3.2 Environmental Release Assessment Results

Table 3-46 summarizes the number of release days and the annual and daily release estimates that were modeled for each release media and scenario assessed for this OES. See Appendix E for additional details on model equations, and different parameters used for Monte Carlo modeling. The Monte Carlo simulation calculated the total D4 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. The *Draft Fabric Finishing OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*, *Draft Use of Cleaning Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*, and *Draft Use of Laundry Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)* also contains additional information about model equations and parameters and calculation results (refer to Appendix G for a reference to this supplemental document).

Table 3-46. Summary of Modeled Environmental Releases for Uses of Residual D4-Containing Products

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Fabric finishing	Fugitive air	2.6E−02	9.0E−02	243	245	1.1E−04	3.7E−04
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	3.4	2.0E01	157	245	2.2E−02	8.3E−02
	Water (to on-site treatment or off-site POTW)	1.0E01	5.9E01	245	245	4.3E−02	2.4E−01
	Landfill	9.2	5.7E01	245	245	3.7E−02	2.3E−01
	Fugitive air	8.0	6.9E01	177	213	4.5E−02	3.2E−01

Modeled Scenario	Environmental Media	Annual Release (kg/site-yr)		Number of Release Days		Daily Release (kg/site-day)[b]	
		Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Cleaning products	Water (to on-site treatment or off-site POTW), or landfill[a]	5.7E01	3.8E02	171	201	3.3E−01	1.9
Laundry products – industrial	Fugitive air	4.4E−02	8.9E−02	208	258	2.1E−04	3.4E−04
	Stack air or water (to on-site treatment or off-site POTW)[a]	5.6E01	1.7E02	203	169	2.7E−01	9.8E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	1.4	3.9	74	73	1.9E−02	5.3E−02
Laundry products – institutional	Fugitive air	4.4E−02	8.9E−02	207	258	2.1E−04	3.4E−04
	Stack air or water (to on-site treatment or off-site POTW)[a]	5.6	1.9E02	136	215	4.1E−02	8.8E−01
	Water (to on-site treatment or off-site POTW), incineration, or landfill[a]	1.4E−01	4.4	8	84	1.8E−02	5.2E−02

[a] When multiple environmental media are addressed together, releases may go all to one media or be split between media depending on site-specific practices. Not enough data were provided to estimate the partitioning between media.
[b] The Monte Carlo simulation calculated the total D4 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.

3.16.4 Occupational Exposure Assessment

3.16.4.1 Worker Activities

During the use of products containing residual levels of D4, worker exposures to D4 may occur via inhalation of vapor or dermal contact with liquid during such activities as handling D4-containing products, equipment cleaning, and/or disposing of product containers. EPA did not identify information on engineering controls or worker PPE used at D4 manufacturing facilities. ONUs include employees (*e.g.*, supervisors, managers) who work at the manufacturing facility but do not directly handle D4. Generally, EPA expects ONUs to have lower inhalation and dermal exposures than workers who handle the chemicals directly. During the use of cleaning products exposure are expected to occur for 8 hours at a high end of 250 days to a central tendency of 218 days. During the use of laundry products exposure are expected to occur for 12 hours at a high end of 250 days to a central tendency of 223 days.

3.16.4.2 Occupational Inhalation Exposure Results

Inhalation exposures were not assessed for the use of fabric finishing products because the modeled results are not expected to differ significantly from other modeled exposures (*e.g.*, cleaning and laundry products). The OES for Use of Cleaning Products uses the methodology provided by the Furnishing

Cleaning GS (U.S. EPA, 2022b). This method uses the concentration of D4 found in products SDSs as a fraction of total VOC content. The Use of Laundry products uses the ESD on the chemicals used in water-based washing operations at industrial and institutional laundries (OECD, 2011c) which specifies the EPA/OPPT Mass Balance inhalation model be used. Exposures during the use of laundry products are expected to occur during container transfer operations, container cleaning, and laundry operations. Exposures during use of cleaning products are expected to occur during activities such as application of product. These models were used to calculate the AC, IADC, and ADC for worker exposures to D4 during this OES. Appendix B describes the approach for estimating AC, IADC, and ADC. The estimated exposures assume that the worker is exposed to D4 in the form of vapor. Table 3-47 summarizes the AC, IADC, and ADC for average adult workers and ONUs. For this OES, ONU-specific estimates were not available, ONU inhalation exposures were assumed to be no greater than central tendency exposures for workers.

Table 3-47. Summary of Estimated Inhalation Exposures for Use of Products Containing Residual D4

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m3)	
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End
Other uses: cleaning products	Worker	8-hr	9.5E−04	1.7E−02	6.5E−04	1.2E−02	4.7E−04	8.5E−03	3.9E−04	7.9E−03
	ONU	8-hr	9.5E−04		6.5E−04		4.7E−04		3.9E−04	4.4E−04
Other uses: laundry – institutional and industrial	Worker	12-hr	4.4E−03	1.6E−02	4.5E−03	1.7E−02	3.3E−03	1.2E−02	2.4E−03	9.5E−03
	ONU	12-hr	4.4E−03		4.5E−03		3.3E−03		2.4E−03	

Note: EPA used the total VOC method in the Furnishing Cleaning GS for the use of cleaning products OES (U.S. EPA, 2022b), which has a rating of medium through EPA's systematic review process. EPA used a Monte Carlo simulation using the EPA/OPPT Mass Balance Inhalation Model with standard EPA parameters for the use of laundry products OES. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure was representative of ONU exposure.

3.16.4.3 Occupational Dermal Exposure Result

EPA estimated dermal exposures for this OES using the dermal absorption modeling approach outlined in Appendix D. The acute, intermediate, and chronic calculations are explained in Appendix B. Since there may be mists deposited on surfaces from this OES, dermal exposures to ONUs from contact with mists on surfaces were assessed. In the absence of data specific to ONU exposure, EPA assumed that worker central tendency exposure is representative of ONU exposure. Dermal exposures were not assessed for the use of fabric finishing products or the use of cleaning products because based on the similar D4 concentration levels the modelled results are not expected to differ significantly from other modeled exposures. Table 3-48 summarizes the APDR, AD, IADD, and ADD for workers and ONUs.

Table 3-48. Summary of Estimated Dermal Exposures for Use of Products Containing Residual D4

<table>
<tr><th rowspan="2">OES</th><th rowspan="2">SEG</th><th colspan="2">Acute Potential Dose Rate (mg/day)</th><th colspan="2">Acute Applied Dose (mg/kg-day)</th><th colspan="2">Intermediate Applied Daily Dose (mg/kg-day)</th><th colspan="2">Chronic Average Applied Daily Dose (mg/kg-day)</th></tr>
<tr><th>Central Tendency</th><th>High-End</th><th>Central Tendency</th><th>High-End</th><th>Central Tendency</th><th>High-End</th><th>Central Tendency</th><th>High-End</th></tr>
<tr><td rowspan="2">Use of cleaning products and Use of laundry products</td><td>Worker</td><td>7.5</td><td>2.2E01</td><td>9.4E−02</td><td>2.8E−01</td><td>6.9E−02</td><td>2.1E−01</td><td>5.6E−02</td><td>1.9E−01</td></tr>
<tr><td>ONU</td><td colspan="2">7.5</td><td colspan="2">9.4E−02</td><td colspan="2">6.9E−02</td><td colspan="2">5.6E−02</td></tr>
<tr><td colspan="10">Note: For high-end estimates, EPA assumed the exposure surface area was equivalent to mean values for two-hand surface areas (i.e., 1070 cm²) (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (i.e., 535 cm²).</td></tr>
</table>

3.17 Waste Handling, Disposal, and Treatment

3.17.1 Waste Disposal – Landfill or Incineration for ongoing COU's

Waste handling, disposal, and or treatment, for OESs that may still be considered as ongoing (*e.g.*, Incorporation into Paints and Coatings, Resins, Articles, etc.) are covered in their relevant sections. This includes water and air releases and well as "waste disposal". Waste disposal, in the context of D4, refers to either landfill or incineration and results from the potential given by the ESD or GS used for that OES. The throughput proportion to either landfill or incineration is not listed in these ESDs or GSs so it may be assumed that these waste streams go to one or both endpoints.

SEHSC provided area monitoring data that was taken from WWTP areas of facilities (SEHSC, 2019). It was further indicated that these areas were not staffed with workers during normal operations but would be accessed for routine and/or non-routine maintenance. The data provided consisted of a single data point for two separate locations (two measurements in total). This area data has been provided in Table 3-49 below for illustrative purposes.

Table 3-49. SEHSC Area Monitoring Data from WWTP

OES	SEG	Exposure Scenario	TWA Exposures 8-, 10-, or 12-Hour TWA (mg/m^3)		Acute Concentration (AC; mg/m^3)		Intermediate Average Daily Concentration, Non-Cancer (IADC; mg/m^3)		Chronic Average Daily Concentration, Non-Cancer Exposures (ADC; mg/m^3)		Physical Form	Data Type
			Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End	Central Tendency	High-End		
Waste handling, treatment, and disposal	WWTP at industrial site – Routine work	8-hr	1.2E01		8.3		6.1		5.7		Vapor	Area (SEHSC data)
Waste handling, treatment, and disposal	WWTP at industrial site – Non-routine maintenance	8-hr	1.2E02		7.9E01		1.1E01	5.3	8.7E−01	4.3E−01		

3.17.2 End of Service Life Disposal of products containing D4

It is anticipated that silicone products that may be created during several OES will ultimately be disposed of at the end of their service life. This could consist of products made of silicone rubber or caulks and sealants that are eventually replaced. It can be assumed that most of these products would ultimately go to a landfill. While it is possible that some of these products could be recycled, silicone recycling is considered a specialty process. The steps involved in the silicone recycling process consist of (Timco Rubber, 2025):

1. Shred the silicone materials until they're broken down into tiny pieces,
2. Heat the pieces up until the remnants vaporize,
3. Cool the vapors until they collect into liquid form, and
4. Filter the liquid multiple times so that it turns into silicone oil.

Recycling of silicone products is not expected to involve the use of D4 as an additive to the process, although it is possible that some amount of residual D4 could remain in the polymer matrix at the end of service life and that this could be released to air. EPA is unable to quantify this and would expect this possible release to be negligible relative to other fugitive air releases of D4.

3.18 Distribution in Commerce

3.18.1 Process Description

Distribution in commerce involves loading and unloading activities (throughout various life cycle stages), transit activities, temporary storage, warehousing, and spill cleanup of D4. Loading and unloading activities are generally interpreted as part of distribution in commerce; however, the releases and exposures resulting from these activities are covered within each individual OES where the activity occurs (*i.e.*, unloading of imported D4 is covered under the Import OES). Similarly, tank cleaning activities which occur after unloading of D4 are also assessed as part of individual OESs where the activity occurs.

4 WEIGHT OF SCIENTIFIC EVIDENCE CONCLUSIONS

4.1 Environmental Releases

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

Table 4-1 summarizes EPA's overall weight of the scientific evidence conclusions for its release estimates for each OES. In general, modeled data had data quality ratings of medium. As a result, the weight of the scientific conclusion was moderate for releases that used GSs/ESDs in tandem with Monte Carlo modeling. Additionally, representativeness of the releases for any COU with respect to the full distribution of releasing sites is unknown.

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

OES	Weight of Scientific Evidence Conclusion in Release Estimates
Manufacturing	EPA found limited chemical specific data for the manufacturing OES and assessed environmental releases using models and model parameters derived from CDR and sources identified through systematic review (including industry supplied data). The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment, with media of release assessed using appropriate default input parameters from EPA models and industry supplied data. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Additionally, Monte Carlo modeling uses many data points (simulation runs) and considers the full distributions of input parameters. The Agency used facility-specific D4 manufacturing volumes for all facilities that reported this information to CDR. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of release estimates toward the true distribution of potential releases. Additional limitations include uncertainties in the representativeness of the generic EPA models used to calculate environmental releases for D4 manufacturing sites. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases considering the strengths and limitations of the reasonably available data.
Repackaging	EPA found limited chemical specific data for the repackaging OES and assessed releases to the environment using the assumptions and values from the Chemical Repackaging Generic Scenario (U.S. EPA, 2022a), which the systematic review process rated medium for data quality. EPA used EPA models combined with Monte Carlo modeling to estimate releases to the environment. The Agency assessed the media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Additionally, Monte Carlo modeling uses a high number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, because the default values in the GS are generic, there is uncertainty in the representativeness of these generic site estimates in characterizing actual releases from real-world sites that repackage D4, therefore, throughput estimates for these sites are based on the site throughput estimates based on the upper bound of the CDR national aggregate PV. These limitations decrease the weight of evidence.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of the reasonably available data.
Processing as a reactant	The D4 Consortium provided data regarding loss fractions to various release media for this OES. EPA used these loss fractions as inputs for models, as well as model parameters derived from CDR and sources identified through systematic review in a Monte Carlo simulation to estimate releases to the environment. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Additionally, Monte Carlo modeling uses many data points (simulation runs) and considers the full distributions of input parameters. The Agency used facility-specific D4 manufacturing volumes for all facilities that reported this information to CDR. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of release estimates toward the true distribution of potential releases. D4 throughput estimates for these sites are based on a mass balance of the upper bound of the national aggregate CDR PV data and D4 lifecycle data from systematic review. Additional limitations include uncertainties in the representativeness of the generic EPA models used to calculate environmental releases for D4 manufacturing sites. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases considering the strengths and limitations of the reasonably available data.
Formulation of adhesives	EPA found limited chemical specific data for the incorporation into adhesives and sealants OES and assessed releases to the environment using the ESD on the Formulation of Adhesives (OECD, 2009a), which has a high data quality rating based on the systematic review process. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using appropriate default input parameters from the ESD and EPA models. The Agency believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentrations in adhesive and sealant products in the analysis to provide more accurate estimates than the generic values provided by the ESD. The safety and product data sheets that EPA obtained these values from have high and medium data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the default values in the ESD

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	may not be representative of actual releases from real-world sites that incorporate D4 into adhesives and sealants. In addition, EPA lacks data on D4-specific facility production volume and number of formulation sites, which are needed to estimate site throughput of D4. The Agency based throughput on the UK RE D4 lifecycle (Brooke et al., 2009) as well as the assumption that the facility could possibly utilize neat D4 in the formulation of these products. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of the reasonably available data.
Rubber compounding	EPA found limited chemical specific data for the plastics compounding OES and assessed releases to the environment using the Revised Draft GS for the Use of Additives in Plastic Compounding (U.S. EPA, 2021b), which has a high data quality rating based on systematic review. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. The generic default concentration values in the GS consider all types of plastic compounding and may not represent releases from real-world sites that compound D4 into specific types of rubber raw material. In addition, EPA lacks data on D4-specific facility production volume and number of formulation sites, which are needed to estimate site throughput of D4. The Agency based throughput on the UK RE D4 lifecycle (Brooke et al., 2009) as well as the assumption that the facility could possibly utilize neat D4 in the formulation of these products. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of the reasonably available data.
Rubber converting	EPA found limited chemical specific data for the plastics converting OES and assessed releases to the environment using the Revised Draft GS on the Use of Additives in the Thermoplastics Converting Industry, which has a high data quality rating based on systematic review (U.S. EPA, 2021c). The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using appropriate default input parameters from the GS and EPA models. The Agency believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	capture actual releases than a discrete value. Monte Carlo also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD are based on all types of thermoplastics converting sites and processes and may not represent actual releases from real-world sites that convert D4-containing raw material into rubber articles using a variety of methods, such as extrusion or calendaring. In addition, EPA lacks data on D4-specific facility production volume and number of processing sites, which are needed to estimate site throughput of D4. The Agency based throughput on the UK RE D4 lifecycle (Brooke et al., 2009). These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of the reasonably available data.
Formulation of paints and coatings	EPA found limited chemical specific data for the incorporation into paints and coatings OES and assessed releases to the environment using the Draft GS for the Formulation of Waterborne Coatings (U.S. EPA, 2014a), which has a high data quality rating based on systematic review. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentrations in paint and coating products to provide more accurate estimates of D4 concentrations than the generic values provided by the GS. The safety and product data sheets that EPA obtained these values from have high and medium data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS are specific to waterborne coatings and may not be representative of releases from real-world sites that incorporate D4 into paints and coatings, particularly for sites formulating other coating types (*e.g.*, solvent-borne coatings). In addition, EPA lacks data on D4-specific facility production volume and number of formulation sites, which are needed to estimate site throughput of D4. The Agency based throughput on the UK RE D4 lifecycle (Brooke et al., 2009) and ranges of downstream sites. These limitations decrease the weight of evidence.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of the reasonably available data.
Formulation of products containing greater than residual D4	EPA found limited chemical specific data for the formulation of greater than residual D4 OES and assessed releases to the environment using the Draft GS for the Formulation of Waterborne Coatings (U.S. EPA, 2014a) as a surrogate, which has a high data quality rating based on systematic review. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentrations in these types of products to provide more accurate estimates of D4 concentrations than generic values. The safety and product data sheets that EPA obtained these values from have high and medium data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS are specific to waterborne coatings and may not be representative of releases from real-world sites that incorporate D4 into other types of formulations, such as solvent based products. In addition, EPA lacks data on D4-specific facility production volume and number of formulation sites; therefore, in addition, EPA lacks data on D4-specific facility production volume and number of formulation sites, which are needed to estimate site throughput of D4. The Agency based throughput on the UK RE D4 lifecycle (Brooke et al., 2009). These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of the reasonably available data.
Formulation of products containing residual D4	EPA found limited chemical specific data for the formulation of greater than residual D4 OES and assessed releases to the environment using the Draft GS for the Formulation of Waterborne Coatings (U.S. EPA, 2014a) as a surrogate, which has a high data quality rating based on systematic review. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment and assessed the media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentrations in these types of products to provide more accurate estimates of D4 concentrations

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	than generic values. The safety and product data sheets that EPA obtained these values from have high and medium data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS are specific to waterborne coatings and may not be representative of releases from real-world sites that incorporate D4 into other types of formulations, such as solvent based products. In addition, EPA lacks data on D4-specific facility production volume and number of formulation sites; therefore, in addition, EPA lacks data on D4-specific facility production volume and number of formulation sites, which are needed to estimate site throughput of D4. The Agency based throughput on the UK RE D4 lifecycle PV percentage (Brooke et al., 2009) as well as the assumption that the facility could possibly utilize neat D4 in the formulation of these products. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of the reasonably available data.
Use of adhesives	EPA found limited chemical specific data for the application of adhesives and sealants OES and assessed releases to the environment using the ESD on the Use of Adhesives (OECD, 2015a), which has a high data quality rating based on systematic review. EPA used EPA models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using appropriate default input parameters from the ESD and EPA models. The Agency believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentration and application methods for different D4-containing adhesives and sealant products in the analysis. These data provide more accurate estimates than the generic values provided by the ESD. The safety and product data sheets from which these values were obtained have high and medium data quality ratings from the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the ESD may not represent releases from real-world sites that use D4 based adhesives and sealants. The overall production volume of D4 for this OES was based on the data using the same assumptions as the Incorporation into Adhesives and Sealants OES. The Agency lacks data on D4-specific facility use volume and number of use sites; therefore, EPA based facility throughput estimates and number of sites on industry-specific default facility throughputs from the ESD. These limitations decrease the weight of evidence.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of reasonably available data.
Use of paints and coatings – spray application	EPA found limited chemical specific data for the application of paints and coatings OES and assessed releases to the environment using the ESD on the Application of Radiation Curable Coatings, Inks and Adhesives and the GS on Coating Application via Spray Painting in the Automotive Refinishing Industry (U.S. EPA, 2014b; OECD, 2011b). These documents have a high data quality rating based on the systematic review process. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment. The Agency assessed media of release using appropriate default input parameters from the ESD, GS, and EPA models and a default assumption that all paints and coatings are applied via spray application. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentration for different D4-containing paints and coatings in the analysis. These data provide more accurate estimates than the generic values provided by the GS and ESD. The safety and product data sheets that EPA obtained these values from have high and medium data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS and ESD may not represent releases from real-world sites that incorporate D4 into paints and coatings. Additionally, EPA assumes spray applications of the coatings, which may not be representative of other coating application methods. In addition, EPA lacks data on D4-specific facility use volume and number of use sites; therefore, EPA based facility throughput estimates and number of sites on industry-specific default facility throughputs from systematic review sources. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of reasonably available data.
Use of solvents (penetrant and cold cleaning)	EPA found limited chemical specific data for use of solvents OES and assessed releases to the environment using the ESD on the Use of Vapor Degreasing (OECD, 2021), the ESD on the Use of Metalworking Fluids (OECD, 2011d), and product data sheets (United Laboratories, 2019b; Safety-Kleen, 2018; Ecolink, 2012). These documents have a medium or high data quality rating based on the systematic review process. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment. The Agency assessed media of release using appropriate default input parameters from the ESD, GS, and EPA models. EPA further provided multiple scenarios

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	that provide two types of application (spray and immersion tank) as well as multiple scenarios for the changeout of spent fluids. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers many data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentration for different D4-containing products in the analysis. These data provide more accurate estimates than the generic values provided by the GS and ESD. The safety and product data sheets that EPA obtained these values from have high and medium data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS and ESD may not represent releases from real-world sites that use D4-containing solvent products. Additionally, EPA assumes that greases, lubricants, and working fluids will have a similar use profile as solvents. In addition, EPA lacks data on overall PV and site-specific facility use volume and number of use sites; therefore, EPA based facility throughput estimates and number of sites on industry-specific default facility throughputs from systematic review sources as well as assumptions (overall PV). These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of reasonably available data.
Use of automotive care products	EPA found limited chemical specific data for use of automotive care products OES and assessed releases to the environment using the Commercial Use of Automotive Detailing Products GS - Methodology Review Draft (U.S. EPA, 2022c) and product data sheets (3M, 2019; Adam's Polishes, 2017; B&B Blending, 2017). These documents have a medium or high data quality rating based on the systematic review process. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment. The Agency assessed media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. Additionally, EPA used D4-specific data on concentration for different D4-containing products in the analysis. These data provide more accurate estimates than the generic values provided by the GS. The safety and product data sheets that EPA obtained these values from have high and medium data quality ratings based on the systematic review process. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	GS and ESD may not represent releases from real-world sites that use D4-containing automotive care products. Additionally, EPA assumes that these products will all be used similarly. In addition, EPA lacks data on overall PV and site-specific facility use volume and number of use sites; therefore, EPA based facility throughput estimates and number of sites on industry-specific default facility throughputs from systematic review sources as well as assumptions (overall PV). These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of reasonably available data.
Use of animal grooming product	EPA found limited chemical specific data for use of animal care products OES and assessed releases to the environment using the Revised Use of Furnishing Cleaning Products GS (U.S. EPA, 2022b) as a surrogate and product data sheets (Claire, 2019). These documents have a medium or high data quality rating based on the systematic review process. The Agency used EPA models combined with Monte Carlo modeling to estimate releases to the environment. The Agency assessed media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS may not represent releases from real-world sites that use D4-containing animal care products. Additionally, EPA assumes that these products will all be used similarly. In addition, EPA lacks data on overall PV, site-specific facility use volume, number of use sites, and D4 concentrations in animal care products; therefore, EPA based facility throughput estimates and number of sites on industry-specific default facility throughputs from systematic review sources as well as assumptions (overall PV and concentrations). These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of reasonably available data.
Use of D4 as a laboratory chemical	EPA found limited chemical specific data for the use of laboratory chemicals OES and assessed releases to the environment using the Draft GS on the Use of Laboratory Chemicals (U.S. EPA, 2023b), which has a high data quality rating based on systematic review. EPA used EPA models combined with Monte Carlo modeling to estimate releases to the environment, and media of release using appropriate default input parameters from the GS and EPA models for liquid D4 materials. The Agency believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. EPA used SDSs from identified laboratory D4 products to inform product concentration and material states. These strengths increase the weight of evidence. EPA believes the primary limitation to be the uncertainty in the representativeness of values toward the true distribution of potential releases. In addition, EPA lacks data on D4-specific laboratory chemical throughput and number of laboratories; therefore, EPA based the number of laboratories and throughput estimates on stock solution throughputs from the Draft GS on the Use of Laboratory Chemicals and on CDR reporting thresholds. Additionally, because no entries in CDR indicate a laboratory use and there were no other sources to estimate the volume of D4 used in this OES, EPA developed a high-end bounding estimate based on the CDR reporting threshold of 25,000 lb/site-yr or 5 percent of total product volume for a given use, which by definition is expected to over-estimate the average release case. These limitations decrease the weight of evidence. Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of reasonably available data.
Use of residual D4-containing products	EPA used multiple environmental release scenarios as a surrogate for uses of residual D4-containing products. For releases these scenarios included the use of fabric finishing products, cleaning products, and laundry products. These scenarios used the Draft ESD on Fabric Finishing (OECD, 2004), Revised Use of Furnishing Cleaning Products GS (U.S. EPA, 2022b), and product data sheets (Ecolab, 2019; Alpine Specialty Chemicals Ltd., 2016). These documents have a medium or high data quality rating based on the systematic review process. This use of multiple scenarios provides a broad range of activities and release points. The Agency used Monte Carlo modeling to estimate releases to the environment for all these scenarios. The Agency assessed media of release using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential release values that are more likely to capture actual releases than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the weight of evidence. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated release values toward the true distribution of potential releases at all sites in this OES. Specifically, the generic default values in the GS may not represent releases from real-world sites that use residual D4-containing products. In addition, EPA lacks data on overall PV, site-specific facility use volume, and number of use sites; therefore, EPA based facility throughput estimates and number of sites on industry-specific default facility throughputs from systematic review sources as well as assumptions of overall PV for each scenario These limitations decrease the weight of evidence.

OES	Weight of Scientific Evidence Conclusion in Release Estimates
	Based on this information, EPA concluded that the weight of scientific evidence for this assessment is moderate, and the assessment provides a reasonable estimate of releases, considering the strengths and limitations of reasonably available data.
Waste handling, treatment, and disposal	For waste handling, treatment, and/or disposal wastes not part of an ongoing OES, no data were available to estimate releases for this OES and there were no suitable surrogate release data or models. Therefore, this is described qualitatively.
Distribution in commerce	These releases are assessed as part of individual OESs where the relevant activities occur.

4.2 Occupational Exposures

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

Table 4-2 provides a summary of EPA's overall confidence in its occupational inhalation and dermal exposure estimates for each of the OESs assessed. Because the same modelling approach was used for all dermal exposures, it is covered as a separate box in Table 4-2.

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OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
Manufacturing	EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine a weight of scientific evidence conclusion for the full-shift TWA inhalation exposure estimates for the Manufacturing OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker's position description. This data was rated medium for data quality from the systematic review process. These strengths increase EPA's confidence in the exposure assessment for the Manufacturing OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating worker inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days and the central tendency exposures also use 250 days. These limitations decrease the confidence in the assessment. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.
Repackaging	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 repackaging OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker's position description. This data was rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment for the Repackaging OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days and the central tendency exposures use 235 days. These limitations decrease the confidence in the assessment for the Repackaging OES. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.
Processing as a reactant	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 processing as a reactant OES. This OES used 27 PBZ monitoring data points found during systematic review for polymer plant workers (Dow Chemical, 1998; Dow Corning, 1989, 1977) and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. This data was rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment of the processing as a Reactant OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days and the central tendency exposures also use 250 days. These limitations decrease the confidence in the assessment of the Processing as a reactant OES. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.(Dow Chemical, 1998; Dow Corning, 1989, 1977)
Formulation of adhesives	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 formulation of adhesives OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker's position description. These data were rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment of the Formulation of adhesives OES.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for “chemical operators” as the basis for estimating inhalation exposures and 1 PBZ datapoint for “Administrative” as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 15 days per year and the central tendency exposures use 1 day. These limitations decrease the confidence in the assessment of the Formulation of adhesives OES. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.
Rubber compounding	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 rubber compounding OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker’s position description. This data was rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment of the Rubber compounding OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for “chemical operators” as the basis for estimating inhalation exposures and 1 PBZ datapoint for “Administrative” as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days and the central tendency exposures use 234 days. These limitations decrease the confidence in the assessment of the Rubber compounding OES. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
Rubber converting	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 rubber converting OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker's position description. This data was rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment of the Rubber converting OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days and the central tendency exposures use 219 days. These limitations decrease the confidence in the assessment of the Rubber converting OES. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.
Formulation of paints and coatings	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 formulation of paints and coatings OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker's position description. This data was rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment of the Formulation of paints and coatings OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	working days capped at 250 days per year based on EPA default assumptions. These limitations decrease the confidence in the assessment of the Formulation of paints and coatings OES. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.
Formulation of products containing greater than residual D4	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 formulation of products containing greater than residual levels of D4 OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker's position description. This data was rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment of the Formulation of products containing greater than residual D4 OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year and the central tendency exposures use 246 days. These limitations decrease the confidence in the assessment of the Formulation of products containing greater than residual D4 OES. Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.
Formulation of products containing residual D4	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 formulation of products containing residual levels of D4 OES. The Agency utilized D4-specific monitoring data provided by the D4 Consortium that was obtained across manufacturing and processing sites and categorized by a worker's position description. This data was rated medium for data quality from the systematic review process. These strengths increase the confidence in the assessment of the Formulation of products containing residual D4 OES.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA relied on 17 PBZ monitoring datapoints for "chemical operators" as the basis for estimating inhalation exposures and 1 PBZ datapoint for "Administrative" as the basis for ONU inhalation exposures for this OES. However, EPA lacks facility-specific information regarding the extent to which that monitoring data are relevant to and representative of this particular OES. Further, the data lacks metadata on the concentrations of D4 being handled, especially at the higher concentration ranges. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year and the central tendency exposures use 246 days. These limitations decrease the confidence in the assessment of the Formulation of products containing residual D4 OES. B Based on this information, EPA concluded that the weight of scientific evidence for worker inhalation assessment is moderate, and the ONU inhalation assessment is slight considering the strengths and limitations of the reasonably available data.
Use of adhesives	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 use of adhesives OES. The Agency utilized the mass balance inhalation model, the ESD on the Use of Adhesives (OECD, 2015b), and product data sheets containing D4 concentration levels, see Appendix F for product concentration data. This data was rated high for data quality from the systematic review process. EPA used this data combined with Monte Carlo modeling to estimate exposures using appropriate default input parameters from the ESD and EPA models for liquid D4 materials. The Agency believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential exposure values that are more likely to capture actual exposures than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the confidence in the assessment of the use of adhesives OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA lacks facility-specific information regarding worker activities. EPA set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 222 days per year and the central tendency exposures use 160 days. These limitations decrease the confidence in the assessment of the use of adhesives OES. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
Use of paints and coatings – spray application	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 use of paints and coatings OES. The Agency utilized Spray Application of Paints & Coatings OES via the All-Data Scenario of the Auto Refinish Sample Data Summary as a surrogate (OECD, 2011a), and product data sheets containing D4 concentration levels, see Appendix F for product concentration data. This data was rated high for data quality from the systematic review process. EPA further provided multiple scenarios of usage that included 1, 2, and 250-days of application. These strengths increase the confidence in the assessment of the use of paints and coatings OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA lacks facility-specific information regarding worker activities. EPA assumes spray applications of the coatings, so the estimates may not be representative of exposure during other coating application methods. Additionally, it is uncertain whether the substrates coated, and products used to generate the surrogate data are representative of those associated with D4-containing coatings. The Agency only assessed mist exposures to D4 over a full 8-hour work shift to estimate the level of exposure, though other activities may result in exposures other than mist and application duration may be variable depending on the job site. These limitations decrease the confidence in the assessment of the use of paints and coatings OES. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Use of solvents (penetrant and cold cleaning)	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 use of solvents OES. The Agency utilized Brake Servicing and Cold Cleaning Near Field Far Field Models and product data sheets containing D4 concentration levels (Ecolink, 2015), (Safety-Kleen, 2016), (United Laboratories, 2019a). This data was rated high for data quality from the systematic review process. EPA further provided multiple scenarios of usage that included the use of spray and immersion tank cold cleaning scenarios. EPA used this data combined with Monte Carlo modeling to estimate exposures using appropriate default input parameters from the ESD and EPA models for liquid D4 materials. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential exposure values that are more likely to capture actual exposures than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions of input parameters. These strengths increase the confidence in the assessment of the use of solvents OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA lacks facility-specific information regarding worker activities, number of sites, and types of equipment used. Additionally, EPA assumes that greases, lubricants, and working fluids will have

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	a similar exposure profile as solvents. These limitations decrease the confidence in the assessment of the use of solvents OES. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Use of automotive care products	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 use of automotive care products OES. EPA utilized the exposure methodology outlined in the Use of Automotive Care Products Generic Scenario (U.S. EPA, 2022c), which estimates total volatile organic compounds and applies the product weight fraction, see Appendix F for product concentration data. This data was rated high for data quality from the systematic review process. These strengths increase the confidence in the assessment of the use of automotive care products OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA lacks facility-specific information regarding worker activities, number of operating days, length of shifts, application methods, and prevalence of the types of products used. EPA set the number of exposure days at between 173 and 260 days per year based on GS default assumptions. These limitations decrease the confidence in the assessment of the use of automotive care products OES. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Use of animal grooming product	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 use of animal grooming products OES. The Agency utilized the exposure methodology outlined in Furnishing Cleaning Generic Scenario as a surrogate for lack of data on the Use of Animal Grooming Products. This exposure methodology estimates total volatile organic compounds present to calculate a TWA (U.S. EPA, 2022b). This data was rated high for data quality from the systematic review process. These strengths increase the confidence in the assessment of the use of animal grooming products OES. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA lacks facility-specific information regarding worker activities, number of operating days, length of shifts, application methods, and prevalence of the types of products used. EPA further lacks concentration data for animal grooming products. EPA set the number of exposure days at 250 days per year based on EPA default assumptions. These limitations decrease the confidence in the assessment of the use of animal grooming products OES.

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Use of D4 as a laboratory chemical	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 use of laboratory chemicals OES. The Agency was provided a single PBZ data point for a Laboratory Technician taken during a sample collection, however, this sample consisted of only a fifteen-minute sampling duration, which is not suitable to use to estimate a full shift exposure estimate. The D4 Consortium also provided area monitoring data for a Laboratory Technician that was taken within the analytical laboratory setting. This data set only contained 3 data points, the highest value was used as the high-end estimate and the midpoint was used as the central tendency. The primary limitation is the uncertainty in the representativeness of values toward the true distribution of potential inhalation exposures. Specifically, EPA lacks facility specific concentrations in air, and the representativeness of the data set used in the model towards sites that handle D4 is uncertain. EPA also assumed 8 exposure hours per day based on continuous exposure while handling D4-containing products on site each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. The Agency set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, and the central tendency exposures use 235 days per year as the exposure frequency based on the 50th percentile of operating days from the release assessment. These limitations decrease the confidence in the assessment of the use of D4 as a laboratory chemical OES. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is slight.
Use of residual D4-containing products	EPA used two occupational scenarios as a surrogate for uses of residual D4-containing products. these scenarios included the use of cleaning products and the use of laundry products. These scenarios used the methodology from the Revised Use of Furnishing Cleaning Products GS (U.S. EPA, 2022b), the mass balance inhalation model for the exposures, and product data sheets for D4 concentration values (Ecolab, 2019), (Alpine Specialty Chemicals Ltd., 2016). These documents have a high data quality rating based on the systematic review process. This use of these scenarios provides multiple models to estimate exposures over both 8- and 12-hour TWAs, which provides greater variability in the results. EPA used Monte Carlo modeling to estimate exposures using the mass balance inhalation model. EPA assessed these exposures using appropriate default input parameters from the GS and EPA models. EPA believes a strength of the Monte Carlo modeling approach is that variation in model input values allow for estimation of a range of potential exposure values that are more likely to capture actual exposures than a discrete value. Monte Carlo modeling also considers a large number of data points (simulation runs) and the full distributions

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	of input parameters. These strengths increase the confidence in the assessment of the use of residual D4-containing products OES. The primary limitation of EPA's approach is the uncertainty in the representativeness of estimated exposure values toward the true distribution of potential exposures at all sites in this OES. Specifically, the default values may not represent exposures from real-world sites that use residual D4-containing products. The Agency set the number of exposure days based on Monte Carlo modeling of the operating days from the release assessment, with a maximum number of working days capped at 250 days per year based on EPA default assumptions. The high-end exposures are based on 250 days per year as the exposure frequency since the 95th percentile of operating days in the release assessment exceeded 250 days per year, and the central tendency exposures use 218 days for use of cleaning products and 223 days for use of laundry products. These limitations decrease the confidence in the assessment of the use of residual D4-containing products OES. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Waste handling, treatment, and disposal	SEHSC provided area monitoring data that was taken from WWTP areas of facilities. It was further indicated that these areas were not staffed with workers during normal operations but would be accessed for routine and/or non-routine maintenance. The data provided consisted of a single data point for two separate locations (two measurements in total). Based on this information, EPA concluded that the weight of scientific evidence for the WWTP data is indeterminate as the monitored values are not representative for workers (3.17). This exposure is better represented by the data available for each individual OES and should be considered as a part of the normal operations that are expected to occur during a given OES.
Distribution in commerce	These releases are assessed as part of individual OESs where the relevant activities occur.
Dermal	For occupational dermal exposure assessment, EPA assumed a standard 8-hour workday and that the chemical is contacted at least once per day. Therefore, absorption of D4 from occupational dermal contact with materials containing D4 may extend up to 8 hours per day (CEB, 1991). For average adult workers, the surface area of contact was assumed equal to the area of one hand (*i.e.*, 535 cm^2), or two hands (*i.e.*, 1,070cm^2), for central tendency exposures, or high-end exposures, respectively (U.S. EPA, 2011c). The standard sources for exposure duration and area of contact received high ratings through EPA's systematic review process. The occupational dermal exposure assessment for contact with liquid materials containing D4 was based on dermal exposure at the highest concentration per OES, as well as standard occupational inputs for exposure duration and area

OES	Weight of Scientific Evidence Conclusion in Exposure Estimates
	of contact, as described above. Based on the strengths and limitations of these inputs. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.

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

This appendix summarizes the methods that EPA used to estimate the number of workers who are potentially exposed to D4 in each of its conditions of use. The method consists of the following steps:

1. Check relevant emission scenario documents (ESDs) and Generic Scenarios (GSs) for estimates on the number of workers potentially exposed.
2. Identify the NAICS codes for the industry sectors associated with each condition of use (COU).
3. Estimate total employment by industry/occupation combination using the Bureau of Labor Statistics' Occupational Employment Statistics (OES) data (U.S. BLS, 2016).
4. Refine the OES estimates where they are not sufficiently granular by using the U.S. BLS (2016) Statistics of U.S. Businesses (SUSB) data on total employment by 6-digit NAICS.
5. Estimate the percentage of employees likely to be using D4 instead of other chemicals (*i.e.*, the market penetration of D4 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 condition of use by:

- Querying the U.S. Census Bureau's NAICS Search tool using keywords associated with each condition of use to identify NAICS codes with descriptions that match the COU.
- Referencing EPA Generic Scenarios (GSs) and Organisation for Economic Co-operation and Development (OECD) Emission Scenario Documents (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 (U.S. EPA, 2020a).

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

Step 2: Estimating Total Employment by Industry and Occupation

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

Among the relevant NAICS codes (identified previously), EPA reviewed the occupation description and identified those occupations (SOC codes) where workers are potentially exposed to D4. Table_Apx A-1 shows the SOC codes EPA classified as occupations potentially exposed to D4. These occupations are classified as workers (W) and occupational non-users (O). All other SOC codes are assumed to represent occupations where exposure is unlikely.

Table_Apx A-1. SOCs with Worker and ONU Designations for All Conditions of Use Except Dry Cleaning

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

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

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

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

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

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

Step 3: Refining Employment Estimates to Account for lack of NAICS Granularity
The third step in EPA's methodology was to further refine the employment estimates by using total employment data in the U.S. Census Bureau (2015) SUSB. In some cases, BLS OES's occupation-specific data are only available at the 4-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 D4 exposure are included. As an example, OES data are available for the 4-digit NAICS 8123 *Drycleaning and Laundry Services*, which includes the following 6-digit NAICS:

- NAICS 812310 Coin-Operated Laundries and Dry cleaners;
- 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 OES data to further refine our estimates of the number of employees with potential exposure. Table_Apx A-3 illustrates this granularity adjustment for NAICS 812320.

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

NAICS	SOC CODE	SOC Description	Occupation Designation	Employment by SOC at 4-digit NAICS level	% of Total Employment	Estimated Employment by SOC at 6-digit NAICS level
8123	41-2000	Retail sales workers	O	44,500	46.0%	20,459
8123	49-9040	Industrial machinery installation, repair, and maintenance workers	W	1,790	46.0%	823
8123	49-9070	Maintenance and repair workers, general	W	3,260	46.0%	1,499
8123	49-9090	Miscellaneous installation, maintenance, and repair workers	W	1,080	46.0%	497
8123	51-6010	Laundry and dry-cleaning workers	W	110,640	46.0%	50,867
8123	51-6020	Pressers, textile, garment, and related materials	W	40,250	46.0%	18,505
8123	51-6030	Sewing machine operators	O	1,660	46.0%	763
8123	51-6040	Shoe and leather workers	O	Not reported for this NAICS code		
8123	51-6050	Tailors, dressmakers, and sewers	O	2,890	46.0%	1,329
8123	51-6090	Miscellaneous textile, apparel, and furnishings workers	O	0	46.0%	0
Total potentially exposed employees				**206,070**		**94,740**
Total workers						**72,190**
Total occupational non-users						**22,551**
W = worker; O = occupational non-user						

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
Note: Numbers may not sum exactly due to rounding Source: U.S. BLS (2016) and U.S. Census Bureau (2015)						

Step 4: Estimating the Percentage of Workers Using D4 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 D4 may be only one of multiple chemicals used for the applications of interest. EPA did not identify market penetration data for any conditions of use. In the absence of market penetration data for a given condition of use, EPA assumed D4 may be used at up to all sites and by up to all workers calculated in this method as a bounding estimate. This assumes a market penetration of 100 percent. Market penetration is discussed for each condition of use in the main body of this report.

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

$$\begin{gathered} \mathit{Number\ of\ Workers\ or\ ONUs\ in\ NAICS/SOC}\ (\mathit{Step}\ 2) \times \mathit{Granularity\ Adjustment\ Percentage}\ (\mathit{Step}\ 3) \\ = \mathit{Number\ of\ Workers\ or\ ONUs\ in\ the\ Industry/Occupation\ Combination} \end{gathered}$$

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

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

Step 6: Estimating the Number of Workers and Sites for a Condition of Use
EPA estimated the number of workers and occupational non-users potentially exposed to D4 and the number of sites that use D4 in a given condition of use through the following steps:

6a. Obtaining the total number of establishments by:

  i. Obtaining the number of establishments from SUSB (U.S. Census Bureau, 2015) at the 6-digit NAICS level (Step 5) for each NAICS code in the condition of use and summing these values; or

  ii. Obtaining the number of establishments from the TRI, DMR, NEI, or literature for the condition of use.

6b. Estimating the number of establishments that use D4 by taking the total number of establishments from Step 6a and multiplying it by the market penetration factor from Step 4.

6c. Estimating the number of workers and occupational non-users potentially exposed to D4 by taking the number of establishments calculated in Step 6b and multiplying it by the average number of workers and occupational non-users per site from Step 5.

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

Appendix B.1 assesses D4 inhalation exposures to workers in occupational settings, presented as 8-, 10-, or 12-hr (*i.e.*, full-shift) time weighted average (TWA). The full-shift TWA exposures are then used to calculate acute exposure concentrations (AC), intermediate average daily concentration (IDC), average daily concentration (ADC) for chronic, non-cancer risks, lifetime average daily concentrations (LADC) for chronic risks.

Appendix B.2 assesses D4 dermal exposures to workers in occupational settings, presented as a dermal acute potential dose rate (APDR). The APDRs are then used to calculate acute retained doses (AD), intermediate average daily doses (IADD), and average daily doses (ADD) for chronic non-cancer risks. This appendix presents the equations and input parameter values used to estimate each exposure metric.

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

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

Equation_Apx B-1

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

Where:

AC	=	Acute exposure concentration (ppm or mg/m^3)
C	=	Contaminant concentration in air (TWA) (ppm or mg/m^3)
ED	=	Exposure duration (hr/day)
BR	=	Breathing rate ratio (unitless, see Section B.3.2)
AT_{acute}	=	Acute averaging time (hr/day)

IADC is used to estimate workplace exposures for intermediate risks and is estimated as follows:

Equation_Apx B-2

$$IADC = \frac{C \times ED \times EF_{Int} \times BR}{AT_{Int}}$$

Equation_Apx B-3

$$AT_{Int} = ID \times 24 \frac{hr}{day}$$

Where:

$IADC$	=	Intermediate average daily concentration (ppm or mg/m^3)
C	=	Contaminant concentration in air (TWA) (ppm or mg/m^3)
ED	=	Exposure duration (hr/day)

BR	=	Breathing rate ratio (unitless)
EF_{Int}	=	Intermediate exposure frequency
AT_{Int}	=	Averaging time (hr) for intermediate exposure
ID	=	Days for intermediate duration (day)

ADC is used to estimate workplace exposures for non-cancer. These exposures are estimated as follows:

Equation_Apx B-4

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

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
C	=	Contaminant concentration in air (TWA)
ED	=	Exposure duration (hr/day)
EF	=	Exposure frequency (day/yr)
WY	=	Working years per lifetime (yr)
BR	=	Breathing rate ratio (unitless)
AT_C	=	Averaging time (hr) for chronic, non-cancer risk
LT	=	Lifetime years (yr) for cancer risk

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

Acute Retained Dose (AD) is used to estimate workplace dermal exposures for acute risks and are calculated using Equation_Apx B-7.

Equation_Apx B-7

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

Where:

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

IADD is used to estimate workplace dermal doses for intermediate risks and is estimated using Equation_Apx B-8.

Equation_Apx B-8

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

Where:

$IADD$	=	Intermediate average daily dose (mg/kg-day)
$APDR$	=	Acute potential dose rate (mg/day)
EF_{Int}	=	Intermediate exposure frequency
BW	=	Body weight (kg)
ID	=	Days for intermediate duration (day)

Applied Daily Dose (ADD) is used to estimate workplace dermal doses for non-cancer risks and are calculated using Equation_Apx B-9.

Equation_Apx B-9

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

Where WY is used in the denominator for ADD.

B.3 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, sub-chronic, 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 conditions of use. The EF and EF_{Int} 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	Symbol	Value	Unit
Exposure duration	ED	8, 10, or 12	hr/day
Breathing rate ratio	BR	2.04	unitless
Exposure frequency	EF	Generally calculated through probabilistic modeling with a maximum of 250	days/yr
Exposure frequency, intermediate	EF_{Int}	Generally calculated through probabilistic modeling with a maximum of 22	days
Days for intermediate duration	ID	30	days
Working years	WY	31 (50th percentile)	years

Parameter	Symbol	Value	Unit
		40 (95th percentile)	
Lifetime years, cancer	LT	78	years
Averaging time, intermediate	AT_{Int}	720	hours
Averaging time, non-cancer	AT	271,560 (central tendency)[a] 350,400 (high-end)[b]	hours
Body weight	BW	80 (average adult worker) 72.4 (female of reproductive age)[c]	Kg

[a] Calculated using 50th percentile value for working years (WY)
[b] Calculated using 95th percentile value for working years (WY)
[c] Not used in calculations due to being less protective value

B.3.1 Exposure Duration (ED)

EPA generally uses an exposure duration of eight hours per day for averaging full-shift exposures with one notable exception: use in laboratory chemicals. For this OES, the full-shift duration can range from 8-hr to 12-hr shifts. EPA used a Monte Carlo model simulation to estimate exposures for the use in laboratory chemicals and used a uniform distribution for ED of 8-hrs, 10-hrs, and 12-hrs. The calculated TWA from each iteration of the Monte Carlo analysis was then used to calculate a corresponding acute, intermediate, and chronic exposure values.

B.3.2 Breathing Rate Ratio (BR)

EPA uses a BR, 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. The typical worker breathes about 10 m^3 of air in 8 hours, or 1.25 m^3/hr (CEB, 1991) while the resting breathing rate is 0.6125 m^3/hr (U.S. EPA, 2011b). The ratio of these two values is equivalent to 2.04.

B.3.3 Exposure Frequency (EF)

EPA generally uses a maximum EF of 250 days per year. However, in many instances for D4, EPA used probabilistic modeling to estimate exposures and their associated exposure frequencies, often resulting in exposure frequencies below 250 days per year. The estimation of the exposure frequency and associated distributions for each OES are described in the relevant section of this report. In general, the EF estimated for each iteration of the model is then used to calculate the corresponding chronic exposure values.

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 that occurs during a subset of the worker's annual working days (AWD). The relationship between exposure frequency and AWD can be described mathematically using Equation_Apx B-10:

Equation_Apx B-10

$$EF = f \times AWD$$

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)

U.S. BLS (2016) 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 conditions of use for the first ten chemicals undergoing risk evaluation. For each NAICS code of interest, EPA looked up the average hours worked per employee per year at the most granular NAICS level available (*i.e.*, 4-digit, 5-digit, or 6-digit). EPA converted the working hours per employee to working days per year per employee assuming employees work an average of eight hours per day. The average number of working days per year, or AWD, ranges from 169 to 282 days per year, with a 50th percentile value of 250 days per year. EPA repeated this analysis for all NAICS codes at the 4-digit level. The average AWD for all 4-digit NAICS codes ranges from 111 to 282 days per year, with a 50th percentile value of 228 days per year. 250 days per year is approximately the 75th percentile of the distribution AWD for the 4-digit NAICS codes. In the absence of industry- and D4-specific data, EPA assumed the parameter, f, is equal to one for all OES.

B.3.4 Intermediate Exposure Frequency (EF_{Int})

For D4, the ID was set at 30 days. EPA estimated the maximum number of working days within the ID, using Equation_Apx B-11 and assuming five working days per week:

Equation_Apx B-11

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

However, in many instances for D4, EPA used probabilistic modeling to estimate exposures and their associated intermediate exposure frequencies, often resulting in intermediate exposure frequencies below 22 days. The estimation of the intermediate exposure frequency and associated distributions for each OES are described in the relevant section of this report. In general, the EF_{Int} estimated for each iteration of the model is then used to calculate the corresponding intermediate exposure values.

B.3.5 Intermediate Duration (ID)

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

B.3.6 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 Survey of Income and Program Participation (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 U.S. BLS (2014) provides information on employee tenure with *current employer* obtained from the Current Population Survey (CPS). CPS is a monthly sample survey of about 60,000 households that provides information on the labor force status of the civilian non-institutional population age 16 and over; CPS data are released every two years. The data are available by demographics and by generic industry sectors but are not available by NAICS codes.

The U.S. Census Bureau (2019) 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, 2019). 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, 2019). For this panel, lifetime tenure data are available by Census Industry Codes, which can be cross-walked with NAICS codes.

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

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

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

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

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

Non-manufacturing sectors (NAICS 42–81)	36.1	36	39	44
Note: Industries where sample size is less than five are excluded from this analysis Source: U.S. BLS (2016)				

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 with Current Employer by Age Group

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

B.3.7 Lifetime Years (LT)

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

B.3.8 Body Weight (BW)

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

Appendix C SAMPLE CALCULATIONS FOR CALCULATING ACUTE AND CHRONIC (NON-CANCER AND CANCER) INHALATION EXPOSURES

Sample calculations for high-end and central tendency acute and chronic (non-cancer) exposure concentrations for one condition of use, Processing – Incorporation into Paints & Coatings are demonstrated below. The explanation of the equations and parameters used is provided in Appendix B.

C.1 Example High-End AC, ADC, and IADC Calculations

Calculate AC_{HE}:

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

$$AC_{HE} = \frac{0.10\ mg/m^3 \times 8\ hr/day \times 2.04}{24\ hr/day} = 6.8 \times 10^{-2}\ mg/m^3$$

Calculate $IADC_{HE}$:

$$IADC_{HE} = \frac{C_{HE} \times ED \times EF_{Int} \times BR}{AT_{Int}}$$

$$IADC_{HE} = \frac{0.10\ mg/m^3 \times 8\frac{hr}{day} \times 22\frac{days}{year} \times 2.04}{24\frac{hr}{day} \times 30\frac{days}{year}} = 5.0 \times 10^{-2}\ mg/m^3$$

Calculate ADC_{HE}:

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

$$ADC_{HE} = \frac{0.10\ mg/m^3 \times 8\frac{hr}{day} \times 38\frac{days}{year} \times 40\ years \times 2.04}{40\ years \times 365\frac{days}{yr} \times 24\frac{hr}{day}} = 7.1 \times 10^{-3} mg/m^3$$

C.2 Example Central Tendency AC, ADC, and IADC Calculations

Calculate AC_{CT}:

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

$$AC_{CT} = \frac{1.7 \times 10^{-2}\ mg/m^3 \times 8\ hr/day \times 2.04}{24\ hr/day} = 1.2 \times 10^{-2}\ mg/m^3$$

Calculate $IADC_{CT}$:

$$IADC_{CT} = \frac{C_{CT} \times ED \times EF_{Int} \times BR}{AT_{Int}}$$

$$IADC_{CT} = \frac{1.7 \times 10^{-2}\ mg/m^3 \times 8\frac{hr}{day} \times 6\frac{days}{year} \times 2.04}{24\frac{hr}{day} \times 30\frac{days}{year}} = 2.3 \times 10^{-3}\ mg/m^3$$

Calculate ADC_{CT}:

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

$$ADC_{CT} = \frac{1.7 \times 10^{-2}\ mg/m^3 \times 8\frac{hr}{day} \times 6\frac{days}{year} \times 31\ years \times 2.04}{31\ years \times 365\frac{days}{yr} \times 24\frac{hr}{day}} = 1.9 \times 10^{-4}\ mg/m^3$$

C.3 Example High-End AD, IADD, and ADD Calculations

Calculate AD_{HE}:

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

$$AD_{HE} = \frac{524\frac{mg}{day}}{80\ kg} = 6.6\frac{mg}{kg\text{-}day}$$

Calculate $IADD_{HE}$:

$$IADD_{HE} = \frac{APDR \times EF_{Int}}{BW \times SCD}$$

$$IADD_{HE} = \frac{524\frac{mg}{day} \times 22\frac{day}{yr}}{80\ kg \times 30\frac{day}{yr}} = 4.8\frac{mg}{kg\text{-}day}$$

Calculate ADD_{HE} (non-cancer):

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

$$ADD_{HE} = \frac{524\,\frac{mg}{day} \times 38\,\frac{day}{yr} \times 40\ years}{80\ kg \times 365\,\frac{day}{yr} \times 40\ years} = 0.68\,\frac{mg}{kg\text{-}day}$$

C.4 Example Central Tendency AD, IADD, and ADD Calculations

Calculate AD_{CT}:

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

$$AD_{CT} = \frac{175\,\frac{mg}{day}}{80\ kg} = 2.2\,\frac{mg}{kg\text{-}day}$$

Calculate $IADD_{CT}$:

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

$$IADD_{CT} = \frac{175\,\frac{mg}{day} \times 6\,\frac{days}{yr}}{80\ kg \times 30\,\frac{days}{yr}} = 0.44\,\frac{mg}{kg\text{-}day}$$

Calculate ADD_{CT} (non-cancer):

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

$$ADD_{CT} = \frac{175\,\frac{mg}{day} \times 6\,\frac{days}{yr} \times 31\ years}{80\ kg \times 11{,}315\ days} = 3.6 \times 10^{-2}\,\frac{mg}{kg\text{-}day}$$

Appendix D DERMAL EXPOSURE ASSESSMENT METHOD

Appendix D presents the modeling approach and equations to estimate occupational dermal exposures. This method was developed through review of relevant literature and consideration of existing exposure models, such as EPA/OPPT models and the European Centre For Ecotoxicology and Toxicology of Chemicals' Targeted Risk Assessment model, Version 3.0 (ECETOC TRA v3).

D.1 Dermal Dose Equation

EPA used Equation_Apx D-1 to estimate the acute potential dose rate (APDR) from occupational dermal exposures:

Equation_Apx D-1

$$APDR = S \times \frac{(Q_u \times f_{abs})}{PF} \times Y_{derm} \times FT$$

Where:

S	=	Surface area of skin in contact with the chemical formulation (cm^2);
Q_u	=	Dermal load (*i.e.*, the quantity of the chemical formulation on the skin after the dermal contact event, mg/cm^2-event);
f_{abs}	=	Fractional absorption of the chemical formulation into the stratum corneum, accounting for evaporation of the chemical from the dermal load, Q_u (unitless, $0 \leq f_{abs} \leq 1$);
Y_{derm}	=	Weight fraction of the chemical of interest in the liquid (unitless, $0 \leq Y_{derm} \leq 1$);
FT	=	Frequency of events (integer, events/day); and
PF	=	Glove protection factor (unitless, $PF \geq 1$)

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

D.2 Model Input Parameters

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

Table_Apx D-1. Summary of Model Input Values

Input Parameter	Symbol	Value	Unit	Rationale
Surface area	S	Workers: 535 (central tendency) 1,070 (high-end) Females of reproductive age: 445 (central tendency) 890 (high-end)	cm^2	See Appendix D.2.1
Dermal load	Q_u	Routine or incidental contact with liquids: 1.4 (central tendency) 2.1 (high-end) Routine immersion in liquids: 3.8 (central tendency) 10.3 (high-end) Routine contact with container surfaces (solids): 0.84 (central tendency) 1.0 (high-end) Routine direct handling of solids: 1.7 (central tendency) 2.9 (high-end)	mg/cm^2-event	See Appendix D.2.2
Fractional absorption	f_{abs}	1	unitless	See Appendix D.2.3
Weight fraction of chemical	Y_{derm}	OES-specific, based on maximum weight fraction expected for the OES	unitless	See Appendix D.2.4
Frequency of events	FT	1	events/day	See Appendix D.2.5
Glove protection factor	PF	1; 5; 10; or 20	unitless	See Appendix D.2.6

D.2.1 Surface Area

EPA used a high-end exposed skin surface area (S) for workers of 1,070 cm^2 based on the mean two-hand surface area for adult males ages 21 or older from Chapter 7 of the EPA's *Exposure Factors Handbook* (U.S. EPA, 2011a). For females of reproductive age, EPA used a high-end exposed skin surface area of 890 cm^2 based on the mean two-hand surface area for adult females ages 21 or older from Chapter 7 of the *Exposure Factors Handbook* (U.S. EPA, 2011a). For central tendency estimates, EPA assumed the exposure surface area was equivalent to only a single hand (or one side of two hands) and used half the mean values for two-hand surface areas (*i.e.*, 535 cm^2 for workers and 445 cm^2 for females of reproductive age).

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

D.2.2 Dermal Load

The dermal load (Q_u) is the quantity of chemical on the skin after the dermal contact event. This value represents the quantity remaining after the bulk chemical formulation has fallen from the hand that cannot be removed by wiping the skin (*e.g.*, the film that remains on the skin). To estimate the dermal load from each activity, EPA used data from references cited by EPA's September 2013 engineering policy memorandum, *Updating CEB's Method for Screening-Level Assessments of Dermal Exposure* (U.S. EPA, 2013). This memorandum provides for the following dermal exposure scenarios:

- Routine and incidental contact with liquids (*e.g.*, maintenance activities, manual cleaning of equipment, filling drums, connecting transfer lines, sampling, and bench-scale liquid transfers);
- Routine immersion in liquids (*e.g.*, handling of wet surfaces and spray painting);
- Routine contact with container surfaces (*e.g.*, handling closed or empty bags of solid materials); and
- Routine, direct handling of solids (*e.g.*, filling/dumping containers of powders/flakes/granules, weighing powder/scooping/mixing, handling wet or dried material in a filtration and drying process).

For liquids, the memorandum uses values of 0.7 to 2.1 mg/cm^2-event for routine or incidental contact with liquids and 1.3 to 10.3 mg/cm^2-event for routine immersion in liquids (U.S. EPA, 2013). EPA used the maximum from each range to estimate high-end dermal loads. The memorandum does not provide recommended values for a central tendency dermal loading estimate. Therefore, EPA analyzed data from EPA's technical report, *A Laboratory Method to Determine the Retention of Liquids on the Surface of the Hands* (U.S. EPA, 1992b) that served as the basis for the liquid dermal loads provided in the 2013 memorandum. To estimate central tendency liquid dermal loading values, EPA used the 50th percentile of the dermal loading results from the study for each type of activity (*i.e.*, routine/incidental contact and immersion). The 50th percentile was 1.7 mg/cm^2-event for routine/incidental contact with liquids and 3.8 mg/cm2-event for routine immersion in liquids.

For solids, the memorandum does not present dermal loads in terms of mass per unit area but rather for mass per dermal exposure event. The memorandum estimates values of up to 1,100 mg/event for routine contact with container surfaces and up to 3,100 mg/event for routine, direct handling of solids. EPA used these values as the high-end dermal loads for solids after dividing each value by the high-end dermal surface area (*i.e.*, 1,070 cm^2) to convert to units of mass per unit area. This results in a high-end dermal load of 1.0 mg/cm^2-event for routine contact with container surfaces and 2.9 mg/cm^2-event for routine, direct handling of solids.

The memorandum does not provide recommended values for central tendency dermal loading values for solids. However, the memorandum indicates the solid dermal loads are based on data reported in Lansink et al. (1996) and both the high-end and central tendency values of these data are given in Lansink et al. (1996). For routine contact with container surfaces, the central tendency dermal load is equal to 450 mg/event as reported in Lansink et al. (1996) and cited in Marquart et al. (2006). This central tendency value pertains to the gathering of closed bags of powder and is designated as the typical case exposure (Marquart et al., 2006).[3] For routine, direct handling of solids, the central tendency dermal load is equal to 900 mg/event as reported in Lansink et al. (1996) and cited in Marquart et al. (2006). This central tendency value pertains to the manual loading of mixers with dusty powder and is

[3] The high-end value of 1,100 mg/event also pertains to the gathering of closed bags of powder. This value corresponds to the value of 1,050 mg/event reported in Marquart et al. (2006) as the reasonable worst-case exposure pertaining to the gathering of closed bags of powder and obtained from Lansink et al. (1996). EPA did not directly cite Lansink et al. (1996) because, as stated in Marquart et al. (2006), this report has not been published in a scientific journal.

designated as the typical case exposure (Marquart et al., 2006).[4] EPA used these values as the central tendency dermal loads for solids after dividing each value by the central tendency dermal surface area (*i.e.*, 535 cm^2) to convert to units of mass per unit area. This results in a central tendency dermal load of 0.84 mg/cm^2-event for routine contact with container surfaces and 1.7 mg/cm^2-event for routine, direct handling of solids.

The dermal loading value EPA used for each OES depends on the specific worker activities within the OES. In some cases, workers may perform multiple activities resulting in different dermal loads for each activity. Because EPA assumed only one exposure event per day (see discussion in Appendix D.2.5), EPA presented exposures for only the activities with the highest potential dermal loads for each OES. Table_Apx D-2 summarizes the dermal loads used for each OES.

Table_Apx D-2. Dermal Loading and Weight Fraction by OES

OES	Type of Dermal Exposure Scenario	Dermal Loading Values (mg/cm^2-event)	Weight Fraction (Y_{derm})
Manufacture of D4	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Repackaging D4	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Processing as a reactant	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Formulation of adhesives	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Rubber compounding	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
	Routine contact with container surfaces (solids)[a]	0.8 (central tendency) 1.0 (high-end)	0.05
Rubber converting	Routine contact with container surfaces (solids)[a]	0.8 (central tendency) 1.0 (high-end)	0.05
Formulation of paints and coatings	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Formulation of products containing greater than residual D4	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Formulation of products containing residual D4	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Use of adhesives	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	0.05
Use of paints and coatings – spray application	Routine/immersion with liquids	3.8 (central tendency) 10.3 (high-end)	0.25

[4] The high-end value of 3,100 mg/event also pertains to manual loading of mixers with dusty powder. This value corresponds to the value of 3,000 mg/event reported in Marquart et al. (2006) as the reasonable worst-case exposure pertaining to loading of mixers and obtained from Lansink et al. (1996). EPA did not directly cite Lansink et al. (1996) because, as stated in Marquart et al. (2006), this report has not been published in a scientific journal.

OES	Type of Dermal Exposure Scenario	Dermal Loading Values (mg/cm^2-event)	Weight Fraction (Y_{derm})
Use of solvents (cold cleaning)	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	0.50
Use of solvents (penetrant)	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	0.10
Use of automotive care products	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	0.55
Use of animal grooming product	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	0.05
Use of D4 as a laboratory chemical	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	1
Use of residual D4-containing products	Routine/incidental contact with liquids	1.4 (central tendency) 2.1 (high-end)	0.02
[a] Typically, EPA assumes that the chemical is entrained in the articles such that dermal exposures are negligible. However, EPA assumed that articles may abrade during transport and processing resulting in the generation of dusts that contain the chemical in solid form. EPA does not have data specific to dermal loading values for dusts generated from handling/processing of articles. Therefore, EPA assumed the dermal loads from these activities would be similar to that from handling closed/empty bags of solid materials.			

D.2.3 Fractional Absorption

Typically, EPA would include a fractional absorption (f_{abs}) value as a parameter of the Dermal Exposure to Volatile Liquids model. In the case of D4, the hazard value (*i.e.*, HED) was calculated using a PBPK model which accounted for the absorption that would occur during dermal exposure events. Therefore, EPA calculated dermal exposure estimates using an applied dose of D4 occurring during a dermal exposure event. This means that the fractional absorption value is 1. More information regarding the use of the PBPK Model can be found in the *Draft Human Health Hazard Assessment for Octamethylcyclotetrasiloxane (D4)* (U.S. EPA, 2025a).

D.2.4 Weight Fraction of Chemical

The weight fraction of D4 (Y_{derm}) refers to the concentration of D4 in the liquid or solid formulation the worker's skin is exposed to. EPA generally assumes that this concentration will be equal to the weight fraction of D4 in the chemical products being handled within the OES. For some OES, D4 may be present at multiple weight fractions (*e.g.*, neat D4 may be formulated down to lower concentrations for use in paints and coatings). In such cases, EPA estimated the dermal exposure using the maximum weight fraction of D4 present within the OES. For example, if workers may be exposed during unloading neat D4 into process equipment as well as loading formulated coatings containing D4 into final packaging, EPA assessed dermal exposures to neat D4. Table_Apx D-3 provides a summary of the Y_{derm} values EPA used for each OES.

D.2.5 Frequency of Events

The frequency of events (FT) refers to the number of dermal exposure events per day. Depending on the OES, workers may perform multiple activities throughout their shift that could potentially result in dermal exposures. Equation_Apx D-1 shows a linear relationship between FT and APDR; however, this fails to account for time between contact events. Because the chemical simultaneously evaporates from and absorbs into the skin, dermal exposure is a function of both the number of contact events per day and the time between contact events. Subsequent dermal exposure events may only meaningfully increase the dermal dose if there is sufficient time between the contact events to allow for significant evaporation/absorption of the previous exposure event. EPA did not identify information on how many contact events may occur and the time between contact events. Therefore, EPA assumes a single contact event per day for estimating dermal exposures for all OES.

D.2.6 Glove Protection Factors

Gloves may mitigate dermal exposures, if used correctly and consistently. However, data about the frequency of effective glove use – that is, the proper use of effective gloves – is very limited in industrial settings. Initial literature review suggests that there is unlikely to be sufficient data to justify a specific probability distribution for effective glove use for a chemical or industry. Instead, the impact of effective glove use should be explored by considering different percentages of effectiveness (*e.g.*, 25 vs. 50 percent effectiveness).

Gloves only offer barrier protection until the chemical breaks through the glove material. Using a conceptual model, Cherrie et al. (2004) proposed a glove workplace protection factor – the ratio of estimated uptake through the hands without gloves to the estimated uptake though the hands while wearing gloves; this protection factor is driven by flux, and thus varies with time. The ECETOC TRA model represents the protection factor of gloves as a fixed, APF equal to 5, 10, or 20 (Marquart et al., 2017). Where, similar to the APR for respiratory protection, the inverse of the protection factor is the fraction of the chemical that penetrates the glove.

Given the limited state of knowledge about the protection afforded by gloves in the workplace, it is reasonable to utilize the PF values of the ECETOC TRA model (Marquart et al., 2017), rather than attempt to derive new values. Table_Apx D-3 presents the PF values from ECETOC TRA model (version 3). In the exposure data used to evaluate the ECETOC TRA model, Marquart et al. (2017) reported that the observed glove protection factor was 34, compared to PF values of 5 or 10 used in the model.

Table_Apx D-3. Exposure Control Efficiencies and Protection Factors for Different Dermal Protection Strategies from ECETOC TRA v3

<table>
<tr><th>Dermal Protection Characteristics</th><th>Affected User Group</th><th>Indicated Efficiency (%)</th><th>Protection Factor (PF)</th></tr>
<tr><td>a. Any glove/gauntlet without permeation data and without employee training</td><td rowspan="3">Both industrial and professional users</td><td>0</td><td>1</td></tr>
<tr><td>b. Gloves with available permeation data indicating that the material of construction offers good protection for the substance</td><td>80</td><td>5</td></tr>
<tr><td>c. Chemically resistant gloves (i.e., as b above) with “basic” employee training</td><td>90</td><td>10</td></tr>
<tr><td>d. Chemically resistant gloves in combination with specific activity training (e.g., procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur</td><td>Industrial users only</td><td>95</td><td>20</td></tr>
</table>

Appendix E MODEL APPROACHES AND PARAMETERS

Appendix E presents the modeling approach and model equations used in estimating environmental releases and occupational exposures for each of the applicable OESs. The models were developed through review of the literature and consideration of existing EPA models, ESDs, and/or GSs. An individual model input parameter could either have a discrete value or a distribution of values. EPA assigned statistical distributions based on reasonably available literature data. A Monte Carlo simulation (a type of stochastic simulation) was conducted to capture variability in the model input parameters. The simulation was conducted using the Latin hypercube sampling method in @Risk Industrial Edition, Version 7.0.0.[5] The Latin hypercube sampling method generates a sample of possible values from a multi-dimensional distribution and is considered a stratified method, meaning the generated samples are representative of the probability density function (variability) defined in the model. EPA performed the model at 100,000 iterations to capture a broad range of possible input values, including values with low probability of occurrence.

EPA used the 95th and 50th percentile Monte Carlo simulation model result values for assessment. The 95th percentile value represents the high-end release amount or exposure level, whereas the 50th percentile value represents the typical release amount or exposure level. The following subsections detail the model design equations and parameters for each of the OESs.

E.1 EPA Standard Models

Appendix E.1 discusses the standard models used by EPA to estimate environmental releases of chemicals and occupational inhalation exposures. All the models presented in this section are models that were previously developed by EPA and are not the result of any new model development work for this risk evaluation. Therefore, this appendix does not provide the details of the derivation of the model equations which have been provided in other documents such as the *Chemical Screening Tool for 4166 Exposures and Environmental Releases (ChemSTEER) User Guide* (U.S. EPA, 2015) (hereinafter referred to as the "ChemSTEER User Guide"), *Chemical Engineering Branch Manual for the Preparation of Engineering Assessments, Volume 1* (CEB, 1991) (hereinafter referred to as the "1991 CEB Manual"), *Evaporation of pure liquids from open surfaces* (Arnold and Engel, 2001), *Evaluation of the Mass Balance Model Used by the References Environmental Protection Agency for Estimating Inhalation Exposure to New Chemical Substances* (Fehrenbacher and Hummel, 1996), and *Releases During Cleaning of Equipment* (PEI Associates, 1988). The models include loss fraction models as well as models for estimating chemical vapor generation rates used in subsequent model equations to estimate the volatile releases to air and occupational inhalation exposure concentrations. The parameters in the equations of this appendix section are specific to calculating environmental releases of D4.

The EPA/OPPT Penetration Model estimates releases to air from evaporation of a chemical from an open, exposed liquid surface. This model is appropriate for determining volatile releases from activities that are performed indoors or when air velocities are expected to be less than or equal to 100 feet per minute. The EPA/OPPT Penetration Model calculates the average vapor generation rate of the chemical from the exposed liquid surface using Equation_Apx E-1 shown below.

Equation_Apx E-1

[5] See Palisade's @RISK software for additional information.

$$G_{activity} = \frac{(8.24 \times 10^{-8}) \times (MW_{D4}^{0.835}) \times F_{correction\_factor} \times VP \times \sqrt{Rate_{air\_speed}} \times (0.25\pi D_{opening}^{2}) \sqrt[4]{\frac{1}{29} + \frac{1}{MW_{D4}}}}{T^{0.05} \times \sqrt{D_{opening}} \times \sqrt{P}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
MW_{D4}	=	D4 molecular weight (g/mol)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	D4 vapor pressure (torr)
$Rate_{air\_speed}$	=	Air speed (cm/s)
$D_{opening}$	=	Diameter of opening (cm)
T	=	Temperature (K)
P	=	Pressure (torr)

The EPA/OPPT Mass Transfer Coefficient Model estimates releases to air from the evaporation of a chemical from an open, exposed liquid surface. This model is appropriate for determining this type of volatile release from activities that are performed outdoors or when air velocities are expected to be greater than 100 feet per minute. The EPA/OPPT Mass Transfer Coefficient Model calculates the average vapor generation rate of the chemical from the exposed liquid surface using Equation_Apx E-2 shown below.

Equation_Apx E-2

$$G_{activity} = \frac{(1.93 \times 10^{-7}) \times \left(MW_{D4}{}^{0.78}\right) \times F_{correction\_factor} \times VP \times Rate_{air\_speed}^{0.78} \times (0.25\pi D_{opening}^{2}) \sqrt[3]{\frac{1}{29} + \frac{1}{MW_{D4}}}}{T^{0.4} D_{opening}^{0.11} (\sqrt{T} - 5.87)^{2/3}}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
MW_{D4}	=	D4 molecular weight (g/mol)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	D4 vapor pressure (torr)
$Rate_{air\_speed}$	=	Air speed (cm/s)
$D_{opening}$	=	Diameter of opening (cm)
T	=	Temperature (K)

The EPA's Office of Air Quality Planning and Standards (OAQPS) AP-42 Loading Model estimates releases to air from the displacement of air containing chemical vapor as a container/vessel is filled with a liquid. This model assumes that the rate of evaporation is negligible compared to the vapor loss from the displacement and is used as the default for estimating volatile air releases during both loading activities and unloading activities. This model is used for unloading activities because it is assumed while one vessel is being unloaded another is assumed to be loaded. The EPA/OAQPS AP-42 Loading Model calculates the average vapor generation rate from loading or unloading using Equation_Apx E-3 shown below.

Equation_Apx E-3

$$G_{activity} = \frac{F_{saturation\_factor} \times MW_{D4} \times V_{container} \times 3{,}785.4\,\frac{cm^3}{gal} \times F_{correction\_factor} \times VP \times \frac{RATE_{fill}}{3{,}600\,\frac{s}{hr}}}{R \times T}$$

Where:

$G_{activity}$	=	Vapor generation rate for activity (g/s)
$F_{saturation\_factor}$	=	Saturation factor (unitless)
MW_{D4}	=	D4 molecular weight (g/mol)
$V_{container}$	=	Volume of container (gal/container)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	D4 vapor pressure (torr)
$RATE_{fill}$	=	Fill rate of container (containers/hr)
R	=	Universal gas constant (L-torr/mol-K)
T	=	Temperature (K)

For each of the vapor generation rate models, the vapor pressure correction factor ($F_{correction\_factor}$) can be estimated using Raoult's Law and the mole fraction of D4 in the liquid of interest. However, in most cases, EPA did not have data on the molecular weights of other components in the liquid formulations; therefore, EPA approximated the mole fraction using the mass fraction of D4 in the liquid of interest. Using the mass fraction of D4 to estimate mole fraction does create uncertainty in the vapor generation rate model. If other components in the liquid of interest have similar molecular weights as D4, then mass fraction is a reasonable approximation of mole fraction. However, if other components in the liquid of interest have much lower molecular weights than D4, the mass fraction of D4 will be an overestimate of the mole fraction. If other components in the liquid of interest have much higher molecular weights than D4, the mass fraction of D4 will underestimate the mole fraction.

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

Equation_Apx E-4

$$Release\_Year_{activity} = Time_{activity} \times G_{activity} \times 3{,}600\,\frac{s}{hr} \times 0.001\,\frac{kg}{g}$$

Where:

$Release\_Year_{activity}$	=	D4 released for activity per site-year (kg/site-yr)
$Time_{activity}$	=	Operating time for activity (hr/site-yr)
$G_{activity}$	=	Vapor generation rate for activity (g/s)

In addition to the vapor generation rate models, EPA uses various loss fraction models to calculate environmental releases, including the following:

- EPA/OPPT Small Container Residual Model
- EPA/OPPT Drum Residual Model
- EPA/OPPT Bulk Residual Model
- EPA/OPPT Multiple Process Vessel Residual Model

- EPA/OPPT Single Process Vessel Residual Model

The loss fraction models apply a given loss fraction to the overall throughput of D4 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 E-5

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

Where:

$Release\_Year_{activity}$	=	D4 released for activity per site-year (kg/site-yr)
PV	=	Production volume throughput of D4 (kg/site-yr)
$F_{activity\_loss}$	=	Loss fraction for activity (unitless)

The EPA/OPPT Mass Balance Inhalation Model estimates a worker inhalation exposure to an estimated concentration of chemical vapors within the worker's breathing zone using a one box model. The model estimates the amount of chemical inhaled by a worker during an activity in which the chemical has volatilized and the airborne concentration of the chemical vapor is estimated as a function of the source vapor generation rate or the saturation level of the chemical in air. First, the applicable vapor generation rate model (Equation_Apx E-1, Equation_Apx E-2, and Equation_Apx E-3) is used to calculate the vapor generation rate for the given activity. With this vapor generation rate, the EPA/OPPT Mass Balance Inhalation Model calculates the volumetric concentration of D4 using Equation_Apx E-6 shown below.

Equation_Apx E-6

$$Cv_{activity} = Minimum\colon \begin{cases} \left[\dfrac{170{,}000 \times T \times G_{activity}}{MW_{D4} \times Q \times k}\right] \\ \left[\dfrac{1{,}000{,}000ppm \times F_{correction\_factor} \times VP}{P}\right] \end{cases}$$

Where:

$Cv_{activity}$	=	Exposure activity volumetric concentration (ppm)
$G_{activity}$	=	Exposure activity vapor generation rate (g/s)
MW_{D4}	=	D4 molecular weight (g/mol)
Q	=	Ventilation rate (ft^3/min)
k	=	Mixing factor (unitless)
T	=	Temperature (K)
$F_{correction\_factor}$	=	Vapor pressure correction factor (unitless)
VP	=	D4 vapor pressure (torr)
P	=	Pressure (torr)

Mass concentration can be estimated by multiplying the volumetric concentration by the molecular weight of D4 and dividing by molar volume at standard temperature and pressure.

EPA uses the above equations in the D4 environmental release and occupational exposure models, and EPA references the model equations by model name and/or equation number within Appendix B.

E.2 Model Approach and Parameters

Appendix E.2 presents the modeling approach and equations used to estimate environmental releases and occupational exposures for D4 during the modeled OESs. This approach utilizes the models and/or parameters identified in the relevant OES subsection of Section 2.7 combined with Monte Carlo simulation (a type of stochastic simulation).

Environmental releases and occupational exposures for D4 during OESs are typically functions of D4 physical properties, container size, mass fractions, and other model parameters. While physical properties are fixed, some model parameters are expected to vary. As described in Section 2.3, 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. EPA used the outputs from a Monte Carlo simulation with 100,000 iterations and the Latin Hypercube sampling method in @Risk to calculate release amounts and exposure concentrations for this OES.

E.2.1 Model Equations

Table_Apx E-1 provides the models and associated variables used to calculate environmental releases for each release source within each iteration of the Monte Carlo simulation. EPA used these environmental releases to develop a distribution of release outputs for the Import – repackaging OES. The variables used to calculate each of the following values include deterministic or variable input parameters, known constants, physical properties, conversion factors, and other parameters. The values for these variables are provided in Appendix E.2.2 and Appendix E.2.3. The Monte Carlo simulation calculated the total D4 release (by environmental media) across all release sources during each iteration of the simulation. EPA then selected 50th percentile and 95th percentile values to estimate the central tendency and high-end releases, respectively.

Table_Apx E-1. Models and Variables Applied for Release Sources

OES(s) (Release Point # [a])	Model(s) Applied	Variables Used
Manufacturing (3, 5) Repackaging (3, 5, 7) Processing as a reactant (7, 9) Formulation of adhesives (2, 5, 7, 9) Formulation of paints and coatings (4, 5, 7, 9, 11) Formulation of greater than residual D4 products (4, 5, 7, 9, 11) Formulation of residual D4 products (5, 7, 9, 11) Rubber compounding (2b) Use of animal grooming products (1) Use of automotive care products (3) Use of adhesive and sealants (2, 5, 6) Use of paints and coating products (4, 6) Laboratory use (4, 6, 7) Residual uses – laundry products 2, 3, 5) Use of solvents (cold cleaning) (3, 4) Residual uses – fabric finishing (4, 6, 7) Residual uses – cleaning products (4)	EPA/OPPT Penetration Model or EPA/OPPT Mass Transfer Coefficient Model, based on air speed (Appendix E.1)	Vapor Generation Rate: F_{D4}; MW_{D4}; VP; $RATE_{air\_speed}$; $D_{opening\_cont-cleaning}$; T; P Operating Time: N_{cont_yr}; $RATE_{fill\_drum}$

OES(s) (Release Point # [a])	Model(s) Applied	Variables Used
Manufacturing (6) Repackaging (8) Processing as a reactant (10) Formulation of adhesives (3, 10) Formulation of paints and coatings (1, 12) Formulation of greater than residual D4 products (1, 12) Formulation of residual D4 products (1, 12) Use of adhesive and sealants (3) Use of paints and coating products (1) Use of solvents (cold cleaning) (2) Use of automotive care products (1) Laboratory use (1) Residual uses – fabric finishing (1) Residual uses – cleaning products (1) Rubber compounding (1)	EPA/OAQPS AP-42 Loading Model (Appendix E.1)	Vapor Generation Rate: F_{D4}; VP; $F_{saturation\_unloading}$; MW_{D4}; V_{import_cont}; R; T; $RATE_{fill\_drum}$ Operating Time: $RATE_{fill\_drum}$
Repackaging (4) Processing as a reactant (2) Formulation of adhesives (1) Rubber compounding (2a) Formulation of paints and coatings (3) Formulation of greater than residual D4 products (3) Formulation of residual D4 products (3)	EPA/OPPT Bulk Transport Residual Model (Appendix E.1)	PV; F_{loss_cont}
Use of paints and coating products (5) Residual uses – fabric finishing (3) Use of animal grooming products (3) Laboratory use (3) Use of adhesive and sealants (1) Residual uses – cleaning products (3) Use of automotive care products (2) Use of solvents (penetrant) (1) Use of solvents (cold cleaning) (1) Residual uses – laundry products (1)	EPA/OPPT Drum/Small Container Residual Model (Appendix E.1)	PV; F_{loss_cont}; Ns
Rubber converting (2)	EPA/OPPT Solid Residuals in Transport Container Model (Appendix E.1)	PV; F_{loss_cont}
Use of paints and coating products (3, 8) Manufacturing (4) Repackaging (6) Processing as a reactant (8) Formulation of adhesives (8) Rubber compounding (5) Formulation of paints and coatings (8) Formulation of greater than residual D4 products (8) Formulation of residual D4 products (8) Rubber converting (5) Laboratory use (5)	EPA/OPPT Multiple Process Vessel Residual Model (Appendix E.1)	PV; $F_{loss\_equip-cleaning}$

OES(s) (Release Point # [a])	Model(s) Applied	Variables Used
Rubber converting (6) Use of adhesive and sealants (4) Residual uses – fabric finishing (5)	EPA/OPPT Single Process Vessel Residual Model (0)	PV; $F_{loss\_equip-cleaning}$
Manufacturing (2) Repackaging (2) Processing as a reactant (6) Formulation of adhesives (6) Formulation of paints and coatings (6) Formulation of greater than residual D4 products (6) Formulation of residual D4 products (6)	Sampling waste(s)	*EPA 2023 Methodology for Estimating Environmental Releases from Sampling Waste*

[a] Release points (number and description) are listed in each OESs relevant Environmental Release section (*e.g.*, Manufacturing in Section 3.1.3.1)

E.2.2 Model Input Parameters

Table_Apx E-2 summarizes the model parameters and their values for Monte Carlo simulation. Additional explanations of EPA's selection of the distributions for each parameter are provided after this table.

4257 **Table_Apx E-2. Summary of Parameter Values and Distributions Used in Models**

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale/Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
Air speed	$RATE_{air\_speed}$	cm/s	10	1.3	202.2	—	Lognormal	See Appendix E.2.5
Container loss fraction	F_{loss_cont}	kg/kg	0.025	0.017	0.03	0.025	Triangular	See Appendix E.2.6
Saturation factor unloading	$F_{saturation\_unloading}$	unitless	0.5	0.5	1.45	0.5	Triangular	See Appendix E.2.8
Saturation factor loading	$F_{saturation\_loading}$	unitless	0.5	0.5	1.45	0.5	Triangular	See Appendix E.2.8
Container volume	V_{cont}	gal/container	Varies by OES/activity	—	—	—	Triangular	See Appendix E.2.9
Number of sites	N_s	sites	Varies by OES	—	—	—	Uniform	“What-if” scenario input
Production volume assessed	PV_lb	lb/year	Varies by OES	N/A	N/A	N/A	N/A	“What-if” scenario input
Production volume	PV	kg/year	Varies by OES	N/A	N/A	N/A	N/A	PV input converted to kilograms
Import concentration	F_{D4_import}	kg/kg	Varies by OES (typically 1.0)	—	—	—	—	Typically assumed pure/neat chemical imported for import–repackaging
Temperature	T	Kelvin	298	—	—	—	—	Process parameter
Pressure	P	torr	760	—	—	—	—	Process parameter
Gas Constant	R	L-torr/mol-K	62.36367	—	—	—	—	Universal constant
D4 Vapor Pressure	VP	mm Hg at 25 °C	0.9338	—	—	—	—	Physical property

Input Parameter	Symbol	Unit	Deterministic Values	Uncertainty Analysis Distribution Parameters				Rationale/Basis
			Value	Lower Bound	Upper Bound	Mode	Distribution Type	
D4 density	R_{D4}	kg/m^3	956.03	—	—	—	—	Physical property
D4 molecular weight	MW_{D4}	g/mol	296.61	—	—	—	—	Physical property
Fill rate of container	$RATE_{fill\_cont}$	containers/hr	Varies by OES/activity	—	—	—	—	See Appendix E.2.10
Diameter of opening for container cleaning	$D_{opening\_cont-cleaning}$	cm	5.08	—	—	—	—	See Appendix E.2.7
Ventilation rate	Q	ft^3/min	3,000	500	10,000	3,000	Triangular	See Appendix E.2.11
Mixing factor	k	unitless	0.5	0.1	1	0.5	Triangular	See Appendix E.2.12

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E.2.3 Throughput Parameters

The facility production rate is calculated as an input value to be used in the model equations during each iteration. The facility production rate is calculated using Equation_Apx E-7 shown below.

Equation_Apx E-7

$$PV_{site} = \frac{PV}{N_s}$$

Where:

PV	=	Production volume (kg/year)
N_s	=	Number of sites (sites)
PV_{site}	=	Facility production rate (kg/site-year)

E.2.4 Operating Hours and Exposure Durations

EPA typically estimates operating hours and exposure durations using calculations and parameters provided by the models and/or parameters found in the ChemSTEER User Guide (U.S. EPA, 2015). The following example is provided to illustrate how the operating time for release and exposure activities associated with container unloading and/or unloading can be calculated using Equation_Apx E-8 shown below.

Equation_Apx E-8

$$Time_{RP1/RP4} = \frac{1}{RATE_{fill\_drum}}$$

Where:

$Time_{RP1/RP4}$	=	Operating time for release sources 1 and 4 (hrs/container)
$RATE_{fill\_drum}$	=	Fill rate of drum (containers/hr)

For the emptying of drums, the ChemSTEER User Guide (U.S. EPA, 2015) indicates a drum fill rate of 20 drums per hour based on the 1991 CEB Manual (CEB, 1991). EPA assumed that one drum is imported and repackaged in a single operating day therefore equating the number of import containers received in a single year to the number of release days per year. For the cleaning of drums, the ChemSTEER User Guide (U.S. EPA, 2015) uses the same drum fill rate as emptying drums to estimate an exposure duration. EPA did not identify any other information on drum fill rates; therefore, EPA used a single deterministic value for fill rate.

The operating hours for both a release source and exposure point can be calculated using Equation_Apx E-9 shown below.

Equation_Apx E-9

$$Time_{RP2} = \frac{V_{import\_cont}}{V_{fill\_cont} \times Rate_{fill_{smallcont}} \times RD}$$

Where:

$Time_{RP2}$	=	Operating time for release source 2 (hrs/site-day)
V_{import_cont}	=	Import container volume (gal/container)
V_{fill_cont}	=	Small container volume (gal/container)
$RATE_{fill\_smallcont}$	=	Fill rate of small container (containers/hr)
RD	=	Release days or Number of import containers (days/site-yr or containers/site-yr)

For filling small containers, see Appendix E.2.9 for details on the distribution of small container volume and Appendix E.2.10 for details on the small container fill rate. Generally, EPA calculated the duration of filling small containers using the container volume and fill rate from the ChemSTEER User Guide (U.S. EPA, 2015). The calculated small container fill duration was used for both the release source (operating hours rate for release source 2) and exposure point (exposure duration for exposure point B).

E.2.5 Air Speed

Baldwin and Maynard (1998) measured indoor air speeds across a variety of occupational settings in the United Kingdom, specifically, 55 work areas were surveyed. EPA analyzed the air speed data from Baldwin and Maynard (1998) and categorized the air speed surveys into settings representative of industrial facilities and representative of commercial facilities. EPA fit separate distributions for these industrial and commercial settings and used the industrial distribution for this OES.

EPA fit a lognormal distribution for the data set as consistent with the authors' observations that the air speed measurements within a surveyed location were lognormally distributed and the population of the mean air speeds among all surveys were lognormally distributed (Baldwin and Maynard, 1998). Since lognormal distributions are bound by zero and positive infinity, EPA truncated the distribution at the largest observed value among all of the survey mean air speeds.

EPA fit the air speed surveys representative of industrial facilities to a lognormal distribution with the following parameter values: mean of 22.414 cm/s and standard deviation of 19.958 cm/s. In the model, the lognormal distribution is truncated at a minimum allowed value of 1.3 cm/s and a maximum allowed value of 202.2 cm/s (largest surveyed mean air speed observed in Baldwin and Maynard (1998)) to prevent the model from sampling values that approach infinity or are otherwise unrealistically small or large (Baldwin and Maynard, 1998).

Baldwin and Maynard (1998) only presented the mean air speed of each survey. The authors did not present the individual measurements within each survey. Therefore, these distributions represent a distribution of mean air speeds and not a distribution of spatially variable air speeds within a single workplace setting. However, a mean air speed (averaged over a work area) is the required input for the model. EPA converted the units to ft/min prior to use within the model equations.

E.2.6 Container Residue Loss Fraction

EPA previously contracted PEI Associates, Inc. (PEI) to conduct a study for providing estimates of potential chemical releases during cleaning of process equipment and shipping containers (PEI Associates, 1988). The study used both a literature review (analyzing cleaning practices and release data) and a pilot-scale experiment to determine the amount of residual material left in vessels. The data from literature and pilot-scale experiments addressed different conditions for the emptying of containers and tanks, including various bulk liquid materials, different container constructions (*e.g.*, lined steel drums or plastic drums), and either a pump or pour/gravity-drain method for emptying. EPA reviewed the pilot-scale data from PEI and determined a range and average percentage of residual material remaining in vessels following emptying from drums by either pumping or pouring as well as tanks by gravity-drain (PEI Associates, 1988).

EPA previously used the study results to generate default central tendency and high-end loss fraction values for the residual models (*e.g.*, EPA/OPPT Small Container Residual Model, EPA/OPPT Drum Residual Model) provided in the ChemSTEER User Guide (U.S. EPA, 2015). Previously, EPA adjusted the default loss fraction values based on rounding the PEI study results or due to policy decisions. EPA used a combination of the PEI study results and ChemSTEER User Guide default loss fraction values to develop probability distributions for various container sizes.

Specifically, EPA paired the data from the PEI study (PEI Associates, 1988) such that the residuals data for emptying drums by pouring was aligned with the default central tendency and high-end values from the EPA/OPPT Small Container Residual Model, and the residuals data for emptying drums by pumping was aligned with the default central tendency and high-end values from the EPA/OPPR Drum Residual Model. EPA applied the EPA/OPPT Small Container Residual Model to containers with capacities less than 20 gallons, and the EPA/OPPT Drum Residual Model to containers with capacities between 20 and 100 gallons (U.S. EPA, 2015).

For unloading drums via pouring, the PEI study experiments showed average container residuals in the range of 0.03 percent to 0.79 percent with a total average of 0.32 percent (PEI Associates, 1988). The EPA/OPPT Small Container Residual Model recommends a default central tendency loss fraction of 0.3 percent and a high-end loss fraction of 0.6 percent (U.S. EPA, 2015). For unloading drums by pumping, the PEI study experiments showed average container residuals in the range of 1.7 percent to 4.7 percent with a total average of 2.6 percent (PEI Associates, 1988).

The EPA/OPPT Drum Residual Model from the ChemSTEER User Guide recommends a default central tendency loss fraction of 2.5 percent and a high-end loss fraction of 3.0 percent (U.S. EPA, 2015). The underlying distribution of the loss fraction parameter for small containers or drums is not known; therefore, EPA assigned a triangular distribution defined by the estimated lower bound, upper bound, and mode of the parameter values. EPA assigned the mode and upper bound values for the loss fraction triangular distributions using the central tendency and high-end values from the respective ChemSTEER User Guide (U.S. EPA, 2015). EPA assigned the lower bound values for the triangular distributions using the minimum average percent residual measured in the PEI study for the respective drum emptying technique (pouring or pumping) (PEI Associates, 1988).

E.2.7 Diameters of Opening

The ChemSTEER User Guide indicates diameters for the openings for various vessels that may hold liquids in order to calculate vapor generation rates during different activities (U.S. EPA, 2015). For container cleaning activities, the ChemSTEER User Guide indicates a single default value of 5.08 cm (U.S. EPA, 2015). Therefore, EPA could not develop a distribution of values for this parameter and used the single value 5.08 cm from the ChemSTEER User Guide.

E.2.8 Saturation Factor

The 1991 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 1991 CEB Manual indicates that saturation concentration for bottom filling was expected to be about 0.5 (CEB, 1991). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the lower bound, upper bound, and mode of the parameter. Because a mode was not provided for this parameter, EPA assigned a mode value of 0.5 for bottom filling as bottom filling minimizes volatilization (CEB, 1991). This value also corresponds to the typical value provided in the ChemSTEER User Guide for the EPA/OAQPS AP-42 Loading Model (U.S. EPA, 2015).

E.2.9 Container Size

EPA assumed facilities receive D4 or D4-containing products, in the full range, from small (1 gallon bottles) to bulk (20,000 gallon rail cars), as provided in the ChemSTEER User Guide (U.S. EPA, 2015). Modeled OESs typically use these values as lower and upper bounds in the Monte Carlo simulation.

E.2.10 Container Fill Rates

The ChemSTEER User Guide (U.S. EPA, 2015) provides a typical fill rate of 20 containers per hour for containers with 20 to 1,000 gallons of liquid, a typical fill rate of 60 containers per hour for containers with less than 20 gallons of liquid, a typical fill rate of 2 containers per hour for tanker trucks (1,000–10,000 gallons), and 1 container per hour for rail cars (>10,000 gallons).

E.2.11 Ventilation Rate

The 1991 CEB Manual indicates general ventilation rates in industry range from 500 to 10,000 ft^3/min, with a typical value of 3,000 ft^3/min (CEB, 1991). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on an estimated lower bound, upper bound, and mode of the parameter. EPA assumed the lower and upper bound using the industry range of 500 to 10,000 ft^3/min and the mode using the 3,000 ft^3/min typical value (CEB, 1991).

E.2.12 Mixing Factor

The CEB Manual indicates mixing factors may range from 0.1 to 1, with 1 representing ideal mixing (CEB, 1991). The CEB Manual references the *1988 American Conference of Governmental Industrial Hygienists (ACGIH) Ventilation Handbook*, which suggests the following factors and descriptions: 0.67 to 1 for best mixing; 0.5 to 0.67 for good mixing; 0.2 to 0.5 for fair mixing; and 0.1 to 0.2 for poor mixing (CEB, 1991). The underlying distribution of this parameter is not known; therefore, EPA assigned a triangular distribution based on the defined lower and upper bound and estimated mode of the parameter. The mode for this distribution was not provided; therefore, EPA assigned a mode value of 0.5 based on the typical value provided in the ChemSTEER User Guide for the EPA/OPPT Mass Balance Inhalation Model (U.S. EPA, 2015).

Appendix F PRODUCT DATA

Appendix F includes a sample of products containing D4. This is not a comprehensive list of products containing D4. In addition, some manufacturers may appear over-represented in Table_Apx F-1. This may mean that they are more likely to disclose product ingredients online than other manufacturers but does not imply anything about use of the chemical compared to other manufacturers in this sector.

Table_Apx F-1 Product Data.

OES	Product Name	Product Concentration		HERO
		Low-End	High-End	
Adhesives and sealants	SIL-BOND RTV 4500	1.00%	1.00%	11581723
Adhesives and sealants	LOCTITE SI 5366, SI 5399; also known as 5399 RED 100ML DK FI NO SE	3.00%	3.00%	11581712
Adhesives and sealants	RTV Silicone Adhesive & Sealant – Black (Pressurized)	1.00%	3.00%	11581720
Adhesives and sealants	SPECTREM 2 WHITE	0.10%	1.00%	11581726
Adhesives and sealants	DOWSIL 734 FLOWABLE SEALANT, CLEAR	0.27%	0.30%	11581710
Adhesives and sealants	NUFLEX 302 HIGH TEMPERATURE GASKET MAKING SILICONE SEALANT	0.10%	1.00%	11581713
Adhesives and sealants	NUFLEX 366 MARINE SILICONE SEALANT	0.10%	1.00%	11581714
Adhesives and sealants	RTV103 Black Silicone Sealant	1.00%	5.00%	11581721
Adhesives and sealants	DOWSIL 3140 RTV Coating	0.05%	0.21%	7310944
Adhesives and sealants	Silicone Rubber Window and Door Sealant (White Lightning)	1.00%	1.00%	7311199
Paints and coatings	Silicone Magic C-5	0.0006	0.019	11581724
Paints and coatings	Thermo-Sil HS 3200 Series High Solids Silicone Roof Coating	0.05	0.15	11581727
Paints and coatings	SpecSilane 20 WB	0.01	0.1	11581725
Paints and coatings	Optic 3101 Clear 5GP	0.001	0.01	11581716
Paints and coatings	Water-Repellent Concrete Sealer	0.001	0.01	11581711
Paints and coatings	Seamlesseal Ultra HSLV	0.01	0.05	11581722

OES	Product Name	Product Concentration		HERO
		Low-End	High-End	
Paints and coatings	Pro-Grade® 988 Silicone Custom Color Roof Coating	0.01	0.05	11581719
Paints and coatings	#203 HS BULLDOG Silicone Coating	0.01	0.05	11581708
Paints and coatings	PRO 1-GL 2PK GLOSS LEATHER BROWN 100VOC	0.1	0.25	7311149
Paints and coatings	SB2445 Oil Repellent Penetrating Sealer	0.05	0.1	7311157
Paints and coatings	SILSHIELD 3100 Neutral Base 5GP	0.001	0.01	7311118
Paints and coatings	AP5400 High Solids Silicone Roof Coating	0.001	0.01	7311186
Solvent	Navsolve	0.25	0.5	7310958
Solvent	QSOL 220 Cleaning Solvent	0.03	0.07	7311151
Solvent	United 101 Moisture Barrier and Electrical Lubricant	0.025	0.05	7311189
Fabric finishing products	Emulsion SM 2112 NPF	0.01	0.03	12391848
Cleaning products	Shine Plus	0.001	0.01	7311182
Degreaser	Antifoam AF 1303 – Antifoam - 17_spectrum	0.013	0.014	12391914
Fabric finishing products	Bluesil Ecosoft	0.001	0.01	
Fabric finishing products	Silamine PD - SDS-4868-Silamine-PD_GHS	0.005	0.005	7311181
Automotive products	Adam's Buttery Wax	0.01	0.05	7310926
Automotive products	Scotchgard Leather and Vinyl Protector, 38601	0.005	0.005	7310925
Fabric finishing products	Niagra Fabric Finish Spray Sizing	0.000	0.001	7311091
Automotive products	Jade Ceramic Coating – Vehicle polish – 44_b&b	0.4	0.55	12381253
Automotive products	White Diamond Black Pearl – Vehicle polish – 53_schultz	0.01	0.05	12391929
Printing inks	Flow Additive 892	0.00	0.002	7291103
Printing inks	Screen Printing UV Ink 9864 Transparent Green (BS)	0.001	0.01	7291202

OES	Product Name	Product Concentration		HERO
		Low-End	High-End	
Cleaning products	Plastic Cleaner (Claire)	0.0001	0.01	7310940
Printing inks	ORALITE 5019i blue (020)	0.000	0.001	11581717
Laundry products	Low Temp Laundry Clearly Soft	0.001	0.01	7310954
Laundry products	Alpine Green Choice Laundry Detergent	0.002	0.005	7310936
Rubber product	Castaldo QuickSil Silicone	0.0010	0.0100	11581709
Rubber product	Rogers Corporation DSP HS-30 Blue	0.01	0.05	12391976
Rubber product	Momentive TUFEL 94605	0.001	<0.01	12391981
Rubber product	Momentive TUFEL 94406	0.03	<0.05	12391983
Rubber product	Momentive TUFEL 94506	0.001	<0.01	12391984
Laboratory standard	Octamethylcyclotetrasiloxane - Sigma Aldrich	100%	100%	11581715
Laboratory standard	Octamethylcyclotetrasiloxane - TCI America	98%	100%	7311185

Appendix G LIST OF SUPPLEMENTAL DOCUMENTS

A list of the supplemental documents that are mentioned in this technical support document and a brief description of each of these documents is given below. These supplemental documents are spreadsheets that contains model equations, parameter values and the results of the probabilistic (stochastic) or deterministic calculations and are available in Docket EPA-HQ-OPPT-2018-0443.

- *Draft Manufacturing OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Import OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Repackaging OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Processing as a Reactant OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Incorporation into Adhesives OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Use of Adhesives OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Formulation of Paints and Coatings OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Use of Paints and Coatings OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Rubber Compounding OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Rubber Converting OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Use of Solvents OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Use of Fabric Finishing OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Incorporation into Formulations Containing Greater than Residual D4 OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Use of Animal Grooming Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Formulation of Residual D4 Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Use of Cleaning Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Use of Laundry Products OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*

- *Draft Use of Laboratory Chemical OES Environmental Release Modeling Results for Octamethylcyclotetrasiloxane (D4)*
- *Draft Occupational Risk Calculator for Octamethylcyclotetrasiloxane (D4)*