United States
Environmental Protection Agency

Office of Chemical Safety and
Pollution Prevention

Draft Risk Evaluation for Methylene Chloride (Dichloromethane, DCM)

DCM Supplemental File:

Supplemental Information on Releases and Occupational Exposure Assessment

CASRN: 75-09-2

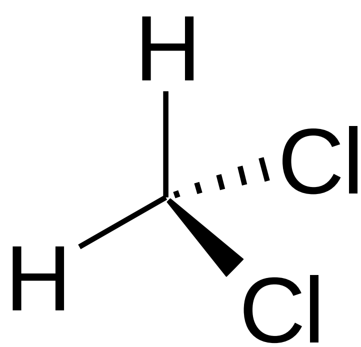

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

ABBREVIATIONS

°C	Degrees Celsius
1-BP	1-Bromopropane
ACGIH	American Conference of Government Industrial Hygienists
ACH	Air Changes per Hour
APF	Assigned Protection Factor
APR	Air Purifying Respirator
atm	Atmosphere(s)
BLS	Bureau of Labor Statistics
CARB	California Air Resources Board
CASRN	Chemical Abstracts Service Registry Number
CBI	Confidential Business Information
CDR	Chemical Data Reporting
CEHD	Chemical Exposure Health Data
CEM	Consumer Exposure Model
cm^3	Cubic Centimeter(s)
cP	Centipoise
CPS	Current Population Survey
CTA	Cellulose Triacetate
DMR	Discharge Monitoring Report
DOD	Department of Defense
ECETOC TRA	European Centre for Ecotoxicology and Toxicology of Chemicals Targeted Risk Assessment
ECHO	Enforcement and Compliance History Online
EDC	Ethylene Dichloride
EPA	Environmental Protection Agency
ESD	Emission Scenario Documents
EU	European Union
g	Gram(s)
HFC	Hydrofluorocarbon
HHE	Health Hazard Evaluation
HSE	Health and Safety Executive (United Kingdom)
HSIA	Halogenated Solvents Industry Association
HPV	High Production Volume
IARC	International Agency for Research on Cancer
IPCS	International Programme on Chemical Safety
kg	Kilogram(s)
L	Liter(s)
lb	Pound
LOD	Limit of Detection
Log K_{ow}	Logarithmic Octanol:Water Partition Coefficient
LPG	Liquefied Petroleum Gas
m^3	Cubic Meter(s)
mg	Milligram(s)
µg	Microgram(s)
mmHg	Millimeter(s) of Mercury
n	Number
NAICS	North American Industry Classification System

NEI	National Emissions Inventory
NIOSH	National Institute of Occupational Safety and Health
NKRA	Not known or reasonably attainable
NMP	N-Methylpyrrolidone
NPDES	National Pollutant Discharge Elimination System
OARS	Occupational Alliance for Risk Sciences
OECD	Organisation for Economic Co-operation and Development
OEL	Occupational Exposure Limit
OES	Occupational Exposure Scenarios
ONU	Occupational Non-User
OPPT	Office of Pollution Prevention and Toxics
OSHA	Occupational Safety and Health Administration
OTVD	Open Top Vapor Degreaser
PCE	Perchloroethylene
PEL	Permissible Exposure Limit
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment
ppm	Part(s) per Million
RCRA	Resource Conservation and Recovery Act
RDF	Refuse-derived fuel
SAR	Supplied-Air Respirator
SCBA	Self-Contained Breathing Apparatus
SDS	Safety Data Sheet
SIPP	Survey of Income and Program Participation
SpERC	Specific Environmental Release Category
STEL	Short-Term Exposure Limit
SUSB	Statistics of U.S. Businesses
TCE	Trichloroethylene
TLV	Threshold Limit Value
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TWA	Time-Weighted Average
U.S.	United States
WHO	World Health Organization
WWTP	Wastewater Treatment Plants

1 INTRODUCTION

1.1 Overview

TSCA § 6(b)(4) requires the United States Environmental Protection Agency (U.S. 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." In December of 2016, EPA published a list of 10 chemical substances that are the subject of the Agency's initial chemical risk evaluations (81 FR 91927), as required by TSCA § 6(b)(2)(A). Methylene chloride was one of these chemicals.

Methylene chloride, also known as dichloromethane and DCM, is a volatile and high production volume (HPV) chemical that is used as a solvent in a wide range of industrial, commercial and consumer applications.

This document supports occupational exposure assessment in the "Risk Evaluation for Methylene Chloride (Dichloromethane, DCM)."

1.2 Scope

Workplace exposures and releases to water have been assessed for the following industrial and commercial occupational exposure scenarios (OES) of methylene chloride:

1. Manufacturing (Section 2.1)
2. Processing as a Reactant (Section 2.2)
3. Processing - Incorporation into Formulation, Mixture, or Reaction Product (Section 2.3)
4. Repackaging (Section 2.4)
5. Batch Open-Top Vapor Degreasing (Section 2.5)
6. Conveyorized Vapor Degreasing (Section 2.6)
7. Cold Cleaning (Section 2.7)
8. Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products) (Section 2.8)
9. Adhesives and Sealants (Section 2.9)
10. Paints and Coatings (Section 2.10)
11. Adhesive and Caulk Removers (Section 2.11)
12. Fabric Finishing (Section 2.12)
13. Spot Cleaning (Section 2.13)
14. Cellulose Triacetate Film Production (Section 2.14)
15. Flexible Polyurethane Foam Manufacturing (Section 2.15)
16. Laboratory Use (Section 2.16)
17. Plastic Product Manufacturing (Section 2.17)
18. Pharmaceutical Production (Section 2.18)
19. Lithographic Printing Plate Cleaning (Section 2.19)
20. Miscellaneous Non-Aerosol Industrial and Commercial Uses (Section 2.20)

21. Waste Handling, Disposal, Treatment, and Recycling (Section 2.21)

For workplace exposures, EPA considered exposures to both workers who directly handle methylene chloride and occupational non-users (ONUs) who do not directly handle methylene chloride but may be exposed to vapors or mists that enter their breathing zone while working in locations in close proximity to where methylene chloride is being used.

For purposes of this report, “releases to water” include both direct discharges to surface water and indirect discharges to publicly-owned treatment works (POTW) or non-POTW wastewater treatment (WWT).

The assessed conditions of use were described in Table 2-3 of the *Problem Formulation of the Risk Evaluation of Methylene Chloride (Dichloromethane, DCM)* (U.S. EPA, 2018d); however, due to expected similarities in both processes and exposures/releases several of the subcategories of use in Table 2-3 were grouped and assessed together into various OES during the risk evaluation process. A crosswalk of the conditions of use in Table 2-3 to the OES assessed in this report is provided in Table 1-1.

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

Life Cycle Stage	Category [a]	Subcategory [b]	Assessed Occupational Exposure Scenarios
Manufacturing	Domestic manufacturing	Manufacturing	Section 2.1 – Manufacturing
	Import	Import	Section 2.4 – Repackaging
Processing	Processing as a reactant	Intermediate in industrial gas manufacturing (e.g., manufacture of fluorinated gases used as refrigerants)	Section 2.2 – Processing as a Reactant
		Intermediate for pesticide, fertilizer, and other agricultural chemical manufacturing	
		CBI function for petrochemical manufacturing	
		Intermediate for other chemicals	
	Incorporated into formulation, mixture, or reaction product	Solvents (for cleaning or degreasing), including manufacturing of: • All other basic organic chemical • Soap, cleaning compound and toilet preparation	Section 2.3 – Processing - Incorporation into Formulation, Mixture, or Reaction Product
		Solvents (which become part of product formulation or mixture), including manufacturing of: • All other chemical product and preparation • Paints and coatings	
		Propellants and blowing agents for all other chemical product and preparation manufacturing	
		Propellants and blowing agents for plastics product manufacturing	
		Paint additives and coating additives not described by other codes for CBI industrial sector	
		Laboratory chemicals for all other chemical product and preparation manufacturing	
		Laboratory chemicals for CBI industrial sectors	
		Processing aid, not otherwise listed for petrochemical manufacturing	
		Adhesive and sealant chemicals in adhesive manufacturing	

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

Life Cycle Stage	Category [a]	Subcategory [b]	Assessed Occupational Exposure Scenarios
		Unknown function for oil and gas drilling, extraction, and support activities	
	Repackaging	Solvents (which become part of product formulation or mixture) for all other chemical product and preparation manufacturing	Section 2.4 – Repackaging
		CBI functions for all other chemical product and preparation manufacturing	
	Recycling	Recycling	Section 2.21 – Waste Handling, Disposal, Treatment, and Recycling
Distribution in commerce	Distribution	Distribution	Section 2.4 – Repackaging
Industrial, commercial and consumer uses	Solvents (for cleaning or degreasing) [d]	Batch vapor degreaser (e.g., open-top, closed-loop)	Section 2.5 – Batch Open-Top Vapor Degreasing
		In-line vapor degreaser (e.g., conveyorized, web cleaner)	Section 2.6 – Conveyorized Vapor Degreasing
		Cold cleaner	Section 2.7 – Cold Cleaning
		Aerosol spray degreaser/cleaner	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)
	Adhesives and sealants	Single component glues and adhesives and sealants and caulks	Section 2.9 – Adhesives and Sealants
	Paints and coatings including paint and coating removers	Paints and coatings use and paints and coating removers, including furniture refinishers [e]	Section 2.10 – Paints and Coatings
		Adhesive/caulk removers	Section 2.11 -- Adhesive and Caulk Removers
	Metal products not covered elsewhere	Degreasers – aerosol and non-aerosol degreasers and cleaners e.g., coil cleaners	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products) Section 2.20 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
	Fabric, textile and leather	Textile finishing and impregnating/ surface treatment products e.g. water repellant	Section 2.12 – Fabric Finishing

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

Life Cycle Stage	Category [a]	Subcategory [b]	Assessed Occupational Exposure Scenarios
	products not covered elsewhere		
	Automotive care products	Function fluids for air conditioners: refrigerant, treatment, leak sealer	Section 2.20 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
		Interior car care – spot remover	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)
	Automotive care products	Degreasers: gasket remover, transmission cleaners, carburetor cleaner, brake quieter/cleaner	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)
	Apparel and footwear care products	Post-market waxes and polishes applied to footwear e.g. shoe polish	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)
	Laundry and dishwashing products	Spot remover for apparel and textiles	Section 2.13 – Spot Cleaning
	Lubricants and greases	Liquid and spray lubricants and greases	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products) Section 2.20 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
		Degreasers – aerosol and non-aerosol degreasers and cleaners	
	Building/ construction materials not covered elsewhere	Cold pipe insulation	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)
	Solvents (which become part of product formulation or mixture)	All other chemical product and preparation manufacturing	Section 2.3 – Processing - Incorporation into Formulation, Mixture, or Reaction Product
	Processing aid not otherwise listed	In multiple manufacturing sectors[f]	Section 2.14 – Cellulose Triacetate Film Production

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

Life Cycle Stage	Category [a]	Subcategory [b]	Assessed Occupational Exposure Scenarios
	Propellants and blowing agents	Flexible polyurethane foam manufacturing	Section 2.15—Flexible Polyurethane Foam Manufacturing
	Arts, crafts and hobby materials	Crafting glue and cement/concrete	Section 2.9 – Adhesives and Sealants
	Other Uses	Laboratory chemicals - all other chemical product and preparation manufacturing	Section 2.16 – Laboratory Use
		Electrical equipment, appliance, and component manufacturing	Section 2.20 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
		Plastic and rubber products	Section 2.17 – Plastic Product Manufacturing
			Section 2.14 – Cellulose Triacetate Film Production
		Anti-adhesive agent - anti-spatter welding aerosol	Section 2.8 – Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)
		Oil and gas drilling, extraction, and support activities	Section 2.20 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
		Functional fluids (closed systems) in pharmaceutical and medicine manufacturing	Section 2.18 – Pharmaceutical Production
		Toys, playground, and sporting equipment - including novelty articles (toys, gifts, etc.)	Section 2.20 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
		Carbon remover, lithographic printing cleaner, wood floor cleaner, brush cleaner	Section 2.19 – Lithographic Printing Plate Cleaning
Disposal	Disposal	Industrial pre-treatment	Section 2.21 – Waste Handling, Disposal, Treatment, and Recycling
		Industrial wastewater treatment	
		Publicly owned treatment works (POTW)	
		Underground injection	
		Municipal landfill	
		Hazardous landfill	
		Other land disposal	
		Municipal waste incinerator	
		Hazardous waste incinerator	

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

Life Cycle Stage	Category [a]	Subcategory [b]	Assessed Occupational Exposure Scenarios
		Off-site waste transfer	

a – These categories of conditions of use appear in the initial life cycle diagram, reflect CDR codes and broadly represent conditions of use for methylene chloride in industrial and/or commercial settings.

b – These subcategories reflect more specific uses of methylene chloride.

c – Industrial and Commercial designations for certain conditions of use denote different dermal risk calculator assessments.

d – Reported for the following sectors in the 2016 CDR for manufacturing of: plastic materials and resins, plastics products, miscellaneous, all other chemical product and preparation. (U.S. EPA, 2016b)

e –This includes uses (paints and coatings removers) assessed in the U.S. EPA (2014) risk assessment and therefore those uses are out of scope for the risk evaluation.

f –Reported for the following sectors in the 2016 CDR for manufacturing of: petrochemicals, plastic materials and resins, plastics products, miscellaneous, all other chemical product and CBI (U.S. EPA, 2016b) which may include chemical processor for polycarbonate resins and cellulose triacetate – photographic film, developer (Abt, 2017).

1.3 Components of the Occupational Exposure and Environmental Release Assessment

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

- **Facility Estimates:** An estimate of the number of sites that use methylene chloride for the given condition of use.
- **Process Description:** A description of the condition of use, including the role of the chemical in the use; process vessels, equipment, and tools used during the condition of use.
- **Worker Activities:** A descriptions of the worker activities, including an assessment for potential points of worker and ONU exposure.
- **Number of Workers and Occupational Non-Users:** An estimate of the number of workers and occupational non-users potentially exposed to the chemical for the given condition of use.
- **Occupational Inhalation Exposure Results:** Central tendency and high-end estimates of inhalation exposure to workers and occupational non-users. See Section XX for a discussion of EPA's statistical analysis approach for assessing inhalation exposure.
- **Water Release Sources:** A description of each of the potential sources of water releases in the process for the given condition of use.
- **Water Release Assessment Results:** Estimates of chemical released into water (surface water, POTW, or non-POTW WWT).

In addition to the above components for each condition of use, a separate dermal exposure section is included that provides estimates of the dermal exposures for all the assessed conditions of use.

1.4 General Approach and Methodology for Occupational Exposures and Environmental Releases

1.4.1 Process Description

EPA performed a literature search to find descriptions of processes involved in each condition of use. Where process descriptions were unclear or not available, EPA referenced relevant ESD's or GS's. Process descriptions for each condition of use can be found in Section 2.

1.4.2 Facility Estimates and Number of Workers and Occupational Non-Users

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

1. Identify the North American Industry Classification System (NAICS) codes for the industry sectors associated with these uses.
2. Estimate total employment by industry/occupation combination using the Bureau of Labor Statistics' Occupational Employment Statistics (OES) data (BLS Data).
3. Refine the OES estimates where they are not sufficiently granular by using the U.S. Census' Statistics of US Businesses (SUSB) (SUSB Data) data on total employment by 6-digit NAICS.
4. Use market penetration data to estimate the percentage of employees likely to be using methylene chloride 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, or NEI.
6. Combine the data generated in Steps 1 through 5 to produce an estimate of the number of employees using methylene chloride in each industry/occupation combination (if available), and sum these to arrive at a total estimate of the number of employees with exposure within the condition of use.

1.4.3 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 ESD's or GS's. Worker activities for each condition of use can be found in Section 2.

Workers may generally be exposed to methylene chloride when performing activities associated with the conditions of use, including, but not limited to:

- Unloading and transferring methylene chloride to and from storage containers to process vessels;
- Using methylene chloride in process equipment (e.g., vapor degreasing machine, process equipment used to manufacture refrigerants);
- Applying formulations and products containing methylene chloride onto substrates (e.g., applying adhesive removers containing methylene chloride onto substrates requiring adhesive removal);
- Cleaning and maintaining equipment;
- Sampling chemical, formulations or products containing methylene chloride for quality control (QC);
- Repackaging chemical, formulations or products containing methylene chloride;
- Handling, transporting and disposing waste containing methylene chloride;
- Performing other work activities in or near areas where methylene chloride is used.

In addition, exposures to ONUs, who do not directly handle the chemical but perform work in an area where the chemical is present are listed. Engineering controls and/or personal protective equipment may impact the occupational exposure levels.

1.4.4 Inhalation Exposure Assessment Approach and Methodology

Based on the high volatility of methylene chloride, EPA anticipates inhalation exposure to vapor to be the most important methylene chloride exposure pathway for workers and ONUs. Additionally, there is the potential for spray application of some products containing methylene chloride; therefore, exposures to mists are also expected for workers and ONUs.

1.4.4.1 General Approach

EPA provided occupational exposure results 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 evaluation, EPA used the 50th percentile (median), mean (arithmetic or geometric), mode, or midpoint values of a distribution as representative of the central tendency scenario. EPA's preference is to use the 50th percentile of the distribution. However, if the full distribution is not known, 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 estimate is assumed to be representative of occupational exposures that occur at probabilities above the 90th percentile but below the exposure of the individual with the highest exposure (U.S. EPA, 1992). For risk evaluation, EPA provided high-end results at the 95th percentile. If the 95th percentile was not available, EPA used a different percentile greater than or equal to the 90th percentile but less than or equal to the 99.9th percentile, depending on the statistics available for the distribution. If the full distribution is not known and the preferred statistics are not available, EPA estimated a maximum or bounding estimate in lieu of the high-end.

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

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

- Deterministic calculations: EPA used combinations of point estimates of each parameter to estimate a central tendency and high-end for each final exposure metric result. EPA documented the method and rationale for selecting parametric combinations to be representative of central tendency and high-end in 4.2.5Appendix C.
- Probabilistic (stochastic) calculations: EPA used Monte Carlo simulations using the full distribution of each parameter to calculate a full distribution of the final exposure metric results and selecting the 50th and 95th percentiles of this resulting distribution as the central tendency and high-end, respectively.
- Combination of deterministic and probabilistic calculations: EPA had full distributions for some parameters but point estimates of the remaining parameters. For example, EPA used Monte Carlo modeling to estimate exposure concentrations, but only had point estimates of exposure duration and frequency, 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 in 4.2.5Appendix C.

EPA follows the following hierarchy in selecting data and approaches for assessing inhalation 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 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. OSHA PEL

c. Voluntary limits (ACGIH TLV, NIOSH REL, Occupational Alliance for Risk Science (OARS) workplace environmental exposure level (WEEL) [formerly by AIHA])

1.4.4.2 Approach for this Risk Evaluation

EPA reviewed workplace inhalation monitoring data collected by government agencies such as OSHA and NIOSH, monitoring data found in published literature (i.e., personal exposure monitoring data and area monitoring data), and monitoring data submitted via public comments. Data found in sources were evaluated using the evaluation strategies laid out in the Application of Systematic Review in TSCA Risk Evaluations (U.S. EPA, 2018b). Results of the evaluations are in the supplemental files titled "Risk Evaluation for Methylene Chloride, Systematic Review Supplemental File: Data Quality Evaluation of Environmental Release and Occupational Exposure Data. Docket ##." (U.S. EPA, 2019b) and "Risk Evaluation for Methylene Chloride, Systematic Review Supplemental File: Data Quality Evaluation of Environmental Release and Occupational Exposure Data Common Sources. Docket ##" (U.S. EPA, 2019a). Data from sources included in the risk evaluation were found acceptable for risk assessment purposes.

Exposures are calculated from the 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 value as a what-if exposure. 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/OPPT's *Guidelines for Statistical Analysis of Occupational Exposure Data* (1994) which recommends using the LOD / $2^{0.5}$ if the geometric standard deviation of the data is less than 3.0 and LOD / 2 if the geometric standard deviation is 3.0 or greater (EPA, 1994). Specific details related to each condition of use can be found in Section 2. For each condition of use, these values were used to calculate acute and chronic (non-cancer and cancer) exposures. Equations and sample calculations for chronic exposures can be found in 4.2.5Appendix C and 4.2.5Appendix D, respectively.

EPA used exposure monitoring data or exposure models to estimate inhalation exposures for workers and ONUs during all conditions of use. Data sources did not often indicate whether methylene chloride exposure concentrations were for occupational users or ONUs. In these cases, EPA/OPPT assumed that inhalation exposure data were applicable for a combination of workers and nearby ONUs. Some nearby ONUs users may have lower inhalation exposures than users, especially when they are further away from the source of exposure. EPA/OPPT assumed that ONUs that may be in close proximity to workers handling methylene chloride usually do not directly contact the liquids containing methylene chloride.

Specific details related to the use of monitoring data for each condition of use can be found in Section 2. Descriptions of the development and parameters used in the exposure models used for this assessment can be found in 4.2.5Appendix F.

1.4.4.3 Respiratory Protection

The Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard (29 CFR 1910.134) provides a summary of respirator types by their assigned protection factor (APF). Assigned Protection Factor (APF) "means the workplace level of respiratory protection that a respirator or class of respirators is expected to provide to employees when the employer implements a continuing, effective respiratory protection program" according to the requirements of OSHA's Respiratory Protection Standard. Because methylene chloride may cause eye irritation or damage, the OSHA standard for methylene chloride (29 CFR 1910.1052) prohibits use of quarter and half mask respirators; additionally, only supplied air respirators (SARs) can be used because methylene chloride may pass through air purifying respirators.

Respirator types and corresponding APFs indicated in bold font in Table 1-2comply with the OSHA standard for protection against methylene chloride. APFs are intended to guide the selection of an appropriate class of respirators to protect workers after a substance is determined to be hazardous, after an occupational exposure limit is established, and only when the exposure limit is exceeded after feasible engineering, work practice, and administrative controls have been put in place. For methylene chloride, the OSHA PEL is 25 ppm, or 87 mg/m3 as an 8-hr TWA, and the OSHA short-term exposure limit (STEL) is 125 ppm, or 433 mg/m3 as a 15-min TWA. For each occupational exposure scenario, EPA compares the exposure data and estimates to the PEL and STEL. Exceedance of the PEL or STEL would indicate that the exposure would need to be addressed, and respirator use would be the last line of defense.

The current OSHA PEL was updated in 1997; prior to the change the OSHA PEL had been 500 ppm as an 8-hr TWA, which was 20 times higher than the current PEL. An analysis of more than 12,000 personal samples obtained from OSHA by Finkel (2017) shows the PEL change appears to have produced a general average reduction from 85 ppm to 72 ppm (about 15%) in methylene chloride exposures. This incremental general exposure reduction due to the PEL change indicates that exposure data from before the PEL change are adequate for EPA's risk evaluation purposes.

Based on the protection standards, inhalation exposures may be reduced by a factor of 25, 50, 1,000, or 10,000, if respirators are required and properly worn and fitted. Air concentration data are assumed to be pre-APF unless indicated otherwise in the source, and APFs acceptable under the OSHA standards are not otherwise considered or used in the occupational exposure assessment but are considered in the risk characterization and risk determination.

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

Type of Respirator	Quarter Mask	Half Mask	Full Facepiece	Helmet/ Hood	Loose-fitting Facepiece
1. Air Purifying Respirator	5	10	50	……………	……………
2. Powered Air-Purifying Respirator	……………	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	……………	……………	**10,000**	**10,000**	……………

a – Note that only APFs indicated in **bold** are acceptable to OSHA for methylene chloride protection.

Based on the protection standards, inhalation exposures may be reduced by a factor of 25, 50, 1,000, or 10,000, assuming that workers/ONUs are complying with the standard.

1.4.5 Dermal Exposure Assessment Approach

Based on the conditions of use EPA expects workers to have potential for skin contact with liquids and vapors. Where workers may be exposed to methylene chloride, the OSHA standard requires that workers are protected from contact (e.g. gloves) (29 CFR 1910.1052). ONUs are not directly handling methylene chloride; therefore, skin contact with liquid methylene chloride is not expected for ONUs but skin contact with vapors is expected for ONUs.

Dermal exposure data was not readily available for the conditions of use in the assessment. Because methylene chloride is a volatile liquid, the dermal absorption of methylene chloride depends on the type and duration of exposure. Where exposure is not occluded, only a fraction of methylene chloride that comes into contact with the skin will be absorbed as the chemical readily evaporates from the skin. However, dermal exposure may be significant in cases of occluded exposure, repeated contacts, or dermal immersion. For example, work activities with a high degree of splash potential may result in methylene chloride liquids trapped inside the gloves, inhibiting the evaporation of methylene chloride and increasing the exposure duration.

EPA estimated dermal exposures using the *Dermal Exposure to Volatile Liquids* Model. This model determines a dermal potential dose rate based on an assumed amount of liquid on skin during one contact event per day and the steady-state fractional absorption for methylene chloride based on a theoretical framework provided by Kasting (2005). The amount of liquid on the skin is adjusted by the weight fraction of methylene chloride in the liquid to which the worker is exposed. Specific details of the dermal exposure assessment can be found in Section 3.2 and equations and sample calculations for estimating dermal exposures can be found in 4.2.5Appendix E.

1.4.6 Water Release Assessment Approach

EPA/OPPT performed a literature search to identify process operations that could potentially result in direct or indirect discharges to water for each condition of use. Where available, EPA/OPPT used 2016 TRI (U.S. EPA, 2017c) and 2016 DMR (U.S. EPA, 2016a) data to provide a basis for estimating releases. Facilities are only required to report to TRI if the facility has 10 or more full-time employees, is included in an applicable NAICS code, and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 pounds for manufacturers and processors of methylene chloride and 10,000 pounds for users of methylene chloride). Due to these limitations, some sites that manufacture, process, or use methylene chloride may not report to TRI and are therefore not included in these datasets.

For the 2016 DMR (U.S. EPA, 2016a), EPA/OPPT used the Water Pollutant Loading Tool within EPA's Enforcement and Compliance History Online (ECHO) to query all methylene chloride point source water discharges in 2016. DMR data are submitted by National Pollutant Discharge Elimination System (NPDES) permit holders to states or directly to the EPA according to the monitoring requirements of the facility's permit. States are only required to load major discharger data into DMR and may or may not load minor discharger data. The definition of major vs. minor discharger is set by each state and could be based on discharge volume or facility size. Due to these limitations, some sites that discharge methylene chloride may not be included in the DMR dataset.

Facilities reporting releases in TRI and DMR also report associated NAICS and SIC industry codes, respectively. EPA reviewed the NAICS and SIC descriptions for each reported release and mapped each facility to a potential condition of use, if possible. For facilities that did not report a NAICS or SIC code, EPA performed supplemental internet search of the specific facility to determine the categorization. Releases that could not be classified were grouped together into an "Other" category.

When possible for each condition of use, EPA/OPPT estimated annual releases, average daily releases, and number of release days per year. Where TRI and/or DMR were available, EPA/OPPT used the reported annual releases for each site and estimated the daily release by averaging the annual release over the expected release days per year. Where releases are expected but TRI and DMR data were not available, EPA/OPPT included a qualitative discussion of potential release sources.

The following guidelines were used to estimate the number of release days per year:

- Manufacturing: For the manufacture of the large-PV solvents, EPA assumes 350 day/yr for release frequency. This assumes the plant runs 7 day/week and 50 week/yr (with two weeks down for turnaround), and assumes that the plant is always producing the chemical.
- Processing as Reactant: Methylene chloride is largely used to manufacture other commodity chemicals, such as refrigerants or other chlorinated compounds, which will likely occur year-round. Therefore, EPA assumes 350 days/yr for release frequency.
- Processing into Formulation Product: For these facilities, EPA does not expect that methylene chloride will be used year-round, even if the facility operates year-round. Therefore, EPA assumes 300 day/yr for release frequency, which is based on an EU SpERC that uses a default of 300 days/yr for release frequency for the chemical industry (Group, 2019).
- Wastewater Treatment Plants: For these facilities, EPA expects that they will be used year-round. Therefore, EPA assumes 365 days/yr for release frequency.
- All Other Scenarios: For all other scenarios, EPA assumes 250 days/yr for release frequency (5 days/week, 50 weeks/yr).

2 Engineering Assessment

2.1 Manufacturing

2.1.1 Process Description

Methylene chloride is primarily manufactured through the gas-phase reaction of hydrogen chloride with methanol to produce methyl chloride, which is then reacted with chlorine to produce methylene chloride, along with chloroform and carbon tetrachloride as coproducts. This reaction is typically driven by high temperature, but may also be driven through catalysis or photolysis. This reaction may alternatively be conducted in the liquid phase at low temperatures and high pressures, which can yield high selectivity of methylene chloride (Holbrook, 2003).

An antiquated production method of methylene chloride is the reaction of excess methane with chlorine at temperatures of approximately 400 to 500°C. Lower reaction temperatures are possible through the use of catalysis or photolysis. This reaction produces methylene chloride with methyl chloride, chloroform and carbon tetrachloride as coproducts and unreacted methane with hydrogen chloride as byproducts. The unreacted methane and hydrogen chloride are removed through a water wash, dried, and recycled. The liquid stream of chlorinated organic products is washed, alkali scrubbed, dried and fractionated (Holbrook, 2003).

Other minor production methods of methylene chloride exist, such as: the reduction of chloroform or carbon tetrachloride with hydrogen over a platinum catalyst; the molten salt oxychlorination of methane; the reaction of phosgene and formaldehyde over an activated carbon catalyst; and the reduction of carbon tetrachloride with ferrous hydroxide in the presence of alkaline hydroxides or carbonates (Holbrook, 2003).

Methylene chloride production is accomplished in an enclosed system and bypasses are considered to be an integral part of the continuous production process. This continuous production process contributes significantly to the elimination or substantial reduction of worker exposure to methylene chloride vapors. After production, methylene chloride is stored in outdoor tanks and is shipped in bulk quantity by rail car, tank truck, barge or in 55-gallon Drums (OSHA, 1991).

2.1.2 Number of Sites and Potentially Exposed Workers

The 2016 Public CDR shows three sites in calendar year 2015 that manufactured methylene chloride domestically, one site that both manufactured and imported methylene chloride, and an additional 10 where the activity is marked as CBI or withheld, as shown in Table 2-1. The table also shows the number of workers reasonably likely to be exposed to methylene chloride at these facilities. The term "reasonably likely to be exposed", for the purpose of CDR, means "an exposure to a chemical substance which, under foreseeable conditions of manufacture, processing, distribution in commerce, or use of the chemical substance, is more likely to occur than not to occur". These exposures would include activities such as charging reactor vessels, drumming, bulk loading, cleaning equipment, maintenance operations, materials handling and transfer, and analytical operations. The estimate also includes persons whose employment requires them to pass through areas where chemical substances are manufactured, processed, or used, i.e., those who may be considered "occupational non-users", such as production workers, foremen, process engineers, and plant managers.

Of the 14 sites, five reported between 225 and 445 workers and ONUs. Assuming 89 workers and ONUs per site, the additional 9 sites may have 801 workers and ONUs. Therefore, EPA assumes a total of 14 sites and up to 1,246 workers and ONUs.

Table 2-1 Number of Potentially Exposed Workers at Manufacturing Facilities (2016 CDR)

Manufacture/ Import	Company	Facility	Facility		Workers[a] likely to be exposed
			City	State	
Manufacture	Olin Corporation	Olin Blue Cube, FREEPORT, TX	Freeport	TX	50 to 99
Manufacture	Tedia Company Inc.	Tedia Company Inc.	Fairfield	OH	50 to 99
Manufacture	Solvay Holding Inc	Advanced Composites Group Inc.	Tulsa	OK	50 to 99
Manufacture /Import	Sempre Avant LLC	Solvents & Chemicals	Pearland	TX	50 to 99
CBI	The Dow Chemical Company	The Dow Chemical Company	Pittsburg	CA	25 to 49
CBI	CBI	EMD Millipore Corp.	Norwood	OH	CBI[b]
CBI	INEOS Chlor Americas Inc.	INEOS Chlor America Inc.	Wilmington	DE	CBI[b]
CBI	CBI	GreenChem	West Palm Beach	FL	CBI[b]
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Geismar	LA	CBI[b]
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Wichita	KS	CBI[b]
Withheld	FRP Services & Co. (America) Inc.	FRP Services & Co. (America) Inc.	New York	NY	Withheld[b]
Withheld	Solvay USA Inc	Solvay USA INC	Princeton	NJ	Withheld[b]
Withheld	Global Chemical Resources Inc.	Global Chemical Resources Inc.	Toledo	OH	Withheld[b]
Withheld	Shrieve Chemical Company	Shrieve Chemical Products, Inc.	The Woodlands	TX	Withheld[b]
Total establishments and number of potentially exposed workers during Manufacture/Import			up to 14 sites		up to 1,200

Source: U.S. EPA (2016b)
NKRA – Not known or reasonably ascertainable
a – May include both workers and ONUs
b – Number of relevant workers and ONUs per site were estimated by assuming up to 445 workers and ONUs over the 5 reported sites (average of 89 workers and ONUs per site, based on known sites)

2.1.3 Exposure Assessment

2.1.3.1 Worker Activities

Typical worker activities at a manufacturing facility include: 1) collecting and analyzing quality control (QC) samples; 2) routine monitoring of the process, making process changes, or responding to process upsets; and 3) loading finished products containing methylene chloride into containers and tank trucks. The specific activity and the potential exposure level may differ substantially depending on the facility's operation, process enclosure, level of automation, engineering control, and PPE.

2.1.3.2 Inhalation Exposures

Table_Apx A-1 and Table_Apx A-2 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride manufacturing that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

The Halogenated Solvents Industry Alliance (HSIA) provided personal monitoring data from 2005 through 2018 at two manufacturing facilities (Halogenated Solvents Industry Alliance, 2018). From this monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. Both the central tendency and high-end 8-hr TWA exposure concentrations for this scenario are at least one order of magnitude below the OSHA PEL value of 87 mg/m3 (25 ppm).

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-2.

Table 2-2. Full-Shift Worker Exposure to Methylene Chloride During Manufacturing

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	136	0.36	4.6
Average Daily Concentration (ADC)		0.08	1.1
Lifetime Average Daily Concentration (LADC)		0.14	2.4

Sources: Halogenated Solvents Industry Alliance (2018)

Table 2-3 summarizes available short-term exposure data for workers provided by HSIA (Halogenated Solvents Industry Alliance, 2018). Because of the number of data points, details are provided in Table_Apx A-2.

Table 2-3. Short-Term Worker Exposure to Methylene Chloride During Manufacturing

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
15-minute [a]	148	9.6	180
30-minute [b]	1	2.6	
1-hour	3	6.6	15

Source: Halogenated Solvents Industry Alliance (2018). Full results are presented in Table_Apx A-2.
a – EPA assumed sampling times of 15 minutes to 29 minutes as 15-minute exposures.
b – EPA assumed sampling times of 30 minutes to 59 minutes as 30-minute exposures.

EPA has not identified data on potential ONU inhalation exposures from methylene chloride manufacturing. Since ONUs do not directly handle methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.1.4 Water Release Assessment

EPA assumed that sites under NAICS 325199 (All Other Basic Organic Chemical Manufacturing) or SIC 2869 (Industrial Organic Chemicals, Not Elsewhere Classified) are potentially applicable to manufacturing of methylene chloride. Note that these NAICS codes may be applicable to other conditions of use (processing as a reactant, processing—incorporation into formulation, mixture, or reaction product); however, insufficient information were available to make these determinations.

Table 2-4 lists all facilities under these NAICS and SIC codes that reported direct or indirect water releases in the 2016 TRI or 2016 DMR. Of the potential manufacturing sites listed in CDR (Table 2-1), only one facility was present in Table 2-4, which reported 128 pounds (58 kg) of methylene chloride transferred off-site to wastewater treatment (Olin Blue Cube, Freeport, TX) (U.S. EPA, 2017c).

Table 2-4. Reported TRI Releases for Organic Chemical Manufacturing Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
COVESTRO LLC	BAYTOWN	TX	1	350	0.004	Surface Water	U.S. EPA (2017c)
EMERALD PERFORMANCE MATERIALS LLC	HENRY	IL	0.5	350	0.001	Surface Water	U.S. EPA (2017c)
FISHER SCIENTIFIC CO LL C	FAIR LAWN	NJ	2	350	0.01	POTW	U.S. EPA (2017c)
FISHER SCIENTIFIC CO LLC	BRIDGEWATER	NJ	2	350	0.01	POTW	U.S. EPA (2017c)
OLIN BLUE CUBE FREEPORT TX	FREEPORT	TX	58	350	0.2	Non-POTW WWT	U.S. EPA (2017c)
REGIS TECHNOLOGIES INC	MORTON GROVE	IL	2	350	0.01	POTW	U.S. EPA (2017c)
SIGMA-ALDRICH MANUFACTURING LLC	SAINT LOUIS	MO	2	350	0.01	POTW	U.S. EPA (2017c)
VANDERBILT CHEMICALS LLC-MURRAY DIV	MURRAY	KY	0.5	350	0.001	Non-POTW WWT	U.S. EPA (2017c)
E I DUPONT DE NEMOURS - CHAMBERS WORKS	DEEPWATER	NJ	76	350	0.2	Surface Water	U.S. EPA (2016a)
BAYER MATERIALSCIENCE BAYTOWN	BAYTOWN	TX	10	350	0.03	Surface Water	U.S. EPA (2016a)
INSTITUTE PLANT	INSTITUTE	WV	3	350	0.01	Surface Water	U.S. EPA (2016a)
MPM SILICONES LLC	FRIENDLY	WV	2	350	0.005	Surface Water	U.S. EPA (2016a)
BASF CORPORATION	WEST MEMPHIS	AR	1	350	0.003	Surface Water	U.S. EPA (2016a)
ARKEMA INC	PIFFARD	NY	0.3	350	0.001	Surface Water	U.S. EPA (2016a)
EAGLE US 2 LLC - LAKE CHARLES COMPLEX	LAKE CHARLES	LA	0.2	350	0.001	Surface Water	U.S. EPA (2016a)
BAYER MATERIALSCIENCE	NEW MARTINSVILLE	WV	0.2	350	0.001	Surface Water	U.S. EPA (2016a)
ICL-IP AMERICA INC	GALLIPOLIS FERRY	WV	0.1	350	0.0004	Surface Water	(U.S. EPA, 2016a)
KEESHAN AND BOST CHEMICAL CO., INC.	MANVEL	TX	0.02	350	0.00005	Surface Water	U.S. EPA (2016a)
INDORAMA VENTURES OLEFINS, LLC	SULPHUR	LA	0.01	350	0.00003	Surface Water	U.S. EPA (2016a)
CHEMTURA NORTH AND SOUTH PLANTS	MORGANTOWN	WV	0.01	350	0.00002	Surface Water	U.S. EPA (2016a)

2.1.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.2 Processing as a Reactant

2.2.1 Process Description

Processing as a reactant or intermediate is the use of methylene chloride as a feedstock in the production of another chemical product via a chemical reaction, in which methylene chloride is consumed to form the product. Methylene chloride is used as an intermediate for the production of difluoromethane, also known as HFC-32, which is used in fluorocarbon blends for refrigerants (Marshall and Pottenger, 2004).

Methylene chloride is also a feedstock in the production of bromochloromethane. Bromochloromethane is produced through a halogen exchange reaction with methylene chloride and either bromine or hydrogen bromide, with an aluminum or aluminum trihalide catalyst. Alternative processes include the gas-phase bromination of methylene chloride with hydrogen bromide and the liquid-phase displacement reaction of methylene chloride with inorganic bromides (Technology, 2011).

2.2.2 Number of Sites and Potentially Exposed Workers

In the 2016 CDR, two submissions reported downstream industrial processing and use of methylene chloride as a chemical intermediate. Based on information reported by these companies, and as shown in Table 2-5, methylene chloride is potentially used as a chemical intermediate at up to 18 sites, where 75 to 148 workers and ONUs are potentially exposed.

Table 2-5. Number of U.S. Establishments, Workers, and ONUs for Processing as a Reactant from 2016 CDR

Industry Sector	Industry Function Category	Number of Establishments	Workers[a] likely to be exposed
CBI	Intermediates	<10	25 to <50
CBI	Intermediates	<10	50 to <100
Total establishments and number of potentially exposed workers and ONUs =		up to 18	up to 150

Source: U.S. EPA (2016b)
a – May include both workers and ONUs.

Table 2-6 presents the estimated numbers of workers and ONUs per site obtained from EPA's analysis of BLS data for the two industry sectors relevant to this condition of use: NAICS 325120 and 325320 (U.S. BLS, 2016; U.S. Census Bureau, 2015). The estimated numbers of workers and ONUs per site are multiplied by the number of establishments reported in the CDR to calculate the total number of potentially exposed workers and ONUs. Based on a high-end estimate of 18 sites, a total of 319 workers and 126 ONUs are potentially exposed (442 total workers and ONUs). It should be noted that the number of sites are reported as ranges in CDR, and the actual number of sites may be significantly lower than 18.

Table 2-6. Number of U.S. Establishments, Workers, and ONUs for Processing as a Reactant

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers per Site [b]	Number of ONUs per Site [b]
325120	Industrial Gas Manufacturing	18 [a]	14	7
325320	Pesticide and Other Agricultural Chemical Manufacturing		25	7
Total establishments and number of potentially exposed workers and ONUs = [c]			319	123

a – Based on CDR estimates in Table 2-5.
b – Rounded to the nearest worker.
c – Unrounded figures were used for total worker and ONU calculations.

2.2.3 Exposure Assessment

2.2.3.1 Worker Activities

At industrial facilities, workers are potentially exposed when unloading methylene chloride from transport containers into intermediate storage tanks and process vessels. Workers may be exposed via inhalation of vapor or via dermal contact with liquids while connecting and disconnecting hoses and transfer lines. Once methylene chloride is unloaded into process vessels, it is consumed as a chemical intermediate.

ONUs are employees who work at the facilities that process and use methylene chloride, but who do not directly handle the material. ONUs may also be exposed to methylene chloride, but are expected to have lower inhalation exposures and are not expected to have dermal exposures. ONUs for this condition of use may include supervisors, managers, engineers, and other personnel in nearby production areas.

2.2.3.2 Inhalation Exposures

Table_Apx A-3 and Table_Apx A-4 in 4.2.5Appendix A summarize the inhalation monitoring data for processing of methylene chloride as a reactant that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

HSIA provided monitoring data from 2010 through 2017 for maintenance workers, operators, and laboratory technicians at a fluorochemical manufacturing facility. Eight-hour exposure concentrations ranged from ND to 13.9 mg/m^3 (15 samples) (Halogenated Solvents Industry Alliance, 2018).

From this monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration is more than an order of magnitude lower than the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end 8-hr TWA exposure concentrations for this scenario is more than 8 times lower than the OSHA PEL.

Table 2-7 presents the calculated the AC, ADC, and LADC for these 8-hr TWA exposure concentrations, as described in 4.2.5Appendix B.

Table 2-7. Worker Exposure to Methylene Chloride During Processing as a Reactant During Fluorochemicals Manufacturing

	Number of Samples	Central Tendency (mg/m³)	High-End (mg/m³)
8-hr TWA Exposure Concentration	15	1.6	10
Average Daily Concentration (ADC)		0.37	2.4
Lifetime Average Daily Concentration (LADC)		0.65	5.3

Sources: Halogenated Solvents Industry Alliance (2018)

Table 2-8 summarizes available short-term exposure data available for "other chemical industry" and during drumming at a pesticide manufacturing site.

Table 2-8. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Processing as a Reactant

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m³)	Exposure Duration (min)
Other Chemical Industry	TNO (CIVO) (1999)	filter changing, charging and discharging, etc	350 (max)	10
Pesticides Mfg	Olin Corp (1979)	Drumming	1,700	25

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.2.4 Water Release Assessment

EPA assumed that sites classified under NAICS 325320 (Pesticide and Other Agricultural Chemical Manufacturing) or SIC 2879 (Pesticides and Agricultural Chemicals, Not Elsewhere Classified) are potentially applicable to processing of methylene chloride as a reactant. Table 2-9 lists all facilities under these NAICS and SIC codes that reported direct or indirect water releases in the 2016 TRI or 2016 DMR.

Table 2-9. Reported 2016 TRI and DMR Releases for Potential Processing as Reactant Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
AMVAC CHEMICAL CO	AXIS	AL	213	350	0.6	Non-POTW WWT	U.S. EPA (2017c)
THE DOW CHEMICAL CO	MIDLAND	MI	25	350	0.1	Surface Water	U.S. EPA (2017c)
FMC CORPORATION	MIDDLEPORT	NY	0.1	350	0.0003	Surface Water	U.S. EPA (2016a)

2.2.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.3 Processing - Incorporation into Formulation, Mixture, or Reaction Product

2.3.1 Process Description

Incorporation into a formulation, mixture or reaction product refers to the process of mixing or blending of several raw materials to obtain a single product or preparation. The uses of methylene chloride that may require incorporation into a formulation include paint removers; adhesives and sealants; paints and coatings; degreasers, cleaners, and spot removers; and lubricants. Methylene chloride-specific formulation processes were not identified; however, several ESDs published by OECD provide general process descriptions for formulating some of these products. For example, the formulation of paints and coatings typically involves dispersion, milling, finishing and filling into final packages (OECD, 2009b). Adhesive/sealant formulation involves mixing together volatile and non-volatile chemical components in sealed, unsealed or heated processes (OECD, 2009a). Sealed processes are most common for adhesive/sealant formulation because many adhesives/sealants are designed to set or react when exposed to ambient conditions (OECD, 2009a). Lubricant formulation typically involves the blending of two or more components, including liquid and solid additives, together in a blending vessel (OECD, 2004). Formulated products are stored in drums or packaged in various size containers. Those drums and other containers are then shipped to industrial end points or to retail markets for consumer use (OSHA, 1991).

Many of these formulated products may be packed in aerosol form. Methylene chloride cannot function alone as a propellent because of its low vapor pressure relative to other propellants. A solvent such as methylene chloride brings the active ingredient into solution with the propellants. It is sometimes desirable to have another liquid present which is not miscible with the propellent (e.g. water and propylene glycol). In these cases, a cosolvent such as methylene chloride or ethyl alcohol is added to obtain a homogeneous mixture. Another function of a solvent such as methylene chloride is to help produce a spray with a particle size most effective for a particular application. Solvents prevent the propellants from evaporating completely in air shortly after discharge from the can. Therefore, a solvent also assists in atomization and allows for a higher delivery rate (OSHA, 1991).

Methylene chloride is used as a solvent in many products because of its high vapor pressure compared to other economically viable solvents, its high boiling point, its compatibility with many types of formulations, and because it depresses the vapor pressure of high pressure propellants. As a result, the flammability of the mixture is reduced and the dispersion of the aerosol spray is enhanced (OSHA, 1991).

Methylene chloride may be shipped in tank cars, or 55-gallon drums. Methylene chloride is either transferred directly from the shipping containers to the packaging line (to avoid loss of solvent due to volatilization), or it is transferred to storage tanks for subsequent mixing with other products (i.e. active ingredients and solvents). The aerosol can is charged with the active ingredients and solvent (either individually or premixed), and then filled with the propellant in an explosion proof room (OSHA, 1991).

2.3.2 Number of Sites and Potentially Exposed Workers

In the 2016 CDR, several submitters reported downstream industrial processing and use of methylene chloride as incorporation into formulation, mixture or reaction products (U.S. EPA, 2016b). Based on information reported by these companies, and as shown in Table 2-10, methylene chloride is potentially used in the formulation of adhesives and sealants; paints and coatings; and pesticide, fertilizer, and other agricultural chemicals, at up to 261 sites and 2,032 workers and ONUs are potentially exposed.

Table 2-10. Number of U.S. Establishments, Workers, and ONUs for Processing – Incorporation into Formulation, Mixture, or Reaction Product from 2016 CDR

Industry Sector	Industry Function Category	Number of Establishments	Workers[a] likely to be exposed
Adhesive manufacturing	Adhesives and sealant chemicals	NKRA[b]	NKRA[b]
Adhesive manufacturing	Adhesives and sealant chemicals	<10	NKRA[b]
All other basic organic chemical manufacturing	Solvents (for cleaning and degreasing)	NKRA[a]	NKRA[b]
All other basic organic chemical manufacturing	Solvents (for cleaning and degreasing)	<10	100 to < 500
All other chemical product and preparation manufacturing	Solvents (which become part of product formulation or mixture)	<10	100 to < 500
All other chemical product and preparation manufacturing	Solvents (which become part of product formulation or mixture)	25 to <100	100 to < 500
All other chemical product and preparation manufacturing	Laboratory chemicals	25 to <100	100 to < 500
Oil and gas drilling, extraction, and support activities	Not known or reasonably ascertainable	NKRA[b]	NKRA[b]
Paint and coating manufacturing	Solvents (which become part of product formulation or mixture)	NKRA[b]	NKRA[b]
Pesticide, fertilizer, and other agricultural chemical manufacturing	Intermediates	<10	<10
Soap, cleaning compound, and toilet preparation manufacturing	Solvents (for cleaning and degreasing)	<10	<10
CBI	Paint additives and coating additives not described by other categories	<10	<10
CBI	Paint additives and coating additives not described by other categories	<10	<10
Total establishments and number of potentially exposed workers and ONUs = [c]		up to 477	up to 4,500

Source: U.S. EPA (2016b)
NKRA – Not known or reasonably ascertainable
a – Assumed <10 sites per similar entries for adhesive manufacturing and all other basic organic chemical manufacturing.
B – Assumed highest values reported for sites (25 to <100) and number of workers (100 to 499) as conservative.

2.3.3 Exposure Assessment

2.3.3.1 Worker Activities

At formulation facilities, workers are potentially exposed during product mixing operations; during packaging and container filling operations; and during methylene chloride transfer activities (OSHA, 1991). The exact activities and associated level of exposure will differ depending on the degree of automation, presence of engineering controls, and use of PPE at each facility.

2.3.3.2 Inhalation Exposures

Table_Apx A-5 and Table_Apx A-6 in 4.2.5Appendix A summarize the inhalation monitoring data that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

U.S. EPA (1985) provided exposure data for packing at paint/varnish and cleaning products sites, ranging from 52 mg/m^3 (mixing) to 2,223 mg/m^3 (valve dropper) (10 data points).

From this monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration for this scenario is approximately twice the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is approximately 21 times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-11.

Table 2-11. Worker Exposure to Methylene Chloride During Processing – Incorporation into Formulation, Mixture, or Reaction Product

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	10	180	1,800
Average Daily Concentration (ADC)		41	410
Lifetime Average Daily Concentration (LADC)		72	920

Sources: US EPA (1985).
a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

TNO (CIVO) (1999) indicated that the peak exposure during filling may be up to 180 mg/m^3, but did not provide exposure duration.

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.3.4 Water Release Assessment

EPA identified six NAICS and SIC codes, listed in Table 2-12, that reported water releases in the 2016 TRI and may be related to use as Processing – Incorporation into Formulation, Mixture, or Reaction Product. Table 2-13 lists all facilities classified under these NAICS and SIC codes that reported direct or indirect water releases in the 2016 TRI or 2016 DMR.

Table 2-12. Potential Industries Conducting Methylene Chloride Processing – Incorporation into Formulation, Mixture, or Reaction Product in 2016 TRI or DMR

NAICS Code	NAICS Description
325180	Other Basic Inorganic Chemical Manufacturing
325510	Paint and Coating Manufacturing
325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing
2819	INDUSTRIAL INORGANIC CHEMICALS
2843	SURF ACTIVE AGENT, FIN AGENTS
2899	CHEMICALS & CHEM PREP, NEC

Table 2-13. Reported 2016 TRI and DMR Releases for Potential Processing—Incorporation into Formulation, Mixture, or Reaction Product Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
ARKEMA INC	CALVERT CITY	KY	31	300	0.1	Surface Water	U.S. EPA (2017c)
MCGEAN-ROHCO INC	LIVONIA	MI	113	300	0.4	POTW	U.S. EPA (2017c)
WM BARR & CO INC	MEMPHIS	TN	0.5	300	0.002	POTW	U.S. EPA (2017c)
BUCKMAN LABORATORIES INC	MEMPHIS	TN	254	300	1	POTW	U.S. EPA (2017c)
EUROFINS MWG OPERON LLC	LOUISVILLE	KY	5,785	300	19	POTW	U.S. EPA (2017c)
SOLVAY - HOUSTON PLANT	HOUSTON	TX	12	300	0.04	Surface Water	U.S. EPA (2016a)
HONEYWELL INTERNATIONAL INC - GEISMAR COMPLEX	GEISMAR	LA	4	300	0.01	Surface Water	U.S. EPA (2016a)
STEPAN CO MILLSDALE ROAD	ELWOOD	IL	2	300	0.01	Surface Water	U.S. EPA (2016a)
ELEMENTIS SPECIALTIES, INC.	CHARLESTON	WV	0.2	300	0.001	Surface Water	U.S. EPA (2016a)

2.3.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.4 Repackaging

2.4.1 Process Description

Commodity chemicals such as methylene chloride may be imported into the United States in bulk via water, air, land, and intermodal shipments (Tomer and Kane, 2015). These shipments take the form of oceangoing chemical tankers, railcars, tank trucks, and intermodal tank containers. Chemicals shipped in bulk containers may be repackaged into smaller containers for resale, such as drums or bottles. Domestically manufactured commodity chemicals may be shipped within the United States in liquid cargo barges, railcars, tank trucks, tank containers, intermediate bulk containers (IBCs)/totes, and drums. Both imported and domestically manufactured commodity chemicals may be repackaged by wholesalers for resale; for example, repackaging bulk packaging into drums or bottles. The type and size of container will vary depending on customer requirement. In some cases, QC samples may be taken at import and repackaging sites for analyses. Some import facilities may only serve as storage and distribution locations, and repackaging/sampling may not occur at all import facilities.

Methylene chloride may be imported neat or as a component in formulation. In the 2016 CDR, most companies reported importing methylene chloride at concentrations greater than 90 percent; one company reported importing a formulation containing 1 to 30 percent methylene chloride (U.S. EPA, 2016b).

2.4.2 Number of Sites and Potentially Exposed Workers

The 2016 Public CDR shows that in calendar year 2015, seven sites imported methylene chloride, one site that both manufactured and imported methylene chloride, and an additional 10 sites were marked as CBI or withheld, as shown in Table 2-14 (U.S. EPA, 2016b). Seven sites provided number of worker estimates. The number of workers and ONUs at the remaining sites was reported as Not Known or Reasonably Ascertainable, CBI, or withheld.

EPA anticipates that most import facilities fall under NAICS 424690, Other Chemical and Allied Product Merchant Wholesalers. This industry sector comprises establishments primarily engaged in the merchant wholesale distribution of chemicals and allied products, including wholesale and distribution of methylene chloride. Based on analysis of BLS data for NAICS 424690, EPA estimates that on average, one worker per site and one ONU per site are potentially exposed. EPA's estimate is generally consistent with the CDR data for import-only sites, where most importers report fewer than 10 employees are potentially exposed. Therefore, EPA assumed up to 10 workers and ONUs may potentially be exposed at the import-only Brenntag North America facility.

For the remaining sites where the number of workers and ONUs were marked as CBI or withheld, EPA assumed up to 99 workers exposed per site, based on the estimate for the manufacture/import site (Sempre Avant). As shown in the table, this results in up to 21 sites and 1,102 workers and ONUs potentially exposed during import and repackaging.

Table 2-14 Number of Potential Import Facilities and Exposed Workers (2016 CDR)

Manufacture/ Import	Company	Facility	Facility		Workers[a] likely to be exposed
			City	State	
Manufacture /Import	Sempre Avant LLC	Solvents & Chemicals	Pearland	TX	50 to 99
Imported	CBI	Tricon International, Ltd.	Houston	TX	<10
Imported	Wego Chemical Group	Wego Chemical & Mineral Corp.	Great Neck	NY	<10
Imported	Univar Inc.	Univar USA Inc.	Redmond	WA	<10
Imported	M.A. Global Resources Inc.	M.A. Global Resources Inc.	Apex	NC	<10
Imported	AllChem Industries Holding Corp.	AllChem Industries Industrial Chemicals Group, Inc.	Gainesville	FL	<10
Imported	Brenntag North America Inc.	Brenntag Southwest Inc.	Longview	TX	NKRA[b]
Imported	Transchem, Inc.	Transchem Corporate	Carlsbad	CA	<10
CBI	The Dow Chemical Company	The Dow Chemical Company	Pittsburg	CA	25 to 49
CBI	CBI	EMD Millipore Corp.	Norwood	OH	CBI[c]
CBI	INEOS Chlor Americas Inc.	INEOS Chlor America Inc.	Wilmington	DE	CBI[c]
CBI	CBI	GreenChem	West Palm Beach	FL	CBI[c]
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Geismar	LA	CBI[c]

Table 2-14 Number of Potential Import Facilities and Exposed Workers (2016 CDR)

Manufacture/ Import	Company	Facility	Facility City	Facility State	Workers[a] likely to be exposed
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Wichita	KS	CBI[c]
Withheld	FRP Services & Co. (America) Inc.	FRP Services & Co. (America) Inc.	New York	NY	Withheld[c]
Withheld	Solvay USA Inc	Solvay USA INC	Princeton	NJ	Withheld[c]
Withheld	Global Chemical Resources Inc.	Global Chemical Resources Inc.	Toledo	OH	Withheld[c]
Withheld	Shrieve Chemical Company	Shrieve Chemical Products, Inc.	The Woodlands	TX	Withheld[c]
Total establishments and number of potentially exposed workers during Manufacture/Import			up to 18 sites		up to 1,100

Source: U.S. EPA (2016b)
NKRA – Not known or reasonably ascertainable
a – May include both workers and ONUs
b – For import-only sites, EPA assumed <10 workers potentially exposed.
c – For sites where the number of workers and ONUs were marked as CBI or withheld, EPA assumed up to 99 workers exposed per site, based on the estimate for the manufacture/import site (Sempre Avant).

For repackaging, CDR reports up to 66 sites and 656 workers and ONUs, as shown in Table 2-15. It should be noted that the number of sites are reported as ranges in CDR, and the actual number of sites may be significantly lower than 66.

Table 2-15. Number of U.S. Establishments, Workers, and ONUs for Processing – Repackaging from 2016 CDR

Industry Sector	Industry Function Category	Number of Establishments	Workers[a] likely to be exposed
Wholesale and retail trade	CBI	CBI[b]	50 to <100
Wholesale and retail trade	Solvents (which become part of product formulation or mixture)	<10	<10
CBI	Intermediates	10 to <25	100 to <500
CBI	Intermediates	10 to <25	NKRA[c]
CBI	Laboratory chemicals	<10	25 to <50
Total establishments and number of potentially exposed workers during Repackaging		up to 75	up to 1,200

Source: U.S. EPA (2016b)
NKRA – Not known or reasonably ascertainable
a – May include both workers and ONUs
b – EPA assumed <10 sites, based on the similar entry for Wholesale and retail trade
c – EPA assumed 100 to <500 workers, based on the similar submission for intermediates.

2.4.3 Exposure Assessment

2.4.3.1 Worker Activities

Workers are not expected to be exposed to methylene chloride during import operations where containers are not opened or unloaded. During repackaging, workers are potentially exposed while connecting and disconnecting hoses and transfer lines to containers and packaging to be unloaded (e.g., railcars, tank trucks, totes), intermediate storage vessels (e.g., storage tanks, pressure vessels), and final packaging containers (e.g., drums, bottles). Workers near loading racks and container filling stations are potentially exposed to fugitive emissions from equipment leaks and displaced vapor as containers are filled. These activities are potential sources of worker exposure through dermal contact with liquid and inhalation of vapors.

ONUs are employees who work at the site where methylene chloride is repackaged, but who do not directly perform the repackaging activity. ONUs for repackaging include supervisors, managers, and tradesmen that may be in the repackaging area but do not perform tasks that result in the same level of exposures as repackaging workers.

2.4.3.2 Inhalation Exposures

Table_Apx A-7 and Table_Apx A-8 in 4.2.5Appendix A summarize the inhalation monitoring data for import and repackaging (distribution) that EPA compiled from published literature sources. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

A 1986 IH study at Unocal Corporation found full-shift exposures during filling drums, loading trucks, and transfer loading to be between 6.0 and 137.8 mg/m^3 (5 data points) (Unocal Corporation, 1986).

Because only five data points were available, EPA assessed the median value of 8.8 mg/m^3 as the central tendency, and the maximum reported value of 137.8 mg/m^3 as the high-end estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration for this scenario is approximately 10 times lower the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is approximately 1.5 times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-21.

Table 2-16. Worker Exposure to Methylene Chloride During Import and Repackaging

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	5	8.8	140
Average Daily Concentration (ADC)		2.0	31
Lifetime Average Daily Concentration (LADC)		3.5	71

Source: Unocal Corporation (1986)

Table 2-17 summarizes available short-term exposure data available from the same source identified above for the 8-hr TWA data (Unocal Corporation, 1986).

Table 2-17. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Import and Repackaging

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m³)	Exposure Duration (min)
Distribution	Unocal Corporation (1986)	Transfer loading from truck to storage tank (4,100 gallons)	0.35	30
		Truck loading (2,000 gal)	330	50
		Truck loading (800 gal)	35	30
		Truck loading (250 gal)	30	47

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.4.4 Water Release Assessment

EPA assumed that sites classified under NAICS 424690 (Other Chemical and Allied Products Merchant Wholesalers) or SIC 5169 (Chemicals and Allied Products) are potentially applicable to import and/or repackaging of methylene chloride. Table 2-18 lists all facilities in these industries that reported direct or indirect water release to the 2016 TRI or 2016 DMR. None of the potential import sites listed in CDR (Table 2-14) reported water releases to TRI or DMR in reporting year 2016.

Table 2-18. Reported 2016 TRI and DMR Releases for Import and Repackaging Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
CHEMISPHERE CORP	SAINT LOUIS	MO	2	250	0.01	POTW	U.S. EPA (2017c)
HUBBARD-HALL INC	WATERBURY	CT	144	250	1	Non-POTW WWT	U.S. EPA (2017c)
WEBB CHEMICAL SERVICE CORP	MUSKEGON HEIGHTS	MI	98	250	0.4	POTW	U.S. EPA (2017c)
RESEARCH SOLUTIONS GROUP INC	PELHAM	AL	0.09	250	0.0003	Surface Water	U.S. EPA (2016a)
EMD MILLIPORE CORP	CINCINNATI	OH	0.03	250	0.0001	Surface Water	U.S. EPA (2016a)

2.4.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 1.4.2.

2.5 Batch Open-Top Vapor Degreasing

2.5.1 Process Description

Methylene chloride is used as a degreasing solvent to remove drawing compounds, cutting fluids, coolants, and lubricants from metal parts. It can be used in cold cleaning, open top vapor degreasing, or conveyorized vapor degreasing. It is difficult to characterize the establishments that use methylene chloride for metal cleaning or degreasing because of widespread and nonspecific use patterns. Methylene chloride is generally chosen when other organic solvents fail to provide the desired characteristics such as nonflammability, nonreactivity with metals, the ability to dissolve a broad range of greases and industrial chemicals, high solvency for most industrial contaminants, and a rapid rate of evaporation (OSHA, 1991).

In batch open top vapor degreasers (OTVDs), a vapor cleaning zone is created by heating the liquid solvent in the OTVD causing it to volatilize. Workers manually load or unload fabricated parts directly into or out of the vapor cleaning zone. The tank usually has chillers along the side of the tank to prevent losses of the solvent to the air. However, these chillers are not able to eliminate emissions, and throughout the degreasing process significant air emissions of the solvent can occur. These air emissions can cause issues with both worker health and safety as well as environmental issues. Additionally, the cost of replacing solvent lost to emissions can be expensive (NEWMOA, 2001). Figure 2-1 illustrates a standard OTVD.

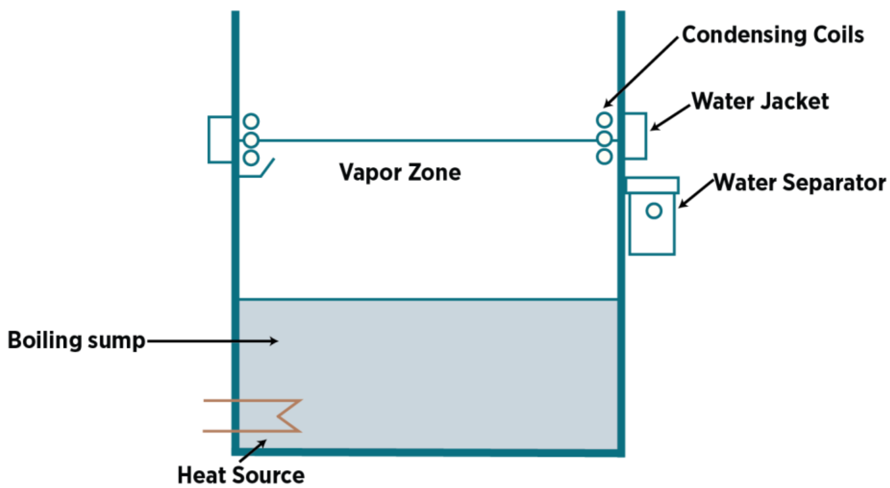

Figure 2-1. Open Top Vapor Degreaser

OTVDs with enclosures operate the same as standard OTVDs except that the OTVD is enclosed on all sides during degreasing. The enclosure is opened and closed to add or remove parts to/from the machine, and solvent is exposed to the air when the cover is open. Enclosed OTVDs may be vented directly to the atmosphere or first vented to an external carbon filter and then to the atmosphere (U.S. EPA; ICF Consulting). Figure 2-2 illustrates an OTVD with an enclosure. The dotted lines in Figure 2-2 represent the optional carbon filter that may or may not be used with an enclosed OTVD.

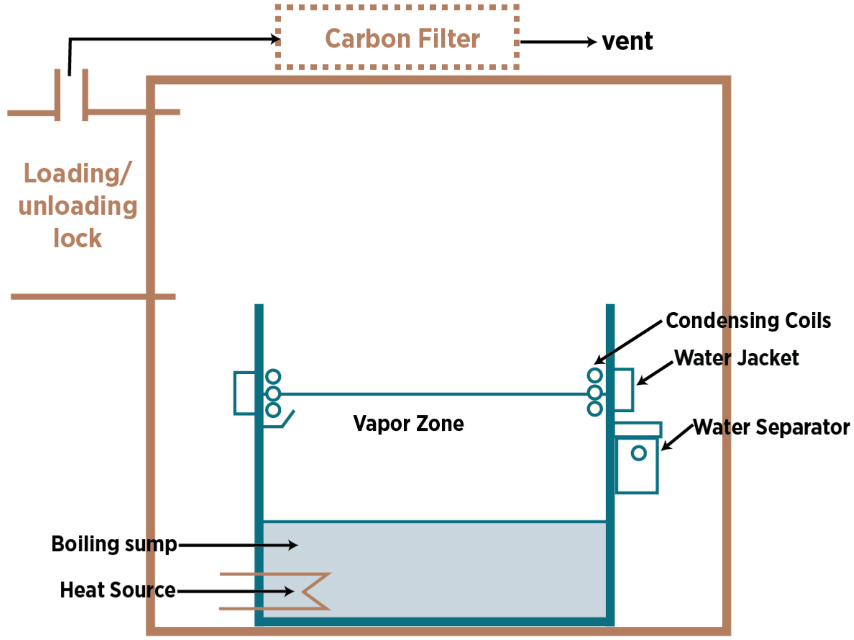

Figure 2-2. Open Top Vapor Degreaser with Enclosure

2.5.2 Number of Sites and Potentially Exposed Workers

The OSHA (1991) proposed rule estimated 271 exposed workers over 124 facilities using 129 methylene chloride open top degreasers (~2 workers per site). It is unclear whether this estimate also includes ONUs.

2.5.3 Exposure Assessment

2.5.3.1 Worker Activities

When operating OTVD, workers manually load or unload fabricated parts directly into or out of the vapor cleaning zone. Worker exposure can occur from solvent dragout or vapor displacement when the substrates enter or exit the equipment, respectively (Kanegsberg and Kanegsberg, 2011). Worker exposure is also possible while charging new solvent or disposing spent solvent.

2.5.3.2 Inhalation Exposures

EPA performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model near-field and far-field exposure concentrations in the OTVD scenario. EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. For workers, the modeled 8-hr TWA exposures are 168.3 mg/m^3 at the 50th percentile and 744.8 mg/m^3 at the 95th percentile. For occupational non-users, the modeled 8-hr TWA exposures are 86.5 mg/m^3 at the 50th percentile and 455.6 mg/m^3 at the 95th percentile. The central tendency 8-hr TWA exposure concentration for this scenario is approximately twice the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is almost nine times higher.

Estimates of Average Daily Concentrations (ADC) and Lifetime Average Daily Concentration (LADC) for use in assessing risk were made using the approach and equations described in 4.2.5Appendix B, and are presented in Table 2-19.

Table 2-19. Statistical Summary of Methylene Chloride 8-hr TWA Exposures (ADC and LADC) for Batch Open-Top Vapor Degreasing

	Central Tendency (mg/m³)	High-End (mg/m³)
Workers (Near-Field)		
8-hr TWA Exposure Concentration	170	740
Average Daily Concentration (ADC)	29	130
Lifetime Average Daily Concentration (LADC)	15	66
Occupational Non-Users (Far-Field)		
8-hr TWA Exposure Concentration	86	460
Average Daily Concentration (ADC)	15	78
Lifetime Average Daily Concentration (LADC)	7.6	40

2.5.4 Water Release Assessment

The primary source of water releases from OTVDs is wastewater from the water separator. Water in the OTVD may come from two sources: 1) Moisture in the atmosphere that condenses into the solvent when exposed to the condensation coils on the OTVD; and/or 2) steam used to regenerate carbon adsorbers used to control solvent emissions on OTVDs with enclosures (Durkee, 2014; Kanegsberg and Kanegsberg, 2011; (NIOSH), 2002a, b; NIOSH, 2002a, b). The water is removed in a gravity separator and sent for disposal ((NIOSH), 2002a, b; NIOSH, 2002a, b). The current disposal practices of the wastewater are unknown; however, a U.S. EPA (1982) report estimated 20% of water releases from metal cleaning (including batch systems, conveyorized systems, and vapor and cold systems) were direct discharges to surface water and 80% of water releases were discharged indirectly to a POTW.

2.5.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.6 Conveyorized Vapor Degreasing

2.6.1 Process Description

In conveyorized systems, an automated parts handling system, typically a conveyor, continuously loads parts into and through the vapor degreasing equipment and the subsequent drying steps. Conveyorized degreasing systems are usually fully enclosed except for the conveyor inlet and outlet portals. Conveyorized degreasers are likely used in shops where there are a large number of parts being cleaned. There are seven major types of conveyorized degreasers: monorail degreasers; cross-rod degreasers; vibra degreasers; ferris wheel degreasers; belt degreasers; strip degreasers; and circuit board degreasers (U.S. EPA, 1977).

- Monorail Degreasers – Monorail degreasing systems are typically used when parts are already being transported throughout the manufacturing areas by a conveyor. They use a straight-line conveyor to transport parts into and out of the cleaning zone. The parts may enter one side and exit and the other or may make a 180° turn and exit through a tunnel parallel to the entrance (U.S. EPA, 1977). Figure 2-3 illustrates a typical monorail degreaser.

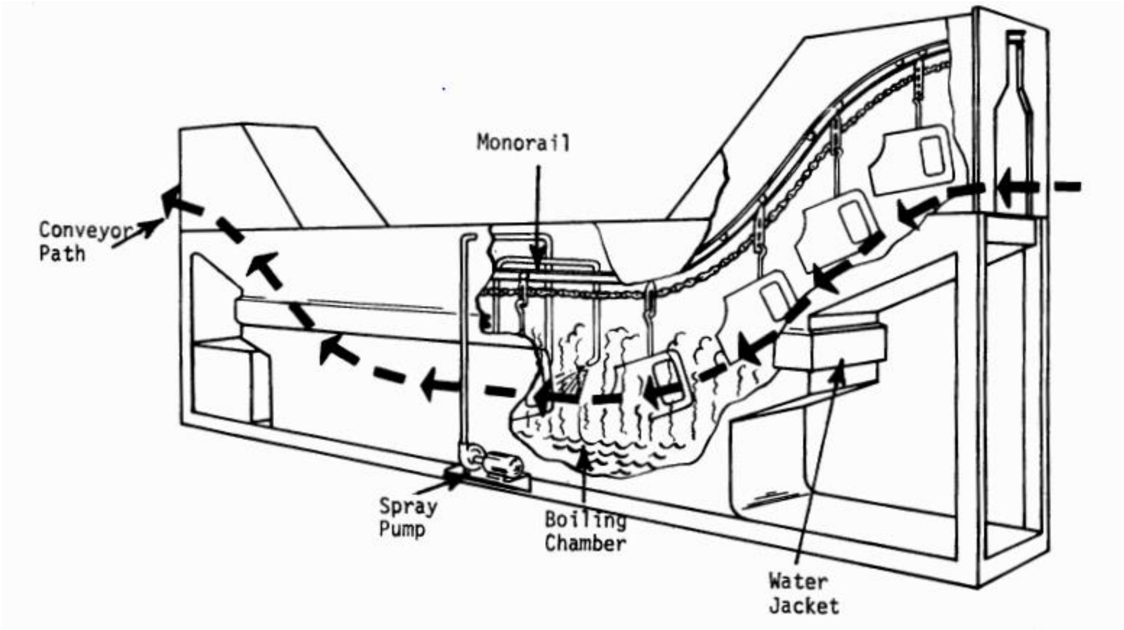

Figure 2-3. Monorail Conveyorized Vapor Degreasing System (U.S. EPA, 1977)

- Cross-rod Degreasers – Cross-rod degreasing systems utilize two parallel chains connected by a rod that support the parts throughout the cleaning process. The parts are usually loaded into perforated baskets or cylinders and then transported through the machine by the chain support system. The baskets and cylinders are typically manually loaded and unloaded (U.S. EPA, 1977). Cylinders are used for small parts or parts that need enhanced solvent drainage because of crevices and cavities. The cylinders allow the parts to be tumbled during cleaning and drying and thus increase cleaning and drying efficiency. Figure 2-4 illustrates a typical cross-rod degreaser.

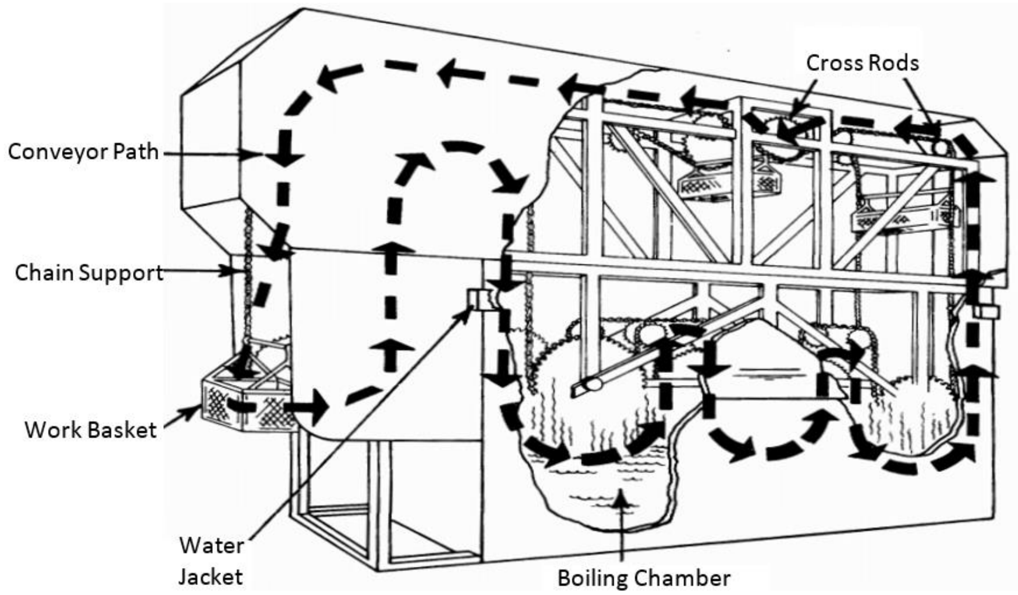

Figure 2-4. Cross-Rod Conveyorized Vapor Degreasing System (U.S. EPA, 1977)

Vibra Degreasers – In vibra degreasing systems, parts are fed by conveyor through a chute that leads to a pan flooded with solvent in the cleaning zone. The pan and the connected spiral elevator are continuously vibrated throughout the process causing the parts to move from the pan and up a spiral elevator to the exit chute. As the parts travel up the elevator, the solvent condenses and the parts are dried before exiting the machine (U.S. EPA, 1977). Figure 2-5 illustrates a typical vibra degreaser (U.S. EPA, 1977).

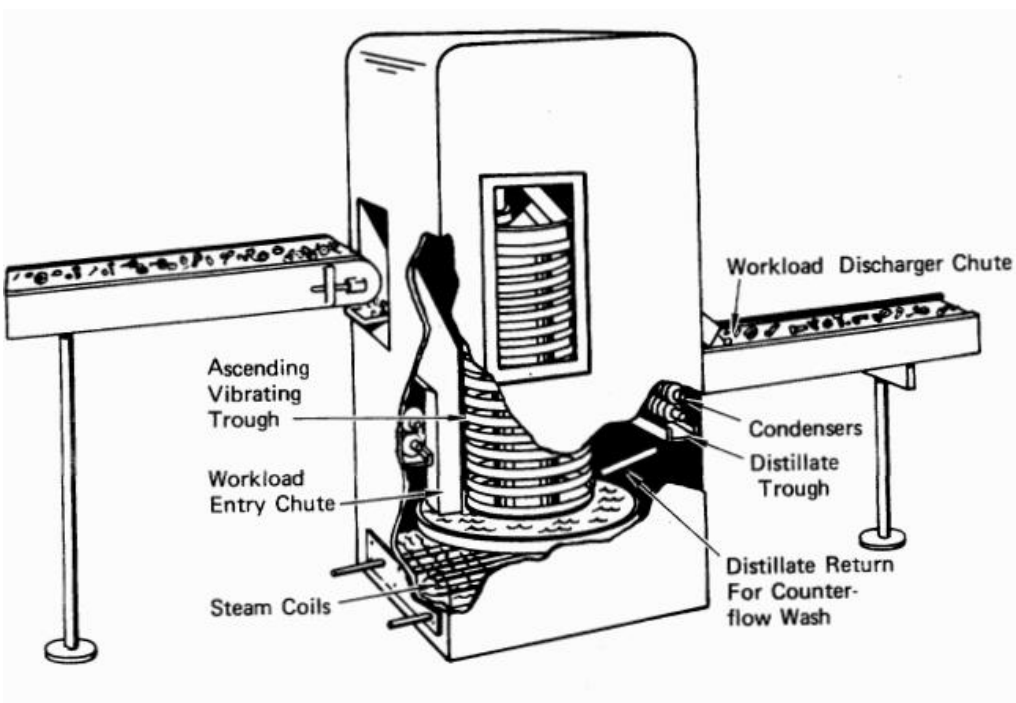

Figure 2-5. Vibra Conveyorized Vapor Degreasing System (U.S. EPA, 1977)

Ferris wheel degreasers – Ferris wheel degreasing systems are generally the smallest of all the conveyorized degreasers (U.S. EPA, 1977). In these systems, parts are manually loaded into perforated baskets or cylinders and then rotated vertically through the cleaning zone and back out. Figure 2-6 illustrates a typical ferris wheel degreaser (U.S. EPA, 1977).

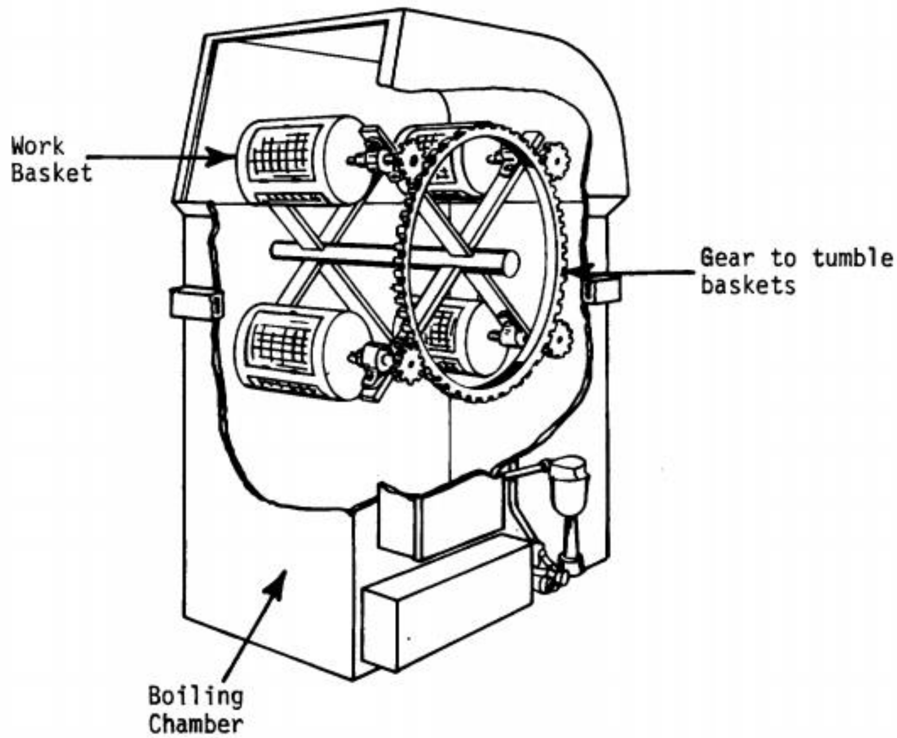

Figure 2-6. Ferris Wheel Conveyorized Vapor Degreasing System (U.S. EPA, 1977)

- Belt degreasing systems (similar to strip degreasers; see next bullet) are used when simple and rapid loading and unloading of parts is desired (U.S. EPA, 1977). Parts are loaded onto a mesh conveyor belt that transports them through the cleaning zone and out the other side. Figure 2-7 illustrates a typical belt or strip degreaser (U.S. EPA, 1977).

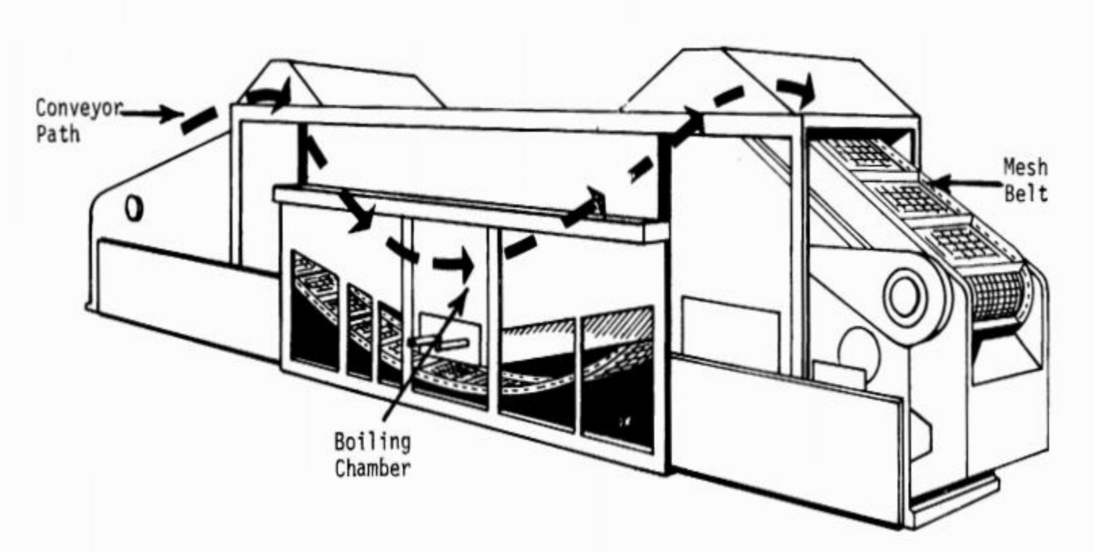

Figure 2-7. Belt/Strip Conveyorized Vapor Degreasing System (U.S. EPA, 1977)

- Strip degreasers – Strip degreasing systems operate similar to belt degreasers except that the belt itself is being cleaned rather than parts being loaded onto the belt for cleaning. Figure 2-7 illustrates a typical belt or strip degreaser (U.S. EPA, 1977).

- Circuit board cleaners – Circuit board degreasers use any of the conveyorized designs. However, in circuit board degreasing, parts are cleaned in three different steps due to the manufacturing processes involved in circuit board production (U.S. EPA, 1977).

Note, methylene chloride cannot be used in vapor degreasing of parts soiled with grease or oil that has a high paraffinic content because a high rate of solvent flushing is required in such circumstances. Furthermore, methylene chloride cannot be used on thin parts because they heat too quickly and good condensation cannot be achieved (OSHA, 1991).

2.6.2 Number of Sites and Potentially Exposed Workers

OSHA estimated 177 exposed workers over 107 facilities (~2 workers per site) in 1991, using 111 methylene chloride conveyorized vapor degreasers (OSHA, 1991). It is unclear whether this estimate also includes ONUs.

2.6.3 Exposure Assessment

2.6.3.1 Worker Activities

For conveyorized vapor degreasing, worker activities can include placing or removing parts from the basket, as well as general equipment maintenance. Depending on the level of enclosure and specific conveyor design, workers can be exposed to vapor emitted from the inlet and outlet of the conveyor portal.

Degreasing equipment must also be cleaned periodically to maintain its efficiency. High exposure to methylene chloride is possible when tanks are being cleaned because the worker often simply empties the tank of solvent, rinses it with water from a high pressure hose and then climbs inside the tank to scrub it with brushes (OSHA, 1991).

2.6.3.2 Inhalation Exposures

EPA performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model near-field and far-field exposure concentrations in the conveyorized vapor degreasing scenario. EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. For workers, the modeled 8-hr TWA exposures are 162.1 mg/m^3 at the 50th percentile and 465.0 mg/m^3 at the 95th percentile. For occupational non-users, the modeled 8-hr TWA exposures are 253.0 mg/m^3 at the 50th percentile and 900 mg/m^3 at the 95th percentile. The central tendency 8-hr TWA worker exposure concentration for this scenario is approximately twice the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is approximately five times higher. Exposure concentrations for ONUs are also considerably higher than the OSHA PEL.

Estimates of Average Daily Concentrations (ADC) and Lifetime Average Daily Concentration (LADC) for use in assessing risk were made using the approach and equations described in 4.2.5Appendix B, and are presented in Table 2-20.

Table 2-20. Statistical Summary of Methylene Chloride 8-hr TWA Exposures (ADC and LADC) for Conveyorized Vapor Degreasing

	Central Tendency (mg/m^3)	High-End (mg/m^3)
Workers (Near-Field)		
8-hr TWA Exposure Concentration	490	1,400
Average Daily Concentration (ADC)	84	240
Lifetime Average Daily Concentration (LADC)	43	120
Occupational Non-Users (Far-Field)		
8-hr TWA Exposure Concentration	250	900
Average Daily Concentration (ADC)	44	150
Lifetime Average Daily Concentration (LADC)	22	79

2.6.4 Water Release Assessment

EPA did not identify quantitative information about water releases during vapor degreasing. Potential sources of water releases for vapor degreasing and cold cleaning are discussed in Section 2.5.4.

2.6.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.7 Cold Cleaning

2.7.1 Process Description

Cold cleaners are non-boiling solvent degreasing units. Cold cleaning operations include spraying, brushing, flushing, and immersion. Figure 2-8 shows the design of a typical batch-loaded, maintenance cold cleaner, where dirty parts are cleaned manually by spraying and then soaking in the tank. After cleaning, the parts are either suspended over the tank to drain or are placed on an external rack that routes the drained solvent back into the cleaner. Batch manufacturing cold cleaners could vary widely, but have two basic equipment designs: the simple spray sink and the dip tank. The dip tank design typically provides better cleaning through immersion, and often involves an immersion tank equipped with agitation (U.S. EPA, 1981). Emissions from batch cold cleaning machines typically result from (1) evaporation of the solvent from the solvent-to-air interface, (2) "carry out" of excess solvent on cleaned parts, and (3) evaporative losses of the solvent during filling and draining of the machine (U.S. EPA, 2006).

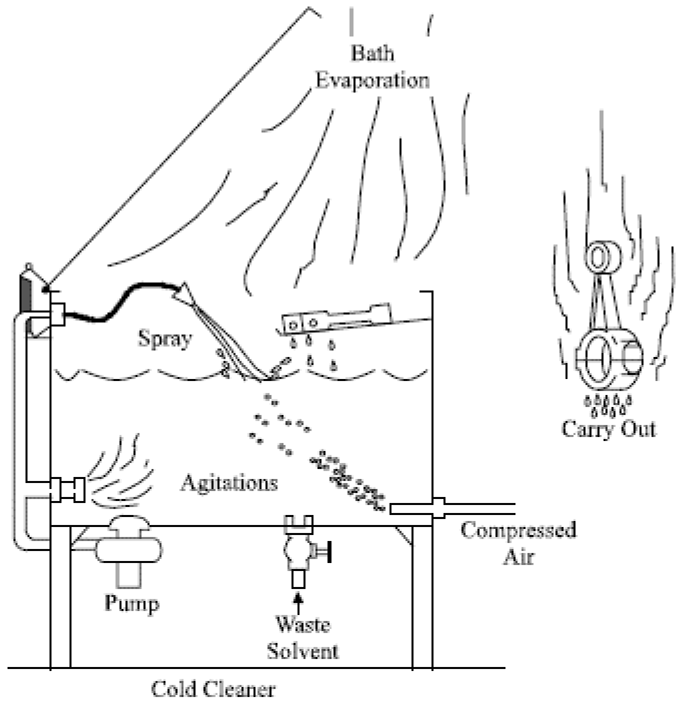

Figure 2-8 Typical Batch-Loaded, Maintenance Cold Cleaner (U.S. EPA, 1981)

Emissions from cold in-line (conveyorized) cleaning machines result from the same mechanisms, but with emission points only at the parts' entry and exit ports (U.S. EPA, 2006).

2.7.2 Number of Sites and Potentially Exposed Workers

The OSHA (1991) proposed rule estimated 90,293 exposed workers over 22,652 facilities (~4 workers per site) using 23,664 methylene chloride cold degreasers. In 1998, OSHA estimated around 23,717 facilities performing cold degreasing and cold cleaning operations using methylene chloride ((OSHA), 1998). EPA assumes 4 workers per site, over the 23,717 facilities in 1998, for up to 95,000 workers potentially exposed. It is unclear whether this estimate also includes ONUs.

2.7.3 Exposure Assessment

2.7.3.1 Worker Activities

The general worker activities for cold cleaning include placing the parts that require cleaning into a vessel. The vessel is usually something that will hold the parts but not the liquid solvent (i.e., a wire basket). The vessel is then lowered into the machine, where the parts could be sprayed, and then completely immersed in the solvent. After a short time, the vessel is removed from the solvent and allowed to drip/air dry. Depending on the industry and/or company, these operations may be performed manually (i.e., by hand) or mechanically. Sometimes parts require more extensive cleaning; in these cases, additional operations are performed including directly spraying solvent on the part, agitation of the solvent or parts, wipe cleaning and brushing (NIOSH, 2001; U.S. EPA, 1997).

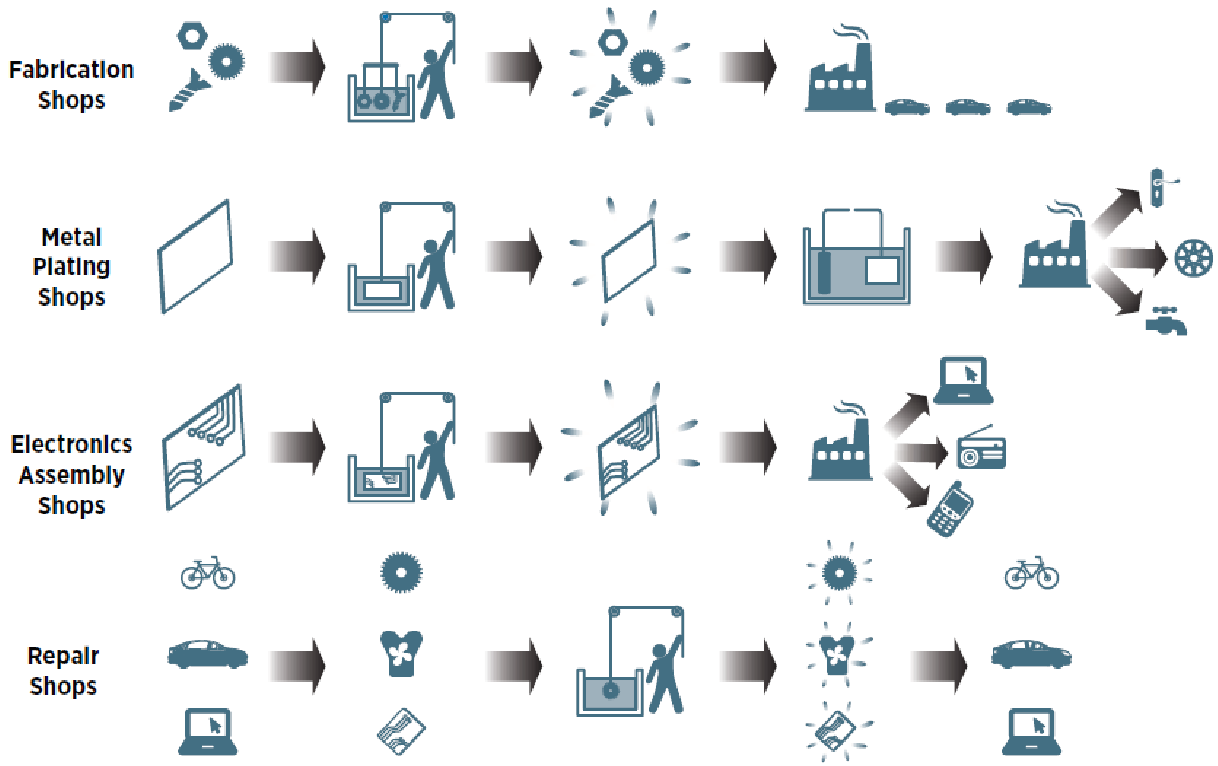

Figure 2-9 Illustration for Use of Cold Cleaner in a Variety of Industries

2.7.3.2 Inhalation Exposures

Table_Apx A-9 in 4.2.5Appendix A summarizes the 8-hr TWA inhalation monitoring data for cold cleaning manufacturing that EPA compiled from published literature sources. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

TNO (CIVO) (1999) indicated that mean exposure values for cold degreasing were found to be approximately 280 mg/m^3 on average, ranging from 14 to over 1,000 mg/m^3. The referenced data were from United Kingdom (UK) Health and Safety Executive (HSE) reports from 1998, but details, including specific worker activities and sampling times were not available.

Because only three data points were available, EPA assessed the average value of 280 mg/m^3 as the central tendency, and the maximum reported value of 1,000 mg/m3 as the high-end estimate of potential occupational inhalation exposure for this life cycle stage. The central tendency 8-hr TWA exposure concentration for this scenario is approximately three times the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is almost 12 times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-21.

Table 2-21. Exposure to Methylene Chloride During Cold Cleaning

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	unknown[a]	280	1,000
Average Daily Concentration (ADC)		64	230
Lifetime Average Daily Concentration (LADC)		110	510

Source: TNO (CIVO) (1999)
a – One source provided a range of values for an unknown number of samples.

EPA has not identified short-term exposure data from cold cleaning using methylene chloride, nor data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

Note that EPA also performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model near-field and far-field exposure concentrations for the cold cleaning scenario. EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. For workers, the modeled 8-hr TWA exposures are 1 mg/m3 at the 50th percentile and 103.8 mg/m3 at the 95th percentile. For ONUs, the modeled 8-hr TWA exposures are 0.5 mg/m3 at the 50th percentile and 60 mg/m3 at the 95th percentile. For the risk evaluation, EPA used the available monitoring data as discussed above, because the modeled data do not capture the full range of possible exposure concentrations identified by the monitored data. Modeling details are in Appendix 4.2.5F.2

2.7.4 Water Release Assessment

EPA did not identify quantitative information about water releases during cold cleaning. Potential sources of water releases for vapor degreasing and cold cleaning are discussed in Section 2.5.4.

2.7.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.8 Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)

2.8.1 Process Description

Aerosol degreasing is a process that uses an aerosolized solvent spray, typically applied from a pressurized can, to remove residual contaminants from fabricated parts. A propellant is used to aerosolize the formulation, allowing it to be sprayed onto substrates. The aerosol droplets bead up on the fabricated part and then drip off, carrying away any contaminants and leaving behind a clean surface. Similarly, aerosol lubricant products use an aerosolized spray to help free frozen parts by dissolving rust and leave behind a residue to protect surfaces against rust and corrosion. Based on identified safety data sheets (SDS), methylene chloride-based formulations typically use carbon dioxide and liquified petroleum gas (LPG) (i.e., propane and butane) as the propellant (Abt, 2017; U.S. EPA, 2017b).

Figure 2-10 illustrates the typical process of using aerosol degreasing to clean components in commercial settings. One example of a commercial setting with aerosol degreasing operations is repair shops, where service items are cleaned to remove any contaminants that would otherwise compromise the service item's operation. Internal components may be cleaned in place or removed from the service item, cleaned, and then re-installed once dry (U.S. EPA, 2014).

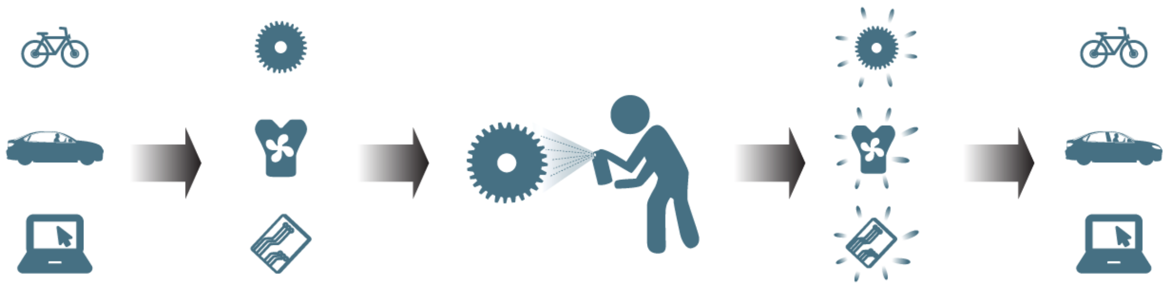

Figure 2-10 Overview of Aerosol degreasing

Aerosol degreasing may occur at either industrial facilities or at commercial repair shops to remove contaminants on items being serviced. Aerosol degreasing products may also be purchased and used by consumers for various applications.

Products containing methylene chloride may be used in aerosol degreasing applications such as brake cleaning, engine degreasing, and metal product cleaning. Additionally, a variety of other commercial aerosol products may contain methylene chloride, including weld spatter protectants, shoe polish spray, carbon cleaners, coil cleaners, and cold pipe insulation (U.S. EPA, 2017b). EPA found very little information on non-automotive commercial aerosol applications. Therefore, EPA assessed all commercial applications using the aerosol degreasing and lubricants scenario.

2.8.2 Number of Sites and Potentially Exposed Workers

EPA/OPPT estimated the number of workers and occupational non-users potentially exposed to aerosol degreasers and aerosol lubricants containing methylene chloride using Bureau of Labor Statistics' OES data (U.S. BLS, 2016) and the U.S. Census' SUSB (U.S. Census Bureau, 2015). The method for estimating number of workers is detailed above in Section 1.4.2. These estimates were derived using industry- and occupation-specific employment data from the BLS and U.S. Census. Table 2-22 presents the NAICS industry sectors relevant to aerosol degreasing and aerosol lubricants.

Table 2-22. NAICS Codes for Aerosol Degreasing and Lubricants

NAICS	Industry
811111	General Automotive Repair
811112	Automotive Exhaust System Repair
811113	Automotive Transmission Repair
811118	Other Automotive Mechanical and Electrical Repair and Maintenance
811121	Automotive Body, Paint, and Interior Repair and Maintenance
811122	Automotive Glass Replacement Shops

811191	Automotive Oil Change and Lubrication Shops
811198	All Other Automotive Repair and Maintenance
811211	Consumer Electronics Repair and Maintenance
811212	Computer and Office Machine Repair and Maintenance
811213	Communication Equipment Repair and Maintenance
811219	Other Electronic and Precision Equipment Repair and Maintenance
811310	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance
811411	Home and Garden Equipment Repair and Maintenance
811490	Other Personal and Household Goods Repair and Maintenance
451110	Sporting Goods Stores
441100	Automobile Dealers

There are 256,850 establishments among the industry sectors expected to use aerosol degreasers and/or aerosol lubricants (U.S. Census Bureau, 2015). Because perchloroethylene (PCE) comprises the majority of the chlorinated solvent-based aerosol degreaser volume, EPA used the PCE market penetration to establish an upper bound for methylene chloride.

In 1997, the California Air Resources Board (CARB) conducted a survey of automotive maintenance and repair facilities, which that approximately 44% of all aerosol brake cleaning products sold in California contained PCE and approximately 37% of aerosol brake cleaning products available contained PCE (CARB, 2000). Similarly, a CARB survey of automotive maintenance and repair facilities found, of the 73% of facilities that use brake cleaning products to perform brake jobs, approximately 38% of these facilities used brake cleaning products containing chlorinated chemicals (CARB, 2000).

These data only relate to aerosol brake cleaning products used in the automotive repair industry; however, aerosol degreasing and lubricant products may also be used in electronics repair, industrial equipment repair, home and garden equipment repair, or other similar industries. Market penetration data for these industries were not identified; therefore, in lieu of other information, EPA assumed a similar market penetration rate as for brake cleaning products. It is also possible the brake cleaning product manufacturer and facility surveys completed by CARB underestimate the total number of establishments that may use a PCE-containing product as some establishments may use an aerosol lubricant containing PCE but not a brake cleaning product containing PCE. However, EPA expects the potential error from this to be relatively small as only approximately 0.1% (317,000 lbs) of the total U.S production volume of PCE is expected to be used in lubricants (U.S. EPA, 2016b). For comparison, based on reported sales in 1996, CARB estimated approximately 2.7 million pounds of PCE were used in brake cleaning products in California alone (CARB, 2000).

EPA assumed the average market penetration rate for PCE aerosol degreasers and lubricants was the average of the low- and high-end values found by CARB, or 40.5% multiplied by the 73% of facilities that use brake cleaning products, or 29.6% (40.5% x 73%=29.6%) (CARB, 2000). This results in approximately 75,938 establishments using aerosol products containing PCE.

Based on the market penetration of 29.6% and data from the BLS and U.S. Census, there are approximately 247,073 workers and 29,399 occupational non-users potentially exposed to PCE as an aerosol degreasing solvent or aerosol lubricant (see Table 2-23) (CARB, 2000) (U.S. BLS, 2016; U.S. Census Bureau, 2015). Therefore, EPA uses these estimates as an upper-bound for methylene chloride.

Table 2-23. Estimated Number of Workers Potentially Exposed to Methylene Chloride During Use of Aerosol Degreasers and Aerosol Lubricants

2016 NAICS	2016 NAICS Title	Number of Establishments [a]	Number of Workers per Site [b]	Number of ONUs per Site [b]
811111	General Automotive Repair	23,724	1	0.1
811112	Automotive Exhaust System Repair	564	0.5	0.0
811113	Automotive Transmission Repair	1,385	1	0.1
811118	Other Automotive Mechanical and Electrical Repair and Maintenance	1,135	1	0.1
811121	Automotive Body, Paint, and Interior Repair and Maintenance	9,948	1	0.1
811122	Automotive Glass Replacement Shops	1,805	1	0.1
811191	Automotive Oil Change and Lubrication Shops	2,478	1	0.1
811198	All Other Automotive Repair and Maintenance	1,224	1	0.1
811211	Consumer Electronics Repair and Maintenance	536	1	0.1
811212	Computer and Office Machine Repair and Maintenance	1,536	1	0.1
811213	Communication Equipment Repair and Maintenance	474	1	0.2
811219	Other Electronic and Precision Equipment Repair and Maintenance	1,026	2	0.2
811310	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	6,422	1	0.2
811411	Home and Garden Equipment Repair and Maintenance	513	0.2	0.2
811490	Other Personal and Household Goods Repair and Maintenance	2,940	0.3	0.2
451110	Sporting Goods Stores	6,472	0.2	0.0
441100	Automobile Dealers	13,757	2	0.2
Total establishments and number of potentially exposed workers and ONUs = [c]		75,938	250,000	29,000

A – All values assume methylene chloride market penetration of 29.6% (based on market penetration of perchloroethylene as an upper-bound).
b – Rounded to the nearest whole number, unless less than one.
c – Unrounded figures were used for total worker and ONU calculations.

2.8.3 Exposure Assessment

2.8.3.1 Worker Activities

For aerosol degreasing, worker activities involve manual spraying of methylene chloride products from an aerosol can onto a substrate, and then subsequently wiping of that substrate. The same worker may also perform other types of degreasing activities, if those process operations are present at the same facility.

Workers at these facilities are expected to be exposed through dermal contact with and inhalation of mists during application of the aerosol product to the service item. ONUs include employees that work at the facility but do not directly apply the aerosol product to the service item and are therefore expected to have lower inhalation exposures and are not expected to have dermal exposures.

2.8.3.2 Inhalation Exposures

As previously discussed in Section 2.8.1, a variety of workplaces can use aerosol degreaser containing methylene chloride. For the purpose of modeling, EPA models worker exposure to methylene chloride during brake servicing as a representative exposure scenario. EPA chooses to model this scenario because the process of brake servicing is well understood and there are sufficient data to construct such a model.

A more detailed description of the modeling approach is provided in 4.2.5Appendix F. Figure 2-11 illustrates the near-field/far-field for the aerosol degreasing scenario. As the figure shows, methylene chloride in aerosolized droplets immediately volatilizes into the near-field, resulting in worker exposures at a concentration C_{NF}. The concentration is directly proportional to the amount of aerosol degreaser applied by the worker, who is standing in the near-field-zone (i.e., the working zone). The volume of this zone is denoted by V_{NF}. The ventilation rate for the near-field zone (Q_{NF}) determines how quickly methylene chloride dissipates into the far-field (i.e., the facility space surrounding the near-field), resulting in occupational non-user exposures to methylene chloride at a concentration C_{FF}. V_{FF} denotes the volume of the far-field space into which the methylene chloride dissipates out of the near-field. The ventilation rate for the surroundings, denoted by Q_{FF}, determines how quickly methylene chloride dissipates out of the surrounding space and into the outside air.

In this scenario, methylene chloride vapors enter the near-field in non-steady “bursts,” where each burst results in a sudden rise in the near-field concentration, followed by a more gradual rise in the far-field concentration. The near-field and far-field concentrations then decay with time until the next burst causes a new rise in near-field concentration.

The product application rate is based on a 2000 CARB report for brake servicing, which estimates that each facility performs on average 936 brake jobs per year, and that each brake job requires approximately 14.4 ounces of product (CARB, 2000). It is uncertain whether this use rate is representative of a typical aerosol degreasing facility. EPA modeled the operating hours per week using a distribution based on the weekly operating hours reported by the responding automotive repair facilities to CARB’s survey. Model parameters and assumptions for aerosol degreasing are presented in 4.2.5Appendix F.

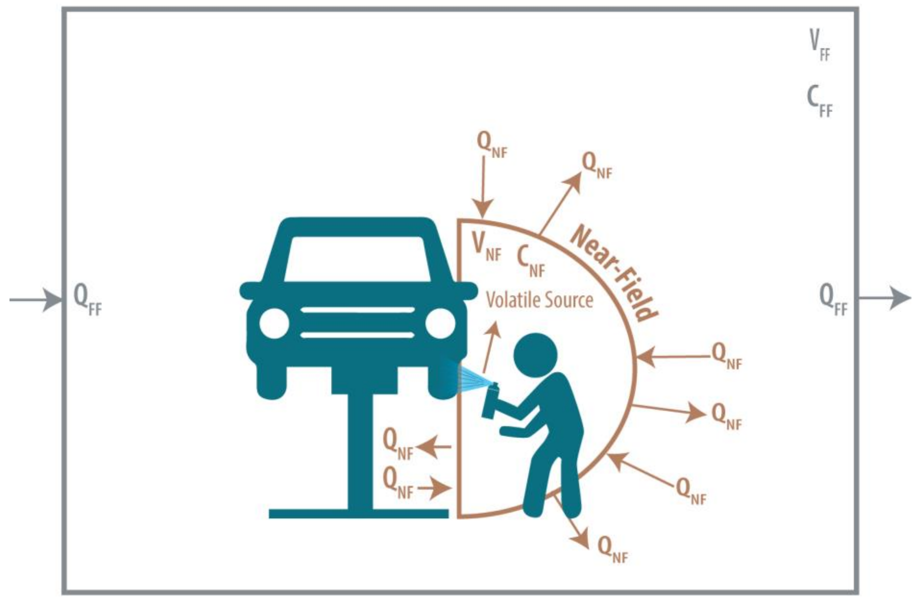

Figure 2-11 Schematic of the Near-Field/Far-Field Model for Aerosol degreasing

EPA performed a Monte Carlo simulation with 100,000 iterations and the Latin hypercube sampling method to model near-field and far-field exposure concentrations in the aerosol degreasing scenario. EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. For workers, the modeled 8-hr TWA exposures are 22.0 mg/m^3 at the 50th percentile and 78.7 mg/m^3 at the 95th percentile; the modeled maximum 1-hr TWA exposures are 68.0 mg/m^3 at the 50th percentile and 230.3 mg/m3 at the 95th percentile. For occupational non-users, the modeled 8-hr TWA exposures are 0.40 mg/m^3 at the 50th percentile and 3.26 mg/m^3 at the 95th percentile; the modeled maximum 1-hr TWA exposures are 1.2 mg/m^3 at the 50th percentile and 9.7 mg/m^3 at the 95th percentile. Both the central tendency and high-end 8-hr TWA exposure concentrations for workers in this this scenario are lower than the OSHA PEL value of 87 mg/m^3 (25 ppm). ONU exposures are an order of magnitude lower.

Estimates of Average Daily Concentrations (ADC) and Lifetime Average Daily Concentration (LADC) for use in assessing risk were made using the approach and equations described in 4.2.5Appendix B, and are presented in Table 2-24.

Table 2-24. Statistical Summary of Methylene Chloride 8-hr TWA Exposures (ADC and LADC) for Aerosol Products Based on Modeling

	Central Tendency (mg/m^3)	**High-End (mg/m^3)**
Workers (Near-Field)		
8-hr TWA Exposure Concentration	22	79
Average Daily Concentration (ADC)	3.8	14
Lifetime Average Daily Concentration (LADC)	1.9	6.9
Maximum 1-hr TWA Exposures	68	230
Occupational Non-Users (Far-Field)		
8-hr TWA Exposure Concentration	0.40	3.3
Average Daily Concentration (ADC)	0.07	0.56

	Central Tendency (mg/m^3)	High-End (mg/m^3)
Lifetime Average Daily Concentration (LADC)	0.04	0.29
Maximum 1-hr TWA Exposures	1.2	9.7

2.8.4 Water Release Assessment

EPA does not expect releases of methylene chloride to water from the use of aerosol products. Due to the volatility of methylene chloride the majority of releases from the use of aerosol products will likely be to air as methylene chloride evaporates from the aerosolized mist and the substrate surface. There is a potential that methylene chloride that deposits on shop floors during the application process could possibly end up in a floor drain (if the shop has one) or could runoff outdoors if garage doors are open. However, EPA expects the potential release to water from this to be minimal as there would be time for methylene chloride to evaporate before entering one of these pathways. This is consistent with estimates from the International Association for Soaps, Detergents and Maintenance Products (AISE) SpERC for Wide Dispersive Use of Cleaning and Maintenance Products, which estimates 100% of volatiles are released to air (Products, 2012). EPA/OPPT expects residuals in the aerosol containers to be disposed of with shop trash that is either picked up by local waste management or by a waste handler that disposes shop wastes as hazardous waste.

2.8.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.9 Adhesives and Sealants

2.9.1 Process Description

Based on products identified in EPA's *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal for Methylene Chloride* (U.S. EPA, 2017b), 2016 CDR reporting (U.S. EPA, 2016b), and the Draft Use and Market Profile for Methylene Chloride and NMP (Abt, 2017), methylene chloride may be used in adhesives and sealants for industrial, commercial, and consumer applications. The *Preliminary Information on Manufacturing, Processing, Distribution, Use and Disposal for Methylene Chloride* (U.S. EPA, 2017b) and Draft Market Profile (Abt, 2017) identify liquid adhesive and sealant and aerosol and canister adhesive and sealant products that contain methylene chloride. In these applications, the methylene chloride likely serves as a solvent and evaporates during adhesive and sealant drying and curing. These adhesive and sealant products are identified for use on substrates such as metal, foam, plastic, rubber, fabric, leather, wood, and fiberglass. The types of adhesives and sealants identified in the *Preliminary Information on Manufacturing, Processing, Distribution, Use and Disposal for Methylene Chloride* (U.S. EPA, 2017b) and Market Profile (Abt, 2017) also include upholstery contact adhesives, crosslinking adhesives, pressure sensitive adhesives, duct and duct liner sealants, gasket sealants, and cements, which contain between 30 and 100 weight percent methylene chloride. The 2015 Use of Adhesives ESD lists typical organic solvent (such as methylene chloride) content between 60 and 75 weight percent in adhesives (OECD, 2015).

In addition to typical adhesive use, EPA's *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal for Methylene Chloride* (U.S. EPA, 2017b) includes two sealant products, which are in gel and aerosol form, containing between 10 and 65 weight percent methylene chloride.

2.9.2 Number of Sites and Potentially Exposed Workers

Application of methylene chloride-based adhesives and sealants are widespread, occurring in many industries. EPA determined the industries likely to use methylene chloride in adhesives and sealants from the following sources: the non-CBI 2016 CDR results for methylene chloride (U.S. EPA, 2016b), the 2017 market profile for methylene chloride (Abt, 2017), the 2017 document on the Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal of NMP (U.S. EPA, 2017b), the 2015 OECD ESD on the Use of Adhesives (OECD, 2015), and NAICS codes reported in monitoring data obtained from OSHA (OSHA, 2019).

The industries that distinctly perform the various methods of adhesive and sealant application are unknown. EPA assumes that all industries may perform all methods of application. EPA compiled the associated NAICS codes for the identified industries in Table 2-25. EPA determined the number of workers associated with each industry from US Economic Census and Bureau of Labor Statistics (BLS) data. The number of establishments within each industry that use methylene chloride-based adhesives and sealants and the number of employees within an establishment exposed to these methylene chloride-based products are unknown. Therefore, EPA provides the total number of establishments as a bounding estimate, and estimates the number of workers and ONUs that are potentially exposed to methylene chloride-based adhesive and sealant products. These estimates likely overestimate the actual number of establishments and employees potentially exposed to methylene chloride during adhesive and sealant application.

Table 2-25. US Number of Establishments and Employees for Industries Conducting Adhesive and Sealant Application

Industry	Source	2016 NAICS	2016 NAICS Title	Number of Establishments	Number of Workers per Site [a]	Number of ONUs per Site [a]
Specialty Trade Contractors	Market Profile	238200	Building Equipment Contractors	176,142	8 [b]	1 [b]
		238330	Flooring Contractors	14,601	4	0
Wood Product Manufacturing	OSHA	321200	Veneer, Plywood, and Engineered Wood Product Manufacturing	1,407	25 [d]	7 [d]
Plastics and Rubber Products Manufacturing		326150	Urethane and Other Foam Product (except Polystyrene) Manufacturing	654	15	4
Fabricated Metal Product Manufacturing		332300	Fabricated Metal Product Manufacturing	12,309	10	3
Machinery Manufacturing		333900	Other General Purpose Machinery Manufacturing	6,048	13	6
Computer and Electronic Product Manufacturing	2015 OECD ESD on Use of Adhesives; OSHA	334100	Computer and Peripheral Equipment Manufacturing	1,091	12 [b]	12 [b]
		334200	Communications Equipment Manufacturing	1,369	13	14
		334300	Audio and Video Equipment Manufacturing	486	6 [b]	6 [b]
		334400	Semiconductor and Other Electronic Component Manufacturing	3,979	30	27
		334500	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	5,231	17	18
		334600	Manufacturing and Reproducing Magnetic and Optical Media	521	6 [b]	6 [b]
		335100	Electric Lighting Equipment Manufacturing	1,104	17	5
		335200	Household Appliance Manufacturing	303	102	20
		335300	Electrical Equipment Manufacturing	2,124	28	12
		335900	Other Electrical Equipment and Component Manufacturing	2,140	23	8
Transportation Equipment Manufacturing		336100	Motor Vehicle Manufacturing	340	234 [b]	97 [b]
		336200	Motor Vehicle Body and Trailer Manufacturing	1,917	40	5
		336300	Motor Vehicle Parts Manufacturing	5,088	51	15
		336400	Aerospace Product and Parts Manufacturing	1,811	75	64
		336500	Railroad Rolling Stock Manufacturing	243	35	15
		336600	Ship and Boat Building	1,541	36	11
Furniture and Related Product Manufacturing	OSHA, Market Profile	337100	Household and Institutional Furniture and Kitchen Cabinet Manufacturing	10,759	5	4
Repair and Maintenance	Market Profile	811420	Personal and Household Goods Repair and Maintenance	3,720	1	1

Industry	Source	2016 NAICS	2016 NAICS Title	Number of Establishments	Number of Workers per Site [a]	Number of ONUs per Site [a]
Total establishments and number of potentially exposed workers and ONUs = [d]				254,928	2,700,000	810,000

a – Rounded to the nearest whole number.
b – No 2016 BLS data was available for this NAICS. Number of relevant workers per site and ONUs per site within this NAICS were calculated using the ratios of relevant workers and ONUs to the number of total employees at the 3-digit NAICS level.
c – No 2016 BLS data was available for this NAICS or at the 3-digit level. Number of relevant workers per site and ONUs per site within this NAICS were calculated using the ratios of relevant workers and ONUs to the number of total employees for all NAICS codes in the table.
d – Unrounded figures were used for total worker and ONU calculations.

2.9.3 Exposure Assessment

2.9.3.1 Worker Activities

The 2015 ESD for Use of Adhesives (OECD, 2015) provides a variety of potential adhesive and sealant application processes, depending on a variety of factors including the type of adhesive/sealant, type of substrate, size and geometry of the substrate, and the precision requirement of the bond. Workers may be exposed to the volatile methylene chloride during container cleaning, container unloading, equipment cleaning, application (spray, roll, curtain, bead), and during drying/curing.

Given the identified applications of methylene chloride in liquid, aerosol, and canister adhesives and sealants (Abt, 2017), EPA anticipates workers may apply adhesives and sealants via any method, with particular use as a spray adhesive/sealant. The adhesives and sealants are likely sold and used in sealed containers such as spray cans or canister tanks.

2.9.3.2 Inhalation Exposures

Table_Apx A-10 and Table_Apx A-11 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride adhesive and sealant application that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

EPA found inhalation exposure data for both spray and non-spray industrial adhesive and sealant application; EPA did not identify non-industrial data. 8-hr TWA data are primarily from a 1985 EPA Risk Assessment that compiled laminating and gluing activities in various industries, ranging from ND to 575 mg/m^3 (97 samples) (US EPA, 1985). A 1984 NIOSH HHE performed at a flexible circuit board manufacturing site encompassed various worker activities in adhesive/sealant mixing and laminating areas, ranging from 86.8 to 458.5 mg/m^3 (12 samples) (NIOSH, 1985).

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. Central tendency 8-hr TWA exposure concentrations for these scenarios are less than half of the OSHA PEL value of 87 mg/m^3 (25 ppm), while worst-case estimates are between three and seven times the OSHA PEL.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-26 and Table 2-27 for industrial non-spray and spray adhesives and sealants application, respectively.

Table 2-26. Exposure to Methylene Chloride During Industrial Non-Spray Adhesives and Sealants Use

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	98	10	300
Average Daily Concentration (ADC)		2.4	70
Lifetime Average Daily Concentration (LADC)		4.2	150

Sources: NIOSH (1985); US EPA (1985)

Table 2-27. Exposure to Methylene Chloride During Industrial Spray Adhesives and Sealants Use

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	16	39	560
Average Daily Concentration (ADC)		8.9	130
Lifetime Average Daily Concentration (LADC)		16	290

Sources: TNO (CIVO) (1999); (IPCS) (1996); US EPA (1985)

Table 2-28 summarizes available short-term exposure data available from the same references and industries identified above for the 8-hr TWA data. Data range from 12 mg/m^3 to 720 mg/m^3 during adhesive/sealant spraying.

Table 2-28. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Industrial Adhesives and Sealants Use

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Metal Window and Door Manufacturing	OSHA (2019)	Adhesive/Sealant Sprayer	720	15
			580	
Wood Kitchen Cabinet and Countertop Manufacturing			140	
			480	
			160	
			360	
			100	
			280	
			12	
Flexible Circuit Board Manufacturing	NIOSH (1985)	Operator, laminator #3 & #4, cleaning (Non-Spray)	420	10
		Employee mixing adhesives/sealants, Dept 12 (Non-Spray)	570	12

Note: The OSHA Short-term exposure limit (STEL) is 433 mg/m^3 as a 15-min TWA.

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.9.4 Water Release Assessment

Based on a mass balance study on the Dutch use of methylene chloride as adhesives/sealants, TNO calculated an emission of 100% to air (TNO (CIVO), 1999). EPA did not find information on potential water releases. Water releases may occur if equipment is cleaned with water.

2.9.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as potential direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.10 Paints and Coatings

2.10.1 Process Description

Based on the *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Methylene Chloride* and *Use and Market Profile for Methylene Chloride*, both available in the public docket (Abt, 2017), methylene chloride may be used in various paints and coatings for industrial, commercial, and consumer applications. Typical industrial and commercial coating applications include manual application with roller or brush, air spray systems, airless and air-assisted airless spray systems, electrostatic spray systems, electrodeposition/electrocoating and autodeposition, dip coating, curtain coating systems, roll coating systems, and supercritical carbon dioxide systems. After application, solvent-based coatings typically undergo a drying stage in which the solvent evaporates from the coating (OECD, 2009b).

2.10.2 Number of Sites and Potentially Exposed Workers

2017 document on the Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal of NMP (U.S. EPA, 2017b) and Market Profile (Abt, 2017) both identified methylene chloride in use in paints and coatings, but did not identify specific products that use methylene chloride. Application of methylene chloride-based paints and coatings are widespread, occurring in many industries. EPA identified potential industries likely to use methylene chloride in paints and coatings based on 2014 NEI data and NAICS codes reported in monitoring data obtained from OSHA.

The industries that distinctly perform the various methods of paint and coating application are unknown. EPA assumes that all industries may perform all methods of application. EPA compiled the associated NAICS codes for the identified industries in Table 2-29. EPA determined the number of workers associated with each industry from US Economic Census and Bureau of Labor Statistics (BLS) data. The number of establishments within each industry that use methylene chloride-based paints and coatings and the number of employees within an establishment exposed to these methylene chloride-based products are unknown. Therefore, EPA provides the total number of establishments as a bounding estimate, and estimates the number of workers and ONUs that are potentially exposed to methylene chloride-based adhesive and sealant products. These estimates likely overestimate the actual number of establishments and employees potentially exposed to methylene chloride during paint and coating application.

Table 2-29. Number of U.S. Establishments, Workers, and ONU for Industries Performing Paint and Coating Application

Industry	Source	2016 NAICS	2016 NAICS Title	Number of Establishments	Number of Workers per Site [a]	Number of ONUs per Site [a]
Specialty Trade Contractors	Market Profile; OSHA	238320	Painting and Wall Covering Contractors	31,943	4	0
Printing and Related Support Activities	OSHA	323113	Commercial Screen Printing	4,956	1	1
Fabricated Metal Product Manufacturing	OSHA; NIOSH HHE	332000	Fabricated Metal Product Manufacturing	54,767	12 [b]	2 [b]
Furniture and Related Product Manufacturing	OSHA	337100	Household and Institutional Furniture and Kitchen Cabinet Manufacturing	10,759	5	4
Clothing and Clothing Accessories Stores	OSHA	448100	Clothing Stores	98,485	6	1
Amusement, Gambling, and Recreation Industries	OSHA	713100	Amusement Parks and Arcades	3,280	28 [b]	5 [b]
Repair and Maintenance	OSHA	811111	General Automotive Repair	80,243	2	0
Total establishments and number of potentially exposed workers and ONUs = [c]				284,433	1,800,000	340,000

a – Rounded to the nearest whole number.
b – No 2016 BLS data was available for this NAICS or at the 3-digit level. Number of relevant workers per site and ONUs per site within this NAICS were calculated using the ratios of relevant workers and ONUs to the number of total employees for all NAICS codes in the table.
c – Unrounded figures were used for total worker and ONU calculations.

2.10.3 Exposure Assessment

2.10.3.1 Worker Activities

Similar to adhesive and sealant use, paint and coating application depends on a variety of factors including the type of adhesive/sealant, type of substrate, size and geometry of the substrate, and the precision requirement of the paint or coating. Workers may be exposed to the volatile methylene chloride during container cleaning, container unloading, equipment cleaning, application (spray, roll, curtain, etc.), and during drying/curing (OECD, 2015).

2.10.3.2 Inhalation Exposures

Table_Apx A-12 and Table_Apx A-13 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride paint and coating application that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

8-hr TWA data during spray coating are primarily from monitoring data at various types of facilities types, such as sporting goods stores, metal products, air conditioning equipment, etc., as compiled in the 1985 EPA assessment (US EPA, 1985). Two additional spray painting data points were available from OSHA inspections between 2012 and 2016, one in the general automotive repair sector, and the other in the Wood Kitchen Cabinet and Countertop Manufacturing sector. The U.S. Department of Defense (DOD) provided five monitoring data points from painting operations during structural repair. The worker activities did not indicate the method of paint application. The activities were also stated to have low durations (0-15 minutes) but provided sampling data that occurred over 2-hr periods. EPA assumed that there was no exposure to methylene chloride over the remainder of the shift, and calculated 8-hr TWA exposures.

Because the method of paint application is unknown, EPA presents the spray application data and the unknown application data separately.

For spray coating operations, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration for this scenario is below the OSHA PEL value of 87 mg/m^3 (25 ppm), but the high-end estimate is approximately four times higher.

For unknown application method operations, because only five data points were available, EPA assessed the median value of 7.1 mg/m^3 as the central tendency, and the maximum reported value of 10.7 mg/m^3 as the high-end estimate of potential occupational inhalation exposures. The central tendency 8-hr TWA exposure concentration for this scenario is an order of magnitude below the OSHA PEL value of 87 mg/m^3 (25 ppm), and the high-end estimate is approximately eight times lower.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-30 and

Table 2-31, respectively for spray paint/coating application and unknown application method paint/coating application.

Table 2-30. Exposure to Methylene Chloride During Paint/Coating Spray Application

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	27	70	360
Average Daily Concentration (ADC)		16	83
Lifetime Average Daily Concentration (LADC)		28	190

Sources: OSHA (2019); US EPA (1985)

Table 2-31. Exposure to Methylene Chloride During Paint/Coating (Unknown Application Method)

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	5	7.1	11
Average Daily Concentration (ADC)		1.6	2.4
Lifetime Average Daily Concentration (LADC)		2.8	5.5

Sources: (DOEHRS-IH) (2018)

Table 2-32 summarizes available short-term exposure data available from the same OSHA inspections and DOD data identified above for the 8-hr TWA data, as well as short-term exposure data during painting at a Metro bus maintenance shop in 1981, and spray painting in a spray booth at a metal fabrication plant in 1973.

Table 2-32. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Paint/Coating Use

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Metro Bus Maintenance Shop	Love and Kern (1981)	Painting	ND (<0.01)	40
		Painting	ND (<0.01)	50
Metal Fabrication Plant	Vandervort and Polakoff (1973)	Spray Painter in Aisle No. 2 (Front) Spray Booth	64	32
			54	32
			63	27
			36	20
			74	29
		Spray Painter in Aisle No. 1 (Rear) Spray Booth	1.0	18
			3.0	23
			4.0	22
Painting/Coating Operations	(DOEHRS-IH) (2018)	Painting Operations	4.1	15
		Painting Operations	4.1	
		Painting Operations	4.1	
		Painting Operations	4.1	

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
		Priming Operations	5.2	
		IND-002-00 Chemical cleaning multi ops.	1.7	
		IND-006-00 Coating Operations, Multiple Operations	1.9	
		IND-006-00 Coating Operations, Multiple Operations	1.9	
		NPS ECE aerosol can painting	13.5	

ND – not detected

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.10.4 Water Release Assessment

EPA did not identify information about potential water releases during application of paints and coatings. Water releases may occur if equipment is cleaned with water; however, industrial and commercial sites would likely be expected to dispose of solvent-based paints as hazardous waste.

2.10.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as potential direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.11 Adhesive and Caulk Removers

2.11.1 Process Description

EPA did not find specific exposure data for adhesive and caulk removers. Products listed in the market profile (Abt, 2017) indicate potential use in flooring adhesive removal. Based on expected worker activities, EPA assumes that the use of adhesive and caulk removers is similar to paint stripping by professional contractors, as outlined in the 2014 Risk Assessment on Paint Stripping Use for Methylene Chloride (U.S. EPA, 2014).

Paint strippers can be used by professional contractors to strip paint and varnish from walls, wood flooring, and kitchen and wood cabinets. Professional contractors are expected to purchase strippers in commercially available container sizes that commonly range from one liter up to 5 gallons, although they may also purchase consumer paint stripper products from hardware stores.

Stripper is typically applied to wall or floor surfaces using a hand-held brush. Strippers used in these applications often have a high viscosity since they can be applied to vertical surfaces. After application, the stripper is allowed to set and soften the old coating. Once the stripper has finished setting, the old coating is removed from the surface by scraping and brushing. During wood floor stripping, old coating and stripper may also be removed using an electric floor buffer. After the old coating is removed, the surface is wiped clean before moving to the next stages of the job. The stripping process is often completed on an incremental basis with treatment for one section of wall or flooring being completed before moving to the next section. Professional contractors can use portable local exhaust ventilation machines to increase ventilation in the vicinity of the paint stripping (U.S. EPA, 2014).

Professional contractors may also be employed to refinish or reglaze bathtubs. Various health case studies have noted the use of methylene chloride -based strippers during bathtub refinishing or reglazing. Case studies have identified professional bathtub refinishers that repaired and resurfaced countertops, tubs, and sinks in both apartment buildings and private homes (U.S. EPA, 2014).

In addition, the OSHA IMIS data identified two OSHA or state health inspections in 2004 and 2007 of two bathtub reglazers/refinishers. The bathtub reglazers' company in the 2007 inspection was identified under NAICS code 811420 – Reupholstery and Furniture Repair (U.S. EPA, 2014). However, this assessment discusses bathtub reglazing/refinishing in the context of professional contractors, as professional contractors and professional bathtub refinishers or reglazers are both expected to perform their work at customer sites (for example, in the cited case studies of bathtub refinishers/reglazers, apartment buildings, and private homes). This professional contractor-type work differs from furniture refinishing, which typically entails the refinishing of customer furniture at fixed furniture refinishing facilities.

Bathtub refinishing or reglazing can involve a worker pouring and brushing stripper onto a bathtub using a paintbrush. The worker then scrapes the finish from the bathtub after leaving the stripper in contact with the bathtub for 20 to 30 minutes. This information was obtained from a case study that noted a stripper methylene chloride concentration of 60 to 100 percent. However, multiple health case studies have reported the use of aircraft and marine coating remover in bathtub refinishing/reglazing (U.S. EPA, 2014).

2.11.1 Number of Sites and Potentially Exposed Workers

EPA estimated the number of workers and occupational non-users potentially exposed to methylene chloride during furniture stripping using Bureau of Labor Statistics' OES data (U.S. BLS, 2016) and the U.S. Census' SUSB (U.S. Census Bureau, 2015). The method for estimating number of workers is detailed above in Section 1.4.2. These estimates were derived using industry- and occupation-specific employment data from the BLS and U.S. Census. No market penetration information was available; therefore, EPA assumed a bounding number of sites, and estimated the associated number of workers and ONUs for each paint stripping scenario, as shown in Table 2-33 (U.S. BLS, 2016; U.S. Census Bureau, 2015).

Table 2-33. Number of U.S. Establishments, Workers, and ONUs for Industries Conducting Paint Stripping

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site [a]	Number of ONUs per Site [a]
Professional Contractors				
238320	Painting and Wall Covering Contractors	31,943	4	0.4
238330	Flooring Contractors	14,601	4	0.3
Total establishments and number of potentially exposed workers and ONUs = [a]		**46,544**	**190,000**	**18,000**

a – Rounded to the nearest worker. Unrounded figures were used for total worker and ONU calculations.

2.11.2 Exposure Assessment

2.11.2.1 Worker Activities

Workers may be exposed to methylene chloride during application of the adhesive remover stripper (brush, spray, dip), soaking of the surfaces, scraping and brushing of the coatings from the surfaces, and washing residuals.

2.11.2.2 Inhalation Exposures

Table_Apx A-14 and Table_Apx A-15in Appendix A summarize the inhalation monitoring data for methylene chloride in professional contractor paint stripping that EPA compiled from published literature sources. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

U.S. EPA (2014) compiled four studies that sampled between 1981 and 2004, resulting in a range of 8-hr TWA exposure concentrations between 60 and 2,980 mg/m^3, and a midpoint of 1,520 mg/m^3. The central tendency 8-hr TWA exposure concentration for this scenario is approximately 17 times the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is almost 34 times higher.

From these personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-34.

Table 2-34. Full-Shift Exposure to Methylene Chloride During Adhesive and Caulk Removal (Using Professional Contractor Paint Stripping Data as Surrogate)

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	unknown	1,500	3,000
Average Daily Concentration (ADC)		350	680
Lifetime Average Daily Concentration (LADC)		600	1,500

Source: U.S. EPA (2014)

Table 2-35 summarizes available short-term exposure data from paint stripping using methylene chloride.

Table 2-35. Short-Term Exposure to Methylene Chloride During Adhesive and Caulk Removal (Using Professional Contractor Paint Stripping Data as Surrogate)

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
Professional Contractors	unknown	7,100	14,100

Source: U.S. EPA (2014)

EPA did not identify exposure data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.11.3 Water Release Assessment

Based on process information, water may be used to rinse stripper containing methylene chloride from substrates during graffiti removal, wood furniture stripping, aircraft stripping, or ship stripping. The wastewater may be is collected and either recycled or disposed of as waste. Therefore, water releases may be expected for these uses, but EPA did not identify quantitative information in the 2016 TRI or 2016 DMR. Commercial stripping operation facilities likely do not handle enough methylene chloride to meet the reporting thresholds of TRI and would not likely report to DMR because they are not industrial facilities.

EPA also did not identify quantitative information on methylene chloride release during other stripping uses (professional contractors, automotive body stripping, and art restoration and conservation). The majority of methylene chloride is expected to evaporate into the air, but releases to water may occur if equipment is cleaned with water.

2.11.4 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as potential direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.12 Fabric Finishing

2.12.1 Process Description

Workers may be potentially exposed to methylene chloride during application on to fabrics, or during volatilization during pressing. It is unclear whether there are additional worker activities that use methylene chloride. The 2017 *Draft Use and Market Profile for Methylene Chloride* did not identify any specific fabric finishing products (Abt, 2017). EPA assumes that fabric finishing operations occur industrially at fabric mills.

2.12.2 Number of Sites and Potentially Exposed Workers

EPA determined the number of workers associated with fabric finishing using US Economic Census and Bureau of Labor Statistics (BLS) data. The number of establishments within the fabric finishing industry that use methylene chloride-based products and the number of employees within an establishment exposed to these methylene chloride-based products are unknown. Therefore, EPA provides the total number of establishments as a bounding estimate of the number of establishments that use methylene chloride and estimates the number of employees that are potentially exposed to methylene chloride-based products at these establishments. These are likely overestimates of the actual number of establishments and employees potentially exposed to methylene chloride. EPA estimates 1,886 establishments, 18,800 workers, and 12,340 ONUs, as shown in Table 2-36 (U.S. BLS, 2016; U.S. Census Bureau, 2015).

Table 2-36. Number of U.S. Establishments, Workers, and ONUs for Fabric Finishing Sites

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site [a]	Number of ONUs per Site [a]
313210	Broadwoven Fabric Mills	281	14	10
313220	Narrow Fabric Mills and Shiffli Machine Embroidery	190	7	6
313230	Nonwoven Fabric Mills	204	19	14
313240	Knit Fabric Mills	174	10	7
313310	Textile and Fabric Finishing Mills	755	7	3
313320	Fabric Coating Mills	167	14	10
Total establishments and number of potentially exposed workers and ONUs = [b]		**1,886**	**19,000**	**12,000**

a – Rounded to the nearest worker.
b – Unrounded figures were used for total worker and ONU calculations.

2.12.3 Exposure Assessment

2.12.3.1 Worker Activities

Workers may be exposed to methylene chloride during pressing or spray finishing.

2.12.3.2 Inhalation Exposure

Table_Apx A-16 in 4.2.5Appendix A summarizes the inhalation monitoring data for methylene chloride for fabric finishing that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

8-hr TWA data are from monitoring data from various OSHA inspections between 1985 and 2008 at apparel manufacturing sites and ranged from 42.0 mg/m^3 to 164.6 mg/m^3(14 data points). Specific worker activities were not identified. Exposures at these facilities was assumed to be representative of exposures for fabric finishing activities (Finkel, 2017).

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration for workers is approximately the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate for workers is approximately twice the PEL value.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-37 for workers and ONUs during fabric finishing.

Table 2-37. Worker Exposure to Methylene Chloride During Fabric Finishing

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	15	87	160
Average Daily Concentration (ADC)		20	37
Lifetime Average Daily Concentration (LADC)		35	84

Source: Finkel (2017); TNO (CIVO) (1999).

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.12.4 Water Release Assessment

EPA did not identify quantitative information about potential water releases during use of methylene chloride in fabric finishing. The majority of methylene chloride is expected to evaporate into the air, but releases to water may occur if equipment or fabric is cleaned with water.

2.12.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as potential direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.13 Spot Cleaning

2.13.1 Process Description

The *Preliminary Information on Manufacturing, Processing, Distribution, Use and Disposal for Methylene Chloride* (U.S. EPA, 2017b) includes use as spot cleaner for apparel and textiles (>60 to 95 percent methylene chloride).

Spot cleaning products can be applied to the garment either before or after the garment is dry cleaned. The process and worker activities associated with commercial dry cleaning and spot cleaning have been previously described in the 1-Bromopropane Draft Risk Assessment (U.S. EPA, 2016c).

On receiving a garment, dry cleaners inspect for stains or spots they can remove as much of as possible before cleaning the garment in a dry cleaning machine. As Figure 2-12 shows, spot cleaning occurs on a spotting board and can involve the use of a spotting agent containing various solvents, such as methylene chloride. The spotting agent can be applied from squeeze bottles, hand-held spray bottles, or even from spray guns connected to pressurized tanks. Once applied, the dry cleaner may come into further contact with the methylene chloride if using a brush, spatula, pressurized air or steam, or their fingers to scrape or flush away the stain (Young, 2012); (NIOSH, 1997).

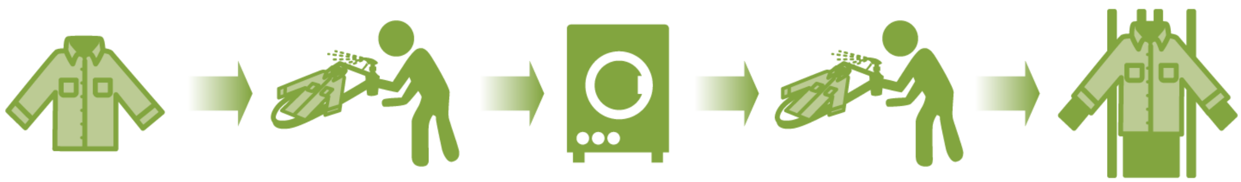

Figure 2-12 Overview of Use of Spot Cleaning at Dry Cleaners

2.13.2 Number of Sites and Potentially Exposed Workers

EPA/OPPT estimated the number of workers and occupational non-users potentially exposed to methylene chloride at dry cleaners using Bureau of Labor Statistics' OES data (U.S. BLS, 2016) and the U.S. Census' SUSB (U.S. Census Bureau, 2015). The method for estimating number of workers is detailed above in Section 1.4.2. These estimates were derived using industry- and occupation-specific employment data from the BLS and U.S. Census.

Table 2-38 presents BLS occupation codes where workers are potentially exposed to dry cleaning solvents. EPA/OPPT designated each occupation code as either "Worker (W)" or "Occupational non-user (O)" to separately estimate the number of potentially exposed workers and occupational non-users. EPA/OPPT classified laundry and dry cleaning workers, pressers, and machine repairers as "Workers" because they are likely to have direct exposure to the dry cleaning solvents. EPA/OPPT classified retail sales workers (e.g., cashiers), sewers, tailors, and other textile workers as "occupational non-users" because they perform work at the dry cleaning shop, but do not directly handle dry cleaning solvents.

Table 2-38. SOC Codes for Worker Exposure in Dry Cleaning

SOC	Occupation	Exposure 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

Source: U.S. BLS (2016)
W – worker, O – occupational non-user

No market penetration information was available; therefore, EPA assesses a bounding estimate of 21,370 establishments, with four workers/site, and 0.4 ONUs/site, as shown in Table 2-39 (U.S. BLS, 2016; U.S. Census Bureau, 2015).

Table 2-39. Number of U.S. Establishments, Workers, and ONUs for Industries Using Spot Removers at Dry Cleaners

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers per Site [a]	Number of ONUs per Site [a]
812320	Drycleaning and Laundry Services (except Coin-Operated)	21,370	4	0.4
Total establishments and number of potentially exposed workers and ONUs = [b]			76,000	7,900

a – Rounded to the nearest worker unless less than one.
b – Unrounded figures were used for total worker and ONU calculations.

2.13.3 Exposure Assessment

2.13.3.1 Worker Activities

As previously described, workers manually apply the spotting agent from squeeze bottles, hand-held spray bottles, or spray guns, either before or after a cleaning cycle. After application, the worker may manually scrape or flush away the stain using a brush, spatula, pressurized air or steam, or their fingers (Young, 2012; NIOSH, 1997).

2.13.3.2 Inhalation Exposures

Table_Apx A-17 and Table_Apx A-18 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

EPA did not find any specific exposure monitoring data for methylene chloride-containing products during use as a spot cleaner. EPA used OSHA data for Industrial Launderers and Drycleaning and Laundry Services (except Coin-Operated) (Finkel, 2017).

Sample times ranged from 173 to 270 minutes. EPA used exposure concentrations with sample times greater than 240 minutes (4 hours) and converted the exposures to 8-hr TWAs assuming zero concentrations outside sampling time.

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. Both the central tendency and high-end 8-hr TWA exposure concentrations for this scenario are below the OSHA PEL value of 87 mg/m3 (25 ppm).

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-40.

Table 2-40. Exposure to Methylene Chloride During Spot Cleaning

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	6	2.6	64
Average Daily Concentration (ADC)		0.58	15
Lifetime Average Daily Concentration (LADC)		1.0	33

Source: Finkel (2017)

Table 2-41 summarizes available short-term exposure data available from the same OSHA source identified above for the 8-hr TWA data (Finkel, 2017).

Table 2-41. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Spot Cleaning

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Industrial Launderers	Finkel (2017)	unknown	67	197
			230	185
			160	187
			8.7	173
			12	174
			980	202
			980	202
			0.29	225

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.13.4 Water Release Assessment

The majority of methylene chloride in spot removers is expected to evaporate into the air, but releases to water may occur if residue remains in the garment during washing. EPA identified one facility in the 2016 DMR with SIC code 7216 (Drycleaning Plants, Excluding Rug Cleaning). This facility reported 0.1 kg annual release of methylene chloride to surface water, as shown in Table 2-42. EPA did not identify any potential spot cleaning facilities in the 2016 TRI that reported water releases. Other facilities in this industry may not dispose to water, or may not use methylene chloride in quantities that meet the TRI reporting threshold.

Table 2-42. Surface Water Releases of Methylene Chloride During Spot Cleaning

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
BOISE STATE UNIVERSITY	BOISE	ID	0.1	250	0.0002	Surface Water	U.S. EPA (2016a)

2.14 Cellulose Triacetate Film Production

2.14.1 Process Description

During Cellulose Triacetate (CTA) film production, CTA is dissolved in an organic solvent (approximately 65% methylene chloride) to make a film substance, which is then poured on a metal drum or a continuous metal belt. After the methylene chloride evaporates, a film having a thickness of 0.02 to 0.03 mm forms. The film then passes through a water sealer by means of a heated cylinder onto a chromium roller where it is dried. For safety reasons, the drum and metal belt are in a hermetically sealed channel separated from the water sealed environment and closed off by a moderately high nitrogen pressure. Note that CTA was historically also used to manufacture CTA fibers, but OSHA indicates that the single CTA fiber manufacturing plant was closed in 1982 (OSHA, 1991). Therefore, EPA did not assess exposures for CTA fiber manufacturing.

2.14.2 Number of Sites and Potentially Exposed Workers

OSHA (1991) estimated that there were two triacetate film manufacturing sites, covering 700 potentially exposed workers (350 workers per site). It is unclear whether these sites still perform these processes using methylene chloride.

2.14.3 Exposure Assessment

2.14.3.1 Worker Activities

During CTA film manufacturing, exposures can occur during evaporation of the methylene chloride, material set up, disruption in apparatus, and pouring CTA-containing film onto the metal drums. Film splicing can also occur, where methylene chloride as a solvent in the glue may be used to splice pieces of film together. The methylene chloride dissolves the plastic interfaces of the pieces and then evaporates, leaving the pieces "welded" together. This process is either done manually or by machine (OSHA, 1991).

2.14.3.2 Inhalation Exposure

Table_Apx A-19 in 4.2.5Appendix A summarizes the inhalation monitoring data for methylene chloride used in CTA film and manufacture that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA’s rationale for inclusion or exclusion of these data in the risk evaluation.

8-hr TWA data are primarily from six studies performed in the 1970s and 1980s. Worker activities encompassed various areas of CTA production, including preparation, extrusion, and coating, but each study compiled data into overall statistics for each worker type instead of presenting separate data points (Ott et al., 1983); (Dell et al., 1999); (TNO (CIVO), 1999).

Because the individual data points were not available, EPA presents the average of the median, and average of maximum values as central tendency and high end, respectively. The central tendency and high end 8-hr TWA exposure concentrations for this scenario are approximately 12 to 16 times the OSHA PEL value of 87 mg/m^3 (25 ppm), respectively.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-43 for CTA film manufacturing.

Table 2-43. Worker Exposure to Methylene Chloride During CTA Film Manufacturing

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	>166[a]	1,000	1,400
Average Daily Concentration (ADC)		240	320
Lifetime Average Daily Concentration (LADC)		410	560

Sources: Dell et al. (1999); TNO (CIVO) (1999); Ott et al. (1983)
a – Various studies were compiled to determine central tendency and high-end estimates; however, not all indicated the number of samples. Therefore, actual number of samples is unknown.

EPA has not identified specific short-term data or data on potential ONU inhalation exposures; some ONUs may be included in the estimates for workers. Since ONUs do not directly handle methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.14.4 Water Release Assessment

EPA identified one facility in the 2016 DMR, potentially related to CTA manufacturing (SIC code 3861 - Photographic Equipment and Supplies) that reported water releases. Release for this facility is summarized in Table 2-44. EPA did not identify any potential CTA manufacturing facilities in the 2016 TRI that reported water releases.

Table 2-44. Reported 2016 TRI and DMR Releases for CTA Manufacturing Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
KODAK PARK DIVISION	ROCHESTER	NY	29	250	0.1	Surface Water	U.S. EPA (2016a)

2.14.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.15 Flexible Polyurethane Foam Manufacturing

2.15.1 Process Description

Methylene chloride is used as a blowing agent and as a solvent for cleaning equipment in the production of polyurethane foam (PU). In the "one shot" PU foam process, foam materials are prepared by simultaneously mixing the co-reactants (polyol and isocyanate) directly with additives (blowing agents [e.g., methylene chloride], catalysts, foam stabilizers, and flame retardants). The variability and the sequence of production processes and the type of equipment needed for each process affect worker exposure to methylene chloride.

In the "two part" PU foam process, polyurethane foam ingredients, polyol and isocyanate, are stored in separate tanks, with auxiliary agents such as blowing agents, catalysts, and pigment pastes added to the polyol tank. If direct metering is used, the additives are blended inline on the suction side of the pump with the use of premix chambers. Components are passed through the mix-head, in which the components are brought together to form the reaction mix. The reaction mix can be poured into open or closed molds. Pouring into open molds or onto a substrate can be done at one spot or along a pattern. Pouring into a closed mold is done through fill holes or gates (OSHA, 1991).

2.15.2 Number of Sites and Potentially Exposed Workers

EPA estimated the number of workers and occupational non-users potentially exposed to methylene chloride during polyurethane foam manufacturing using Bureau of Labor Statistics' OES data (U.S. BLS, 2016) and the U.S. Census' SUSB (U.S. Census Bureau, 2015). The method for estimating number of workers is detailed above in Section 1.4.2. These estimates were derived using industry- and occupation-specific employment data from the BLS and U.S. Census. No market penetration information was available; this assumes a bounding estimate of 654 establishments, with an estimated 9,567 workers and 2,707 ONUs, as shown in Table 2-45 (U.S. BLS, 2016; U.S. Census Bureau, 2015).

Table 2-45. Number of U.S. Establishments, Workers, and ONUs for Industries Conducting Polyurethane Foam Manufacturing

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site [a]	Number of ONUs per Site [a]
326150	Urethane and Other Foam Product (except Polystyrene) Manufacturing	654	15	4
Total establishments and number of potentially exposed workers and ONUs = [b]			9,600	2,700

a – Rounded to the nearest worker.
b – Unrounded figures were used for total worker and ONU calculations.

Alternatively, an industry survey compiled for the 1991 proposed OSHA rule indicated 1,169 exposed workers at 180 foam blowing sites (approximately seven workers per site) (OSHA, 1991). Based on the overall decline in methylene chloride usage from the 1980s through 2011 (U.S. EPA, 2014), EPA assumes that this is an upper-bound estimate for the number of potentially exposed workers. Because the data from the 1991 OSHA study were specific to sites using methylene chloride, EPA assumes there are up to 1,169 workers potentially exposed.

Note that regulations have limited the use of methylene chloride in polyurethane foam production and fabrication. OAR's July 16, 2007 Final NESHAP for Area Sources: Polyurethane

Foam Production and Fabrication (72 FR 38864) prohibited the use of methylene chloride-based mold release agents at molded and rebond foam facilities, methylene chloride-based equipment cleaners at molded foam facilities, and the use of methylene chloride to clean mix heads and other equipment at slabstock facilities. Slabstock area source facilities are required to comply with emissions limitations for methylene chloride used as an auxiliary blowing agent, install controls on storage vessels, and comply with management practices for equipment leaks. The rule also prohibits methylene chloride-based adhesives for foam fabrication. The April 4, 2007 proposed area source rule (72 FR 16636) indicated that there were hundreds of facilities in the Flexible Polyurethane Foam Production and Flexible Polyurethane Foam Fabrication area source categories, which were listed because of the use of methylene chloride. However, because of several reasons, including State air emissions standards and OSHA worker exposure limits, methylene chloride use was expected to be virtually eliminated. The August 15, 2014 NESHAP Final Residual Risk and Technology Review for the Flexible Polyurethane Foam Production Source Category (79 FR 48073) identified 13 major source facilities, a subset of which may use methylene chloride. It is unclear how many total sources continue to use methylene chloride in the present day.

2.15.3 Exposure Assessment

2.15.3.1 Worker Activities

Workers use methylene chloride as a blowing agent in the production of flexible PU and as a flushing media of the mixing head in the production of rigid foam. The cleaning of the mixing chamber and all the elements of the mixers with agitators is usually done by purging solvents, such as methylene chloride. The small volumes of the impingement mixers allow purging with air. For example, in the process of mixing some of the reaction mixture is left behind in the mixing chamber after each pour. Methylene chloride is used to flush the residual foam mix if the duration between shots is longer than the time for the foam reaction to begin (OSHA, 1991).

2.15.3.2 Inhalation Exposures

Table_Apx A-20. and Table_Apx A-21 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride used in polyurethane foam blowing that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation. Note that these data were prior to promulgation of the polyurethane foam NESHAPs, as discussed in Section 2.15.2.

8-hr TWA data are from various sources, and cover activities such as application of mold release, foam manufacturing (blowing), blending, and sawing. that include use as a blowing and mold release agent. Exposures varied from 0.3 mg/mg^3 from purge operations, to 2,200.9 mg/m^3 during laboratory operations.

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration for this scenario is approximately 2.5 times higher than the OSHA PEL value of 87 mg/m^3 (25 ppm), while the high-end estimate is almost 12 times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-46 for flexible polyurethane foam manufacturing.

Table 2-46. Exposure to Methylene Chloride During Industrial Polyurethane Foam Manufacturing

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	82	210	1,000
Average Daily Concentration (ADC)		48	230
Lifetime Average Daily Concentration (LADC)		84	510

Sources: IARC (2016); TNO (CIVO) (1999); (IPCS) (1996); Vulcan Chemicals (1991); Reh and Lushniak (1990); Cone Mills Corp (1981a); Cone Mills Corp (1981b); US EPA (1985);Olin Chemicals (1977)

Table 2-47 summarizes available short-term exposure data.

Table 2-47. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Polyurethane Foam Manufacturing

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Polyurethane Foam Manufacturing	US EPA (1985)	Foam Blowing	5.2	360
		Foam Blowing	13	360
		Foam Blowing	19	360
		Foam Blowing	17	360
		Foam Blowing	5.2	240
		Foam Blowing	38	360
		Foam Blowing	11	360
		Nozzle Cleaning	55	30

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.15.4 Water Release Assessment

EPA assumed that sites classified under NAICS code 326150 (Urethane and Other Foam Product (except Polystyrene) Manufacturing) are potentially applicable to polyurethane foam manufacturing.

Table 2-48 lists one facility under this NAICS code that reported direct or indirect water releases in the 2016 TRI. EPA did not identify water releases for polyurethane manufacturing sites in the 2016 DMR. This facility (Previs Innovative Packaging, Inc. in Wurtland, KY), reported 2 kilograms release to surface water (U.S. EPA, 2017c). Other facilities in this industry may not dispose to water, or may not use methylene chloride in quantities that meet the TRI reporting threshold.

Table 2-48. Water Releases Reported in 2016 TRI for Polyurethane Foam Manufacturing

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
PREGIS INNOVATIVE PACKAGING INC	WURTLAND	KY	2	250	0.01	Surface Water	U.S. EPA (2017c)

For chemical industries (including blowing agent in PUR production), calculations for the Dutch chemical industry estimated emissions of 0.2 % to water, 64.8 % to air and 35 % to waste, based on a mass balance study (TNO (CIVO), 1999).

2.15.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. In addition to uncertainties identified for this use discussed in Section 4.2, NESHAPs on Polyurethane Foam Production and Fabrication (discussed in Section 2.15.2) have regulated the use of methylene chloride. The effects of these regulations on the number of workers potentially exposed and potential exposure levels is not known due to a lack of recent data.

2.16 Laboratory Use

2.16.1 Process Description

Methylene chloride has various laboratory uses in gas and liquid chromatography (0.3 to 100% methylene chloride) (Abt, 2017). Specific uses are unclear.

2.16.2 Number of Sites and Potentially Exposed Workers

EPA determined the number of workers associated with laboratory use from US Economic Census and Bureau of Labor Statistics (BLS) data, using NAICS codes from OSHA monitoring data. The number of establishments within the laboratory sector that use methylene chloride-based products and the number of employees within an establishment exposed to these methylene chloride-based products are unknown. Therefore, EPA provides the total number of establishments as a bounding estimate of the number of establishments that use methylene chloride and estimates the number of employees that are potentially exposed to methylene chloride-based products at these establishments. These are likely overestimates of the actual number of establishments and employees potentially exposed to methylene chloride. EPA estimates 17,511 establishments, 17,511 workers, 151,506 ONUs, as shown in Table 2-49 (citation for BLS and Census).

Table 2-49. Number of U.S. Establishments, Workers, and ONUs for Testing Laboratories

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site [a]	Number of ONUs per Site [a]
541380	Testing Laboratories	17,511	1	9
625511	Medical Laboratories		1[b]	9[b]
Total establishments and number of potentially exposed workers and ONUs = [c]			17,000	150,000

a – Rounded to the nearest worker.
b – No 2016 BLS data was available for this NAICS. Number of relevant workers per site and ONUs per site within this NAICS were calculated using the ratios of relevant workers and ONUs to the number of total employees under NAICS 541380 – Testing Laboratories.
c – Unrounded figures were used for total worker and ONU calculations.

2.16.3 Exposure Assessment

2.16.3.1 Worker Activities

Workers in laboratory settings may be potentially exposed during sample preparation and transfers.

2.16.3.2 Inhalation Exposure

Table_Apx A-22 and Table_Apx A-23 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride used in laboratories that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

8-hr TWA data are primarily from a 1989 NIOSH inspection of an analytical laboratory (Mccammon, 1990), an IH study at Texaco (Texaco Inc, 1993), and samples from the U.S. DOD ((DOEHRS-IH), 2018). Worker descriptions include laboratory staff, and activities include sample preparation and transfer. Note that the NIOSH data were for various sample durations; EPA included samples that were more than 4 hours long as full-shift exposures and adjusted the exposures to 8-hr TWAs, assuming that the exposure concentration for the remainder of the time was zero, because workers were not expected to perform the activities all day.

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration for this scenario is an order of magnitude lower than the OSHA PEL value of 87 mg/m^3 (25 ppm), while the high-end estimate is seven times lower.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-50.

Table 2-50. Worker Exposure to Methylene Chloride During Laboratory Use

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	10	3.5	12
Average Daily Concentration (ADC)		0.79	2.7
Lifetime Average Daily Concentration (LADC)		1.4	6.0

Sources: (Mccammon, 1990); (Texaco Inc, 1993); ((DOEHRS-IH), 2018)

Table 2-51 summarizes available short-term exposure data available from the 1989 NIOSH inspection and the DOD provided data identified above for the 8-hr TWA data.

Table 2-51. Worker Personal Short-Term Exposure Data for Methylene Chloride During Laboratory Use

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Analytical Laboratory	Mccammon (1990)	sample concentrating	2.7	233
		sample sonification	3.9	218
		sample sonification	4.5	218
		washing separatory funnels in sink near CLLE	110	10
		column cleaning	10	200
		sample concentrating	30	210
		sample concentrating	4.2	234
		sample concentrating	6.8	198
		transferring 100 ml MeCl into soil samples	9.8	115
		collecting waste chemicals & dumping into waste chemical storage	1,000	24
	(DOEHRS-IH) (2018)	Miscellaneous lab operations	3.1	244
		Miscellaneous lab operations	3.1	238
		Sample extraction and analysis (3809, OCD)	34.7	180
		(3)GC Extraction	0.7	154
		134: Extraction of PCB in water samples (Rm 221 - Prep & Rm 227 - GC)	22.5	130
		134: Extraction of total volatiles (TCLP)(Rm 227)	64.7	130
		Analysis, chemical (Laboratory Operations)	1.7	59
		Analysis, chemical (Laboratory Operations)	2.4	48
		LAB ACTIVITIES	3.3	31
		LAB ACTIVITIES	6.4	30
		LAB ACTIVITIES	16.6	30

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m³)	Exposure Duration (min)
		LAB ACTIVITIES	3.4	30
		LAB ACTIVITIES	3.4	30
		LAB ACTIVITIES	3.4	30
		LAB ACTIVITIES	3.4	30
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	30
		514A Using Solvents	1830.0	25
		EXTRACTION OP	3.6	19
		EXTRACTION OP	24.8	19
		(3)GC Extraction	10.4	15
		(3)GC Extraction	10.4	15
		Sample extraction and analysis (3809, OCD)	62.5	15
		Miscellaneous lab operations	6.7	15
		EXTRACTION OP	4.6	15
		EXTRACTION OP	4.6	15
		134: Extraction of PCB in water samples (Rm 221 - Prep & Rm 227 - GC)	5.3	15
		134: Extraction of total volatiles (TCLP)(Rm 227)	5.0	15
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	15
		IND-025-10 HM/HW HANDLING CLEANUP, CONTAINER SAMPLE/OPEN	6.1	15
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	10.9	15
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	13.2	15

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle products containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.16.4 Water Release Assessment

EPA did not identify quantitative information about potential water releases during laboratory use of methylene chloride. The majority of methylene chloride is expected to evaporate into the air or disposed as hazardous waste, but releases to water may occur if equipment is cleaned with water.

2.16.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as potential direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.17 Plastic Product Manufacturing

2.17.1 Process Description

According to OSHA, methylene chloride has had confirmed use in interfacial polymerization for polycarbonate plastic manufacturing (OSHA, 1991). In this process, a jacketed vessel equipped with an agitator is charged with the reactants and methylene chloride solvent. The polymerized liquified reactor contents are then pumped to wash tanks to remove residual pyridine using hydrochloric acid and water. Methylene chloride is removed by steam stripping. The polycarbonate polymer is precipitated from the polymer methylene chloride stream and is separated by filtration. At this stage, the various producers use a number of different processes, including devolatilization extrusion, granulation, and spray drying (OSHA, 1991). EPA has not found specific information on other types of plastic processing; therefore, it is unknown whether methylene chloride is used in other types of plastic manufacturing.

2.17.2 Number of Sites and Potentially Exposed Workers

EPA determined five NAICS codes potentially applicable to the use of methylene chloride in plastics manufacturing based on NAICS codes reported in TRI and OSHA. Using these NAICS codes, EPA determined the number of workers associated with plastics manufacturing using US Economic Census and Bureau of Labor Statistics (BLS) data. The number of establishments within the plastics manufacturing sector that use methylene chloride-based products and the number of employees within an establishment exposed to these methylene chloride-based products are unknown. Therefore, EPA provides the total number of establishments as a bounding estimate of the number of establishments that use methylene chloride and estimates the number of employees that are potentially exposed to methylene chloride-based products at these establishments. These are likely overestimates of the actual number of establishments and employees potentially exposed to methylene chloride. EPA estimates 7,974 establishments, 212,422 workers, and 90,096 ONUs, as shown in Table 2-52 (U.S. BLS, 2016; U.S. Census Bureau, 2015).

Table 2-52. Number of U.S. Establishments, Workers, and ONUs for Testing Laboratories

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site [a]	Number of ONUs per Site [a]
325211	Plastics Material and Resin Manufacturing	1,135	27	12
325212	Synthetic Rubber Manufacturing	153	25	11
325220	Artificial and Synthetic Fibers and Filaments Manufacturing	126	47	21
325991	Custom Compounding of Purchased Resins	432	20	7
326199	All Other Plastics Product Manufacturing	6,128	27 [b]	11 [b]
Total establishments and number of potentially exposed workers and ONUs = [c]		7,974	210,000	90,000

a – Rounded to the nearest worker.
b – No 2016 BLS data was available for this NAICS. Number of relevant workers per site and ONUs per site within this NAICS were calculated using the ratios of relevant workers and ONUs to the number of total employees for other listed NAICS.
c – Unrounded figures were used for total worker and ONU calculations.

2.17.3 Exposure Assessment

2.17.3.1 Worker Activities

Workers are potentially exposed when unloading methylene chloride from transport containers into storage tanks and process vessels. Workers may be exposed via inhalation of vapor or via dermal contact with liquids while connecting and disconnecting hoses and transfer lines, or during solvent recovery.

ONUs are employees who work at the facilities that process and use methylene chloride, but who do not directly handle the material. ONUs may also be exposed to methylene chloride, but are expected to have lower inhalation exposures and are not expected to have dermal exposures. ONUs for this condition of use may include supervisors, managers, engineers, and other personnel in nearby production areas. One sample was for an OSHA inspector and may or may not be reflective of industry ONUs, but was included to increase the sample size.

2.17.3.2 Inhalation Exposure

Table_Apx A-24 and Table_Apx A-25 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride in plastic product manufacturing that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

8-hr TWA data are primarily from monitoring data from HSIA sampling from 2005 through 2017, for production technicians during plastic product manufacturing. Exposure concentrations ranged from 3.9 to 134.1 mg/m^3 (20 samples) (Halogenated Solvents Industry Alliance, 2018). Additional data were found for various other sources that ranged from 9 mg/m3 to 2,685.1

mg/m^3 (for hop area operator)(Halogenated Solvents Industry Alliance, 2018; Fairfax and Porter, 2006; (IPCS), 1996; GE, 1989).

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentrations for workers and ONUs is approximately six times lower the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate for workers is three times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-53 for workers and ONUs during plastic product manufacturing.

Table 2-53. Worker and ONU Exposure to Methylene Chloride During Plastic Product Manufacturing

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
Workers			
8-hr TWA Exposure Concentration	30	14	260
Average Daily Concentration (ADC)		3.2	60
Lifetime Average Daily Concentration (LADC)		5.5	130
ONUs			
8-hr TWA Exposure Concentration	1	9.0	9.0
Average Daily Concentration (ADC)		2.1	2.1
Lifetime Average Daily Concentration (LADC)		3.6	4.6

Sources: OSHA (2019); Halogenated Solvents Industry Alliance (2018); Fairfax and Porter (2006); (IPCS) (1996); GE (1989).

Table 2-54 summarizes available short-term exposure data for workers and ONUs from the same OSHA inspections identified above for the 8-hr TWA data, as well as short-term data provided by HSIA (2018).

Table 2-54. Worker Short-Term Exposure Data for Methylene Chloride During Plastic Product Manufacturing

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Plastic Product Manufacturing	OSHA (2019)	Plastics Manufacturer	ND	15
			28	15
			21	20
Plastics Material and Resin Manufacturing	Halogenated Solvents Industry	Operator	100	13
		Operator	74	18
		Operator	94	14
		Operator	66	20

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m³)	Exposure Duration (min)
	Alliance (2018)	Operator	66	20
		Operator	60	22
		Operator	130	10
		Operator	66	20
		Operator	100	13
		Operator	170	8
		Operator	110	12
		Operator	83	15
		Product technician	120	11
		Product technician	69	19
		Product technician	83	16
		Product technician	63	21
		Product technician	88	15
		Product technician	83	16
		Product technician	100	13
		Product technician	110	12
		Product technician	51	26

ND – not detected

2.17.4 Water Release Assessment

EPA identified facilities classified under four NAICS and SIC codes, listed in Table 2-55, that reported water releases in the 2016 TRI and 2016 DMR and may be related to plastic product manufacturing. Table 2-56 lists all facilities classified under these NAICS and SIC codes that reported direct or indirect water releases in the 2016 TRI or 2016 DMR.

Table 2-55. Potential Industries Conducting Plastics Product Manufacturing in 2016 TRI or DMR

NAICS Code	NAICS Description
325211	Plastics Material and Resin Manufacturing
2821	PLSTC MAT./SYN RESINS/NV ELAST
2822	SYN RUBBER (VULCAN ELASTOMERS)
3081	UNSUPPORTED PLSTICS FILM/SHEET

Table 2-56. Reported 2016 TRI and DMR Releases for Potential Plastics Product Manufacturing Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
SABIC INNOVATIVE PLASTICS US LLC	BURKVILLE	AL	8	250	0.03	Surface Water	U.S. EPA (2017c)
SABIC INNOVATIVE	MOUNT VERNON	IN	28	250	0.1	Surface Water	U.S. EPA (2016a)

PLASTICS MT. VERNON, LLC							
SABIC INNOVATIVE PLASTICS US LLC	SELKIRK	NY	9	250	0.03	Surface Water	U.S. EPA (2016a)
EQUISTAR CHEMICALS LP	LA PORTE	TX	9	250	0.03	Surface Water	U.S. EPA (2016a)
CHEMOURS COMPANY FC LLC	WASHINGTON	WV	7	250	0.03	Surface Water	U.S. EPA (2016a)
SHINTECH ADDIS PLANT A	ADDIS	LA	3	250	0.01	Surface Water	U.S. EPA (2016a)
STYROLUTION AMERICA LLC	CHANNAHON	IL	0.2	250	0.001	Surface Water	U.S. EPA (2016a)
DOW CHEMICAL CO DALTON PLANT	DALTON	GA	0.3	250	0.001	Surface Water	U.S. EPA (2016a)
PREGIS INNOVATIVE PACKAGING INC	WURTLAND	KY	0.02	250	0.0001	Surface Water	U.S. EPA (2016a)

2.17.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.18 Pharmaceutical Production

2.18.1 Process Description

OSHA (1991) indicated that the pharmaceutical industry utilizes methylene chloride as an extraction solvent in the purification of pharmaceutical products and in pill coatings. However, because of health concerns, methylene chloride was expected to be phased out of pill coatings. Methylene chloride is released during storage, reaction, separation, purification, and drying processes. Storage emissions result from displacement of air containing the solvent during tank charging. Reactor emissions result from displacement of air containing methylene chloride during reactor charging, solvent evaporation during the reaction cycle, venting of uncondensed methylene chloride from the overhead condenser during refluxing, purging of vaporized methylene chloride following a solvent wash, and opening of reactors during the reaction cycle to take quality control samples. Distillation condensers can emit methylene chloride as uncondensed solvent. During crystallization, emissions can result from the venting of vaporized solvent if the crystallization is being done by solvent evaporation. If crystallization is accomplished by cooling of the solution, there is little emission. Dryers are potential large emission sources, emission rates vary during drying cycles, and with the type of dryer being used. Emissions from air dryers are normally greater than those from vacuum dryers mainly because air dryers emissions are more dilute and difficult to control (OSHA, 1991).

2.18.2 Number of Sites and Potentially Exposed Workers

In 1991, OSHA estimated that 28 million pounds of methylene chloride was used in 76 pharmaceutical production facilities, exposing an estimated 1,007 workers. Most of the methylene chloride was used in pill coatings (OSHA, 1991). Because of the uncertainty in pill coating use, EPA determined the number of workers associated with pharmaceutical production using US Economic Census and Bureau of Labor Statistics (BLS) data. The number of establishments within the pharmaceutical industry that use methylene chloride-based products and the number of employees within an establishment exposed to these methylene chloride-based products are unknown. Therefore, EPA provides the total number of establishments as a bounding estimate of the number of establishments that use methylene chloride and estimates the number of employees that are potentially exposed to methylene chloride-based products at these establishments. These are likely overestimates of the actual number of establishments and employees potentially exposed to methylene chloride. EPA estimates 18,687 establishments, 39,836 workers, and 19,010 ONUs, as shown in Table 2-61 (U.S. BLS, 2016; U.S. Census Bureau, 2015).

Table 2-57. Number of U.S. Establishments, Workers, and ONUs for Testing Laboratories

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site [a]	Number of ONUs per Site [a]
325411	Medicinal and Botanical Manufacturing	461	44[b]	27[b]
325412	Pharmaceutical Preparation Manufacturing	1,290	44	27
Total establishments and number of potentially exposed workers and ONUs = [c]		1,751	77,000	47,000

a – Rounded to the nearest whole number.
b – No 2016 BLS data was available for this NAICS. Number of relevant workers per site and ONUs per site within this NAICS were calculated using the ratios of relevant workers and ONUs to the number of total employees for NAICS code 325412 – Pharmaceutical Preparation Manufacturing.
c – Unrounded figures were used for total worker and ONU calculations.

2.18.3 Exposure Assessment

2.18.3.1 Worker Activities

Based on the process description, the main potential for worker exposures appear to be during storage tank and reactor charging, when methylene chloride is added into the process.

2.18.3.2 Inhalation Exposure

Table_Apx A-28 in 4.2.5Appendix A summarizes the 8-hr TWA inhalation monitoring data for methylene chloride used in lithographic printing cleaning that EPA compiled from published literature sources. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

TNO (CIVO) (1999) reported that for pharmaceutical process operators, 8-hr exposure concentrations can be between 3.5 to 10 mg/m3. IPCS (1996) also indicated that sealed processes, high recovery rates, and careful handling of discharges can bring exposure rates to around 106 mg/m^3. Additional data were available from the 1985 EPA assessment, which covered production workers at pharmaceutical manufacturing facilities and reported exposures between ND (during film coating) and 4,628 mg/m^3 (during production)(12 data points).

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentration for this scenario is approximately three times higher than the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is approximately 41 times higher than the PEL.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-58.

Table 2-58. Worker Exposure to Methylene Chloride During Pharmaceutical Production

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	15	230	3,600
Average Daily Concentration (ADC)		52	820
Lifetime Average Daily Concentration (LADC)		91	1,800

Sources: TNO (CIVO) (1999); US EPA (1985).

2.18.4 Water Release Assessment

EPA identified facilities classified under three NAICS and SIC codes, listed in Table 2-59, that reported water releases in the 2016 TRI or 2016 DMR and may be related to use in pharmaceutical manufacturing. Table 2-60 lists all facilities classified under these NAICS and SIC codes that reported direct or indirect water releases. Other facilities in this industry may not dispose to water, or may not use methylene chloride in quantities that meet the TRI reporting threshold.

Table 2-59. Potential Industries Conducting Pharmaceutical Production in 2016 TRI or DMR

NAICS Code	NAICS Description
325411	Medicinal and Botanical Manufacturing
325412	Pharmaceutical Preparation Manufacturing
2833	MEDICINAL CHEM/BOTANICAL PRODU

Table 2-60. Reported 2016 TRI and DMR Releases for Pharmaceutical Manufacturing Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
ABBVIE-NORTH CH ICAGO FACILITY	NORTH CHICAGO	IL	2	300	0.01	POTW	U.S. EPA (2017c)
EUTICALS INC	SPRINGFIELD	MO	0.5	300	0.002	POTW	U.S. EPA (2017c)
MALLINCKRODT LLC	SAINT LOUIS	MO	7	300	0.02	POTW	U.S. EPA (2017c)
NORAMCO INC	WILMINGTON	DE	2	300	0.01	POTW	U.S. EPA (2017c)
AMRI RENSSELAER INC	RENSSELAER	NY	340	300	1	POTW	U.S. EPA (2017c)
E R SQUIBB & SONS LLC	NORTH BRUNSWICK	NJ	113	300	0.4	POTW	U.S. EPA (2017c)
EVONIK CORP TIPPECANOE LABORATORIES	LAFAYETTE	IN	2	300	0.01	Surface Water	U.S. EPA (2017c)
PACIRA PHARMACEUTICALS INC	SAN DIEGO	CA	40	300	0.1	POTW	U.S. EPA (2017c)
PCI SYNTHESIS	NEWBURYPORT	MA	0	300	0.002	POTW	U.S. EPA (2017c)
PFIZER PHARMACEUTICALS LLC	BARCELONETA	PR	20	300	0.1	POTW	U.S. EPA (2017c)
PHARMACIA & UPJOHN CO LLC A SUBSIDIARY OF PFIZER INC	PORTAGE	MI	2,588	300	9	99.9% POTW 0.1% Surface Water	U.S. EPA (2017c)
SI GROUP INC	ORANGEBURG	SC	42	300	0.1	Surface Water	U.S. EPA (2017c)
TEVA PHARMACEUTICALS USA	MEXICO	MO	10	300	0.03	POTW	U.S. EPA (2017c)
EVONIK DEGUSSA CORP TIPPECANOE LABORATORIES	LAFAYETTE	IN	3	300	0.01	Surface Water	U.S. EPA (2016a)

2.18.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.19 Lithographic Printing Plate Cleaning

2.19.1 Process Description

Solvents are used in lithographic printing to clean the blankets and rollers. Press operators commonly apply the solvent to a wipe cloth and wipe across the blanket to remove the ink, while companies have automated blanket wash systems where the solvent is applied to the blankets with a spray bar. It is generally necessary with these automated systems to periodically also clean the blankets by hand since they are not cleaned adequately with the automated systems. Press operators commonly clean the ink roller train by standing above the rollers and dispensing the cleaner from a squeeze bottle across the length of the top roller. Pressure is applied to the rollers with a squeegee and an ink tray is placed at the bottom of the roller train to catch the solvent/ink combination after it passes through the train ((IRTA), 2006). EPA has identified several lithographic printing cleaners (9.94 to 88.5 weight percent methylene chloride) (U.S. EPA, 2017b).

2.19.2 Number of Sites and Potentially Exposed Workers

EPA determined the number of workers associated with printing plate cleaning using US Economic Census and Bureau of Labor Statistics (BLS) data. The number of establishments within the lithographic printing sector that use methylene chloride-based products and the number of employees within an establishment exposed to these methylene chloride-based products are unknown. Therefore, EPA provides the total number of establishments as a bounding estimate of the number of establishments that use methylene chloride and estimates the number of employees that are potentially exposed to methylene chloride-based products at these establishments. These are likely overestimates of the actual number of establishments and employees potentially exposed to methylene chloride. EPA estimates 18,687 establishments, 39,836 workers, and 19,010 ONUs, as shown in Table 2-61 (U.S. BLS, 2016; U.S. Census Bureau, 2015).

Table 2-61. Number of U.S. Establishments, Workers, and ONUs for Printing

<table>
<tr><th>NAICS Codes</th><th>NAICS Description</th><th>Number of Establishments</th><th>Number of Workers Site [a]</th><th>Number of ONUs per Site [a]</th></tr>
<tr><td>323111</td><td>Commercial Printing (except Screen and Books)</td><td rowspan="2">18,687</td><td>2</td><td>1</td></tr>
<tr><td colspan="2">Total establishments and number of potentially exposed workers and ONUs = [b]</td><td>40,000</td><td>19,000</td></tr>
</table>

a – Rounded to the nearest worker.
b – Unrounded figures were used for total worker and ONU calculations.

2.19.3 Exposure Assessment

2.19.3.1 Worker Activities

As discussed in the process description, workers may be exposed to methylene chloride when manually wipe cleaning print blankets.

2.19.3.2 Inhalation Exposure

Table_Apx A-26 and Table_Apx A-27 in 4.2.5Appendix A summarize the inhalation monitoring data for methylene chloride used in lithographic printing cleaning that EPA compiled from published literature sources, including 8-hour TWA, short-term, and partial shift sampling results. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

8-hr TWA data are primarily from the 1985 EPA assessment covering various printers and activities, which ranged from ND (during printing) to 547.9 (during screen making for commercial letterpress) (44 data points) (US EPA, 1985). Additional data were also obtained from a 1998 occupational exposure study and a 1980 NIOSH inspection of a printing facility (Ukai et al., 1998); (Ahrenholz, 1980). Exposure data were for workers involved in the printing plate/roll cleaning. The 1998 occupational exposure study only presented the min, mean, and max values for 61 samples, while the 1980 NIOSH inspection included two full-shift readings (ND to 17.0 mg/m^3; ND was assessed as zero).

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentrations for this scenario is one order of magnitude lower than the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate is approximately three times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-62 for workers during printing.

Table 2-62. Worker Exposure to Methylene Chloride During Printing Plate Cleaning

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	>105[a]	3.7	270
Average Daily Concentration (ADC)		0.84	62
Lifetime Average Daily Concentration (LADC)		1.5	140

Sources: Ukai et al. (1998); US EPA (1985); Ahrenholz (1980)

a – One study indicated that statistics were based on 61 samples, but only provided the minimum, maximum, and mean values. Another study provided two exposure values, one of which was ND. ND was assessed as zero

Table 2-63 summarizes the available 4-hr TWA exposure data for workers from the same source identified above for the 8-hr TWA data. Data were taken in two 4-hr shifts.

Table 2-63. Worker Short-Term Exposure Data for Methylene Chloride During Printing Plate Cleaning

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Lithographic Printing Plate Cleaning	Ukai et al. (1998)	Cleaning of printing rolls / solvent in production	3.5	240
			940	
			3.6	
			480	

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.19.4 Water Release Assessment

EPA identified one facility in the 2016 DMR, potentially related to lithographic printing (SIC code 2752 - Commercial Printing, Lithographic) that reported water releases. Release for this facility is summarized in Table 2-64. EPA did not identify any potential lithographic printing facilities in the 2016 TRI that reported water releases. Other facilities in this industry may not dispose to water or may not use methylene chloride in quantities that meet the TRI reporting threshold.

Table 2-64. Reported 2016 TRI and DMR Releases for Potential Lithographic Printing Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
FORMER REXON FACILITY AKA ENJEMS MILLWORKS	WAYNE TWP	NJ	0.001	250	0.000004	Surface Water	U.S. EPA (2016a)

2.19.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.20Miscellaneous Non-Aerosol Industrial and Commercial Uses

2.20.1 Process Description

Based on products identified in EPA's *Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Methylene Chloride,* a variety of other non-aerosol uses may exist for methylene chloride, including use in crafting glues and cements, novelty items, and miscellaneous cleaners (U.S. EPA, 2017b). It is unclear at this time the total volume of methylene chloride used in any of these applications.

2.20.2 Number of Sites and Potentially Exposed Workers

Because of the breadth of industrial and commercial uses, the number of potential workers is unknown. In the 1980s and 1990s, there were an estimated 1.4 million workers potentially exposed to methylene chloride in the U.S., which is assumed as an upper bound (IARC, 2016, 3827786).

2.20.3 Exposure Assessment

2.20.3.1 Worker Activities

Workers using non-aerosol products containing methylene chloride in a commercial setting would likely perform various manual activities, such as applying the product on to substrates (wipe, brush, roller), or engage in transferring liquids between containers.

2.20.3.2 Inhalation Exposure

EPA compiled various miscellaneous 8-hr TWA monitoring data for non-aerosol commercial settings as shown in Table_Apx A-29 of 4.2.5Appendix A. 8-hr TWA data are from various

OSHA inspection at wholesalers and retail stores, and include generic worker activities, such as plant workers, service workers, laborers, etc. Exposure concentrations for various workers ranged from ND to 1,294.8 mg/m^3 (US EPA, 1985).

From available personal monitoring data, EPA calculated the 50th and 95th percentile 8-hr TWA concentrations to represent a central tendency and worst-case estimate of potential occupational inhalation exposures, respectively, for this life cycle stage. The central tendency 8-hr TWA exposure concentrations for workers is approximately three times higher than the OSHA PEL value of 87 mg/m3 (25 ppm), while the high-end estimate for workers is more than nine times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-65 for workers during industrial and commercial non-aerosol use.

Table 2-65. Worker Exposure to Methylene Chloride During Industrial and Commercial Non-Aerosol Use

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	108	57	930
Average Daily Concentration (ADC)		13	210
Lifetime Average Daily Concentration (LADC)		23	480

Sources: US EPA (1985).

EPA has not identified data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

2.20.4 Water Release Assessment

EPA did not identify quantitative information about potential water releases during non-aerosol use of methylene chloride. The majority of methylene chloride is expected to evaporate into the air, but releases to water may occur if equipment is cleaned with water.

2.20.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as potential direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.21 Waste Handling, Disposal, Treatment, and Recycling

2.21.1 Process Description

Each of the conditions of use of methylene chloride may generate waste streams of the chemical that are collected and transported to third-party sites for disposal, treatment, or recycling. Industrial sites that treat or dispose onsite wastes that they themselves generate are assessed in each condition of use assessment. Similarly, point source discharges of methylene chloride to surface water are assessed in each condition of use assessment in Sections 2.1 through 2.20

(point source discharges are exempt as solid wastes under RCRA). Wastes of methylene chloride that are generated during a condition of use and sent to a third-party site for treatment, disposal, or recycling may include the following:

- Wastewater: Methylene chloride may be contained in wastewater discharged to POTW or other, non-public treatment works for treatment. Industrial wastewater containing methylene chloride discharged to a POTW may be subject to EPA or authorized NPDES state pretreatment programs. The assessment of wastewater discharges to POTWs and non-public treatment works of methylene chloride is included in each of the condition of use assessments in Sections 2.1 through 2.20.

- Solid Wastes: Solid wastes are defined under RCRA as any material that is discarded by being: abandoned; inherently waste-like; a discarded military munition; or recycled in certain ways (certain instances of the generation and legitimate reclamation of secondary materials are exempted as solid wastes under RCRA). Solid wastes may subsequently meet RCRA's definition of hazardous waste by either being listed as a waste at 40 CFR §§ 261.30 to 261.35 or by meeting waste-like characteristics as defined at 40 CFR §§ 261.20 to 261.24. Solid wastes that are hazardous wastes are regulated under the more stringent requirements of Subtitle C of RCRA, whereas non-hazardous solid wastes are regulated under the less stringent requirements of Subtitle D of RCRA.

  Methylene chloride is a U-listed hazardous waste under code U080 under RCRA; therefore, discarded, unused pure and commercial grades of methylene chloride are regulated as a hazardous waste under RCRA (40 CFR § 261.33(f)). Additionally, methylene chloride is included in multiple waste codes under the F-list of non-specific source wastes (40 CFR § 261.31(a)).

- Wastes Exempted as Solid Wastes under RCRA: Certain conditions of use of methylene chloride may generate wastes of methylene chloride that are exempted as solid wastes under 40 CFR § 261.4(a). For example, the generation and legitimate reclamation of hazardous secondary materials of methylene chloride may be exempt as a solid waste.

2016 TRI data lists off-site transfers of methylene chloride to land disposal, wastewater treatment, incineration, and recycling facilities. About 93% of off-site transfers were incinerated, 6% sent to wastewater treatment, and less than 1% is recycled off-site or sent for land disposal (U.S. EPA, 2017c); see Figure 2-13.

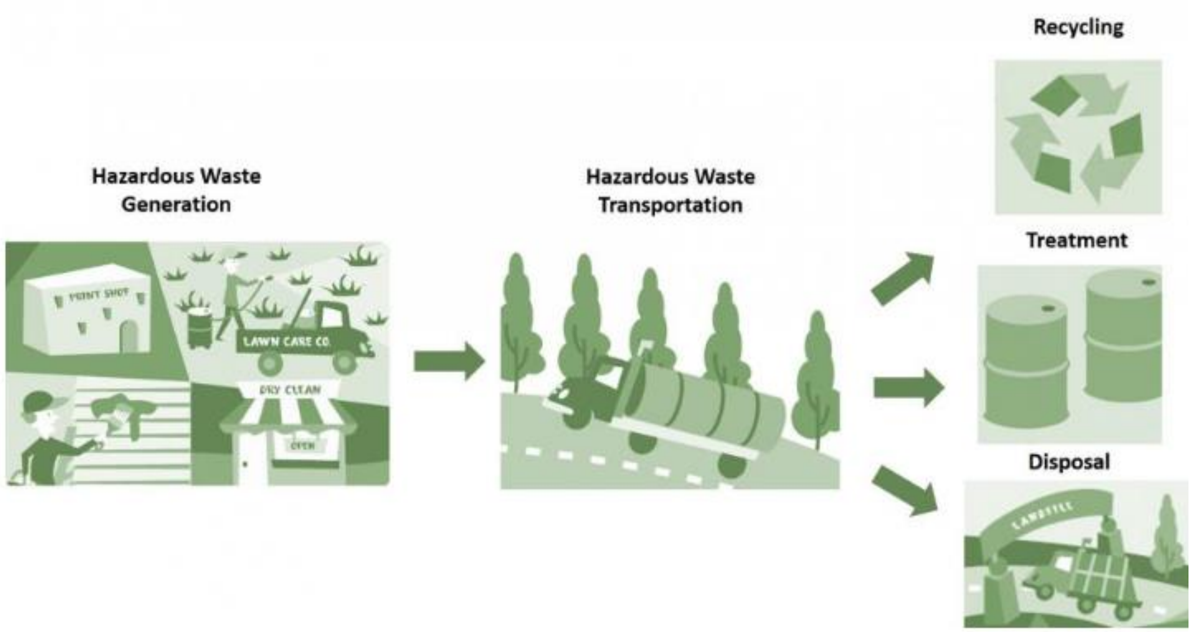

Figure 2-13. Typical Waste Disposal Process (U.S. EPA, 2017a)

Municipal Waste Incineration

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

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

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

Hazardous Waste Incineration

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

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

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

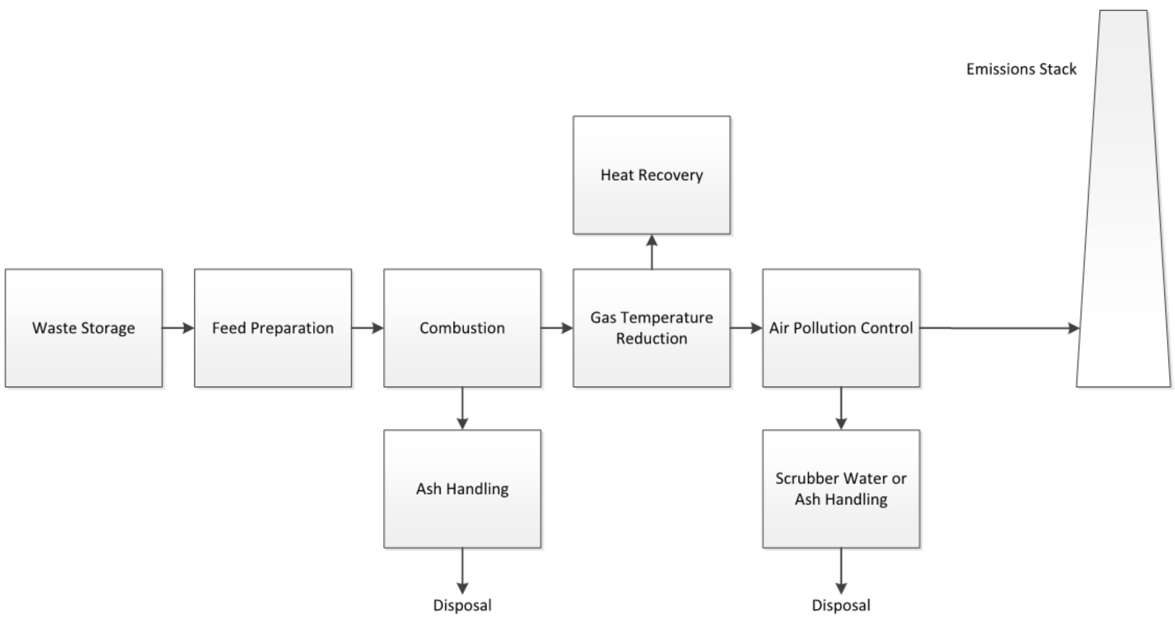

Figure 2-14. Typical Industrial Incineration Process

Municipal Waste Landfill

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

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

Hazardous Waste Landfill

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

2.21.2 Number of Sites and Potentially Exposed Workers

The total number of sites that treat and disposal wastes containing methylene chloride is not known. According to an OSHA source, there were an estimated 40 recovery facilities employing approximately 161 workers in 1991 (OSHA, 1991). For reporting year 2016, TRI included 26 facilities that reported releases of methylene chloride under NAICS code 562 (Waste Management and Remediation Services) (U.S. EPA, 2017c). Table 2-66 presents the estimated number of workers and ONUs at these facilities based on EPA's analysis of typical employment on those industry sectors (U.S. BLS, 2016; U.S. Census Bureau, 2015). It is possible that additional hazardous waste treatment facilities treat and dispose methylene chloride, but do not meet the TRI reporting threshold for reporting year 2016. In addition, it is possible that some consumer products containing methylene chloride may be improperly disposed as municipal solid wastes, and that some amount of methylene chloride is present in non-hazardous waste streams. Therefore, there may be up to 12,260 workers and 7,633 ONUs potentially exposed to methylene chloride.

Table 2-66. Number of U.S. Establishments, Workers, and ONUs for Waste Handling

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers per Site [a]	Number of ONUs per Site [a]
562211	Hazardous Waste Treatment and Disposal	892	9	5
562213	Solid Waste Combustors and Incinerators	102	13	8
562920	Materials Recovery Facilities	1,455	2	2
Total establishments and number of potentially exposed workers and ONUs = [bs]		2,449	12,000	7,600

a – Rounded to the nearest worker.
b – Unrounded figures were used for total worker and ONU calculations.

2.21.3 Exposure Assessment

2.21.3.1 Worker Activities

At waste disposal sites, workers are potentially exposed via dermal contact with waste containing methylene chloride or via inhalation of methylene chloride vapor. Depending on the concentration of methylene chloride in the waste stream, the route and level of exposure may be similar to that associated with container unloading activities. See Section 2.4.3.1 for the assessment of worker exposure from chemical unloading activities during import/repackaging.

Municipal Waste Incineration

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

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

Hazardous Waste Incineration

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

Municipal and Hazardous Waste Landfill

At landfills, typical worker activities may include operating refuse vehicles to weigh and unload the waste materials, operating bulldozers to spread and compact wastes, and monitoring, inspecting, and surveying and landfill site (CalRecycle, 2018).

2.21.3.2 Inhalation Exposures

EPA assumes that any exposures related to on-site waste treatment and disposal are addressed in the assessments for those uses in this report; therefore, this section assesses exposures to workers for wastes transferred from the use site to an off-site waste treatment and disposal facility.

Bulk Shipments of Liquid Hazardous Waste

EPA assumes methylene chloride wastes that are generated, transported, and treated or disposed as hazardous waste are done so as bulk liquid shipments. For example, a facility that uses methylene chloride as a processing aid may generate and store the waste processing aid as relatively pure methylene chloride and have it shipped to hazardous waste TSDFs for ultimate treatment, disposal, or recycling.

Table_Apx A-30 and Table_Apx A-31 in 4.2.5Appendix A summarize the 8-hr TWA inhalation monitoring data for waste handling and disposal that EPA compiled from published literature sources. This appendix also includes EPA's rationale for inclusion or exclusion of these data in the risk evaluation.

EPA's 1985 assessment included three full-shift data points for solvent reclaimers at solvent recovery sites, ranging from 10.5 to 19.2 mg/m^3 (US EPA, 1985). The U.S. DOD also provided four data points during waste disposal and sludge operations ranging from 0.4 to 2.3 mg/m^3 ((DOEHRS-IH), 2018). EPA assessed the 50th percentile value of 18.5 mg/m^3 as the central tendency, and the 95% percentile value of 19.0 mg/m^3 as the high-end estimate of potential occupational inhalation exposures for this life cycle stage. The central tendency exposure concentration for this scenario is an order of magnitude lower than the OSHA PEL value of 87 mg/m^3 (25 ppm) and high-end 8-hr TWA exposure concentration is approximately 4.5 times lower.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in 4.2.5Appendix B. The results of these calculations are shown in Table 2-21.

Table 2-67. Exposure to Methylene Chloride During Waste Handling and Disposal

	Number of Samples	Central Tendency (mg/m^3)	High-End (mg/m^3)
8-hr TWA Exposure Concentration	7	2.3	19
Average Daily Concentration (ADC)		0.5	4.4
Lifetime Average Daily Concentration (LADC)		0.9	9.7

Source: (DOEHRS-IH) (2018); US EPA (1985)

Table 2-68 summarizes the available short-term exposure data for workers from the DOD data.

Table 2-68. Worker Short-Term Exposure Data for Methylene Chloride During Waste Handling and Disposal

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m^3)	Exposure Duration (min)
Waste Handling	(DOEHRS-IH) (2018)	Transfer of solvent during waste disposal	2.9	30
			2.9	30
			1.8	144
			5.8	158
			2.7	159
			2.8	163
			0.8	173
			3.4	156

EPA has not identified exposure data on potential ONU inhalation exposures. Since ONUs do not directly handle formulations containing methylene chloride, EPA expects ONU inhalation exposures to be lower than worker inhalation exposures.

Municipal Solid Wastes

Certain commercial and consumer conditions of use of methylene chloride may generate solid wastes that are sent to municipal waste combustors or landfills. For example, spent aerosol degreasing cans containing residual methylene chloride used by mechanics or consumers may be disposed as household hazardous waste, which is exempted as a hazardous waste under RCRA. While some municipalities may have collections of household hazardous wastes to prevent the comingling of household hazardous wastes with municipal waste streams, some users may inappropriately dispose of household hazardous wastes in the municipal waste stream.

EPA is not able to quantitatively assess worker or ONU exposures to methylene chloride within municipal solid waste streams. The quantities of methylene chloride are expected to be diluted among the comingled municipal solid waste stream, and uses of methylene chloride, such as aerosol degreasing, result in waste methylene chloride being contained in a sealed can. Exposures to methylene chloride in spent pressurized cans are only expected if the can is punctured during waste handling.

2.21.4 Water Release Assessment

EPA identified facilities classified under five NAICS and SIC codes, listed in Table 2-69, that reported water releases in the 2016 TRI and 2016 DMR and may be related to recycling/disposal.

Table 2-70 lists all facilities classified under these NAICS and SIC codes that reported direct or indirect water releases in the 2016 TRI or 2016 DMR. To estimate the daily release, EPA/OPPT used a default assumption of 250 days/yr of operation and averaged the annual release over the operating days.

Table 2-69. Potential Industries Conducting Waste Handling, Disposal, Treatment, and Recycling in 2016 TRI or DMR

NAICS/SIC Code	NAICS/SIC Description
331492	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)
562211	Hazardous Waste Treatment and Disposal
4953	REFUSE SYSTEMS
7699	REPAIR SHOPS & RELATED SERVICE
9511	AIR & WATER RES & SOL WSTE MGT

Table 2-70. Reported 2016 TRI and DMR Releases for Potential Recycling/Disposal Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
JOHNSON MATTHEY	WEST DEPTFORD	NJ	620	250	2	Non-POTW WWT	U.S. EPA (2017c)
CLEAN HARBORS DEER PARK LLC	LA PORTE	TX	522	250	2	Non-POTW WWT	U.S. EPA (2017c)
CLEAN HARBORS EL DORADO LLC	EL DORADO	AR	113	250	0.5	Non-POTW WWT	U.S. EPA (2017c)
TRADEBE TREATMENT & RECYCLING LLC	EAST CHICAGO	IN	19	250	0.1	Non-POTW WWT	U.S. EPA (2017c)
VEOLIA ES TECHNICAL SOLUTIONS LLC	WEST CARROLLTON	OH	2	250	0.01	POTW	U.S. EPA (2017c)
VEOLIA ES TECHNICAL SOLUTIONS LLC	AZUSA	CA	0	250	0.002	POTW	U.S. EPA (2017c)
VEOLIA ES TECHNICAL SOLUTIONS LLC	MIDDLESEX	NJ	115,059	250	460	99.996% Non-POTW WWT 0.004% POTW	U.S. EPA (2017c)
CHEMICAL WASTE MANAGEMENT	EMELLE	AL	4	250	0.01	Surface Water	U.S. EPA (2016a)
OILTANKING HOUSTON INC	HOUSTON	TX	1	250	0.003	Surface Water	U.S. EPA (2016a)
HOWARD CO ALFA RIDGE LANDFILL	MARRIOTTSVILLE	MD	0.1	250	0.0002	Surface Water	U.S. EPA (2016a)

CLIFFORD G HIGGINS DISPOSAL SERVICE INC SLF	KINGSTON	NJ	0.02	250	0.0001	Surface Water	U.S. EPA (2016a)
CLEAN WATER OF NEW YORK INC	STATEN ISLAND	NY	2	250	0.01	Surface Water	U.S. EPA (2016a)
FORMER CARBORUNDU M COMPLEX	SANBORN	NY	0.2	250	0.001	Surface Water	U.S. EPA (2016a)

2.21.5 Uncertainties

In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

2.22 Other Reported Water Releases

Table 2-71 lists surface water releases of methylene chloride reported in the 2016 DMR from wastewater treatment plants.

Table 2-71. Reported 2016 DMR Releases for Wastewater Treatment Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
EDWARD C. LITTLE WRP	EL SEGUNDO	CA	4	365	0.01	Surface Water	U.S. EPA (2016a)
JUANITA MILLENDER-MCDONALD CARSON REGIONAL WRP	CARSON	CA	1	365	0.002	Surface Water	U.S. EPA (2016a)
LONDON WTP	LONDON	OH	0.4	365	0.001	Surface Water	U.S. EPA (2016a)
LONG BEACH (C) WPCP	LONG BEACH	NY	2,730	365	7	Surface Water	U.S. EPA (2016a)
MIDDLESEX COUNTY UTILITIES AUTHORITY	SAYREVILLE	NJ	1,634	365	4	Surface Water	U.S. EPA (2016a)
JOINT WATER POLLUTION CONTROL PLANT	CARSON	CA	604	365	1.7	Surface Water	U.S. EPA (2016a)
HYPERION TREATMENT PLANT	PLAYA DEL REY	CA	164	365	0.5	Surface Water	U.S. EPA (2016a)
SD CITY PT LOMA	SAN DIEGO	CA	164	365	0.5	Surface Water	U.S. EPA (2016a)

Site Identity	City	State	Annual Release (kg/site -yr)	Annual Release Days (days/yr)	Daily Release (kg/site -day)	Release Media	Sources & Notes
WASTEWATER TREATMENT							
REGIONAL SANITATION DISTRICT	ELK GROVE	CA	86	365	0.2	Surface Water	U.S. EPA (2016a)
BERGEN POINT STP & BERGEN AVE DOCK	W BABYLON	NY	65	365	0.2	Surface Water	U.S. EPA (2016a)
NEW ROCHELLE STP	NEW ROCHELLE	NY	15	365	0.04	Surface Water	U.S. EPA (2016a)
SIMI VLY CNTY SANITATION	SIMI VALLEY	CA	7	365	0.02	Surface Water	U.S. EPA (2016a)
OCEANSIDE OCEAN OUTFALL	OCEANSIDE	CA	4	365	0.01	Surface Water	U.S. EPA (2016a)
SANTA CRUZ WASTEWATER TREATMENT PLANT	SANTA CRUZ	CA	2	365	0.01	Surface Water	U.S. EPA (2016a)
CORONA WWTP 1	CORONA	CA	2	365	0.005	Surface Water	U.S. EPA (2016a)
BLIND BROOK SD WWTP	RYE	NY	1	365	0.003	Surface Water	U.S. EPA (2016a)
MCKINLEYVILLE CSD - WASTEWATER TREATMENT PLANT	MCKINLEYVILLE	CA	1	365	0.003	Surface Water	U.S. EPA (2016a)
SAN JOSE CREEK WATER RECLAMATION PLANT	WHITTIER	CA	0.4	365	0.001	Surface Water	U.S. EPA (2016a)
CARMEL AREA WASTEWATER DISTRICT TREATMENT FACILITY	CARMEL	CA	0.3	365	0.001	Surface Water	U.S. EPA (2016a)
CAMERON TRADING POST WWTP	CAMERON	AZ	0.2	365	0.001	Surface Water	U.S. EPA (2016a)
CITY OF RED BLUFF WASTEWATER RECLAMATION PLANT	RED BLUFF	CA	0.2	365	0.001	Surface Water	U.S. EPA (2016a)
91ST AVE WASTEWATER TREATMENT PLANT	TOLLESON	AZ	31	365	0.1	Surface Water	U.S. EPA (2016a)
EVERETT WATER	EVERETT	WA	30	365	0.1	Surface Water	U.S. EPA (2016a)

Site Identity	City	State	Annual Release (kg/site -yr)	Annual Release Days (days/yr)	Daily Release (kg/site -day)	Release Media	Sources & Notes
POLLUTION CONTROL FACILITY							
PIMA COUNTY - INA ROAD WWTP	TUCSON	AZ	27	365	0.1	Surface Water	U.S. EPA (2016a)
23RD AVENUE WASTEWATER TREATMENT PLANT	PHOENIX	AZ	19	365	0.1	Surface Water	U.S. EPA (2016a)
SUNNYSIDE STP	SUNNYSIDE	WA	2	365	0.005	Surface Water	U.S. EPA (2016a)
AGUA NUEVA WRF	TUCSON	AZ	1	365	0.003	Surface Water	U.S. EPA (2016a)
PORT OF SUNNYSIDE INDUSTRIAL WWTF	SUNNYSIDE	WA	1	365	0.002	Surface Water	U.S. EPA (2016a)
APACHE JUNCTION WWTP	APACHE JUNCTION	AZ	0.1	365	0.0003	Surface Water	U.S. EPA (2016a)

Table 2-72 lists surface water releases of methylene chloride reported in the 2016 TRI from for facilities that were unable to be associated with specific conditions of use outlined in Sections 2.1 through 2.21.

Table 2-72. Reported 2016 TRI and DMR Releases for Unclassified Facilities

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
APPLIED BIOSYSTEM S LLC	PLEASANTON	CA	42	250	0.2	Non-POTW WWT	U.S. EPA (2017c)
EMD MILLIPORE CORP	JAFFREY	NH	2	250	0.01	POTW	U.S. EPA (2017c)
GBC METALS LLC SOMERS THIN STRIP	WATERBURY	CT	0.2	250	0.001	Surface Water	U.S. EPA (2016a)
HYSTER-YALE GROUP, INC	SULLIGENT	AL	0.0002	250	0.000001	Surface Water	U.S. EPA (2016a)
AVNET INC (FORMER IMPERIAL SCHRADE)	ELLENVILLE	NY	0.005	250	0.00002	Surface Water	U.S. EPA (2016a)

Site Identity	City	State	Annual Release (kg/site-yr)	Annual Release Days (days/yr)	Daily Release (kg/site-day)	Release Media	Sources & Notes
BARGE CLEANING AND REPAIR	CHANNELVIEW	TX	0.1	250	0.0003	Surface Water	U.S. EPA (2016a)
AC & S INC	NITRO	WV	0.01	250	0.00005	Surface Water	U.S. EPA (2016a)
MOOG INC - MOOG IN-SPACE PROPULSION ISP	NIAGARA FALLS	NY	0.003	250	0.00001	Surface Water	U.S. EPA (2016a)
OILTANKING JOLIET	CHANNAHON	IL	1	250	0.003	Surface Water	U.S. EPA (2016a)
NIPPON DYNAWAVE PACKAGING COMPANY	LONGVIEW	WA	22	250	0.1	Surface Water	U.S. EPA (2016a)
TREE TOP INC WENATCHEE PLANT	WENATCHEE	WA	0.01	250	0.00003	Surface Water	U.S. EPA (2016a)
CAROUSEL CENTER	SYRACUSE	NY	0.001	250	0.000002	Surface Water	U.S. EPA (2016a)

3 Summary of Occupational Exposure Assessment

3.1 Inhalation Exposure Assessment

Table 3-1 summarizes the inhalation exposure assessment for each Occupational Exposure Scenario as described in Section 2. For each scenario, central tendency and high-end estimates are provided.

Table 3-1. Summary of Acute and Chronic Inhalation Exposures to Methylene Chloride for Central and Higher-End Scenarios by Use

OES	Occupational Exposure Scenario	Category	Acute Exposures		Chronic, Non-Cancer Exposures (ADCs)		Chronic, Cancer Exposures	
			AC_{DCM}, 8-hr TWA (mg/m3)		ADC_{DCM}, 24-hr TWA (mg/m3)		$LADC_{DCM}$, 24-hr TWA (mg/m3)	
			Central Tendency	High End	Central Tendency	High End	Central Tendency	High End
1	Manufacturing	Worker & ONU	0.36	4.6	0.08	1.1	0.14	2.4
2	Processing as a Reactant	Worker & ONU	1.6	10	0.37	2.4	0.65	5.3

3	Processing - Incorporation into Formulation	Worker & ONU	180	1,800	41	410	72	920
4	Import and Repackaging	Worker & ONU	8.8	140	2.0	31	3.50	71
5	Batch Open-Top Vapor Degreasing (Modeled)	Worker	170	740	29	130	15	66
5	Batch Open-Top Vapor Degreasing (Modeled)	ONU	86	460	15	78	7.6	40
6	Conveyorized Vapor Degreasing (Modeled)	Worker	490	1,400	84	240	43	120
6	Conveyorized Vapor Degreasing (Modeled)	ONU	250	900	44	150	22	79
7	Cold Cleaning	Worker & ONU	280	1,000	64	230	110	510
8	Aerosol Degreasing/Lubricants (Modeled)	Worker	22	79	3.8	14	1.9	6.9
8	Aerosol Degreasing/Lubricants (Modeled)	ONU	0.40	3.3	0.07	0.56	0.04	0.29
9	Adhesives/Sealants (Spray)	Worker & ONU	39	560	8.9	130	16.0	290
9	Adhesives/Sealants (Non-Spray)	Worker & ONU	10	300	2.4	68	4.2	150
10	Paints and Coatings (Spray)	Worker & ONU	70	360	16	83	28	190
10	Paints and Coatings (Unknown Application Method)	Worker & ONU	7.1	11	1.6	2.4	2.80	5.5
11	Adhesive and Caulk Removers	Worker & ONU	1,500	3,000	350	680	600	1,500
12	Fabric Finishing	Worker & ONU	87	160	20	37	35.0	84
13	Spot Cleaning	Worker & ONU	2.6	64	0.6	15	1.00	33.0
14	CTA Manufacturing	Worker & ONU	1,000	1,400	240	320	410	560
15	Flexible PU Foam Manufacturing	Worker & ONU	210	1,000	48	230	84	510
16	Laboratory Use	Worker & ONU	3.5	12.0	0.8	2.7	1.40	6
17	Plastic Product Manufacturing	Worker	14	260	3.2	60	5.5	130
17	Plastic Product Manufacturing	ONU	9.0	9.0	2.1	2.1	3.6	4.6
18	Pharmaceutical	Worker & ONU	230	3,600	53	820	91	1,800
19	Lithographic Printing Cleaner	Worker & ONU	3.7	270	0.84	62	1.50	140

20	Non-Aerosol Commercial Use (Cleaning Solvent)	Worker & ONU	57	930	13	210	23.0	480
21	Waste Handling, Disposal, Treatment, and Recycling	Worker & ONU	2.3	19	0.5	4.3	0.9	9.7

3.2 Dermal Exposure Assessment

Because methylene chloride is a volatile liquid, the dermal absorption of methylene chloride depends on the type and duration of exposure. Where exposure is not occluded, only a fraction of methylene chloride that comes into contact with the skin will be absorbed as the chemical readily evaporates from the skin. However, dermal exposure may be significant in cases of occluded exposure, repeated contacts, or dermal immersion. For example, work activities with a high degree of splash potential may result in methylene chloride liquids trapped inside the gloves, inhibiting the evaporation of methylene chloride and increasing the exposure duration.

To assess exposure, EPA used the equations and parameter values in 4.2.5Appendix E to calculate the dermal retained dose for both non-occluded and occluded scenarios. The equation modifies the *EPA/OPPT 2-Hand Dermal Exposure to Liquids Model* by incorporating a "fraction absorbed (f_{abs})" parameter to account for the evaporation of volatile chemicals and a "protection factor (PF)" to account for glove use. Default PF values, which vary depending on the type of glove used and the presence of employee training program, are shown in Table 3-2:

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

Where:

S is the surface area of contact (cm^2)
Q_u is the quantity remaining on the skin (mg/cm^2-event)
Y_{derm} is the weight fraction of the chemical of interest in the liquid ($0 \leq Y_{derm} \leq 1$)
FT is the frequency of events (integer number per day)
f_{abs} is the fraction of applied mass that is absorbed (Default: 0.08 for methylene chloride during industrial use; 0.13 for methylene chloride during commercial use)
PF is the glove protection factor (Default: see Table 3-2)

The steady state fractional absorption (f_{abs}) for methylene chloride is estimated to be 0.08 and 0.13, for industrial use, and commercial use, respectively, based on a theoretical framework provided by Kasting (2005), meaning approximately 8 to 13 percent of the applied dose is absorbed through the skin following exposure.

Table 3-2. Glove Protection Factors for Different Dermal Protection Strategies

Dermal Protection Characteristics	Setting	Protection Factor, PF
a. No gloves used, or any glove / gauntlet without permeation data and without employee training	Industrial and Commercial Uses	1

b. Gloves with available permeation data indicating that the material of construction offers good protection for the substance		5
c. Chemically resistant gloves (i.e., as *b* above) with "basic" employee training		10
d. Chemically resistant gloves in combination with specific activity training (e.g., procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur	Industrial Uses Only	20

Table 3-3 presents the estimated dermal retained dose for *workers* in various exposure scenarios, including what-if scenarios for glove use. The dose estimates assume one exposure event (applied dose) per work day and that approximately 8 to 13 percent[1] of the applied dose is absorbed through the skin. Table 3-3 also includes estimated dermal retained dose for occluded scenarios for conditions of use where EPA determined occlusion was reasonably expected to occur. Occluded scenarios are generally expected where workers are expected to come into contact with bulk liquid methylene chloride during use in open systems (e.g., during solvent changeout in vapor degreasing and dry cleaning) and not expected in closed-type systems (e.g., during connection/disconnection of hoses used in loading of bulk containers in manufacturing). See discussion on occlusion in for further description of these scenarios. The exposure estimates are provided for each condition of use, where the conditions of use are "binned" based on the maximum possible exposure concentration (Y_{derm}), the likely level of exposure, and potential for occlusion. The exposure concentration is determined based on EPA's review of currently available products and formulations containing methylene chloride.

- **Bin 1:** Bin 1 covers industrial uses that generally occur in closed systems. For these uses, dermal exposure is likely limited to chemical loading/unloading activities (e.g., connecting hoses). and taking quality control samples. EPA assesses the following glove use scenarios for Bin 1 conditions of use:
  - No gloves used: Operators in these industrial uses, while working around closed-system equipment, may not wear gloves or may wear gloves for abrasion protection or gripping that are not chemical resistant.
  - Gloves used with a protection factor of 5, 10, and 20: Operators may wear chemical-resistant gloves when taking quality control samples or when connecting and disconnecting hoses during loading/unloading activities. EPA assumes gloves may offer a range of protection, depending on the type of glove and employee training provided.
  - Scenarios not assessed: EPA does not assess occlusion as workers in these industries are not likely to come into contact with bulk liquid methylene chloride that could lead to chemical permeation under the cuff of the glove or excessive liquid contact time leading to chemical permeation through the glove.
- **Bin 2:** Bin 2 covers industrial degreasing uses, which are not closed systems. For these uses, there is greater opportunity for dermal exposure during activities such as charging and draining degreasing equipment, drumming waste solvent, and removing waste sludge. EPA assesses the following glove use scenarios for Bin 2 conditions of use:

[1] The absorbed fraction (f_{abs}) is a function of indoor air speed, which differs for industrial and commercial settings.

    - No gloves used: Due to the variety of shop types in these uses the actual use of gloves is uncertain. EPA assumes workers may not wear gloves or may wear gloves for abrasion protection or gripping that are not chemical resistant during routine operations such as adding and removing parts from degreasing equipment.
    - Gloves used with a protection factor of 5, 10, and 20: Workers may wear chemical-resistant gloves when charging and draining degreasing equipment, drumming waste solvent, and removing waste sludge. EPA assumes gloves may offer a range of protection, depending on the type of glove and employee training provided.
    - Occluded Exposure: Occlusion may occur when workers are handling bulk liquid methylene chloride when charging and draining degreasing equipment, drumming waste solvent, and removing waste sludge that could lead to chemical permeation under the cuff of the glove or excessive liquid contact time leading to chemical permeation through the glove.
- **Bin 3:** Bin 3 covers the use of methylene chloride in commercial activities that may involve spray application. Workers (sprayers) can be dermally exposed when mixing product, charging product to spray equipment, and cleaning spray equipment. Other workers (non-sprayers) may also have incidental contact with the applied product during subsequent fabrication steps. EPA assesses the following glove use scenarios for Bin 3 conditions of use:
    - No gloves used: Actual use of gloves in this use is uncertain. EPA assumes workers may not wear gloves or may wear gloves for abrasion protection or gripping that are not chemical resistant during routine operations such as spray applications and fabrication steps (non-sprayers).
    - Gloves used with a protection factor of 5 and 10: Workers may wear chemical-resistant gloves when mixing adhesive/sealant, charging adhesive/sealant to spray equipment, and cleaning adhesive/sealant spray equipment. EPA assumes the commercial facilities in Bin 3 do not offer activity-specific training on donning and doffing gloves.
    - Occluded Exposure: Occlusion may occur when workers are handling bulk liquid methylene chloride when mixing adhesive/sealant, charging adhesive/sealant to spray equipment, and cleaning adhesive/sealant spray equipment that could lead to chemical permeation under the cuff of the glove or excessive liquid contact time leading to chemical permeation through the glove.
    - Scenarios not assessed: EPA does not assess glove use with protection factors of 20 as EPA assumes chemical-resistant gloves used in these industries would either not be accompanied by training or be accompanied by basic employee training, but not activity-specific training.
- **Bin 4:** Bin 4 covers non-aerosol commercial activities of similar maximum concentration, such as in laboratories, or miscellaneous uses such as novelty item manufacturing, general cleaning, or crafting products. Workers will likely apply the products to relatively small surfaces via brush, roller, or wipe, or transfer liquids from various containers. EPA assesses the following glove use scenarios for Bin 4 conditions of use:

  - No gloves used: Actual use of gloves in this use is uncertain. EPA assumes workers may not wear gloves during routine operations (e.g., spot cleaning).
  - Gloves used with a protection factor of 5 and 10: Workers may wear chemical-resistant gloves when charging and draining solvent to/from machines, removing and disposing sludge, and maintaining equipment. EPA assumes site-specific training practices on glove use may vary including potentially no training activities for employees.
  - Gloves used with a protection factor of 10: Workers may wear chemical-resistant gloves when charging and draining solvent to/from machines, removing and disposing sludge, and maintaining equipment. EPA assumes the commercial facilities in Bin 4 do not offer activity-specific training on donning and doffing gloves.
  - Occluded Exposure: Occlusion may occur when workers are handling bulk liquid methylene chloride when charging and draining solvent to/from machines, removing and disposing sludge, and maintaining equipment that could lead to chemical permeation under the cuff of the glove or excessive liquid contact time leading to chemical permeation through the glove.
  - Scenarios not assessed: EPA does not assess glove use with protection factors of 20 as EPA assumes chemical-resistant gloves used in these industries would either not be accompanied by training or be accompanied by basic employee training, but not activity-specific training.
- **Bin 5:** Bin 5 covers aerosol uses, where workers are likely to have direct dermal contact with film applied to substrate and incidental deposition of aerosol to skin. EPA assesses the following glove use scenarios for Bin 5 conditions of use:
  - No gloves used: Actual use of gloves in this use is uncertain. EPA assumes workers may not wear gloves or may wear gloves for abrasion protection or gripping that are not chemical resistant during routine aerosol applications.
  - Gloves used with a protection factor of 5 and 10: Workers may wear chemical-resistant gloves when applying aerosol products. EPA assumes the commercial facilities in Bin 5 do not offer activity-specific training on donning and doffing gloves.
  - Gloves used with a protection factor of 10: Workers may wear chemical-resistant gloves when applying aerosol products. EPA assumes site-specific training practices on glove use may vary and that the commercial facilities in Bin 5 may offer basic employee training on glove use but not activity-specific training on donning and doffing gloves.
  - Scenarios not assessed: EPA does not assess glove use with protection factors of 20 as EPA assumes chemical-resistant gloves used in these industries would either not be accompanied by training or be accompanied by basic employee training, but not activity-specific training. EPA does not assess occlusion for aerosol applications because methylene chloride formulation is often supplied in an aerosol spray can and contact with bulk liquid is unlikely. EPA also does not assess occlusion for non-aerosol niche uses because the potential for occlusion is unknown

As shown in the table, the calculated retained dose is low for all non-occluded scenarios as methylene chloride evaporates quickly after exposure. Dermal exposure to liquid is not expected for occupational non-users, as they do not directly handle methylene chloride.

Table 3-3. Modeled Dermal Retained Dose (mg/day) for Workers in All Conditions of Use

Occupational Exposure Scenario	Bin	Max Y_{derm}	Non-Occluded Exposure (mg/day)				Occluded Exposure
			No Gloves (PF = 1)	**Protective Gloves** (PF = 5)	**Protective Gloves** (Commercial uses, PF = 10)	**Protective Gloves** (Industrial uses, PF = 20)	
Manufacturing Import and Repackaging Processing as a Reactant Processing - Incorporation into Formulation, Mixture, or Rxn Product Pharmaceutical Waste Handling, Disposal, Treatment, and Recycling	Bin 1 - Industrial	1.0	60 (CT) 180 (HE)	12 (CT) 36 (HE)	6 (CT) 18 (HE)	3 (CT) 9 (HE)	N/A – occlusion not expected
Use of Adhesives and Sealants Use of Paints and Coatings Flexible PU Foam Manufacturing Batch Open-Top Vapor Degreasing Conveyorized Vapor Degreasing Cold Cleaning CTA Film Production Plastic Product Manufacturing	Bin 2 - Industrial	1.0	60 (CT) 180 (HE)	12 (CT) 36 (HE)	6 (CT) 18 (HE)	3 (CT) 9 (HE)	2,247
Use of Adhesives and Sealants Use of Paints and Coatings	Bin 3 - Commercial	1.0	94 (CT) 280 (HE)	19 (CT) 57 (HE)	9 (CT) 28 (HE)	5 (CT) 14 (HE)	2,247
Fabric Finishing		0.95	90 (CT) 270 (HE)	18 (CT) 54 (HE)	9 (CT) 27 (HE)	4 (CT) 13 (HE)	2,135
Adhesive and Caulk Removers Spot Cleaning		0.9	85 (CT) 260 (HE)	17 (CT) 51 (HE)	9 (CT) 26 (HE)	4 (CT) 13 (HE)	2,022
Lithographic Printing Cleaner		0.885	84 (CT) 250 (HE)	17 (CT) 50 (HE)	8 (CT) 25 (HE)	4 (CT) 13 (HE)	1,989

Table 3-3. Modeled Dermal Retained Dose (mg/day) for Workers in All Conditions of Use

Occupational Exposure Scenario	**Bin**	**Max Y_{derm}**	**Non-Occluded Exposure (mg/day)**				**Occluded Exposure**
			No Gloves (PF = 1)	**Protective Gloves** (PF = 5)	**Protective Gloves** (Commercial uses, PF = 10)	**Protective Gloves** (Industrial uses, PF = 20)	
Laboratory Use Miscellaneous Non-Aerosol Commercial Uses (crafting glues and cements, novelty items)	Bin 4 – Commercial	1.0	94 (CT) 280 (HE)	19 (CT) 57 (HE)	9 (CT) 28 (HE)	5 (CT) 14 (HE)	2,247
Miscellaneous Non-Aerosol Industrial Uses (solvents and degreasers)	Bin 4-Industrial	1.0	60 (CT) 180 (HE)	12 (CT) 36 (HE)	6 (CT) 18 (HE)	3 (CT) 9 (HE)	2,247
Commercial Aerosol Products	Bin 5 - Commercial	1.0	94 (CT) 280 (HE)	19 (CT) 57 (HE)	9 (CT) 28 (HE)	5 (CT) 14 (HE)	N/A – occlusion not expected

CT – Central Tendency; HE – High End

4 Discussion of Uncertainties and Limitations

4.1 Variability

EPA addressed variability in models by identifying key model parameters to apply a statistical distribution that mathematically defines the parameter's variability. EPA defined statistical distributions for parameters using documented statistical variations where available. Where the statistical variation is not known, assumptions are made to estimate the parameter distribution using available literature data.

4.2 Uncertainties and Limitations

Uncertainty is "the lack of knowledge about specific variables, parameters, models, or other factors" and can be described qualitatively or quantitatively (U.S. EPA, 2001; HERO 201612). The following sections discuss uncertainties in each of the assessed methylene chloride use scenarios.

4.2.1 Number of Workers

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

CDR data are used to estimate the number of workers associated with manufacturing. There are inherent limitations to the use of CDR data as they are reported by manufacturers and importers of methylene chloride. Manufacturers and importers are only required to report if they manufactured or imported methylene chloride in excess of 25,000 pounds at a single site during any calendar from 2012 to 2015; as such, CDR may not capture all sites and workers associated with any given chemical.

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

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

4.2.2 Analysis of Exposure Monitoring Data

In most scenarios where data were available, EPA did not find enough data to determine complete statistical distributions of actual air concentrations for the workers exposed to methylene chloride. Ideally, EPA would like to know 50th and 95th percentiles for each exposed population. In the absence of percentile data for monitoring, the air concentration means and medians (means are preferred over medians) of the data sets served as substitutes for 50th percentiles (central tendencies) of the actual distributions, whereas high ends of ranges served as substitutes for 95th percentiles of the actual distributions. However, these substitutes are uncertain and are weak substitutes for the ideal percentiles. For instance, in the few cases where enough data were found to determine statistical means and 95th percentiles, the associated substitutes (i.e., medians and high ends of ranges) were shown to overestimate exposures, sometimes significantly. While it is clear that most air concentration data represent real exposure levels, EPA cannot determine whether these concentrations are representative of the statistical distributions of actual air concentrations to which workers are exposed. It is unknown whether these uncertainties overestimate or underestimate exposures.

This report uses existing worker exposure monitoring data to assess exposure to methylene chloride during all conditions of use. To analyze the exposure data, EPA categorized each PBZ and area data point as either “worker” or “occupational non-user”. The categorizations are based on descriptions of worker job activity as provided in literature and EPA’s judgment. In general, PBZ samples are categorized as “worker” and area samples are categorized as “occupational non-user”.

Exposures for occupational non-users can vary substantially. Most data sources do not sufficiently describe the proximity of these employees to the exposure source. As such, exposure levels for the “occupational non-user” category will have high variability depending on the specific work activity performed. It is possible that some employees categorized as “occupational non-user” have exposures similar to those in the “worker” category depending on their specific work activity pattern.

Some data sources may be inherently biased. For example, bias may be present if exposure monitoring was conducted to address concerns regarding adverse human health effects reported following exposures during use. Similarly, OSHA CEHD are obtained from OSHA inspections, which may be the result of worker complaints, and may provide exposure results that are generally more conservative than the industry average.

Some air concentration data comes from sources pre-dating the most recent PEL update for methylene chloride in 1997. PEL changes can drive improvements in engineering controls or other efforts to reduce ambient exposure to meet the PEL. Use of pre-PEL data may overestimate some exposures in some OESs.

Due to data limitations in most OESs, EPA combined inhalation data from two or more data sets when metadata were not available to distinguish between OES subcategories. These combinations introduce uncertainties as to whether data from disparate worker populations had been combined into one OES or OES subcategory. This same uncertainty applies to mixing data collected pre-PEL change with data collected post-PEL change.

Some scenarios have limited exposure monitoring data in literature, if any. Where there are few data points available, it is unlikely the results will be representative of worker exposure across the industry.

Where data were not available, the modeling approaches used to estimate air concentrations also have uncertainties. Parameter values used in models did not all have distributions known to represent the modeled scenario. It is also uncertain whether the model equations generate results that represent actual workplace air concentrations. It is unknown whether these uncertainties overestimate or underestimate exposures. Additional model-specific uncertainties are included below.

EPA calculated ADC values assuming a high-end exposure duration of 250 days per year over 40 years and LADC values assuming a high-end exposure duration of 250 days per year over 78 years. This assumes the workers and occupational non-users are regularly exposed during their entire working lifetime, which likely results in an overestimate. Individuals may change jobs during the course of their career such that they are no longer exposed to methylene chloride, and that actual ADC and LADC values become lower than the estimates presented.

4.2.3 Near-Field/Far-Field Model Framework

The near-field/far-field approach is used as a framework to model inhalation exposure for many conditions of use. The following describe uncertainties and simplifying assumptions generally associated with this modeling approach:

- There is some degree of uncertainty associated with each model input parameter. In general, the model inputs were determined based on review of available literature. Where the distribution of the input parameter is known, a distribution is assigned to capture uncertainty in the Monte Carlo analysis. Where the distribution is unknown, a uniform distribution is often used. The use of a uniform distribution will capture the low-end and high-end values but may not accurately reflect actual distribution of the input parameters.
- The model assumes the near-field and far-field are well mixed, such that each zone can be approximated by a single, average concentration.
- All emissions from the facility are assumed to enter the near-field. This assumption will overestimate exposures and risks in facilities where some emissions do not enter the airspaces relevant to worker exposure modeling.
- The exposure models estimate airborne concentrations. Exposures are calculated by assuming workers spend the entire activity duration in their respective exposure zones (i.e., the worker in the near-field and the occupational non-user in the far-field). Since vapor degreasing and cold cleaning involve automated processes, a worker may actually walk away from the near-field during part of the process and return when it is time to unload the degreaser. As such, assuming the worker is exposed at the near-field concentration for the entire activity duration may overestimate exposure.

- For certain applications (e.g. vapor degreasing), methylene chloride vapor is assumed to emit continuously while the equipment operates (i.e. constant vapor generation rate). Actual vapor generation rate may vary with time. However, small time variability in vapor generation is unlikely to have a large impact in the exposure estimates as exposures are calculated as a time-weighted average.
- The exposure models represent model workplace settings for each methylene chloride condition of use. The models have not been regressed or fitted with monitoring data.

Each subsequent section below discusses uncertainties associated with the individual model.

4.2.3.1 Vapor Degreasing Models

The OTVD and conveyorized vapor degreasing assessments use a near-field/far-field approach to model worker exposure. In addition to the uncertainties described above, the vapor degreasing models have the following uncertainties:

- To estimate vapor generation rate for each equipment type, EPA used a distribution of the emission rates reported in the 2014 NEI for each degreasing equipment type. NEI only contains information on major sources not area sources. Therefore, the emission rate distribution used in modeling may not be representative of degreasing equipment emission rates at area sources.
- The emission rate for conveyorized vapor degreasing is based on equipment at a single site and the emission rates for web degreasing are based on equipment from two sites. It is uncertain how representative these data are of a "typical" site.
- EPA assumes workers and occupational non-users remove themselves from the contaminated near- and far-field zones at the conclusion of the task, such that they are no longer exposed to any residual methylene chloride in air.

4.2.3.2 Brake Servicing Model

The aerosol degreasing assessment also uses a near-field/far-field approach to model worker exposure. Specific uncertainties associated with the aerosol degreasing scenario are presented below:

- The model references a CARB study (citation) on brake servicing to estimate use rate and application frequency of the degreasing product. The brake servicing scenario may not be representative of the use rates for other aerosol degreasing applications involving methylene chloride
- Because market penetration data were not available for methylene chloride-containing products, EPA assumed the market penetration for PCE as an upper bound, because PCE comprises the majority of the chlorinated solvent-based degreaser volume (CARB, 2000).
- EPA found 10 different aerosol degreasing formulations containing methylene chloride. For each Monte Carlo iteration, the model determines the methylene chloride concentration in product by selecting one of 10 possible formulations, assuming the distribution for each formulation is equal. It is uncertain if this distribution is representative of all sites in the U.S.
- Aerosol formulations were taken from available safety data sheets, and most were provided as ranges. For each Monte Carlo iteration the model selects a methylene chloride concentration within the range of concentrations using a uniform distribution. In

reality, the methylene chloride concentration in the formulation may be more consistent than the range provided.

4.2.4 Modeling Dermal Exposures

The *Dermal Exposure to Volatile Liquids Model* used for modeling occupational dermal exposures offers an improvement over the existing *EPA/OPPT 2-Hand Dermal Exposure* model by accounting for the effect of evaporation on dermal absorption for volatile chemicals and the potential exposure reduction due to glove use. The model assumes an infinite dose scenario and does not account for the transient exposure and exposure duration effect, which likely overestimates exposures. The model assumes one exposure event per day, which likely underestimates exposure as workers often come into repeat contact with the chemical throughout their work day. Surface areas of skin exposure are based on skin surface area of hands from EPA's Exposure Factors Handbook, but actual surface areas with liquid contact are unknown and uncertain for all OESs. For many OESs, the high end assumption of contact over the full area of two hands likely overestimates exposures. Weight fractions are usually reported to CDR and shown in other literature sources as ranges, and EPA assessed only upper ends of ranges. The glove protection factors are "what-if" assumptions and are highly uncertain. EPA does not know the actual frequency, type, and effectiveness of glove use in specific workplaces of the OESs. Except where specified above, it is unknown whether most of these uncertainties overestimate or underestimate exposures. The representativeness of the modeling results toward the true distribution of dermal doses for the OESs is uncertain.

4.2.5 Release Estimates

EPA used 2016 TRI and 2016 DMR data to estimate releases. However, both data sources have reporting requirements that limit the number of reporters. Due to these limitations, some sites that manufacture, process, or use methylene chloride may not report to these datasets and are therefore not included:

- Facilities are only required to report to TRI if the facility has 10 or more full-time employees, is included in an applicable NAICS code, and manufactures, processes, or uses the chemical in quantities greater than a certain threshold (25,000 pounds for manufacturers and processors and 10,000 pounds for users).
- DMR data are submitted by National Pollutant Discharge Elimination System (NPDES) permit holders to states or directly to the EPA according to the monitoring requirements of the facility's permit. States are only required to load major discharger data into DMR and may or may not load minor discharger data. The definition of major vs. minor discharger is set by each state and could be based on discharge volume or facility size. Due to these limitations, some sites that discharge methylene chloride may not be included in the DMR dataset.

When possible for each condition of use, EPA/OPPT also estimated average daily releases and number of release days per year. Because operational data were typically not available, EPA typically assumed 350 days/yr for manufacturing and processing as a reactant because of potentially large-scale operations. EPA assumed 300 days/yr for processing into formulation based on an EU SpERC, and 250 days for all other operations (5 days/yr week, 50 weeks/yr)(see

Section 1.4.6 for additional details). Actual release days may various across and between industries and may not be accurately represented by these assumed default values.

APPENDICES

APPENDIX A INHALATION MONITORING DATA

This appendix summarizes the personal monitoring data EPA found for each life cycle stage, as well as EPA's rationale for inclusion or exclusion in the risk evaluation.

A.1 Manufacturing

Table_Apx A-1 lists the results of full-shift monitoring for manufacturing sites:

- Rows 1 through 136 were full-shift monitoring data provided by the Halogenated Solvents Industry Alliance (HSIA), with sampling dates between 2005 and 2017, for various worker activities during manufacturing (Halogenated Solvents Industry Alliance, 2018).
- Rows 137 through 140 contain data from the 1999 EC report (TNO (CIVO), 1999). In this report, a number of previous risk evaluations were re-examined for facilities that manufacture methylene chloride. The data reflect sampling of plant workers and maintenance personal at one of these facilities.

Table_Apx A-2 presents short-term data:

- Rows 1 through 159 contain monitoring data provided by HSIA, with sampling dates between 2005 and 2017, with various sample times and worker activities (Halogenated Solvents Industry Alliance, 2018).

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Manufacturing	Personal	Loaded and sampled 2 methyl railcars, 1 methyl trailer, 2 chloroform railcars and 1 carbon tetrachloride railcar. Unloaded 2 methanol railcars and unhooked a spent sulfuric railcar.	2.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
2	Manufacturing	Personal	Loaded a spent sulfuric railcar, loaded and sampled a methylene railcar, a methyl trailer, prepped for what needed loaded next week, and unloaded 2 methanol cars.	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
3	Manufacturing	Personal	Loaded 1 methyl chloride trailer, 2 chloroform cars, and unloaded a methanol trailer.	0.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
4	Manufacturing	Personal	Full-Shift - made and shot standards.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
5	Manufacturing	Personal	Full-Shift - helped run organic sample rounds and worked on lab instruments.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
6	Manufacturing	Personal	Full-Shift - Loaded tank cars all day off loaded one Carbon Tetrachloride tank car. Loaded perchloroethylene tank car. Dried one methylene chloride tank car.	11.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
7	Manufacturing	Personal	Load product/locomotive and rail activities	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
8	Manufacturing	Personal	Routine lab samples - 2 methylene, 5 chloroform, 2 carbon tetrachloride, 5 methyl chloride, 6 crude gas, 1 sulfuric and 2 mallinckrodt samples, and washed solvent bottles.	3.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
9	Manufacturing	Personal	Shot 20 GC samples, retrieved a jar of carbon tetrachloride from CLM2, and helped hook up a cylinder of methyl chloride to VCRU.	1.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
10	Manufacturing	Personal	Shot 12 samples on the GCs, some carbon tetrachloride, some chloroform and some methylene; performed 20 wet tests on methyl chloride.	2.1	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
11	Manufacturing	Personal	Shot 14 methyl shots on GCs, paperwork, shot 6 GC shots, and went to CLM2 to pick up an empty cylinder from the previous day.	1.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
12	Manufacturing	Personal	Paperwork, shot 12 methyl shots, and 1 GC shot.	1.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
13	Manufacturing	Personal	Worked on aquastar analyzer, shot 2 methylene, 3 chloroform and 4 carbon tet samples, 2 crudes and 3 methyls on GCs.	2.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
14	Manufacturing	Personal	Full-Shift - loaded two methyl chloride tank cars and loaded one methyl chloride tank truck. Disconnected all 3.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
15	Manufacturing	Personal	Full-Shift - loaded two methyl chloride tank cars and loaded one methyl chloride tank truck. Disconnected all 3.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
16	Manufacturing	Personal	Full-Shift - loaded two methyl chloride tank cars and loaded one methyl chloride tank truck. Disconnected all 3.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
17	Manufacturing	Personal	Full-Shift - worked on Electrical Systems on EDC reactors and compressors.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
18	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
19	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
20	Manufacturing	Personal	Full-Shift - worked on monitor on F-1 deck, worked in the 230 yard in the CL2 unit.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
21	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
22	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
23	Manufacturing	Personal	Full-Shift - worked in the chlorine unit on electrical problems.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
24	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
25	Manufacturing	Personal	Loaded and sampled 2 chloroform railcars and 1 methyl railcar. Drained a methylene line to prep for maintenance. Unloaded a methanol car and hooked up a methyl car to sniff.	3.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
26	Manufacturing	Personal	Sniff tested ST-8 for maintenance and loaded a methyl trailer and sampled.	0.6	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
27	Manufacturing	Personal	Perfomed environmental sampling - composited the deepwell samples, shot 4 trichlor samples, 1 carbon tet, 7 methylene and 1 chloroform. Shot 2 methyl chloride samples. Made a purge and trap standard using the organic mix.	0.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
28	Manufacturing	Personal	Shot 12 methyl chloride samples, picked up 1 methylene chloride sample at CLM2 and shot it on the GC; ran 5 purge and trap samples; weighed out chloroform, methyl chloride, and methylene chloride to make a bottoms standard and shot it 6 times.	1.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
29	Manufacturing	Personal	Shot 17 methyl chloride shots, 1 methylene chloride, 1 chloroform, 1 carbon tetrachloride, and 2 purge and trap shots.	0.6	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
30	Manufacturing	Personal	Load product/locomotive and rail activities	3.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
31	Manufacturing	Personal	Full-Shift - Ran samples	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
32	Manufacturing	Personal	Full-Shift - Worked in the environmental lab and helped in the inorganic area.	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
33	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
34	Manufacturing	Personal	Perform maintenance on instrumentation - worked on analyzers in the chlorine diaphragm unit and in shop.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
35	Manufacturing	Personal	Full-Shift - worked in the membrane chopper room and on the top of TK1801.	3.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
36	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
37	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
38	Manufacturing	Personal	Full-Shift - worked on electrical systems in MCI unit and worked in the old MCFII unit.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
39	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
40	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
41	Manufacturing	Personal	Full-Shift - loaded two methyl chloride tank cars and loaded one methyl chloride tank truck. Disconnected all 3.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
42	Manufacturing	Personal	Full-Shift - Loaded one methyl chloride tank car. Disconnected tank cars and collected methyl chloride samples.	0.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
43	Manufacturing	Personal	Full-Shift - Loaded 3 methyl chloride tank trucks and on tank car. Caught product quality samples.	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
44	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
45	Manufacturing	Personal	Loaded and sampled 1 methyl trailer; loaded and sampled 2 chloroform railcars; unloaded 1 methanol railcar.	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
46	Manufacturing	Personal	Loaded and sampled 3 chloroform railcars; loaded and sampled a methyl chloride car; hooked up another methyl car to prep for loading; loaded a methyl trailer and sampled it; unloaded a methanol railcar.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
47	Manufacturing	Personal	Full-Shift - ran organic samples; ran wets and RCLs.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
48	Manufacturing	Personal	Full-Shift - helped run organic samples most of the day. Helped with caustic samples. Dumped organic retains.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
49	Manufacturing	Personal	Full-Shift - ran organic samples and dumped sample retains.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
50	Manufacturing	Personal	Full-Shift - ran organic samples, doing RCL and wet test analysis. Dumped days process retains under hood.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
51	Manufacturing	Personal	Load product/locomotive and rail activities	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
52	Manufacturing	Personal	Full-Shift - worked the 8 hr day job loading tank cars. Loaded perc and carbon tetrachloride.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
53	Manufacturing	Personal	Load product/locomotive and rail activities	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
54	Manufacturing	Personal	Loaded and sampled 1 methyl chloride railcar, 1 methyl chloride trailer; loaded and sampled a chloroform railcar, unloaded a methanol railcar; loaded 12 drums of chloroform.	0.8	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
55	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
56	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
57	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	1.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
58	Manufacturing	Personal	Full-Shift - Blocked tank car on the west methyl chloride loading rack, prepped PSV558-2 for maintenance, hooked up methyl tank truck, prepped PSV573A for maintenance, loaded tank truck, disconnected East/West methyl tank car spots and disconnect truck.	1.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
59	Manufacturing	Personal	Full-Shift - gave maintenance the PSVs on CP542 and off loaded a methyl chloride tank car on the east gate.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
60	Manufacturing	Personal	Full-Shift - prepped and gave to maintenance PSV's on ST500, 501, 502, CP542 and P573A. Loaded methyl chloride truck, stopped loading methyl chloride tank car on west spot, sample a new rental tank.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
61	Manufacturing	Personal	Full-Shift - worked in the utilities F1 area, worked in the 5CP unit and in the electrical shop.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
62	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
63	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
64	Manufacturing	Personal	Full-Shift - worked all day installing heaters on the perc reactor.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
65	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
66	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
67	Manufacturing	Personal	Full-Shift - worked electrical problems in the caustic unit and in the chlorine unit.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
68	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
69	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
70	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.6	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
71	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.6	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
72	Manufacturing	Personal	Loaded 1 methyl chloride trailer, offloaded a methanol railcar; shipped a chloroform order.	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
73	Manufacturing	Personal	Vented a methyl railcar to VCRU; shipped a drum of chloroform.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
74	Manufacturing	Personal	Sampled TK11, sampled 1 chloroform drum; filled 40 chloroform drums.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
75	Manufacturing	Personal	Loaded and sampled 2 chloroform and 1 methylene railcar. Hooked up 1 methyl, 2 chloroform, and 1 methylene railcar. Sampled 1 chloroform and 1 methylene railcar.	4.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
76	Manufacturing	Personal	Prepared some drums to ship.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
77	Manufacturing	Personal	Hooked up a methyl railcar; unloaded and unhooked 2 methanol railcars; hooked up 2 methanol railcars; hooked up, sampled, and unhooked 1 carbon tet railcar and 2 chloroform railcars.	3.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
78	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	1.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
79	Manufacturing	Personal	Drumming chloroform most of shift; drummed 40 chloroform drums, sampled 1 drum, and dumped excess to waste solvents drum.	4.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
80	Manufacturing	Personal	Unloaded 2 methanol railcars, topped off a methylene railcar, and vented 1 each methylene	5.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			and chloroform cars; shipped 2 drum orders.						
81	Manufacturing	Personal	Loaded/filled 40 drums of chloroform.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
82	Manufacturing	Personal	Drummed 40 drums of chloroform, helped on 2 chloroform cars, 1 methanol car, 1 methyl car and sampled drums of chloroform.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
83	Manufacturing	Personal	Filled 24 drums of carbon tetrachloride.	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
84	Manufacturing	Personal	Loaded a methyl chloride railcar and sampled it. Unloaded and disconnected a methanol railcar. Loaded, sampled, and disconnected a methyl chloride ISO container.	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
85	Manufacturing	Personal	Loaded and sampled a methyl railcar and an ISO container. Loaded 2 carbon tet railcars and sampled 1. Loaded and sampled 1 methylene chloride railcar. Unloaded 2 methanol railcars and unhooked 1.	3.8	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
86	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
87	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	1.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
88	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	10.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
89	Manufacturing	Personal	Drummed 40 drums of carbon tetrachloride and collected 4 samples from drums.	7.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
90	Manufacturing	Personal	Unloaded 1 methanol railcar; loaded and sampled 1 chloroform railcar; loaded and sampled 1 methyl chloride trailer; hooked up a methyl chloride trailer to air; hooked up methyl railcar to vent; hooked up 3 solvent railcars to vent.	2.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
91	Manufacturing	Personal	Sampled methyl chloride railcar; evacuated lines and disconnected methyl railcar; unloaded a methanol railcar; unloaded 2 chloroform railcars and sampled one; unloaded 1 carbon tetrachloride railcar and sampled it.	0.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
92	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
93	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
94	Manufacturing	Personal	Load product/locomotive and rail activities	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
95	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.6	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
96	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
97	Manufacturing	Personal	Hooked up and offloaded a methanol railcar; hooked up and loaded a methyl trailer; hooked up and loaded a carbon tet railcar; sampled both railcars that were loaded and then worked on the methyl evac rack.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
98	Manufacturing	Personal	Offloaded a methanol railcar; loaded a methylene railcar; sampled methylene railcar; sealed methylene railcar; hooked up a carbon tet railcar to air; hooked up a methylene railcar to air.	9.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
99	Manufacturing	Personal	Loaded 1 methylene and 1 chloroform trailer, 1 methyl trailer and offloaded a methanol railcar.	1.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
100	Manufacturing	Personal	Loaded 1 chloroform railcar and 1 methyl railcar; offloaded 1 methanol railcar.	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
101	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
102	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.8	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
103	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	10.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
104	Manufacturing	Personal	Full-Shift - routine supervision duties.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
105	Manufacturing	Personal	Full-Shift - routine supervision duties.	0.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
106	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
107	Manufacturing	Personal	General 8-hour exposure	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
108	Manufacturing	Personal	Analytical work	2.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
109	Manufacturing	Personal	General 8-hour exposure	0.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
110	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
111	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
112	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
113	Manufacturing	Personal	General 8-hour exposure	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
114	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
115	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
116	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
117	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
118	Manufacturing	Personal	General 8-hour exposure	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
119	Manufacturing	Personal	General 8-hour exposure	3.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
120	Manufacturing	Personal	General 8-hour exposure	2.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
121	Manufacturing	Personal	General 8-hour exposure	0.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
122	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
123	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
124	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
125	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
126	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
127	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
128	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
129	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
130	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
131	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
132	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
133	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
134	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
135	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
136	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Full-Shift TWA-Worker
137	Manufacturing	Personal	Plant and Packing Personnel	3.5	1	8-hr TWA	TNO (CIVO) (1999)	2.3	Excluded in favor of direct monitoring data
138	Manufacturing	Personal	Plant and Packing Personnel	35.0	1	8-hr TWA	TNO (CIVO) (1999)	2.3	Excluded in favor of direct monitoring data
139	Manufacturing	Personal	Plant and Packing Personnel-Maintenance	219.0	1	8-hr TWA	TNO (CIVO) (1999)	2.3	Excluded in favor of direct monitoring data
140	Manufacturing	Personal	Plant and Packing Personnel-Maintenance	374.0	1	8-hr TWA	TNO (CIVO) (1999)	2.3	Excluded in favor of direct monitoring data

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
2	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
3	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
4	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
5	Outside operator	Personal	Catch samples - other	5.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
6	Logistics distribution operator	Personal	Loading/unloading – sampling and disconnect loading hose	298.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
7	Outside operator	Personal	Lab – analysis	5.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
8	Outside operator	Personal	Catch samples – other	4.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
9	Outside operator	Personal	Catch samples - other	4.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
10	Logistics distribution operator	Personal	Loading/unloading – sampling and connect loading hose	4.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
11	Outside operator	Personal	Lab - analysis	4.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
12	Logistics distribution operator	Personal	Loading/unloading – sampling and connect loading hose	2.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
13	Logistics distribution operator	Personal	Loading/unloading – sampling and connect loading hose	1.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
14	Logistics distribution operator	Personal	Loading/unloading – sampling and disconnect loading hose	16.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
15	Logistics distribution operator	Personal	Loading/unloading – sampling and disconnect loading hose	6.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
16	Machinist	Personal	Line and equipment opening	1.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
17	VCRU Technician	Personal	Change D530 Filters	0.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
18	VCRU Technician	Personal	Change D530 Filters	0.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
19	VCRU Technician	Personal	Change D530 Filters	0.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
20	VCRU Technician	Personal	Sample D517, stabilized D518	0.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
21	CLM2 Thermal Technician	Personal	Sample Round	9.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
22	Control Lab Technician	Personal	Special Samples	11.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
23	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	6.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
24	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	6.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
25	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	14.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
26	Chloromethanes II Thermal Technician	Personal	Sample rounds	4.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
27	Chloromethanes II Thermal Technician	Personal	Sample rounds	20.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
28	VCRU Technician	Personal	Change D530 Filters	0.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
29	VCRU Technician	Personal	Change D530 Filters	0.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
30	VCRU Technician	Personal	Change D530 Filters	3.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
31	VCRU Technician	Personal	D530 Filter Change	2.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
32	VCRU Technician	Personal	D530 Filter Change	27.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
33	VCRU Technician	Personal	D530 Filter Change	2.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
34	VCRU Technician	Personal	D530 Filter Change	3.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
35	Tank Area	Personal	Sample Collection	170.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
36	VCRU Technician	Personal	Special Samples	59.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
37	Chloromethanes II Thermal Technician	Personal	Sample rounds	3.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
38	Chloromethanes II Thermal Technician	Personal	Sample rounds	4.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
39	Chloromethanes II Thermal Technician	Personal	Sample rounds	6.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
40	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	215.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
41	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	298.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
42	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	152.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
43	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	104.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
44	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	45.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
45	Control Lab Technician	Personal	Dumping Jugs	79.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
46	Control Lab Technician	Personal	Dumping Jugs	125.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
47	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	125.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
48	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	132.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
49	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	145.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
50	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	159.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
51	Control Lab Technician	Personal	Dumping Jugs	138.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
52	Tank Area	Personal	Sample Collection	21.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
53	Tank Area	Personal	Sample Collection	111.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
54	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	72.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
55	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	86.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
56	Control Lab Technician	Personal	Dumping Jugs	90.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
57	VCRU Technician	Personal	D530 Filter Change	0.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
58	Chloromethanes II Thermal Technician	Personal	Sample Collection	6.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
59	Chloromethanes II Thermal Technician	Personal	Sample Collection	12.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
60	Tank Area	Personal	Sample Collection	62.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
61	VCRU Technician	Personal	D530 Filter Change	5.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
62	VCRU Technician	Personal	D530 Filter Change	8.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
63	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	45.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
64	Control Lab Technician	Personal	Dumping Jugs	180.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
65	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	100.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
66	Tank Area	Personal	Sample Collection	17.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
67	Control Lab Technician	Personal	Dumping Jugs	86.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
68	Chloromethanes II Thermal Technician	Personal	Sample Collection	24.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
69	Chloromethanes II Thermal Technician	Personal	Sample Collection	2.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
70	Chloromethanes II Thermal Technician	Personal	Sample Collection	2.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
71	Control Lab Technician	Personal	Dumping Jugs	486.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
72	Control Lab Technician	Personal	Dumping Jugs	184.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
73	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	104.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
74	VCRU Technician	Personal	D530 Filter Change	2.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
75	Control Lab Technician	Personal	Dumping Jugs	198.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
76	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	18.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
77	VCRU Technician	Personal	D530 Filter Change	1.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
78	Chloromethanes II Thermal Technician	Personal	Sample Collection	15.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
79	Control Lab Technician	Personal	Dumping Jugs	125.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
80	Chloromethanes II Thermal Technician	Personal	Sample Collection	10.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
81	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	184.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
82	Chloromethanes II Thermal Technician	Personal	Sample Collection	9.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
83	VCRU Technician	Personal	D530 Filter Change	11.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
84	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	18.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
85	Control Lab Technician	Personal	Dumping Jugs	253.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
86	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	24.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
87	Chloromethanes II Thermal Technician	Personal	Sample Collection	1.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
88	Control Lab Technician	Personal	Dumping Jugs	41.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
89	VCRU Technician	Personal	D530 Filter Change	1.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
90	Tank Area	Personal	Sample Collection	59.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
91	VCRU Technician	Personal	D530 Filter Change	1.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
92	Chloromethanes II Thermal Technician	Personal	Sample Collection	121.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
93	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	24.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
94	VCRU Technician	Personal	D530 Filter Change	3.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
95	Control Lab Technician	Personal	Dumping Jugs	128.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
96	Tank Area	Personal	Sample Collection	11.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
97	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	41.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
98	VCRU Technician	Personal	D530 Filter Change	4.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
99	Control Lab Technician	Personal	Purged sample line into waste jug; filled 2 sample bottles, then drained sample line into waste jug.	1.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
100	Control Lab Technician	Personal	Lab tech had jugs loaded onto a cart. he pushed the cart outside, dumped 7	18.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			jugs into the solvent for recovery tote, put empty jugs back on the cart and rolled it back into the lab.						
101	Tank Area	Personal	Sample Collection	10.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
102	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	2.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
103	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	41.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
104	Chloromethanes II Thermal Technician	Personal	Collected 0600 samples - T503 bottoms, T503 reflux, T504 bottoms, T505 bottoms, T505 after, T506 after, Trap.	32.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
105	Solvent Loader	Personal	Connected air line to blow the load line out. disconnected load hose. connected air line to pressure up railcar. connected sampling apparatus to railcar. started purging sample line into a waste bucket. filled sample bottle and rinsed it. dumped that into a waste bucket. filled sample bottle and capped it. disconnected sampling	9.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			apparatus. closed air line and finished disconnecting railcar and sealed it up.						
106	VCRU Technician	Personal	Drained filter casing into a waste bucket. removed filter casing lid. scraped excess carbon into filter. pulled filter from casing and put it over a waste bucket. transferred to D530 filter satellite drum. placed a new filter in the casing and re-bolted the lid on. repeated this process for the 2nd filter casing.	9.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
107	Methanes Distillation Technician	Personal	Collected process sample from DR-520	3.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
108	Methanes Distillation Technician	Personal	Collected process sample from DR-517. Open bleed sampling station.	3.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
109	Methanes Distillation Technician	Personal	Collected process sample from DR-503.	3.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
110	Methanes Distillation Technician	Personal	Collected process sample from DR-503.	3.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
111	Methanes Distillation Technician	Personal	Collected process sample from DR-520. Open bleed sampling station.	4.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
112	Methanes Distillation Technician	Personal	Collected process sample from DR-517.	4.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
113	Methanes Distillation Technician	Personal	Collected process sample from DR-517. Closed loop sampling station.	4.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
114	Methanes Hydrochlor Technician	Personal	Collected process sample from DR-503.	4.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
115	Methanes Distillation Technician	Personal	Collected process sample from T- 504 OH.	4.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
116	Methanes Distillation Technician	Personal	Collected process sample from DR-520.	4.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
117	Methanes Distillation Technician	Personal	Collected process sample from DR-503.	6.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
118	Methanes Distillation Technician	Personal	Collected process sample from T- 504 OH.	8.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
119	Methanes Distillation Technician	Personal	Collected process sample from DR-520.	11.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
120	Control Lab Technician	Personal	Took sample bottles to Chlorine plant to sample trailer. went with chlorine plant operator to trailer. filled 2 sample bottles, after purging sample line into a waste jug. took samples	4.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			and waste jug back to lab. dumped contents of waste jug into solvent for recovery tote. placed sample bottles on magnetic stirrer.						
121	Control Lab Technician	Personal	Screwed on the funnel for the solvent for recovery tote. Dumped 7 jugs into the tote. closed the funnel. unscewed funnel from tote and capped the tote.	22.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
122	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	16.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
123	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	48.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
124	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	48.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
125	Solvent Loader	Personal	Opened drum. inserted tube into drum. filled sample bottle and capped it. Sealed drum back up.	14.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
126	Solvent Loader	Personal	Opened drum. inserted sample tube into drum. filled sample bottle, then sealed drum.	3.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
127	Solvent Loader	Personal	Connected sampling apparatus to railcar. turned on air to pressure up railcar. purged sample line into a waste bucket. filled sample bottle, rinsed it into a waste bucket. filled sample bottle again and capped it. disconnected sampling apparatus and sealed up railcar.	19.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
128	Control Lab Technician	Personal	Sampled pre-cooler trailer, with the assistance of the chlorine plant operator. purged sample line into a waste jug, then filled 2 sample bottles. purged excess from sample line into waste jug and then took jug back to lab and put into the solvent for recovery tote.	14.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
129	VCRU Technician	Personal	D530 Filter Change	6.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
130	Chloromethanes II Thermal Technician	Personal	Sample Collection	10.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
131	VCRU Technician	Personal	Blocked in filter. Drained filter casing into waste jugs from bleed valves.	41.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			removed filter casing lid. removed carbon and filter from filter casing. put a new filter in. poured carbon tet from waste buckets into the filter casing. replaced the lid of the filter casing. repeated this process for 2nd filter.						
132	Control Lab Technician	Personal	Special Samples	10.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
133	Chloromethanes II Thermal Technician	Personal	Sample Collection	8.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
134	VCRU Technician	Personal	D530 Filter Change	26.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
135	Control Lab Technician	Personal	Dumping Jugs	26.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
136	Solvent Loader	Personal	Special Samples	8.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
137	Solvent Loader	Personal	Special Samples	32.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
138	Chloromethanes II Thermal Technician	Personal	Sample Collection	1.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
139	Control Lab Technician	Personal	Dumping Jugs	3.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
140	VCRU Technician	Personal	D530 Filter Change	194.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
141	Chloromethanes II Thermal Technician	Personal	Sample Collection	7.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
142	Control Lab Technician	Personal	Special Samples	4.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
143	Solvent Loader	Personal	Special Samples	1.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
144	Control Lab Technician	Personal	Dumping Jugs	9.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
145	VCRU Technician	Personal	D530 Filter Change	48.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
146	Solvent Loader	Personal	Special Samples	3.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
147	Control Lab Technician	Personal	Special Samples	1.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
148	VCRU Technician	Personal	D530 Filter Change	3.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
149	Control Lab Technician	Personal	Special Samples	6.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
150	Chloromethanes II Thermal Technician	Personal	Sample Collection	8.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
151	Control Lab Technician	Personal	Dumping Jugs	22.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
152	Solvent Loader	Personal	Special Samples	5.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker
153	Solvent Loader	Personal	Special Samples	3.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Included 15-min STEL - Worker

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.2 Processing as a Reactant

Table_Apx A-3 presents full-shift monitoring data for processing as a reactant.

- Rows 1 through 19 include TWA monitoring data provided by HSIA from a facility that uses methylene chloride in the manufacturing process of fluorochemicals, with sampling dates between 2010 and 2017 (Halogenated Solvents Industry Alliance, 2018).
- Row 20 provided a range of samples from "closed industrial applications" but was not specific to processing as a reactant and therefore was excluded from the dataset (TNO (CIVO), 1999).
- Rows 21 through 24 present monitoring data provided by Olin Corporation for operators and assistant operators during the production process (Olin Corp, 1979).
- Row 25 presents data provided by Arkema Inc. for a fluorochemicals manufacturing facility. The data were claimed as Confidential Business Information and are not included in this assessment. Higher quality data from HSIA were used instead (Bernstein, 2017).

Table_Apx A-4 present short-term monitoring data:

- Row 1 provides a range of samples from "closed industrial applications" and is used as surrogate data (TNO (CIVO), 1999).
- Row 2 presents a 30-minute STEL provided by Olin Corporation during drumming operations (Olin Corp, 1979)

Table_Apx A-3. Summary of Full-Shift Inhalation Monitoring Data for Processing as a Reactant

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Fluorochemicals Production	Personal	Maintenance	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
2	Fluorochemicals Production	Personal	Maintenance	0.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
3	Fluorochemicals Production	Personal	Maintenance	ND	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
4	Fluorochemicals Production	Personal	Chemical operator	ND	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
5	Fluorochemicals Production	Personal	Chemical operator	13.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
6	Fluorochemicals Production	Personal	Chemical operator	5.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
7	Fluorochemicals Production	Personal	Chemical operator	ND	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
8	Fluorochemicals Production	Personal	Laboratory technician	1.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
9	Fluorochemicals Production	Personal	Laboratory technician	8.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
10	Fluorochemicals Production	Personal	Maintenance	1.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
11	Fluorochemicals Production	Personal	Chemical operator	1.6	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA

Table_Apx A-3. Summary of Full-Shift Inhalation Monitoring Data for Processing as a Reactant

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
12	Fluorochemicals Production	Personal	Chemical operator	1.6	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
13	Fluorochemicals Production	Personal	Chemical operator	1.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
14	Fluorochemicals Production	Personal	Chemical operator	8.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
15	Fluorochemicals Production	Personal	Chemical operator	3.1	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included-Worker Full-Shift TWA
16	Fluorochemicals Production	Area	Chemical operator	0.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Excluded - used personal samples
17	Fluorochemicals Production	Area	Chemical operator	2.0	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Excluded - used personal samples
18	Fluorochemicals Production	Area	Chemical operator	1.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Excluded - used personal samples
19	Fluorochemicals Production	Area	Chemical operator	ND	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Excluded - used personal samples
20	Other Chemical Industry	Personal	Closed Industrial Applications	0 – 160 20 (mean)	unknown	8-hr TWA	TNO (CIVO) (1999)	2.3	Excluded - used direct monitoring data instead
21	Olin Corporation – Crop Protection	Personal	Operator	10.16	1	6.5-hr TWA	Olin Corp (1979)	2.2	Excluded – used higher quality data
22	Olin Corporation – Crop Protection	Personal	Operator	0.15	1	6.5-hr TWA	Olin Corp (1979)	2.2	Excluded – used higher quality data
23	Olin Corporation – Crop Protection	Personal	Asst Operator	21.77	1	6.5-hr TWA	Olin Corp (1979)	2.2	Excluded – used higher quality data

Table_Apx A-3. Summary of Full-Shift Inhalation Monitoring Data for Processing as a Reactant

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
24	Olin Corporation – Crop Protection	Personal	Asst Operator	0.27	1	6.5-hr TWA	Olin Corp (1979)	2.2	Excluded – used higher quality data
25	Fluorochemicals Production	Personal	Not specified	CBI	Unknown	8-hr TWA	Bernstein (2017)	1.8	Excluded – used higher quality data

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-4. Summary of Short-Term Inhalation Monitoring Data for Processing as a Reactant

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Other Chemical Industry	Personal	Filter changing, charging, discharging	350	1	10-min TWA	TNO (CIVO) (1999)	2.3	Included - 10-min STEL
2	Olin Corporation – Crop Protection	Personal	Drumming	1,692.7	1	30-min TWA	Olin Corp (1979)	2.2	Included - 30-min STEL

A.3 Processing – Incorporation into Formulation, Mixture, or Reaction Product

Table_Apx A-5 presents full-shift data for processing methylene chloride into formulation, mixtures, or reaction products.

- Row 1 presents 8-hr TWA concentrations ranging from 3.5 to 17.7 mg/m^3 during filling containers of methylene chloride-containing products (aerosols), as reported in a 1999 European Commission report (TNO (CIVO), 1999).
- Row 2 presents 8-hr TWA concentrations ranging from 95 to 628 mg/m^3 during aerosol product filling ((IPCS), 1996). The exposure data provided by IPCS is consolidated from various health and environmental evaluations presented in other published literature. Therefore, information about the specific facilities and other details corresponding to the exposure data is not provided.
- Rows 3 through 12 contain 8-hr TWA exposure data compiled in EPA's 1985 exposure and release assessment for processing into formulation. Exposure concentrations for various workers ranged from 52 to 1,260mg/m^3, mainly during packing operations (US EPA, 1985).

Table_Apx A-6 presents short-term data for processing methylene chloride into formulation, mixtures, or reaction products.

- Row 1 presents a peak exposure of 180 mg/m^3 during filling containers of methylene chloride-containing products (aerosols), as reported in a 1999 European Commission report (TNO (CIVO), 1999).

Table_Apx A-5. Summary of Full-Shift Inhalation Monitoring Data for Processing – Incorporation into Formulation, Mixture, or Reaction Product

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Formulation of DCM containing products (aerosols)	Personal	Filling	3.5 – 17.7	Unknown	8-hr TWA	TNO (CIVO) (1999)	2.3	Not used in favor of individual data points
2	Aerosol Products Manufacturing	Personal	Aerosol Filling	95 – 628	Unknown	8-hr TWA	(IPCS) (1996)	2.3	Not used in favor of individual data points
3	Paint Manufacture	Personal	Aerosol Line Filler	101	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
4	Specialty Cleaning	Personal	Line Operator	101	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
5	Specialty Cleaning	Personal	Line Operator	349	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
6	Specialty Cleaning	Personal	Valve Dropper	171	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
7	Specialty Cleaning	Personal	Valve Dropper	454	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
8	Paint, Varnish, Etc.	Personal	Batch Mixer	52	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
9	Paint, Varnish, Etc.	Personal	Package Grinding	464	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
10	Paint, Varnish, Etc.	Personal	Tipper Operator	1260	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
11	Paint, Varnish, Etc.	Personal	Valve Dropper	2223	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA
12	Paint, Varnish, Etc.	Personal	Tub Cleaner	529	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker Full-Shift TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-6. Summary of Short-Term Inhalation Monitoring Data for Processing – Incorporation into Formulation, Mixture, or Reaction Product

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Formulation of DCM containing products (aerosols)	Personal	Filling	180	Unknown	Peak	TNO (CIVO) (1999)	2.3	Not included – duration not provided.

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.4 Import and Repackaging

Table_Apx A-7 presents the results of full-shift monitoring during distribution:

- Rows 1 through 5 contain full-shift exposure data at a distribution site during filling drums, loading trucks, and transfer loading, ranging between 6.0 and 137.8 mg/m^3 (Unocal Corporation, 1986).

Table_Apx A-8 presents the results of short-term monitoring:

- Rows 1 through 4 contain short-term exposure data for the same site and activities as presented for the full-shift data (Unocal Corporation, 1986).

Table_Apx A-7. Summary of Full-Shift Inhalation Monitoring Data for Import and Repackaging

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Distribution	Personal	Filling drums / loading trucks	39.64	1	Full-shift	Unocal Corporation (1986)	2.0	Included – Full-Shift TWA - Worker
2	Distribution	Personal	Filling drums / loading trucks	2.54	1	Full-shift	Unocal Corporation (1986)	2.0	Included – Full-Shift TWA - Worker
3	Distribution	Personal	Filling drums / loading trucks	2.54	1	Full-shift	Unocal Corporation (1986)	2.0	Included – Full-Shift TWA - Worker
4	Distribution	Personal	Truck loading & unloading	1.74	1	Full-shift	Unocal Corporation (1986)	2.0	Included – Full-Shift TWA - Worker
5	Distribution	Personal	Drumming solvent	14.47	1	Full-shift	Unocal Corporation (1986)	2.0	Included – Full-Shift TWA - Worker

Table_Apx A-8. Summary of Short-Term Inhalation Monitoring Data for Import and Repackaging

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Distribution	Personal	Transfer loading from truck to storage tank (4,100 gallons)	0.1	1	0.5-hr TWA	Unocal Corporation (1986)	2.0	Included – Short-Term TWA - Worker
2	Distribution	Personal	Truck loading (2,000 gal)	94	1	1-hr TWA	Unocal Corporation (1986)	2.0	Included – Short-Term TWA - Worker
3	Distribution	Personal	Truck loading (800 gal)	10	1	0.5-hr TWA	Unocal Corporation (1986)	2.0	Included – Short-Term TWA - Worker

Table_Apx A-8. Summary of Short-Term Inhalation Monitoring Data for Import and Repackaging

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
4	Distribution	Personal	Truck loading (250 gal)	8.6	1	1-hr TWA	Unocal Corporation (1986)	2.0	Included – Short-Term TWA - Worker

A.5 Cold Cleaning

Table_Apx A-9 presents shows the full shift data available for cold cleaning:

- Row 1 provides a summary of a search of data from the UK Health and Safety Executive’s (HSE’s) database, giving a range of exposures during cold degreasing between 14-1,000 mg/m^3 and a mean value if 280 mg/m^3 for cold degreasing activities (TNO (CIVO), 1999).
- Row 2 indicates that exposure levels can be kept below 124 mg/m^3 if stringent controls are applied; however, the specific type of degreasing is not specified for this exposures; nor was any sample duration for this data. Therefore, this data point was not used in the analysis (TNO (CIVO), 1999).
- Row 3 contains the results of EPA Monte Carlo modeling for cold degreasing for both workers and ONUs (see Appendix F.2).

Table_Apx A-9. Summary of Full-Shift Inhalation Monitoring Data for Cold Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Unknown	unknown	Cold degreasing	14 – 1,000 280 (mean)	Unknown	Unknown	TNO (CIVO) (1999)	2.3	Included – Worker Full-Shift TWA
2	Unknown	unknown	Degreasing	124	Unknown	Unknown	TNO (CIVO) (1999)	2.3	Excluded – type of degreasing not specified

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.6 Adhesives and Sealants

Full-shift data are summarized in Table_Apx A-10:

- Rows 1 through 12 contain personal 8-hr TWA sample data from a NIOSH Health Hazard Evaluation in 1984 at the Sheldahl, Inc. facility in Northfield, MN (NIOSH, 1985). The facility manufactured flexible printed circuitry and employed approximately 650 workers, including 300 administrative personnel, 340 production workers, and 12 maintenance workers. NIOSH took various personal and area samples in the lamination departments, where methylene chloride was used as a major component of the adhesives/sealants and as a cleaning agent for the laminating machine and parts (non-spray). Sample times ranged from 192 to 477 minutes.
- Row 13 presents full-shift spraying data included a 1999 European Commission report (TNO (CIVO), 1999). In the EC report, a number of previous risk evaluations were re-examined for facilities where workers apply adhesives/sealants. Data were available from sampling the plant workers and maintenance personal at one of these facilities where spray adhesives/sealants were used.
- Row 14 provides a range of exposure data from glue spraying in the foam industry, using local exhaust ventilation ((IPCS), 1996)
- Rows 15 through 111 contain data from EPA’s 1985 Occupational Exposure and Environmental Release Assessment of Methylene Chloride, which compiled 8-hr TWA adhesive/sealant use data (spray and non-spray (US EPA, 1985)
- Rows 112 and 113 contain area sample data that were not used; personal sampling data were prioritized.

Short-term data are summarized in Table_Apx A-11:

- Rows 1 through 10 contain provided monitoring data from OSHA for adhesive/sealant sprayers from various inspections occurring between 2011 and 2016 (OSHA, 2019)
- Rows 11 through 17 contain short-term personal monitoring data from the 1984 NIOSH study discussed above. Rows 13 through 17 are excluded from the dataset, however, because they are representative of a cleaning scenario and not relevant to adhesives/sealants use (NIOSH, 1985).
- Rows 18 and 19 contain data from a 2016 NIOSH HHE that summarized adhesive/sealant use at a federal crime lab between 2012-2014, for activities such as transferring methylene chloride and bonding plastics. These data were excluded from the dataset because the activities are relatively small scale, and likely not applicable to full-scale industrial and commercial use (Beaucham et al., 2016).

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Flexible Circuit Board Manufacturing	Personal	Operator, Laminator #1	295.3	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
2	Flexible Circuit Board Manufacturing	Personal	Operator, Laminator #4	250.1	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
3	Flexible Circuit Board Manufacturing	Personal	Tape Machine, Dept. 12	458.5	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
4	Flexible Circuit Board Manufacturing	Personal	Laminator #1, Dept. 14	218.8	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
5	Flexible Circuit Board Manufacturing	Personal	Laminator #3 & 4, Dept. 14	225.8	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
6	Flexible Circuit Board Manufacturing	Personal	Laminator #1, Dept. 14	132.0	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
7	Flexible Circuit Board Manufacturing	Personal	Adhesive mixer, Dept. 14	90.3	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
8	Flexible Circuit Board Manufacturing	Personal	Tape Machine, Dept. 12	204.9	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
9	Flexible Circuit Board Manufacturing	Personal	Laminator #4, Dept. 14	114.6	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
10	Flexible Circuit Board Manufacturing	Personal	Mixing room employee, Dept. 14	302.2	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
11	Flexible Circuit Board Manufacturing	Personal	Laminator #1, Dept. 14	86.8	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
12	Flexible Circuit Board Manufacturing	Personal	36" Laminator, Dept. 12	364.7	1	8-hr TWA	NIOSH (1985)	1.6	Included – full-shift TWA (non-spray)
13	Adhesives	Personal	Spray application	3.5 – 1,500 200 (average)	unknown	8-hr TWA	TNO (CIVO) (1999)	2.3	Included – full-shift TWA (spray)
14	Foam Industry	Personal	Glue spraying	85 – 244	unknown	8-hr TWA	(IPCS) (1996)	2.3	Included – full-shift TWA (spray)
15	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
16	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
17	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
18	Fiberglass Boats	Personal	Deck Lamination	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
19	Fiberglass Boats	Personal	Gel Kote	17.45	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
20	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
21	Fiberglass Boats	Personal	Lamination	1.745	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
22	Fiberglass Boats	Personal	Lamination	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
23	Fiberglass Boats	Personal	Lamination	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
24	Fiberglass Boats	Personal	Gel Kote	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
25	Fiberglass Boats	Personal	Hull Lamination	20.94	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
26	Fiberglass Boats	Personal	Hull Lamination	17.45	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
27	Fiberglass Boats	Personal	Hull Lamination	28.94	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
28	Fiberglass Boats	Personal	Hull Lamination	53.84	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
29	Fiberglass Boats	Personal	Lam Stiffening	17.45	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
30	Fiberglass Boats	Personal	Hull Lamination	17.45	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
31	Fiberglass Boats	Personal	Gel Kote	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
32	Fiberglass Boats	Personal	Mold Repair	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
33	Fiberglass Boats	Personal	Deck Lamination	26.94	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
34	Fiberglass Boats	Personal	Hull Lamination	27.92	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
35	Fiberglass Boats	Personal	Deck Lamination	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
36	Fiberglass Boats	Personal	Deck Lamination	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
37	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
38	Fiberglass Boats	Personal	Stiffening	13.96	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
39	Fiberglass Boats	Personal	Gel Kote	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
40	Fiberglass Boats	Personal	Hull Lamination	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
41	Fiberglass Boats	Personal	Hull Lamination	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
42	Fiberglass Boats	Personal	Hull Lamination	10.47	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
43	Fiberglass Boats	Personal	Hull Lamination	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
44	Fiberglass Boats	Personal	Hull Lamination	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
45	Fiberglass Boats	Personal	Hull Lamination	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
46	Fiberglass Boats	Personal	Stiffening	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
47	Fiberglass Boats	Personal	Stiffening	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
48	Fiberglass Boats	Personal	Gel Kote	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
49	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
50	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
51	Fiberglass Boats	Personal	Lamination	13.96	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
52	Fiberglass Boats	Personal	Gel Kote	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
53	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
54	Fiberglass Boats	Personal	Lamination	30.39	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
55	Fiberglass Boats	Personal	Lamination	6.98	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
56	Fiberglass Boats	Personal	Stringer	3.49	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
57	Plastics Materials	Personal	Laminator Helper	0.073	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
58	Plastics Materials	Personal	Laminator Helper	87.25	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
59	Plastics Materials	Personal	Laminator Helper	87.25	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
60	Plastics Materials	Personal	Mold Controller	87.25	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
61	Plastics Materials	Personal	PM Laminator	48.86	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
62	Building Paper	Personal	Laborer	223.36	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
63	Building Paper	Personal	Laminator	177.99	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
64	Building Paper	Personal	Laminator Laborer	87.25	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
65	Misc. Plastic Products	Personal	Laminator	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
66	Misc. Plastic Products	Personal	Lead Man	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
67	Misc. Plastic Products	Personal	Lead Man	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
68	Misc. Plastic Products	Personal	Laminator	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
69	Wood Household Furniture	Personal	Laminator	79.118	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
70	Boat Building	Personal	Sprayer	60.028	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
71	Boat Building	Personal	Foreman	72.941	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
72	Boat Building	Personal	Foreman/Sprayer	60.796	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
73	Boat Building	Personal	Roller/Sprayer	86.23	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
74	Boat Building	Personal	Sprayer	43.555	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
75	Boat Building	Personal	Gel Coat Sprayer	34.481	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
76	Boat Building	Personal	Sprayer Helper	93.637	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
77	Boat Building	Personal	Layup Sprayer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
78	Boat Building	Personal	Layup Sprayer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
79	Boat Building	Personal	Sprayer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
80	Boat Building	Personal	Layup Sprayer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
81	Boat Building	Personal	Layup Sprayer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (spray)
82	Boat Building	Personal	Layup	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
83	Boat Building	Personal	Layup	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
84	Boat Building	Personal	Layup	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
85	Boat Building	Personal	Layup	0.14	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
86	Boat Building	Personal	Layup	4.18	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
87	Air Brake Manufacture	Personal	Gluer	205.918	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
88	Foam Products	Personal	Glue Mixing	0.007	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
89	Abrasive Products	Personal	Gluer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
90	Abrasive Products	Personal	Gluer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
91	Abrasive Products	Personal	Gluer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
92	Abrasive Products	Personal	Portable Belt Gluer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
93	Public Bldg. Furniture	Personal	Glue Gun Operator	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
94	Public Bldg. Furniture	Personal	Glue Gun Operator	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
95	Foam Products	Personal	Hot Wire Cutting	0.698	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
96	Foam Products	Personal	Hot Wire Cutting	0.698	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
97	Foam Products	Personal	Hot Wire Cutting	0.349	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
98	Foam Products	Personal	Foam Processing	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
99	Foam Products	Personal	Foam Processing	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
100	Foam Products	Personal	Adhesive Storage	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
101	Foam Products	Personal	Adhesive Storage	0.044	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
102	Abrasive Products	Personal	Presser	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
103	Plastic Materials	Personal	Medical Device Ass.	575.05	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
104	Plastic Materials	Personal	Micro Flush Assembly	206.1	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
105	Plastic Materials	Personal	Assembler	20.94	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
106	Plastic Materials	Personal	Micro Flush Assembly	397.162	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
107	Rubber & Plastic Footwear	Personal	Sock Liner	145.917	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
108	Rubber & Plastic Footwear	Personal	Lacer	77.827	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
109	Rubber & Plastic Footwear	Personal	Sock Liner	120.405	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
110	Rubber & Plastic Footwear	Personal	Sock Liner	187.364	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
111	Public Bldg. Furniture	Personal	Upholsterer	0	1	TWA	US EPA (1985)	1.4	Included – full-shift TWA (non-spray)
112	Flexible Circuit Board Manufacturing	Area	Area Sample, Laminator #4	284.8	1	TWA	NIOSH (1985)	1.6	Excluded – prioritized personal samples

Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
113	Cabinet Manufacturing	Area	Spray contact cement	1,042 – 1,736	unknown	TWA	Mahmud and Kales (1999)	2.3	Excluded – prioritized personal samples

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-11. Summary of Short-Term Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Metal Window and Door Manufacturing	Personal	Adhesive Sprayer	719.0	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
2	Metal Window and Door Manufacturing	Personal	Adhesive Sprayer	576.6	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
3	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	142.4	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
4	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	225.8	1	6-min-STEL	OSHA (2019)	1.3	Excluded in favor of 15 -minute sample times
5	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	479.4	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
6	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	159.8	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
7	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	361.3	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
8	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	100.7	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
9	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	284.8	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
10	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	12.2	1	15-min-STEL	OSHA (2019)	1.3	Included – Industrial 15-min STEL - Spray
11	Flexible Circuit Board Manufacturing	Personal	Operator, laminator #3 & #4, cleaning	423.8	1	15-min-STEL	NIOSH (1985)	1.6	Included – Industrial 15-min STEL - Non-Spray
12	Flexible Circuit Board Manufacturing	Personal	Employee mixing adhesives, Dept 12	569.7	1	15-min-STEL	NIOSH (1985)	1.6	Included – Industrial 15-min STEL - Non-Spray
13	Flexible Circuit Board Manufacturing	Personal	Employee cleaning parts in room with no ventilation	6085.8	1	Short Term	NIOSH (1985)	1.6	Excluded – cleaning operations
14	Flexible Circuit Board Manufacturing	Personal	Operator cleaning 39 inch laminator, Dept 12	2539.2	1	Short Term	NIOSH (1985)	1.6	Excluded – cleaning operations
15	Flexible Circuit Board Manufacturing	Personal	Operator cleaning tape machine, Dept 12	1754.2	1	Short Term	NIOSH (1985)	1.6	Excluded – cleaning operations
16	Flexible Circuit Board Manufacturing	Personal	Employee cleaning "tunnel" of laminator #10, Dept 14	1545.8	1	Short Term	NIOSH (1985)	1.6	Excluded – cleaning operations

Table_Apx A-11. Summary of Short-Term Inhalation Monitoring Data for Application of Adhesives and Sealants

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
17	Flexible Circuit Board Manufacturing	Personal	Employee cleaning "tunnel" of laminator #10, Dept 14	930.9	1	Short Term	NIOSH (1985)	1.6	Excluded – cleaning operations
18	Federal Crime Lab	Personal	Pouring MeCl into secondary container (2 min)	ND (<69.5)	1	Short Term	Beaucham et al. (2016)	2.3	Excluded – Not typical scale of industrial/commercial applications.
13	Federal Crime Lab	Personal	Using MeCl to connect pieces of plastic in the shop (few seconds)	ND (<69.5)	1	Short Term	Beaucham et al. (2016)	2.3	Excluded – Not typical scale of industrial/commercial applications.

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.7 Paints and Coatings

Full-shift monitoring data for paints and coatings are presented in Table_Apx A-12:

- Rows 1 and 2 contain 8-hr TWA data points for paint sprayers in unknown industries, ranging from 14.2 to 222.3 mg/m^3, from OSHA inspections (OSHA, 2019)
- Rows 2 through 27 contain data from EPA's 1985 exposure and release assessment, which compiled full-shift TWA data for spray painters in various industries. These exposure concentrations ranged from ND to 439.7 mg/m^3 (US EPA, 1985)
- Rows 28 through 32 contain exposure data compiled by DOD in 2016 during structural repair and painting. DOD indicated that typical operation duration times are zero to 15 minutes, although samples were taken over ~2 hrs. EPA assumed that no other exposure to workers occurs over the remaining 6 hour period and averaged the exposures over an 8-hr period to calculate 8-hr TWAs ((DOEHRS-IH), 2018).

Short-term monitoring data are presented in Table_Apx A-13:

- Rows 1 and 2 contain short-term data from a NIOSH Health Hazard Evaluation in 1981 at a Metro Bus Maintenance Shop in Washington D.C. The HHE reported ND exposure concentrations over 40-50 minute sample durations (Love and Kern, 1981).
- Rows 3 through 10 contain short-term data from a NIOSH Health Hazard Evaluation in 1973 at a metal fabrication plant. The HHE reported exposures from 1.0 - 74.0 mg/m^3 during spray painting activities (Vandervort and Polakoff, 1973).
- Rows 11 through 19 contain 15-min exposure data compiled by DOD during painting and coating operations. Only one data point indicated spray coating ((DOEHRS-IH), 2018).

Table_Apx A-12. Summary of Full-Shift Inhalation Monitoring Data for Application of Paints and Coatings

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Unknown	Personal	Paint Sprayer	14.2	1	8-hr TWA	OSHA (2019)	1.3	Included – full-shift TWA
2	Unknown	Personal	Paint Sprayer	222.3	1	8-hr TWA	OSHA (2019)	1.3	Included – full-shift TWA
3	Sporting Goods	Personal	Spray Painter	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
4	Sporting Goods	Personal	Spray Painter	76.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
5	Sporting Goods	Personal	Spray Painter	270.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
6	Sporting Goods	Personal	Spray Painter	35.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
7	Metal Products	Personal	Spray Painter	22.5	1	6-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
8	Metal Products	Personal	Spray Painter	377.3	1	6-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
9	Metal Products	Personal	Spray Painter	313.5	1	6-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
10	A/C Equipment	Personal	Spray Painter	64.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
11	A/C Equipment	Personal	Spray Painter	54.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
12	A/C Equipment	Personal	Spray Painter	63.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
13	A/C Equipment	Personal	Spray Painter	36.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
14	A/C Equipment	Personal	Spray Painter	74.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
15	A/C Equipment	Personal	Spray Painter	0.5	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
16	A/C Equipment	Personal	Spray Painter	3.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
17	A/C Equipment	Personal	Spray Painter	4.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
18	Fabr. Rubber Products NEC	Personal	Spray Painter	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
19	Public Bldg. Furniture	Personal	Spray Painter	65.6	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
20	A/C & Heating Equipment	Personal	Spray Painter	87.3	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
21	A/C & Heating Equipment	Personal	Spray Painter	87.3	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
22	Airports	Personal	Spray Painter	69.8	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
23	Surgical Instruments	Personal	Spray Painter	42.2	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA

Table_Apx A-12. Summary of Full-Shift Inhalation Monitoring Data for Application of Paints and Coatings

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
24	Misc. Plastic Products	Personal	Spray Painter	156.7	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
25	Misc. Plastic Products	Personal	Spray Painter	439.7	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
26	Misc. Plastic Products	Personal	Spray Painter	255.0	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
27	Misc. Plastic Products	Personal	Spray Painter	264.5	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
28	DOD	Personal	009A-5, STRUCTURAL REPAIR, PAINTING OPS	0.9	1	2-hr TWA	((DOEHRS-IH), 2018)	1.3	Included – full-shift TWA (averaged over 8-hr)
29	DOD	Personal	009A-5, STRUCTURAL REPAIR, PAINTING OPS	10.7	1	2-hr TWA	((DOEHRS-IH), 2018)	1.3	Included – full-shift TWA (averaged over 8-hr)
30	DOD	Personal	009A-5, STRUCTURAL REPAIR, PAINTING OPS	10.6	1	2-hr TWA	((DOEHRS-IH), 2018)	1.3	Included – full-shift TWA (averaged over 8-hr)
31	DOD	Personal	009A-5, STRUCTURAL REPAIR, PAINTING OPS	7.1	1	2-hr TWA	((DOEHRS-IH), 2018)	1.3	Included – full-shift TWA (averaged over 8-hr)
32	DOD	Personal	009A-5, STRUCTURAL REPAIR, PAINTING OPS	2.8	1	2-hr TWA	((DOEHRS-IH), 2018)	1.3	Included – full-shift TWA (averaged over 8-hr)

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-13. Summary of Short-Term Inhalation Monitoring Data for Application of Paints and Coatings

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Metro Bus maintenance shop	Personal	Painting	ND (<0.01)	1	STEL	Love and Kern (1981)	1.8	Worker 1-hr STEL
2	Metro Bus maintenance shop	Personal	Painting	ND (<0.01)	1	STEL	Love and Kern (1981)	1.8	Worker 1-hr STEL
3	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	64.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
4	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	54.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
5	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	63.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
6	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	36.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
7	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	74.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
8	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 1 (Rear) Spray Booth	1.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
9	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 1 (Rear) Spray Booth	3.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
10	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 1 (Rear) Spray Booth	4.0	1	STEL	Vandervort and Polakoff (1973)	1.7	Worker 30-min STEL
11	DOD	Personal	Painting Operations	4.1	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL
12	DOD	Personal	Painting Operations	4.1	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL
13	DOD	Personal	Painting Operations	4.1	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL
14	DOD	Personal	Painting Operations	4.1	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL
15	DOD	Personal	Priming Operations	5.2	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL

Table_Apx A-13. Summary of Short-Term Inhalation Monitoring Data for Application of Paints and Coatings

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
16	DOD	Personal	IND-002-00 Chemical cleaning multi ops.	1.7	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL
17	DOD	Personal	IND-006-00 Coating Operations, Multiple Operations	1.9	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL
18	DOD	Personal	IND-006-00 Coating Operations, Multiple Operations	1.9	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL
19	DOD	Personal	NPS ECE aerosol can painting	13.5	1	STEL	((DOEHRS-IH), 2018)	1.3	Worker 15-min STEL

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.8 Adhesive and Caulk Removers

Note that this section was extracted from the 2014 Risk Assessment on Methylene Chloride (U.S. EPA, 2014), as data from paint stripping by professional contractors was used as a surrogate scenario for adhesive and caulk remover use.

Inhalation exposure monitoring data of methylene chloride during paint stripping, specifically full-shift 8-hr TWA breathing zone or personal samples, were used for risk analyses. Data monitoring of over 5 hour duration are assumed adequate to represent full shift exposure levels.

Methylene chloride exposure data for paint stripping conducted by professional contractors were not identified in the literature search. However, TNO (CIVO) (1999) reported some methylene chloride exposure data for consumer use of methylene chloride -based paint strippers/ The EU report states that there is "*probably…no fundamental difference between the application of paint removers by professional painters and consumers*" and goes on to further state that, in regard to the cited consumer exposure studies, "*the test situations and data described/are assumed valid for occupational exposure during professional use as well*" (TNO (CIVO), 1999).

There are differences between the consumer and occupational use of methylene chloride -based paint strippers by professional contractors. For instance, professional contractors are expected to have higher frequencies and durations of exposure, and a likely higher prevalence of respirator use, as compared to consumers. It is also not clear whether overall activity patterns and practices of contractors match those of consumers or whether the overall distributions of exposures of contractors and consumers have any semblance to one another. Despite these uncertainties, EPA/OPPT considered some of the literature data for consumers in the occupational exposure assessment of paint strippers.

The EU report conducted a literature review and identified the following consumer exposures to methylene chloride during paint stripping (TNO (CIVO), 1999):

- A 1990 EPA investigation estimated consumer exposure levels ranging from 35 mg/m^3 (10 ppm) to a few short-term exposures of over 14,100 mg/m^3 (4,063 ppm)[2]. The majority of the exposures were below 1,770 mg/m^3 (510 ppm) (TNO (CIVO), 1999).
- A separate study conducted by a solvent manufacturer measured methylene chloride exposures during testing in a small room. One test conducted with ventilation measured a 2-hr TWA exposure of 289 mg/m^3 (83.3 ppm), but the ventilation rate or air change rate was not specified. The peak exposure during application was 460 mg/m^3 (133 ppm). The peak exposure during scrape-off ranged from 710 to 1,410 mg/m^3 (205 to 406 ppm), and the observed maximum during the study was 3,530 mg/m^3 (1,017 ppm). When no ventilation was used, the worst-case exposure exceeded 14,000 mg/m^3 (4,035 ppm). Based on the solvent manufacturer, 8-hr TWA exposures under supplier-recommended ventilation would be 187 to 226 mg/m^3 (54 to 65 ppm) (TNO (CIVO), 1999).
- A literature review conducted by the United Kingdom (UK) in 1998 identified 1-hr TWA exposures of 840 to 2,765 mg/m^3 (240 to 790 ppm) in an unventilated room, and 129.5 to 948 mg/m^3 (37 to 270 ppm) with the door open (TNO (CIVO), 1999).
- An older study from 1981 found 8-hr TWA exposures of 460 to 2,980 mg/m^3 (133 to 859 ppm)[3] in unventilated rooms and 60 to 400 mg/m^3 (17 to 115 ppm) ventilated rooms (TNO (CIVO), 1999).

[2] The short-term exposure of over 14,100 mg/m^3 (4,063 ppm) was selected to represent the high end of the range of short-term and other non-8-hr TWA values for professional contractors in Table_Apx A-14 (TNO (CIVO), 1999). EPA/OPPT calculated the midpoint values from the high-end values reported by the study authors.

[3] The methylene chloride air concentrations of 60 mg/m^3 (17 ppm) and 2,980 mg/m^3 (859 ppm) were selected to represent the low and high ends of the range of 8-hr TWA values, respectively, for professional contractors in Table_Apx A-14 (TNO (CIVO), 1999). EPA/OPPT calculated midpoint values from the high and low values reported by the study authors.

Another EU report described a 2004 study that cited several case studies of methylene chloride monitoring during paint stripping of buildings in the UK (EU, 2007).

An average personal methylene chloride exposure of 182 mg/m^3 (52 ppm), ranging from 21 to 318 mg/m^3 (6 to 92 ppm), was reported for "paint stripping at a block of flats" (EU, 2007).

- A case study of paint stripping in a building stairway reported an average personal methylene chloride exposure of 86 mg/m^3 (25 ppm) (EU, 2007).
- Another case study observed an average personal methylene chloride exposure of 710 mg/m^3 (205 ppm) while paint stripping a ceiling. The methylene chloride air concentration was measured during brush application and stripping over approximately 40 minutes (EU, 2007).
- A 2003 case study of the paint stripping of an external façade observed personal monitoring methylene chloride concentrations with a maximum of 400 mg/m^3 (115 ppm) and a minimum of zero mg/m^3.[4] The average of all of the reported means was approximately 62 mg/m^3 (18 ppm) (EU, 2007).

Midwest Research Institute (MRI) prepared a report for EPA in 1994 that documented an experimental investigation of consumer exposures to solvents used in paint stripping products with eliminated or reduced methylene chloride content. MRI investigated five paint strippers, two of which contained methylene chloride (along with other solvents, but the concentrations were not specified). The paint stripping was conducted in a laboratory-based, environment-controlled, room-sized test chamber. The paint strippers were used on a plywood panel coated with a primer coat and two finish coats. The air exchange rate for the experiments ranged from 0.54 to 0.76 air changes per hr (ACH), with an average of 0.58 ACH. The air exchange rate of approximately 0.5 ACH was intended to replicate the ventilation rate of an enclosed room in a typical residence as a worst-case scenario (U.S. EPA, 2014).

During each experiment, the following samples were taken for the spray and brush applications: a personal breathing zone sample of the test subject using the paint stripper; two stationary air samples for the duration of the paint stripping task; and one stationary air sample beginning at the start of the paint stripping and lasting for 8 hrs (U.S. EPA, 2014). The results are summarized below.

- For the spray application of the methylene chloride -based paint stripper, MRI reported breathing zone methylene chloride concentrations of 3,000 and 3,400 mg/m^3 (865 and 980 ppm) over 1.7-and 1.5-hour sampling times, respectively. The stationary length-of-task concentrations ranged from 2,900 to 3,600 mg/m^3 (836 to 1,037 ppm). The stationary, 8-hr TWA concentration ranged from 1,700 to 2,000 mg/m^3 (490 to 576 ppm) (U.S. EPA, 2014).
- MRI reported breathing zone concentrations of 380 and 430 mg/m^3 (110 and 124 ppm) over sampling times of approximately 2 hours for the brush application. The stationary length-of task concentrations ranged from 300 to 490 mg/m^3 (86 to 141 ppm). The stationary, 8-hr TWA concentration ranged from 230 to 270 mg/m^3 (66 to 78 ppm) (U.S. EPA, 2014).

Table_Apx A-14 and Table_Apx A-15 present a summary of exposure data.

[4] The short-term exposure of 0 mg/m^3 was selected to represent the low end of the range of short-term and other non-8-hr TWA values for professional contractors in Table_Apx A-14 (TNO (CIVO), 1999).

Table_Apx A-14. Summary of Full-Shift Inhalation Monitoring Data for Paint Stripping by Professional Contractors

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Estimated Methylene Chloride Airborne Concentration (mg/m^3) [a, b]				Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
				Mean	High	Midpoint	Low					
1	Professional Contractors	Personal	-	-	2,980	1,520	60	>4	8-hr TWA	U.S. EPA (2014)	1.1	Included as best available data source (surrogate)

Table_Apx A-15. Summary of Short-Term Inhalation Monitoring Data for Paint Stripping by Professional Contractors

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Estimated Methylene Chloride Airborne Concentration (mg/m^3) [a, b]				Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
				Mean	High	Midpoint	Low					
1	Professional Contractors	Personal	-	-	14,100	7,050	0	>38	STEL	U.S. EPA (2014)	1.1	Included as best available data source (surrogate)

A.9 Fabric Finishing

Table_Apx A-16 presents full-shift monitoring data for fabric finishing.

- Row 1 contains data from a 1999 European Commission report that cited an HSE study on methylene chloride use for caffeine extraction, but noted that other exposure of other open industrial applications, such as printing, gauze coating and fabric coating, are in the same range as those known for extraction processes (TNO (CIVO), 1999).
- Rows 2 through 15 contain OSHA data submitted in a public comment (Finkel, 2017). The exposure data come from textile and fabric industries, such as “Men's and Boys' Cut and Sew Apparel Mfg,” “Apparel Accessories and Other Apparel Mfg,” and “All Other Misc. Textile Product Mills.” However, worker activities for these exposure data points are not known. Sample times vary - however, exposures were adjusted to 8-hr TWAs.

Table_Apx A-16. Summary of Full-Shift Inhalation Monitoring Data for Fabric Finishing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Caffeine Extraction (surrogate data)	Personal	Caffeine Extraction (surrogate)	110.0	1	Unknown	TNO (CIVO) (1999)	2.3	Excluded – Used direct monitoring data
2	Men's and Boys' Cut and Sew Apparel Mfg.	Personal	unknown	162.4	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
3	Men's and Boys' Cut and Sew Apparel Mfg.	Personal	unknown	162.8	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
4	Men's and Boys' Cut and Sew Apparel Mfg.	Personal	unknown	164.6	1	ONU 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
5	Men's and Boys' Cut and Sew Apparel Mfg.	Personal	unknown	157.8	1	ONU 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
6	Women's, Misses', and Juniors' Outerwear, Not Elsewhere Classified	Personal	unknown	42.6	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
7	Women's, Misses', and Juniors' Outerwear, Not Elsewhere Classified	Personal	unknown	42.0	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
8	Pleating, Decorative and Novelty Stitching, and Tucking for the Trade	Personal	unknown	55.9	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
9	Pleating, Decorative and Novelty Stitching, and Tucking for the Trade	Personal	unknown	53.4	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
10	Pleating, Decorative and Novelty Stitching, and Tucking for the Trade	Personal	unknown	53.4	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
11	Apparel Accessories and Other Apparel Mfg.	Personal	unknown	86.8	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
12	Apparel Accessories and Other Apparel Mfg.	Personal	unknown	86.8	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA

Table_Apx A-16. Summary of Full-Shift Inhalation Monitoring Data for Fabric Finishing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a, b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
13	Apparel Accessories and Other Apparel Mfg.	Personal	unknown	86.8	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
14	Apparel Accessories and Other Apparel Mfg.	Personal	unknown	86.8	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA
15	All Other Misc. Textile Product Mills	Personal	unknown	86.1	1	Worker 8-hr TWA	Finkel (2017)	2.0	Included – full-shift TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.10 Spot Cleaning

Table_Apx A-17 presents full-shift inhalation monitoring data for the use of methylene chloride for at industrial launderers:

- The monitoring data shown is taken from one source, which provided exposure data for workers in drycleaning, laundry services, and industrial launderers (Finkel, 2017). The specific worker activities corresponding to the exposure data is not provided . The exposure data presented is for sample times ranging from 252 to 270 minutes, and is thus adjusted to 8-hr TWA data.

Table_Apx A-18 shows short-term data for the use of methylene chloride for industrial launderer:

- The monitoring data shown is taken from the same source as the data in Table_Apx A-17, and is for industrial launderers (Finkel, 2017). The specific worker activities correspond to the exposure data is not provided. The exposure data presented is for sample times ranging from 173 to 225 minutes.

Table_Apx A-17. Summary of Full-Shift Inhalation Monitoring Data for Spot Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b,c]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Drycleaning and Laundry Services (Except Coin-Operated)	Personal	unknown	0.0	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 8-hr TWA
2	Industrial Launderers	Personal	unknown	83.7	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 8-hr TWA
3	Industrial Launderers	Personal	unknown	3.0	1	TWA	Finkel (2017)	1.8	Included - no other data available. Data adjusted to 8-hr TWA
4	Industrial Launderers	Personal	unknown	2.7	1	TWA	Finkel (2017)	1.8	Included - no other data available. Data adjusted to 8-hr TWA
5	Industrial Launderers	Personal	unknown	2.4	1	TWA	Finkel (2017)	1.8	Included - no other data available. Data adjusted to 8-hr TWA
6	Industrial Launderers	Personal	unknown	2.4	1	TWA	Finkel (2017)	1.8	Included - no other data available. Data adjusted to 8-hr TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)
c –EPA/OPPT converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

Table_Apx A-18. Summary of Short-Term Inhalation Monitoring Data for Spot Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Industrial Launderers	Personal	unknown	67.4	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA
2	Industrial Launderers	Personal	unknown	234.5	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA
3	Industrial Launderers	Personal	unknown	159.4	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA
4	Industrial Launderers	Personal	unknown	8.7	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA
5	Industrial Launderers	Personal	unknown	11.5	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA
6	Industrial Launderers	Personal	unknown	975.1	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA
7	Industrial Launderers	Personal	unknown	975.1	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA
8	Industrial Launderers	Personal	unknown	0.3	1	TWA	Finkel (2017)	2.0	Included - no other data available. Data adjusted to 4-hr TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.11 Cellulose Triacetate Film Production

Table_Apx A-19 shows full-shift personal monitoring data for settings involved with the use or production of cellulose triacetate (CTA) film:

- Rows 1 through 4 present data for a CTA fiber production facility in Rock Hill, SC, where methylene chloride was the major component of the solvent system for CTA production. The study provided measured full-shift exposures from 208 to 1,216 mg/m^3 (Ott et al., 1983).
- Rows 5 through 25 present personal monitoring data compiled for various facilities involved with CTA film production. Exposures ranged from 6.9 to 5,905 mg/m^3 (Dell et al., 1999).
- Row 26 contains data for CTA production summarized from two studies (TNO (CIVO), 1999)
    - UK HSEs reported 8-hr TWA exposures between 0 and 60 mg/m^3; 20 mg/m^3 (mean).
    - An IPCS study reported 8-hr TWA exposures up to 350 mg/m^3

Table_Apx A-19. Summary of Full-Shift Inhalation Monitoring Data for Cellulose Triacetate Film Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]			Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
				Min	Max	Mean/ Median					
1	CTA Film Manufacturing	Personal	Cellulose Triacetate Block I Extrusion And Preparation (Low Mecl)	208.42	1,215.77	486.31	84	8-hr TWA	Ott et al. (1983)	2.2	Included – full-shift TWA
2	CTA Film Manufacturing	Personal	Cellulose Triacetate Tow Extrusion And Service (Moderate Mecl)	173.68	1,632.60	972.61	19	8-hr TWA	Ott et al. (1983)	2.2	Included – full-shift TWA
3	CTA Film Manufacturing	Personal	Cellulose Triacetate - Block II Extrusion And Preparation (High Mecl)	729.46	2,396.80	1,649.97	63	8-hr TWA	Ott et al. (1983)	2.2	Included – full-shift TWA
4	CTA Film Manufacturing	Personal	Cellulose Triacetate - Preparation Area	17.37	1,319.98	-	26	8-hr TWA	Ott et al. (1983)	2.2	Included – full-shift TWA
5	CTA Film Manufacturing	Personal	CTA film-base production / Group Leader	34.74	1,389.45	395.99	168	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
6	CTA Film Manufacturing	Personal	CTA film-base production / Coater and swing crew aide	17.37	1,042.09	166.73	61	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
7	CTA Film Manufacturing	Personal	CTA film-base production / Coater's Assistant	10.42	1,042.09	138.94	60	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
8	CTA Film Manufacturing	Personal	CTA film-base production / Cleaner, mechanic, pipe fitter, chemical worker	10.42	694.72	79.89	339	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
9	CTA Film Manufacturing	Personal	CTA film-base production / Instrument mechanic, quality-control tech	6.95	347.36	48.63	191	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
10	CTA Film Manufacturing	Personal	CTA film-base production / Film inspector, head dispatcher, office worker	6.95	173.68	34.74	44	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
11	CTA Film Manufacturing	Personal	CTA film-base production / MeCl work area, not otherwise spec	0.00	868.40	138.94	57	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
12	CTA Film Manufacturing	Personal	CTA film-base production / MeCl work area, not otherwise spec	142.42	653.04	316.10	28	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA

Table_Apx A-19. Summary of Full-Shift Inhalation Monitoring Data for Cellulose Triacetate Film Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]			Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
				Min	Max	Mean/ Median					
13	CTA Film Manufacturing	Personal	CTA film-base production / MeCl work area, not otherwise spec	347.36	521.04	413.36	4	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
14	CTA Film Manufacturing	Personal	CTA film-base production / MeCl work area, not otherwise spec	31.26	1215.77	274.42	188	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
15	CTA Film Manufacturing	Personal	CTA film-base production / extrusion & preparation areas	DL	5905.15	-	-	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
16	CTA Film Manufacturing	Personal	CTA film-base production / Extrusion & spinning areas, or employed as jet wipers	1,042.09	4342.02	-	-	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
17	CTA Film Manufacturing	Personal	CTA film-base production / Dope section	-	-	253.57	47	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
18	CTA Film Manufacturing	Personal	CTA film-base production / Operator (D block)	-	-	305.68	47	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
19	CTA Film Manufacturing	Personal	CTA film-base production / Operator (B/C blocks)	-	-	111.16	47	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
20	CTA Film Manufacturing	Personal	CTA film-base production / Solvent Recovery	-	-	93.79	47	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
21	CTA Film Manufacturing	Personal	CTA film-base production / Cleaning	-	-	86.84	47	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
22	CTA Film Manufacturing	Personal	CTA film-base production / Subwash operator	-	-	34.74	47	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
23	CTA Film Manufacturing	Personal	CTA film-base production / Laboratory	-	-	24.32	47	8-hr TWA	Dell et al. (1999)	2.1	Included – full-shift TWA
24	CTA Film Manufacturing	Personal	CTA film-base production / Polyester film worker and electroplater				21		Dell et al. (1999)	2.1	Included – full-shift TWA
25	CTA Film Manufacturing	Personal	CTA film-base production / MeCl work area, not otherwise spec				30		Dell et al. (1999)	2.1	Included – full-shift TWA
26	CTA Film Manufacturing	Personal	CTA production	0	60 3650	20	unknown		TNO (CIVO) (1999)	2.3	Included – full-shift TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.

b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.12 Flexible Polyurethane Foam Manufacturing

Table_Apx A-20 shows full-shift monitoring data available in published literature for the polyurethane (PU) foam manufacturing industry:

- Rows 1 and 2 present 8-hr TWA methylene chloride exposure for workers utilizing methylene chloride as a blowing agent (13 – 570 mg/m^3) and during miscellaneous tasks in PU foam production (7 – 700 mg/m^3, mean 231 mg/m^3) (TNO (CIVO), 1999).
- Row 3 presents an 8-hr TWA data exposure concentration of 27.8 mg/m^3 over a sample time of approximately 9 hours. The OSHA evaluation came after a complaint by an employee of six employees being exposed to chemicals involved with heating and mixing of ingredients in an oven with no exhaust ventilation (IARC, 2016)
- Rows 4 through 8 present data from a 1987 NIOSH HHE at the Trailmobile Inc. in Charleston, Illinois. The facility manufactured tractor trailers used widely in the trucking industry. Personal 8-hr TWA monitoring data for workers in foaming areas ranged from 4.5 to 27.8 mg/m^3 (Reh and Lushniak, 1990).
- Rows 9 through 12 present 8-hr TWA occupational exposure data for workers exposed to methylene chloride during activities in PU manufacturing, including glue spraying and moulding, ranging from 7.1 to 1,090 mg/m^3. The exposure data provided by IPCS is consolidated from various health and environmental evaluations presented in other published literature. Therefore, information about the specific facilities and procedures corresponding to the exposure data is not provided ((IPCS), 1996).
- Rows 13 through 15 present results from a 1983 monitoring study at the Cone Mills Corporation, for 6-hr exposures during mold release spray coating, ranging from 86.8 through 114.6 mg/m^3 (Cone Mills Corp, 1981a)
- Rows 16 through 28 present results from a 1981 monitoring study at the Cone Mills Corporation, for 4-6-hr exposures during PU foam production, ranging from 13.9 through 972.6 mg/m^3 (Cone Mills Corp, 1981b).
- Rows 29 through 31 present exposures from a 1989 monitoring study a Vulcan Chemicals facility, which used MeCl as an auxillary blowing agent in PU foam production. Full-shift TWA exposures for a saw operator, quality control operator, and flat top operator ranged from 654.5 to 773.1 mg/m^3 (Vulcan Chemicals, 1991).
- Rows 32 through 49 present exposures from a 1977 monitoring study an Olin Chemicals facility, for various workers during PU foam production. Full-shift TWA exposures ranged from 0.3 to 2,200.9 mg/m^3 (Olin Chemicals, 1977).
- Rows 50 through 77 contain 8-hr TWA exposure data compiled in EPA's 1985 exposure and release assessment for PU foam production. Exposure concentrations for various workers ranged from ND to 1,001.9mg/m^3 (US EPA, 1985). EPA assumed zero for the ND value because the limit of detection was not provided and the relative magnitude of the other data points.

Table_Apx A-21 presents the short-term data:

- Rows 1 through 8 contain 0.5 and 3-hr TWA exposure data compiled in EPA's 1985 exposure and release assessment for PU foam production. Exposure concentrations for various workers were 54.5 mg/mg^3 (0.5-hr TWA) and 5.5 to 38.0 mg/m^3 (3-hr TWA) (US EPA, 1985).

Table_Apx A-20. Summary of Full-Shift Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Foam Industry	Personal	Blowing Agent	13 - 570	1	8-hr TWA	TNO (CIVO) (1999)	2.3	Included min and max values – full-shift TWA
2	Foam Industry	Personal	Other Tasks in PUR Production	7 – 700 231 (mean)	1	8-hr TWA	TNO (CIVO) (1999)	2.3	Included min and max values – full-shift TWA
3	Polyurethane Manufacture	Personal	Mix and Heat Ingredients in Oven	27.8	1	8-hr TWA	IARC (2016)	1.9	Included – full-shift TWA
4	Tractor Trailer Construction	Personal	Foam Operator	4.5	1	8-hr TWA	Reh and Lushniak (1990)	1.7	Included – full-shift TWA
5	Tractor Trailer Construction	Personal	Foam Operator	17.4	1	8-hr TWA	Reh and Lushniak (1990)	1.7	Included – full-shift TWA
6	Tractor Trailer Construction	Personal	Foam Operator	10.8	1	8-hr TWA	Reh and Lushniak (1990)	1.7	Included – full-shift TWA
7	Tractor Trailer Construction	Personal	Foam Operator	17.7	1	8-hr TWA	Reh and Lushniak (1990)	1.7	Included – full-shift TWA
8	Tractor Trailer Construction	Personal	Foam Operator	15.6	1	8-hr TWA	Reh and Lushniak (1990)	1.7	Included – full-shift TWA
9	Foam industry	Personal	Moulding	88-1,090	unknown	8-hr TWA	(IPCS) (1996)	2.3	Included – full-shift TWA
10	Foam industry	Personal	Moulding	<247	unknown	8-hr TWA	(IPCS) (1996)	2.3	Included – full-shift TWA
11	Foam industry	Personal	Unknown	7.1-- 251	unknown	8-hr TWA	(IPCS) (1996)	2.3	Included – full-shift TWA
12	Foam industry	Personal	Various jobs	18 -- 580	unknown	8-hr TWA	(IPCS) (1996)	2.3	Included – full-shift TWA
13	Cone Mills Corporation-Corporate Medical Department	Personal	Spraying	111.2	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
14	Cone Mills Corporation-Corporate Medical Department	Personal	Spraying	114.6	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
15	Cone Mills Corporation-Corporate Medical Department	Personal	Spraying	86.8	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
16	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	13.9	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
17	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	38.2	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
18	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	243.2	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA

Table_Apx A-20. Summary of Full-Shift Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
19	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	625.3	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
20	Cone Mills Corporation-Corporate Medical Department	Personal	Crane Operator in Foam Storage Removal	833.7	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
21	Cone Mills Corporation-Corporate Medical Department	Personal	Cut-Off Saw Operator in Foam Storage Removal	521.0	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
22	Cone Mills Corporation-Corporate Medical Department	Personal	Overhead Crane Operator - Cured Foam Storage	173.7	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
23	Cone Mills Corporation-Corporate Medical Department	Personal	Crane Operator in Foam Storage	208.4	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
24	Cone Mills Corporation-Corporate Medical Department	Personal	Crane Operator in Foam Storage Removal	104.2	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
25	Cone Mills Corporation-Corporate Medical Department	Personal	Cut-Off Saw Operator in Foam Storage Removal	138.9	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
26	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Storage Crane Operators	486.3	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
27	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Storage Removal Crane Operator	972.6	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
28	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Storage Crane Operators	521.0	1	8-hr TWA	Cone Mills Corp (1981a)	1.7	Included – full-shift TWA
29	Vulcan Chemicals	Personal	Saw Operator	654.5	1	8-hr TWA	Vulcan Chemicals (1991)	1.9	Included – full-shift TWA
30	Vulcan Chemicals	Personal	Quality Control Operator	773.1	1	8-hr TWA	Vulcan Chemicals (1991)	1.9	Included – full-shift TWA
31	Vulcan Chemicals	Personal	Flat Top Operator	682.9	1	8-hr TWA	Vulcan Chemicals (1991)	1.9	Included – full-shift TWA
32	Olin Chemicals	Personal	Batch operations	91.0	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
33	Olin Chemicals	Personal	Batch operations	167.1	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA

Table_Apx A-20. Summary of Full-Shift Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
34	Olin Chemicals	Personal	Drumming	94.1	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
35	Olin Chemicals	Personal	Drumming	377.2	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
36	Olin Chemicals	Personal	Purge Operations	110.8	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
37	Olin Chemicals	Personal	Purge Operations	0.3	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
38	Olin Chemicals	Personal	Cylinder cleaning	620.0	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
39	Olin Chemicals	Personal	Cylinder cleaning	515.1	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
40	Olin Chemicals	Personal	Blending	112.9	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
41	Olin Chemicals	Personal	Blending	38.9	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
42	Olin Chemicals	Personal	Blending	225.1	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
43	Olin Chemicals	Personal	Laboratory Operations	2200.9	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
44	Olin Chemicals	Personal	Laboratory Operations	1039.3	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
45	Olin Chemicals	Personal	Batch operations	336.2	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
46	Olin Chemicals	Personal	Batch operations	242.1	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
47	Olin Chemicals	Personal	Laboratory Operations	266.1	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
48	Olin Chemicals	Personal	Laboratory Operations	323.0	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA
49	Olin Chemicals	Personal	Filter cleaning, MDA tank	1400.6	1	8-hr TWA	Olin Chemicals (1977)	1.9	Included – full-shift TWA

Table_Apx A-20. Summary of Full-Shift Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
50	Plastic Products	Personal	Foam Gun Operator	558.4	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
51	Plastic Products	Personal	Foam Gun Operator	942.3	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
52	Plastic Products	Personal	Foam Gun Operator	767.8	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
53	Plastic Products	Personal	Foam Gun Operator	698	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
54	Plastic Products	Personal	Inj. Mold Operator	24.43	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
55	Plastic Products	Personal	Inj. Mold Operator	34.98	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
56	Household Refrigerators	Personal	Foam Operator	173.104	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
57	Household Refrigerators	Personal	Foam Operator	169.265	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
58	Household Refrigerators	Personal	Foam Operator	87.25	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
59	Prefab Metal Buildings	Personal	Foamline Operator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA; assumed zero value
60	Food Product Machinery	Personal	Foam Injecting	111.331	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
61	Plastic Products	Personal	Crusher	296.63	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
62	Plastic Products	Personal	Crusher	17.45	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
63	Plastic Products	Personal	Crusher	146.58	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
64	Plastic Products	Personal	Skin Layer	523.58	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
65	Plastic Products	Personal	Skin Layer	272.22	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
66	Plastic Products	Personal	Skin Layer	122.15	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
67	Plastic Products	Personal	Beader	1001.9	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
68	Plastic Products	Personal	Beader	418.88	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
69	Plastic Products	Personal	Beader	383.9	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
70	Plastic Products	Personal	Beader	97.72	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
71	Plastic Products	Personal	Waxer	558.4	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
72	Plastic Products	Personal	Waxer	872.5	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
73	Plastic Products	Personal	Vacuum Former	216.3	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
74	Plastic Products	Personal	Crimper	6.9	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
75	Plastic Products	Personal	Mold Opener	254.77	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA

Table_Apx A-20. Summary of Full-Shift Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
76	Plastic Products	Personal	Mold Opener	167.52	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA
77	Plastic Products	Personal	Shearing Machine	17.45	1	8-hr TWA	US EPA (1985)	1.4	Included – full-shift TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-21. Summary of Short-Term Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Appliance Manufacturing	Personal	Foam Blowing	5.2	1	STEL	US EPA (1985)	1.4	4-hr TWA
2	Appliance Manufacturing	Personal	Foam Blowing	13.1	1	STEL	US EPA (1985)	1.4	4-hr TWA
3	Appliance Manufacturing	Personal	Foam Blowing	18.5	1	STEL	US EPA (1985)	1.4	4-hr TWA
4	Appliance Manufacturing	Personal	Foam Blowing	17.0	1	STEL	US EPA (1985)	1.4	4-hr TWA
5	Appliance Manufacturing	Personal	Foam Blowing	5.2	1	STEL	US EPA (1985)	1.4	4-hr TWA
6	Appliance Manufacturing	Personal	Foam Blowing	38.0	1	STEL	US EPA (1985)	1.4	4-hr TWA
7	Appliance Manufacturing	Personal	Foam Blowing	10.5	1	STEL	US EPA (1985)	1.4	4-hr TWA
8	Toys	Personal	Nozzle Cleaning	54.5	1	STEL	US EPA (1985)	1.4	0.5-hr TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.13 Laboratory Use

Table_Apx A-22 presents full-shift data for laboratory use.

- Rows 1 through 3 contain data from a NIOSH Health Hazard Evaluation in 1989 of the Standards Preparation and Organic Extraction areas at the Rocky Mountain Analytical Laboratory, a division of Enesco, Inc. Samples longer than 4 hours long were adjusted to 8-hr TWAs, and resulted in 8-hr TWA exposures from 2.8 to 3.5 mg/m^3 (Mccammon, 1990).
- Rows 4 through 6 contain monitoring data from a study at Texaco for research laboratory staff. Full-shift exposures for methylene chloride were less than detectable (3.5 mg/m^3) (Texaco Inc, 1993).
- Row 7 included data from another Texaco monitoring study, but contained data that were already provided in Rows 4 through 6 (Texaco Inc, 1993).
- Rows 8 through 11 contain 8-hr TWA exposure data compiled by DOD during laboratory sample preparation and instrument analysis. Exposure concentrations for various workers ranged from 4.9 to 16.6mg/m^3 ((DOEHRS-IH), 2018).
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Table_Apx A-23 presents short-term data for laboratory use.

- Rows 1 through 12 include shorter-term monitoring data from the 1989 NIOSH HHE described in the full-shift data (Mccammon, 1990)
- Row 13 presents a data point from IARC that indicated short-term exposures less than 3.5 mg/m^3, but did not provide additional details; therefore, this data point was excluded in favor of higher quality data (IARC, 2016).
- Rows 14 through 44 contain short-term exposure data compiled by DOD during laboratory operations. Exposure concentrations for various workers ranged from 0.7 to 1,830 mg/m^3 (various sample times) ((DOEHRS-IH), 2018).

Table_Apx A-22. Summary of Full-Shift Inhalation Monitoring Data for Laboratory Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3)[a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Analytical Laboratory	Personal	Sample prep, transfer of mecl from separatory funnels	3.5[a]	1	TWA	Reh and Lushniak (1990)	1.8	Included – full-shift TWA
2	Analytical Laboratory	Personal	Transferring sample from 250-ml beakers, load on steam bath	3.3[a]	1	TWA	Reh and Lushniak (1990)	1.8	Included – full-shift TWA
3	Analytical Laboratory	Personal	Sample concentrating	2.8[a]	1	TWA	Reh and Lushniak (1990)	1.8	Included – full-shift TWA
4	Laboratory	Personal	Research lab staff	3.5	1	TWA	Texaco Inc (1993)	1.9	Included – full-shift TWA
5	Laboratory	Personal	Research lab staff	3.5	1	TWA	Texaco Inc (1993)	1.9	Included – full-shift TWA
6	Laboratory	Personal	Pro lab Staff	3.5	1	TWA	Texaco Inc (1993)	1.9	Included – full-shift TWA
7	Laboratory	Personal	Research lab staff	3.5	1	TWA	Texaco Inc (1993)	1.9	Excluded – repeat of above data
8	DOD Laboratory	Personal	INSTRUMENT ANALYSIS	4.9	1	TWA	((DOEHRS-IH), 2018).	1.3	Included – full-shift TWA
9	DOD Laboratory	Personal	LAB SAMPLE PREPARATION	6.4	1	TWA	((DOEHRS-IH), 2018).	1.3	Included – full-shift TWA
10	DOD Laboratory	Personal	LAB SAMPLE PREPARATION	3.3	1	TWA	((DOEHRS-IH), 2018).	1.3	Included – full-shift TWA
11	DOD Laboratory	Personal	LAB SAMPLE PREPARATION	16.6	1	TWA	((DOEHRS-IH), 2018).	1.3	Included – full-shift TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)
a – Adjusted to 8-hr TWA

Table_Apx A-23. Summary of Short-Term Inhalation Monitoring Data for Laboratory Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Analytical Laboratory	Personal	sample concentrating	2.7	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
2	Analytical Laboratory	Personal	sample sonification	3.9	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
3	Analytical Laboratory	Personal	sample sonification	4.5	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
4	Analytical Laboratory	Personal	washing separtory funnels in sink near CLLE	113.0	1	STEL	Mccammon (1990)	1.8	Included - Worker 15-min STEL
5	Analytical Laboratory	Personal	column cleaning	10.0	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
6	Analytical Laboratory	Personal	sample concentrating	30.0	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
7	Analytical Laboratory	Personal	sample concentrating	4.2	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
8	Analytical Laboratory	Personal	sample concentrating	6.8	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
9	Analytical Laboratory	Personal	transfering 100 ml MeCl into soil samples	9.8	1	STEL	Mccammon (1990)	1.8	Included - Worker 4-hr TWA
10	Analytical Laboratory	Personal	collecting waste chemicals & dumping into waste chemical storage	995.0	1	STEL	Mccammon (1990)	1.8	Included - Worker 30-min TWA
11	Analytical Laboratory	Personal	above refrigerator #G in organic lab storage	17.0	1	STEL	Mccammon (1990)	1.8	Excluded - Personal Samples Prioritized
12	Analytical Laboratory	Personal	on top of refrigerator #F in organics lab storage	11.0	1	STEL	Mccammon (1990)	1.8	Excluded - Personal Samples Prioritized
13	Analytical Laboratory	Personal	Laboratory worker	3.5	1	STEL	IARC (2016)	2.2	Excluded - no info on type of sampling
14	DOD Laboratory	Personal	Miscellaneous lab operations	3.1	1	4-hr TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 4-hr TWA
15	DOD Laboratory	Personal	Miscellaneous lab operations	3.1	1	4-hr TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 4-hr TWA
16	DOD Laboratory	Personal	Sample extraction and analysis (3809, OCD)	34.7	1	3-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data

Table_Apx A-23. Summary of Short-Term Inhalation Monitoring Data for Laboratory Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
									point, but not used to calculate risk.
17	DOD Laboratory	Personal	(3)GC Extraction	0.7	1	2.5-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
18	DOD Laboratory	Personal	134: Extraction of PCB in water samples (Rm 221 - Prep & Rm 227 - GC)	22.5	1	2-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
19	DOD Laboratory	Personal	134: Extraction of total volatiles (TCLP)(Rm 227)	64.7	1	2-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
20	DOD Laboratory	Personal	Analysis, chemical (Laboratory Operations)	1.7	1	1-hr TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 1-hr TWA
21	DOD Laboratory	Personal	Analysis, chemical (Laboratory Operations)	2.4	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
22	DOD Laboratory	Personal	LAB ACTIVITIES	3.3	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
23	DOD Laboratory	Personal	LAB ACTIVITIES	6.4	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
24	DOD Laboratory	Personal	LAB ACTIVITIES	16.6	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
25	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
26	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
27	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
28	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA

Table_Apx A-23. Summary of Short-Term Inhalation Monitoring Data for Laboratory Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
29	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
30	DOD Laboratory	Personal	514A Using Solvents	1830.0	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
31	DOD Laboratory	Personal	EXTRACTION OP	3.6	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
32	DOD Laboratory	Personal	EXTRACTION OP	24.8	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 30-min TWA
33	DOD Laboratory	Personal	(3)GC Extraction	10.4	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
34	DOD Laboratory	Personal	(3)GC Extraction	10.4	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
35	DOD Laboratory	Personal	Sample extraction and analysis (3809, OCD)	62.5	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
36	DOD Laboratory	Personal	Miscellaneous lab operations	6.7	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
37	DOD Laboratory	Personal	EXTRACTION OP	4.6	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
38	DOD Laboratory	Personal	EXTRACTION OP	4.6	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
39	DOD Laboratory	Personal	134: Extraction of PCB in water samples (Rm 221 - Prep & Rm 227 - GC)	5.3	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
40	DOD Laboratory	Personal	134: Extraction of total volatiles (TCLP)(Rm 227)	5.0	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
41	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
42	DOD Laboratory	Personal	IND-025-10 HM/HW HANDLING CLEANUP, CONTAINER SAMPLE/OPEN	6.1	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA
43	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	10.9	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA

Table_Apx A-23. Summary of Short-Term Inhalation Monitoring Data for Laboratory Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
44	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	13.2	1	15-min TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 15-min TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.14 Plastic Product Manufacturing

Table_Apx A-24 presents full-shift monitoring data for plastics product manufacturing.

- Rows 1 through 5 contain 8-hr TWA data from various OSHA inspections at a number of plastic product supply and manufacturing companies that were conducted between 2012 and 2016. Exposure concentrations ranged from 9 to 2,685.1 mg/m^3. Specific worker activities were not specified (OSHA, 2019).
- Row 6 presents an 8-hr TWA of 28.5 mg/m^3 during mixing and heating ingredients from polyurethane part manufacturing (casting) (Fairfax and Porter, 2006).
- Row 7 present an exposure concentration of 208 to 304 mg/m^3 from fabrication of rubber products ((IPCS), 1996).
- Rows 8 through 27 contain monitoring data provided by the Halogenated Solvents Industry Alliance (HSIA), with sampling dates between 2005 and 2017, for production technicians during plastic product manufacturing. Exposure concentrations ranged from 3.9 to 134.1 mg/m^3 (Halogenated Solvents Industry Alliance, 2018).
- Rows 28 through 30 present exposure concentration for operators, maintenance, shift leaders, and lab technicians at a General Electric plastic polymer plant, ranging from 11.5 to 170.2 mg/m^3 (GE, 1989).

Table_Apx A-25 presents short-term monitoring data for plastics product manufacturing.

- Rows 1 through 3 contain short-term exposure data from various OSHA inspections at plastic product manufacturing companies that were conducted between 2012 and 2016. Exposure concentrations ranged from ND to 27.8 mg/m^3. Specific worker activities were not specified. (OSHA, 2019).
- Rows 4 through 24 contain monitoring data provided by the Halogenated Solvents Industry Alliance (HSIA), with sampling dates between 2005 and 2017, for operators and production technicians during plastic product manufacturing. Exposure concentrations ranged from 50.7 to 166.7mg/m^3 (Halogenated Solvents Industry Alliance, 2018).

Table_Apx A-24. Summary of Full-Shift Inhalation Monitoring Data for Plastic Product Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	All Other Plastics Product Manufacturing	Personal	Ada Area	9.0	1	8-hrTWA	OSHA (2019)	1.3	Included – full-shift TWA
2	All Other Plastics Product Manufacturing	Personal	Hop Area Operator	11.5	1	8-hrTWA	OSHA (2019)	1.3	Included – full-shift TWA
3	All Other Plastics Product Manufacturing	Personal	Hop Area Operator	2674.7	1	8-hrTWA	OSHA (2019)	1.3	Included – full-shift TWA
4	All Other Plastics Product Manufacturing	Personal	Injection Molding Operator	35.8	1	8-hrTWA	OSHA (2019)	1.3	Included – full-shift TWA
5	All Other Plastics Product Manufacturing	Personal	Injection Molding Operator	32.7	1	8-hrTWA	OSHA (2019)	1.3	Included – full-shift TWA
6	Polyurethane Part Manufacturing (Casting)	Personal	Mix and heat ingredients in oven	28.5	1	8-hr TWA	Fairfax and Porter (2006)	1.6	Included – full-shift TWA
7	Rubber Products	Personal	Fabrication	208 – 304	Unknown	8-hr TWA	(IPCS) (1996)	2.3	Included – full-shift TWA
8	Plastics material and resin manufacturing	Personal	Production technician	5.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
9	Plastics material and resin manufacturing	Personal	Production technician	5.2	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
10	Plastics material and resin manufacturing	Personal	Production technician	25.5	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
11	Plastics material and resin manufacturing	Personal	Production technician	31.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
12	Plastics material and resin manufacturing	Personal	Production technician	4.9	1	8-hr TWA	Halogenated Solvents	1.6	Included – full-shift TWA

Table_Apx A-24. Summary of Full-Shift Inhalation Monitoring Data for Plastic Product Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
							Industry Alliance (2018)		
13	Plastics material and resin manufacturing	Personal	Production technician	7.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
14	Plastics material and resin manufacturing	Personal	Production technician	3.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
15	Plastics material and resin manufacturing	Personal	Production technician	3.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
16	Plastics material and resin manufacturing	Personal	Production technician	6.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
17	Plastics material and resin manufacturing	Personal	Production technician	3.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
18	Plastics material and resin manufacturing	Personal	Production technician	3.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
19	Plastics material and resin manufacturing	Personal	Production technician	14.9	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
20	Plastics material and resin manufacturing	Personal	Production technician	134.1	1	8-hr TWA	Halogenated Solvents	1.6	Included – full-shift TWA

Table_Apx A-24. Summary of Full-Shift Inhalation Monitoring Data for Plastic Product Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
							Industry Alliance (2018)		
21	Plastics material and resin manufacturing	Personal	Production technician	16.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
22	Plastics material and resin manufacturing	Personal	Production technician	7.7	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
23	Plastics material and resin manufacturing	Personal	Production technician	20.3	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
24	Plastics material and resin manufacturing	Personal	Production technician	11.4	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
25	Plastics material and resin manufacturing	Personal	Production technician	12.8	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
26	Plastics material and resin manufacturing	Personal	Production technician	5.1	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
27	Plastics material and resin manufacturing	Personal	Production technician	17.1	1	8-hr TWA	Halogenated Solvents Industry Alliance (2018)	1.6	Included – full-shift TWA
28	Plastic Polymer Plant	Personal	Operators	170.2	1	8-hr TWA	GE (1989)	2.0	Included – full-shift TWA

Table_Apx A-24. Summary of Full-Shift Inhalation Monitoring Data for Plastic Product Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
29	Plastic Polymer Plant	Personal	Operators/Maintenance/ Lab technicians	37.9	1	8-hr TWA	GE (1989)	2.0	Included – full-shift TWA
30	Plastic Polymer Plant	Personal	Shift leaders/lab technicians	11.5	1	8-hr TWA	GE (1989)	2.0	Included – full-shift TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-25. Summary of Short-Term Inhalation Monitoring Data for Plastic Product Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	All Other Plastics Product Manufacturing	Personal	Plastics Manufacturer	ND	1	STEL	OSHA (2019)	1.3	Excluded – Did not include ND from OSHA data.[c]
2	All Other Plastics Product Manufacturing	Personal	Plastics Manufacturer	27.8	1	STEL	OSHA (2019)	1.3	Worker - 15-min STEL
3	All Other Plastics Product Manufacturing	Personal	Plastics Manufacturer	20.8	1	STEL	OSHA (2019)	1.3	Worker - 15-min STEL
4	Plastics material and resin manufacturing	Personal	Operator	102.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
5	Plastics material and resin manufacturing	Personal	Operator	73.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
6	Plastics material and resin manufacturing	Personal	Operator	94.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
7	Plastics material and resin manufacturing	Personal	Operator	65.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
8	Plastics material and resin manufacturing	Personal	Operator	65.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
9	Plastics material and resin manufacturing	Personal	Operator	60.2	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
10	Plastics material and resin manufacturing	Personal	Operator	131.6	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
11	Plastics material and resin manufacturing	Personal	Operator	65.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL

Table_Apx A-25. Summary of Short-Term Inhalation Monitoring Data for Plastic Product Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
12	Plastics material and resin manufacturing	Personal	Operator	102.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
13	Plastics material and resin manufacturing	Personal	Operator	166.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
14	Plastics material and resin manufacturing	Personal	Operator	111.1	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
15	Plastics material and resin manufacturing	Personal	Operator	83.3	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
16	Plastics material and resin manufacturing	Personal	Product technician	119.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
17	Plastics material and resin manufacturing	Personal	Product technician	69.4	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
18	Plastics material and resin manufacturing	Personal	Product technician	82.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
29	Plastics material and resin manufacturing	Personal	Product technician	62.8	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
20	Plastics material and resin manufacturing	Personal	Product technician	88.0	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
21	Plastics material and resin manufacturing	Personal	Product technician	82.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
22	Plastics material and resin manufacturing	Personal	Product technician	101.5	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL

Table_Apx A-25. Summary of Short-Term Inhalation Monitoring Data for Plastic Product Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
23	Plastics material and resin manufacturing	Personal	Product technician	109.9	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 15-min STEL
24	Plastics material and resin manufacturing	Personal	Product technician	50.7	1	STEL	Halogenated Solvents Industry Alliance (2018)	1.6	Worker - 30-min STEL

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)
c – OSHA indicated that Non-detect samples may be the result of many different inspector intentions when deciding to sample; therefore, ND values from OSHA were excluded.

A.15 Lithographic Printing Plate Cleaning

Table_Apx A-26 presents full-shift monitoring data for lithographic printing plate cleaning.

- Row 1 presents 8-hr TWA data for 61 workers with occupational exposure to methylene chloride through 8-hr shifts cleaning up printing rolls with methylene chloride or using methylene chloride as a solvent in production. The monitoring data was split up into 4-hr TWA samples, as the workers' 8-hr days were split into 4-hr morning and afternoon shifts. The full 8-hr exposures ranged from 3.5 to 625.3 mg/m^3, with a mean of 34.4 mg/m^3 (Ukai et al., 1998).
- Rows 2 and 3 present data from a NIOSH HHE performed in 1980 at Looart Press Incorporated, Colorado Springs, Colorado. The evaluation was requested over concerns about the platemaking and pressroom areas. Two personal TWA exposure samples were determined for methylene chloride exposure, resulting in ND and 17 mg/m^3 (Ahrenholz, 1980).
- Row 4 presents a data point from IARC (2016) that indicated exposure of 24.3 mg/m^3 during cleaning presses , but did not indicate whether the exposure was an 8-hr TWA; therefore, this data point was excluded in favor of higher quality data (IARC, 2016).
- Rows 5 and 6 present modeled exposure concentrations from printing and ink cleaning, ranging from 0 to 1,632 mg/m^3; these data points were excluded for actual monitoring data (Yamada et al., 2014); (Yamada et al., 2015)
- Rows 7 through 50 contain 8-hr TWA exposure data compiled in EPA's 1985 exposure and release assessment for printing operations. Exposure concentrations for various workers ranged from ND to 547.9mg/m^3 (US EPA, 1985).

Table_Apx A-27 presents short-term data.

- Row 1 presents the 4-hr TWA exposure concentrations as described in Row 1 of Table_Apx A-26. Worker exposures ranged from 3.5 to 937.9 mg/m^3 Ukai (1998).

Table_Apx A-26. Summary of Full-Shift Inhalation Monitoring Data for Lithographic Printing Plate Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Printing	Personal	Cleaning of printing rolls / solvent in production	3.5 – 625.3 34.3 (mean)	61	8-hrTWA	Ukai et al. (1998)	2.1	Included – 8-hr TWA-Monitoring Study
2	Printing	Personal	Platemaking Employees - Cleaning step and repeat machine	ND	1	Full-Shift	Ahrenholz (1980)	1.7	Included – full-shift TWA-NIOSH HHE
3	Printing	Personal	Platemaking Employees - Cleaning step and repeat machine	17	1	Full-Shift	Ahrenholz (1980)	1.7	Included – full-shift TWA-NIOSH HHE
4	Printing	Personal	Cleaning Presses	24.31	1	Full-Shift	IARC (2016)	1.9	Excluded-Used actual monitoring data
5	Printing	Personal	Printing/Ink Cleaning (modeled)	0 – 521.04	n/a	Full-Shift (modeled)	Yamada et al. (2015)	4.0	Excluded-Used actual monitoring data
6	Printing	Personal	Printing/Ink Cleaning (modeled)	69.47 – 1,632.6	n/a	Full-Shift (modeled)	Yamada et al. (2015)	4.0	Excluded-Used actual monitoring data
7	Graphic Arts	Personal	Multilith Operator	62.8	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
8	Screen Printing	Personal	Printing	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
9	Screen Printing	Personal	Printing	10.5	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
10	Screen Printing	Personal	Printing	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
11	Screen Printing	Personal	Printing	17.5	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
12	Department Stores	Personal	Asst. Printer	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
13	Department Stores	Personal	Sign Maker	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA

Table_Apx A-26. Summary of Full-Shift Inhalation Monitoring Data for Lithographic Printing Plate Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
14	Department Stores	Personal	Printing Shop	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
15	Department Stores	Personal	Printer	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
16	Department Stores	Personal	Printer	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
17	Direct Selling Est.	Personal	Virkotype Printer	3.5	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
18	Direct Selling Est.	Personal	Offset Printer	3.5	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
19	Government	Personal	Printer	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
20	Newspapers	Personal	Pressman	77.4	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
21	Newspapers	Personal	Pressman	152.9	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
22	Newspapers	Personal	Pressman	76.4	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
23	Newspapers	Personal	Pressman	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
24	Lithographic Printing	Personal	Pressman	3.7	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
25	Lithographic Printing	Personal	Printing Press	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
26	Lithographic Printing	Personal	First Feeder	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
27	Lithographic Printing	Personal	Printing Press	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
28	Lithographic Printing	Personal	Pressman	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
29	Lithographic Platemaking	Personal	Proof Press Operator	139.7	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA

Table_Apx A-26. Summary of Full-Shift Inhalation Monitoring Data for Lithographic Printing Plate Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
30	Industrial Controls	Personal	Screen Washer	76.0	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
31	Industrial Controls	Personal	Silk Screen Oper.	179.0	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
32	Fabr. Textile Products NEW	Personal	Screen Washer	36.9	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
33	Fabr. Textile Products NEW	Personal	Screen Washer	18.0	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
34	Stationery Products	Personal	Platemaker	17.0	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
35	Stationery Products	Personal	Platemaker	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
36	Graphic Arts	Personal	Platemaker	19.2	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
37	Graphic Arts	Personal	Platemaker	30.7	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
38	Graphic Arts	Personal	Plate Cleaner	221.3	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
39	Lithographic Printing	Personal	Helper	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
40	Lithographic Platemaking	Personal	Etcher Operator	296.7	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
41	Graphic Arts	Personal	Mat Preparation	62.8	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
42	Graphic Arts	Personal	Film Processor	22.7	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
43	Screen Printing	Personal	Image Making	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
44	Screen Printing	Personal	Chopping	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
45	Screen Printing	Personal	Trimming	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA

Table_Apx A-26. Summary of Full-Shift Inhalation Monitoring Data for Lithographic Printing Plate Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
46	Screen Printing	Personal	Cutting	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
47	Screen Printing	Personal	Sewing	ND	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
48	Graphic Arts	Personal	Stripper	24.4	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
49	Commercial Letterpress	Personal	Clean-up Man	157.1	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA
50	Commercial Letterpress	Personal	Screen Maker	547.9	1	8-hr TWA	US EPA (1985)	1.4	Included – Worker 8-hr TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m³ by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

Table_Apx A-27. Summary of Short-Term Inhalation Monitoring Data for Lithographic Printing Plate Cleaning

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Printing	Personal	Cleaning of printing rolls / solvent in production	3.5 -- 938 35.4 (mean)	61	4-hrTWA	Ukai et al. (1998)	2.1	Used as 4-hr TWA data
2	Printing	Personal	Platemaking Employees - Cleaning step and repeat machine	3.5 – 476 25 (mean)	61	4-hrTWA	Ukai et al. (1998)	2.1	Used as 4-hr TWA data

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m³ by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.16 Pharmaceutical Manufacturing

Table_Apx A-28 presents full-shift data for pharmaceutical manufacturing.

- Rows 1 through 3 includes various data points from a 1999 European Commission report. One reference reported that in the pharmaceutical industry, sealed processes, high recovery rates and careful handling of discharges can bring exposure rates to around 106 mg/m^3. Alternate data from the UK HSE's (1998) occupational exposure database showed that for process operators in pharmacy the values can in practice be much lower, in the range of 3.5 to 10 mg/m^3. Finally, according to a feasibility study, workers in production facilities without adequate control measurements could be exposed to levels between 7 and 3,750 mg/m^3 (TNO (CIVO), 1999).
- Rows 4 through 15 contain 8-hr TWA exposure data compiled in EPA's 1985 exposure and release assessment for production workers during pharmaceutical manufacturing. Exposure concentrations for various workers ranged from ND to 4,628 mg/m^3 (US EPA, 1985).

Table_Apx A-28. Summary of Full-Shift Inhalation Monitoring Data for Pharmaceutical Manufacturing

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Pharmaceuticals	Personal	unknown	106	unknown	8-hr TWA	TNO (CIVO) (1999)	2.3	Included- Worker 8-hr TWA
2	Pharmaceuticals	Personal	Unknown	3.5 – 10	Unknown	8-hr TWA	TNO (CIVO) (1999)	2.3	Included- Worker 8-hr TWA
3	Pharmaceuticals	Personal	unknown	7 – 3,750	Unknown	8-hr TWA	TNO (CIVO) (1999)	2.3	Excluded - used more recent data (consistent with EC, 1999)
4	Pharmaceuticals	Personal	Operator	1	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
5	Pharmaceuticals	Personal	Operator	587	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
6	Pharmaceuticals	Personal	Film Coater	ND	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
7	Pharmaceuticals	Personal	Film Coater	142	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
8	Pharmaceuticals	Personal	Operator	230	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
9	Pharmaceuticals	Personal	Operator	467	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
10	Pharmaceuticals	Personal	Production	2003	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
11	Pharmaceuticals	Personal	Production	2865	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
12	Pharmaceuticals	Personal	Production	4628	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
13	Pharmaceuticals	Personal	Lead	ND	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
14	Pharmaceuticals	Personal	Chemical Operator	315	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA
15	Pharmaceuticals	Personal	Chemical Operator	192	1	8-hr TWA	US EPA (1985)	1.4	Included- Worker 8-hr TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.17 Non-Aerosol Industrial and Commercial Use

Table_Apx A-29 presents full-shift data for non-aerosol industrial and commercial use.

- Rows 1 through 108 contain 8-hr TWA exposure data compiled in EPA's 1985 exposure and release assessment for production workers during general cleaning uses. Exposure concentrations for various workers ranged from ND to 1,294.8 mg/m^3 (US EPA, 1985).

Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Air Transport	Personal	Maintenance Utility	423.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
2	Air Transport	Personal	Maintenance Utility	313.4	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
3	Air Transport	Personal	Maintenance Utility	491.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
4	Air Transport	Personal	Maintenance Utility	197.2	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
5	Alkalies & Chlorine	Personal	Maintenance Man	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
6	Colleges	Personal	Janitorial	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
7	Colleges	Personal	Janitorial	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
8	Consulting Services	Personal	Maintenance Man	65.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
9	Consulting Services	Personal	Maintenance Man	39.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
10	Sporting Goods	Personal	Paint Operator	65.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
11	Totalizing Fluid Meters	Personal	Painter	70.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
12	Nonferrous Foundies NEC	Personal	Painter	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
13	Nonferrous Foundies NEC	Personal	Painter	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
14	Electronic Components	Personal	Pour Head Operator	101.2	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
15	Electronic Components	Personal	Pour Head Operator	167.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
16	Sporting Goods	Personal	Rim Operator	43.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA

Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
17	Sporting Goods	Personal	Rim Operator	59.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
18	Sporting Goods	Personal	Rim Operator	31.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
19	Sporting Goods	Personal	Rim Operator	2.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
20	Sporting Goods	Personal	Rim Operator	2.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
21	Sporting Goods	Personal	Sole Operator	72.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
22	Sporting Goods	Personal	Sole Operator	104.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
23	Sporting Goods	Personal	Glue Operator	12.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
24	Sporting Goods	Personal	Glue Operator	62.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
25	Sporting Goods	Personal	Clean-Up Operator	64.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
26	Sporting Goods	Personal	Glue Operator	69.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
27	Sporting Goods	Personal	Glue Operator	131.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
28	Sporting Goods	Personal	Glue Operator	28.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
29	Sporting Goods	Personal	Tongue Ass. Oper	15.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
30	Sporting Goods	Personal	Tongue Ass. Oper	16.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
31	Sporting Goods	Personal	Cuff Glue Oper.	29.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
32	Sporting Goods	Personal	Hot Max Oper.	22.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA

Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
33	Sporting Goods	Personal	Hot Max Oper.	11.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
34	Mineral Wool	Personal	Utility Operator	84.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
35	Mineral Wool	Personal	Pt. Applicator	94.9	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
36	Mineral Wool	Personal	Dyken Operator	84.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
37	Mineral Wool	Personal	Pt. Operator	84.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
38	Aluminum Foundries	Personal	Core Machine Operator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
39	Brass Foundries	Personal	Griner	0.6	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
40	Misc Plastic Products	Personal	Equipment Operator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
41	Misc Plastic Products	Personal	Equipment Operator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
42	Pumping Equipment	Personal	Inpres. Operator	83.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
43	Wholesale Comm. Machines	Personal	DCR Operator	127.7	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
44	Motor Vehicle Parts	Personal	Micell. Mach. Oper.	20.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
45	Motor Vehicle Parts	Personal	Micell. Mach. Oper.	41.2	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
46	Special Dies & Tools	Personal	Press Operator	87.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
47	A/C & Heatig	Personal	Machine Operator	174.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
48	U.S. Postal Service	Personal	Mail Process Eqpt.	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA

Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
49	U.S. Postal Service	Personal	Mail Process Eqpt.	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
50	Hand & Edge Tools	Personal	Induction Machine	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
51	Hand & Edge Tools	Personal	Unassigned Machine	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
52	Coating & Engraving	Personal	Machine Operator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
53	Coating & Engraving	Personal	Asst. Machine Oper.	232.4	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
54	Industrial Controls	Personal	Machine Operator	966.7	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
55	Petroleum Refining	Personal	Machinist	10.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
56	Electric Repair	Personal	Assembler	1294.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
57	Electric Repair	Personal	Assembler	621.2	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
58	Electric Repair	Personal	Assembler	1294.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
59	Electric Repair	Personal	Assembler	621.2	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
60	Service Ind. Machines NEC	Personal	Assembler	1017.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
61	Service Ind. Machines NEC	Personal	Assembler	205.9	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
62	Service Ind. Machines NEC	Personal	Assembler	764.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
63	Service Ind. Machines NEC	Personal	Assembler	862.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
64	Sporting Goods	Personal	Mold Cleaner	40.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA

Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
65	Sporting Goods	Personal	Mold Cleaner	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
66	Sporting Goods	Personal	Mold Cleaner	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
67	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
68	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
69	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
70	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
71	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
72	Plastic Products	Personal	Fabricator	59.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
73	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
74	Plastic Products	Personal	Helper	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
75	Plastic Products	Personal	Helper	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
76	Plastic Products	Personal	Helper	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
77	Sporting Goods	Personal	Lead Lady	81.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
78	Sporting Goods	Personal	Lead Lady	319.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
79	Sporting Goods	Personal	Riveter	15.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
80	Soaps & Detergents	Personal	Supervisor	376.9	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA

Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
81	Soaps & Detergents	Personal	Mixer	150.9	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
82	Aluminum Products	Personal	Inspector	54.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
83	Brass Foundries	Personal	Art Chase	2.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
84	U.S. Postal Service	Personal	Electronics Technician	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
85	Cleaning Services	Personal	Asst. Supervisor	468.7	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
86	Misc. Plastic Products	Personal	Mixer	137.9	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
87	Transportation Eqpt. NEC	Personal	Mechanic	311.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
88	Oil Field Machinery	Personal	Helper	188.2	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
89	Machine Tools	Personal	Snipper	90.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
90	A/C & Heating Eqpt.	Personal	Disassembler Steam	323.0	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
91	Metal Doors	Personal	Sealer	87.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
92	Auto Repair	Personal	Installer	51.1	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
93	Metal Household Furniture	Personal	Set-up Man	1129.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
94	Measurement Instruments	Personal	Washer	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
95	Photographic Equipment	Personal	Transport Cleaner	76.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
96	Photographic Equipment	Personal	Transport Cleaner	76.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA

Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
97	Photographic Equipment	Personal	Transport Cleaner	76.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
98	Electroplating	Personal	Watch Band Cleaner	61.6	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
99	Electroplating	Personal	Compounder	1092.4	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
100	Coating & Engraving	Personal	Line Helper	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
101	Small Arms Ammo	Personal	Applier	59.3	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
102	Small Arms Ammo	Personal	Applier	247.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
103	Motors & Generators	Personal	Grinder Washer	23.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
104	Petroleum Refining	Personal	Ketone Operator	46.8	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
105	Refuse Systems	Personal	Foreman	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
106	Refuse Systems	Personal	Drum Cutter	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
107	Refuse Systems	Personal	Operator	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
108	Refuse Systems	Personal	General Laborer	ND	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA

a – Statistics provided by the cited source and are presented here as they were presented in the source.
b – Values provided in ppm were converted to mg/m^3 by multiplying the measurement in ppm by the molecular weight of methylene chloride (84.93 g/mol) and dividing by molar volume (24.45 L)

A.18 Waste Handling, Disposal, Treatment, and Recycling

Table_Apx A-30 presents full-shift data for from waste handling, disposal, treatment, and recycling.

- Rows 1 through 3 contain 8-hr TWA exposure data compiled in EPA's 1985 exposure and release assessment for solvent reclaimers during solvent recovery. Exposure concentrations for various workers ranged from 10.5 to 19.2 mg/m^3 (US EPA, 1985).
- Rows 4 through 7 contain full-shift exposure data compiled by DOD from 2015 and 2017 during waste disposal and sludge operations. Exposure concentrations for various workers ranged from 0.4 to 2.3 mg/m^3 (various sample times) ((DOEHRS-IH), 2018). Note that the data were provided over various sample times that corresponded with the process durations; therefore, EPA averaged the exposures over an 8-hr period to calculate 8-hr TWAs.

Table_Apx A-31 presents short-term data for from waste handling, disposal, treatment, and recycling.

- Rows 1 through 8 contain short-term exposure data compiled by DOD from 2014 and 2015 during waste transfer. Exposure concentrations for various workers ranged from 1.8 to 5.8 mg/m^3 (various sample times) ((DOEHRS-IH), 2018).

Table_Apx A-30. Summary of Full-Shift Inhalation Monitoring Data for Waste Handling, Disposal, Treatment, and Recycling

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Solvent Recovery	Personal	Solvent Reclaimer	19.2	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
2	Solvent Recovery	Personal	Solvent Reclaimer	18.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
3	Solvent Recovery	Personal	Solvent Reclaimer	10.5	1	8-hr TWA	US EPA (1985)	1.4	Included - Worker 8-hr TWA
4	DOD Waste Disposal and Sludge Handling	Personal	Waste Disposal	0.4	1	8-hr TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 8-hr TWA
5	DOD Waste Disposal and Sludge Handling	Personal	313A Sludge Operations	2.3	1	8-hr TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 8-hr TWA
6	DOD Waste Disposal and Sludge Handling	Personal	313A Sludge Operations	2.3	1	8-hr TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 8-hr TWA
7	DOD Waste Disposal and Sludge Handling	Personal	313A Sludge Operations	2.3	1	8-hr TWA	((DOEHRS-IH), 2018)	1.3	Included - Worker 8-hr TWA

Table_Apx A-31. Summary of Short-Term Inhalation Monitoring Data for Waste Handling, Disposal, Treatment, and Recycling

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and from the bowser and storage tanks, addition of chemicals to tanks	2.9	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included – Worker 30-min TWA
2	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and from the bowser and storage tanks, addition of chemicals to tanks	2.9	1	30-min TWA	((DOEHRS-IH), 2018)	1.3	Included – Worker 30-min TWA
3	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and	1.8	1	2.5-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2-

Table_Apx A-31. Summary of Short-Term Inhalation Monitoring Data for Waste Handling, Disposal, Treatment, and Recycling

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m³) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			from the bowser and storage tanks, addition of chemicals to tanks						or 3-hr TWA. Presented data point, but not used to calculate risk.
4	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and from the bowser and storage tanks, addition of chemicals to tanks	5.8	1	2.5-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
5	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and from the bowser and storage tanks, addition of chemicals to tanks	2.7	1	2.5-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
6	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and from the bowser and storage tanks, addition of chemicals to tanks	2.8	1	2.5-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
7	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and from the bowser and storage tanks, addition of chemicals to tanks	0.8	1	3-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
8	DOD Waste Disposal and Sludge Handling	Personal	IND-025-00 Hazardous Waste Disposers: Transfer chemical to and	3.4	1	2.5-hr TWA	((DOEHRS-IH), 2018)	1.3	No health comparisons for 2- or 3-hr TWA.

Table_Apx A-31. Summary of Short-Term Inhalation Monitoring Data for Waste Handling, Disposal, Treatment, and Recycling

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m^3) [a,b]	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			from the bowser and storage tanks, addition of chemicals to tanks						Presented data point, but not used to calculate risk.

APPENDIX B APPROACH FOR ESTIMATING NUMBER OF WORKERS

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

1. Identify the North American Industry Classification System (NAICS) codes for the industry sectors associated with each condition of use.
2. Estimate total employment by industry/occupation combination using the Bureau of Labor Statistics' Occupational Employment Statistics (OES) data (U.S. BLS, 2016).
3. Refine the OES estimates where they are not sufficiently granular by using the U.S. Census' Statistics of U.S. Businesses (SUSB) data (U.S. Census Bureau, 2015) on total employment by 6-digit NAICS.
4. Estimate the percentage of employees likely to be using methylene chloride instead of other chemicals (i.e., the market penetration of methylene chloride in the condition of use).
5. Estimate the number of sites and number of potentially exposed employees per site.
6. Estimate the number of potentially exposed employees within the condition of use.

Step 1: Identifying Affected NAICS Codes

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

- Querying the U.S. Census Bureau's *NAICS Search* tool using keywords associated with each condition of use to identify NAICS codes with descriptions that match the condition of use.
- Referencing EPA/OPPT Generic Scenarios (GS's) and Organisation for Economic Co-operation and Development (OECD) Emission Scenario Documents (ESDs) for a condition of use to identify NAICS codes cited by the GS or ESD.
- Reviewing Chemical Data Reporting (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.

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

Step 2: Estimating Total Employment by Industry and Occupation

BLS's (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/OPPT reviewed the occupation description and identified those occupations (SOC codes) where workers are potentially exposed to methylene chloride. Table_Apx B-1 shows the SOC codes EPA/OPPT classified as occupations potentially exposed to methylene chloride. These occupations are classified into workers (W) and occupational non-users (O). All other SOC codes are assumed to represent occupations where exposure is unlikely.

Table_Apx B-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/OPPT made different SOC code worker and ONU assignments for this condition of use. Table_Apx B-2 summarizes the SOC codes with worker and ONU designations used for dry cleaning facilities.

Table_Apx B-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

SOC	Occupation	Designation
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/OPPT 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/OPPT's methodology was to further refine the employment estimates by using total employment data in the U.S. Census Bureau's (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 methylene chloride exposure are included. As an example, OES data are available for the 4-digit NAICS 8123 *Drycleaning and Laundry Services*, which includes the following 6-digit NAICS:

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

In this example, only NAICS 812320 is of interest. The Census data allow EPA/OPPT 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 B-3 illustrates this granularity adjustment for NAICS 812320.

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

NAICS	SOC CODE	SOC Description	Occupation Designation	Employment by SOC at 4-	% of Total Employment	Estimated Employment

				digit NAICS level		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**

Note: numbers may not sum exactly due to rounding.
W = worker
O = occupational non-user
Source: U.S. BLS (2016); U.S. Census Bureau (2015)

Step 4: Estimating the Percentage of Workers Using Methylene Chloride Instead of Other Chemicals

In the final step, EPA/OPPT accounted for the market share by applying a factor to the number of workers determined in Step 3. This accounts for the fact that methylene chloride may be only one of multiple chemicals used for the applications of interest. EPA/OPPT did not identify market penetration data for any number of conditions of use. In the absence of market penetration data for a given condition of use, EPA/OPPT assumed methylene chloride 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%. 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/OPPT calculated the number of workers and occupational non-users in each industry/occupation combination using the formula below (granularity adjustment is only applicable where SOC data are not available at the 6-digit NAICS level):

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

EPA/OPPT 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/OPPT 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/OPPT estimated the number of workers and occupational non-users potentially exposed to methylene chloride and the number of sites that use methylene chloride in a given condition of use through the following steps:

- 6.A. 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 Toxics Release Inventory (TRI), Discharge Monitoring Report (DMR) data, National Emissions Inventory (NEI), or literature for the condition of use.
- 6.B. Estimating the number of establishments that use methylene chloride by taking the total number of establishments from Step 6.A and multiplying it by the market penetration factor from Step 4.
- 6.C. Estimating the number of workers and occupational non-users potentially exposed to methylene chloride by taking the number of establishments calculated in Step 6.B and multiplying it by the average number of workers and occupational non-users per site from Step 5.

APPENDIX C EQUATIONS FOR CALCULATING ACUTE AND CHRONIC EXPOSURES FOR NON-CANCER AND CANCER

This report assesses exposures to methylene chloride for workers in occupational settings, presented as 8-hr time weighted averages (TWA). The 8-hr TWA exposures are then used to calculate acute exposure, average daily concentration (ADC) for chronic, non-cancer risks, and lifetime average daily concentration (LADC) for chronic, cancer risks.

Acute workplace exposures are assumed to be equal to the contaminant concentration in air (8-hr TWA), per Equation C-1.

Equation C-1

$$AEC = \frac{C \times ED}{AT_{acute}}$$

Where:

AEC = acute exposure concentration
C = contaminant concentration in air (TWA)
ED = exposure duration (8 hr/day)
AT_{acute} = acute averaging time (8 hr)

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

Equation C-2

$$\boldsymbol{ADC\ or\ LADC = \frac{C \times ED \times EF \times WY}{AT\ or\ AT_C}}$$

Where:

ADC = average daily concentration (8-hr TWA) used for chronic non-cancer risk calculations
LADC = lifetime average daily concentration (8-hr TWA) used for chronic cancer risk calculations
C = contaminant concentration in air (8-hr TWA)
ED = exposure duration (8 hr/day)
EF = exposure frequency (250 days/yr)
WY = exposed working years per lifetime (50^{th} percentile = 31; 95^{th} percentile = 40)
AT = averaging time, non-cancer risks (WY × 365 days/yr × 24 hr/day)
AT_c = averaging time, cancer risks (lifetime (LT) x 250 days/year x 8 hr/day; where LT = 78 years); this averaging time corresponds to the cancer benchmark

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

Parameter Name	Symbol	Value	Unit
Exposure Duration	ED	8	hr/day
Exposure Frequency	EF	250	days/year
Working Years	WY	31 (50th percentile) 40 (95th percentile)	years
Lifetime, cancer	LT	78	years
Averaging Time, non-cancer	AT	271,560 (CT)[a] 350,400 (HE)[b]	hr
Averaging Time, cancer	AT_c	156,000	hr

[a] Calculated using the 50th percentile value for working years (WY)
[b] Calculated using the 95th percentile value for working years (WY)

Exposure Duration (ED)
EPA uses an exposure duration of 8 hours per day for averaging full-shift exposures.

Exposure Frequency (EF)
EPA uses an exposure frequency of 250 days per year. Exposure frequency (EF) is expressed as the number of days per year a worker is exposed to the chemical being assessed. In some cases, it may be reasonable to assume a worker is exposed to the chemical on each working day. In other cases, it may be more appropriate to estimate a worker's exposure to the chemical occurs during a subset of the worker's annual working days. The relationship between exposure frequency and annual working days can be described mathematically as follows:

$$EF = f \times AWD$$

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 (2015) 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 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 days per year worked, or AWD, ranges from 169 to 282 days per year, with a 50th percentile value of 250 days per year. EPA repeated this analysis for all NAICS codes at the 4-digit level. The average AWD for all 4-digit NAICS codes ranges from 111 to 282 days per year, with a 50th percentile value of 228 days per year. 250 days per year is approximately the 75th percentile.

In the absence of industry- and methylene chloride-specific data, EPA assumes the parameter *f* is equal to one for all conditions of use.

Working Years (WY)

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

- Minimum value: BLS CPS tenure data with current employer as a low-end estimate of the number of lifetime working years: 10.4 years;
- Mode value: The 50th percentile tenure data with all employers from SIPP as a mode value for the number of lifetime working years: 36 years; and
- Maximum value: The maximum average tenure data with all employers from SIPP as a high-end estimate on the number of lifetime working years: 44 years.

This triangular distribution has a 50th percentile value of 31 years and a 95th percentile value of 40 years. EPA uses these values for central tendency and high-end ADC and LADC calculations, respectively.

The 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 (2019a) Survey of Income and Program Participation (SIPP) provides information on *lifetime tenure with all employers*. SIPP is a household survey that collects data on income, labor force participation, social program participation and eligibility, and general demographic characteristics through a continuous series of national panel surveys of between 14,000 and 52,000 households (U.S. Census Bureau, 2019b). EPA analyzed the 2008 SIPP Panel Wave 1, a panel that began in 2008 and covers the interview months of September 2008 through December 2008 (U.S. Census Bureau, 2019a, b). For 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.[5] Census household surveys use different industry codes than the NAICS codes

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

used in its firm surveys, so these were converted to NAICS using a published crosswalk (U.S. Census Bureau, 2013). EPA calculated the average tenure for the following age groups: 1) workers age 50 and older; 2) workers age 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 C-2 summarizes the average tenure for workers age 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 C-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 10 chemicals undergoing risk evaluation	35.9	36	39	44
Manufacturing sectors (NAICS 31-33)	35.7	36	39	40
Non-manufacturing sectors (NAICS 42-81)	36.1	36	39	44

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

BLS CPS data provides the median years of tenure that wage and salary workers had been with their current employer. Table_Apx C-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 age 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 C-3. Median Years of Tenure with Current Employer by Age Group

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

Source: U.S. BLS (2014)

Lifetime Years (LT)

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

APPENDIX D SAMPLE CALCULATIONS FOR CALCULATING ACUTE AND CHRONIC (NON-CANCER AND CANCER) INHALATION EXPOSURES

Sample calculations for high-end and central tendency chronic exposure concentrations for one setting, Manufacturing, are demonstrated below. The explanation of the equations and parameters used is provided in Appendix B.

Example High-End ADC and LADC

Calculate ADC_{HE}:

$$ADC_{HE} = \frac{C_{HE} \times ED \times EF \times WY_{HE}}{AT_{HE}}$$

$$ADC_{HE} = \frac{4.6\,\frac{mg}{m^3} \times 8\,\frac{hr}{day} \times 250\,\frac{days}{year} \times 40\ years}{350{,}400\ \text{hours}} = 1.1\,\frac{mg}{m^3}$$

Calculate $LADC_{HE}$:

$$LADC_{HE} = \frac{C_{HE} \times ED \times EF \times WY_{HE}}{AT_C}$$

$$LADC_{HE} = \frac{4.6\,\frac{mg}{m^3} \times 8\,\frac{hr}{day} \times 250\,\frac{days}{year} \times 40\ years}{156{,}000\ \text{hours}} = 2.4\,\frac{mg}{m^3}$$

D.2 Example Central Tendency ADC and LADC

Calculate ADC_{CT}:

$$ADC_{CT} = \frac{C_{CT} \times ED \times EF \times WY_{CT}}{AT_{CT}}$$

$$ADC_{CT} = \frac{0.36\,\frac{mg}{m^3} \times 8\,\frac{hr}{day} \times 250\,\frac{days}{year} \times 31\ years}{271{,}560\ \text{hours}} = 0.1\,\frac{mg}{m^3}$$

Calculate $LADC_{CT}$:

$$LADC_{CT} = \frac{C_{CT} \times ED \times EF \times WY_{CT}}{AT_C}$$

$$LADC_{CT} = \frac{0.36\,\frac{mg}{m^3} \times 8\,\frac{hr}{day} \times 250\,\frac{days}{year} \times 31\ years}{156{,}000\ \text{hours}} = 0.14\,\frac{mg}{m^3}$$

APPENDIX E DERMAL EXPOSURE ASSESSMENT METHOD

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 (ECETOC TRA).

E.1 Incorporating the Effects of Evaporation

E.1.1 Modification of EPA/OPPT Models

Current EPA/OPPT dermal models do not incorporate the evaporation of material from the dermis. The dermal potential dose rate, D_{exp} (mg/day), is calculated as (U.S. EPA, 2013):

Equation E-1

$$D_{exp} = S \times Q_u \times Y_{derm} \times FT$$

Where:

S is the surface area of contact (cm^2; defaults: 535 cm^2 (central tendency); 1,070 cm^2 (high end) = full area of one hand (central tendency) or two hands (high end), a mean value for men > 21 yr (U.S. EPA, 2011), the highest exposed population)
Qu is the quantity remaining on the skin (mg/cm^2-event; defaults: 1.4 mg/cm2-event (central tendency); 2.1 mg/cm2-event (high end))
Y_{derm} is the weight fraction of the chemical of interest in the liquid ($0 \leq Y_{derm} \leq 1$)
FT is the frequency of events (integer number per day).

Here Q_u does not represent the quantity remaining after evaporation, but represents the quantity remaining after the bulk liquid has fallen from the hand that cannot be removed by wiping the skin (e.g., the film that remains on the skin).

One way to account for evaporation of a volatile solvent would be to add a multiplicative factor to the EPA/OPPT model to represent the proportion of chemical that remains on the skin after evaporation, f_{abs} ($0 \leq f_{abs} \leq 1$):

Equation E-2

$$D_{exp} = S \times (Q_u \times f_{abs}) \times Y_{derm} \times FT$$

This approach simply removes the evaporated mass from the calculation of dermal uptake. Evaporation is not instantaneous, but the EPA/OPPT model already has a simplified representation of the kinetics of dermal uptake.

E.2 Calculation of f_{abs}

Kasting and Miller (2006) developed a diffusion model to describe the absorption of volatile compounds applied to the skin. As of part of the model, Kasting and Miller define a ratio of the liquid evaporation to absorption, χ. They derive the following definition of χ (which is dimensionless) at steady-state:

Equation E-3

$$\chi = 3.4 \times 10^{-3} u^{0.78} \frac{P_{vp} MW^{3.4}}{K_{oct}^{0.76} S_W}$$

Where:

- u is the air velocity (m/s)
- K_{oct} is the octanol:water partition coefficient
- MW is the molecular weight
- S_W is the water solubility (μg/cm^3)
- P_{vp} is the vapor pressure (torr)

Chemicals for which χ >> 1 will largely evaporate from the skin surface, while chemicals for which χ << 1 will be largely absorbed; χ = 1 represents a balance between evaporation and absorption. Equation E-3Equation is applicable to chemicals having a log octanol/water partition coefficient less than or equal to three (log Kow ≤ 3)[6]. The equations that describe the fraction of the initial mass that is absorbed (or evaporated) are rather complex (Equations 20 and 21 of Kasting and Miller (2006)) but can be solved.

E.2.1 Small Doses (Case 1: $M_0 \leq M_{sat}$)

In the small dose scenario, the initial dose (M_0) is less than that required to saturate the upper layers of the stratum corneum ($M_0 \leq M_{sat}$), and the chemical is assumed to evaporate from the skin surface at a rate proportional to its local concentration.

For this scenario, FH (2012) calculated the fraction of applied mass that is absorbed, based on the infinite limit of time (i.e. infinite amount of time available for absorption after exposure):

Equation E-4

$$f_{abs} = \frac{m_{abs}(\infty)}{M_0} = \frac{2 + f\chi}{2 + 2\chi}$$

Where:

- m_{abs} is the mass absorbed
- M_0 is the initial mass applied
- *f* is the relative depth of penetration in the *stratum corneum* (*f* = 0.1 can be assumed)
- χ is as previously defined

Note the simple algebraic solution in Equation E-4 provides a theoretical framework for the total mass that is systemically absorbed after exposure to a small finite dose (mass/area) of chemical, which depends on the relative rates of evaporation, permeation, and the initial load. At "infinite time", the applied dose is either absorbed or evaporated (FH, 2012). The finite dose is a good model for *splash-type exposure in the workplace* (Frasch and Bunge, 2015).

[6] For simplification, Kasting and Miller (2006) does not consider the resistance of viable tissue layers underlying the *stratum corneum*, and the analysis is applicable to hydrophilic-to-moderately lipophilic chemicals. For small molecules, this limitation is equivalent to restricting the analysis to compounds where Log $K_{ow} \leq 3$.

The fraction of the applied mass that evaporates is simply the complement of that absorbed:

Equation E-5

$$\frac{m_{evap}(\infty)}{M_0} = 1 - f_{abs} = \frac{2\chi - f\chi}{2 + 2\chi}$$

Where:

m_{evap} is the mass evaporated

The fraction absorbed can also be represented as a function of dimensionless time τ (Dt/h^2), as shown in Equation E-6:

Equation E-6

$$\boldsymbol{f_{abs} = \frac{m_{abs}}{M_0} = 2\sum_{n=1}^{\infty}\frac{1}{\lambda_n}\left(1 - e^{-\lambda_n{}^2\tau}\right)\left(\frac{\chi^2 + \lambda_n{}^2}{\chi^2 + \lambda_n{}^2 + \chi}\right)\cdot\left(\frac{cos(1-f)\,\lambda_n - cos\lambda_n}{f\cdot\lambda_n}\right)}$$

where the eigenvalues λ_n are the positive roots of the equation:

Equation E-7

$$\boldsymbol{\lambda_n \cdot \cot(\lambda_n) + \chi = 0}$$

Equation E-6 and Equation E-7must be solved analytically. It should be noted that the dimensionless time τ is not a representation of exposure duration for a work activity; rather, it represents the amount of time available for absorption after the initial exposure dose is applied. Since most dermal risk assessments are typically more concerned with the quantity absorbed, rather than the time course of absorption, the simple algebraic solution is recommended over the analytical solution.

E.2.2 Large Doses (Case 2: $M_0 > M_{sat}$)

For large doses ($M_0 > M_{sat}$), the chemical saturates the upper layers of the stratum corneum, and any remaining amount forms a residual layer (or pool) on top of the skin. The pool acts as a reservoir to replenish the top layers of the membrane as the chemical permeates into the lower layer. In this case, absorption and evaporation approach steady-state values as the dose is increased, similar to an infinite dose scenario.

The steady-state fraction absorbed can be approximated by Equation E-8:

Equation E-8

$$f_{abs}(\infty) = \frac{1}{\chi + 1}$$

Table_Apx E-1 presents the estimated absorbed fraction calculated using the steady-state approximation for large doses (Equation E-8) for methylene chloride.

Table_Apx E-1. Estimated Fraction Evaporated and Absorbed (fabs) using Equation E 8

Chemical Name	Methylene Chloride
CASRN	**75-09-2**
Molecular Formula	**CH_2Cl_2**
Molecular Weight (g/mol)	84.93
P_{VP} (torr)	435
Universal gas constant, R (L*atm/K*mol)	0.0821
Temperature, T (K)	303
Log K_{ow}	1.25
K_{oct}	17.8
S_w (g/L)	13
S_w ($\mu g/cm^3$)	13,000
Industrial Setting	
u (m/s)[a]	0.1674
Evaporative Flux, χ	11.46
Fraction Evaporated	0.92
Fraction Absorbed	**0.08**
Commercial Setting	
u (m/s)[a]	0.0878
Evaporative Flux, χ	6.93
Fraction Evaporated	0.87
Fraction Absorbed	**0.13**

[a] EPA used air speeds from) Baldwin and Maynard (1998): the 50th percentile of industrial occupational environments of 16.74 cm/s is used for industrial settings and the 50th percentile of commercial occupational environments of 8.78 cm/s is used for commercial settings.

E.3 Comparison of f_{abs} to Experimental Values for 1-BP

Sections E.2 and **Error! Reference source not found.** present theoretical frameworks for estimating the fraction of volatile chemical absorbed in finite dose, infinite dose, and transient exposure scenarios. It is unclear whether these frameworks have been validated against measured data for the specific chemicals of current OPPT interest. Where available, experimental studies and actual measurements of absorbed dose are preferred over theoretical calculations.

In a 2011 study, Frasch et al. tested dermal absorption characteristics of 1-BP. For the finite dose scenario, Frasch et al. (2011) determined that unoccluded exposure resulted in less than 0.2 percent of applied 1-BP dose penetrated the skin – a value substantially lower than the theoretical ~6 percent absorbed estimated using Equation E-8. While this discrepancy is unexplained, the 2011 Frasch et al. study recognized the large standard deviation of certain experimental results, and the difficulty of spreading a small, rapidly evaporating dose of 1-BP evenly over the skin surface. Frasch et al. (2011) also raised the possibility that 1-BP may dehydrate the *stratum corneum*, thereby decreasing the skin permeability after initial exposure.

E.4 Potential for Occlusion

Gloves can prevent the evaporation of volatile chemicals from the skin, resulting in occlusion.

Chemicals trapped in the glove may be broadly distributed over the skin (increasing S in Equation E-1), or if not distributed within the glove, the chemical mass concentration on the skin at the site of contamination may be maintained for prolonged periods of time (increasing Q_u in Equation E-1 Equation). Conceptually, occlusion is similar to the "infinite dose" study design used in *in vitro* and *ex vivo* dermal penetration studies, in which the dermis is exposed to a large, continuous reservoir of chemical.
The impact of occlusion on dermal uptake is complex: continuous contact with the chemical may degrade skin tissues, increasing the rate of uptake, but continuous contact may also saturate the skin, slowing uptake (Dancik et al., 2015). These phenomena are dependent upon the chemical, the vehicle and environmental conditions. It is probably not feasible to incorporate these sources of variability in a screening-level population model of dermal exposure without chemical-specific studies.

Existing EPA/OPPT dermal models (Equation E-1) could theoretically be modified to account for the increased surface area and/or increased chemical mass in the glove. This could be achieved through a multiplicative variable (such as used in Equation E-2 to account for evaporative loss) or a change in the default values of S and/or Q_u. It may be reasonable to assume that the surface area of hand in contact with the chemical, S, is the area of the whole hand owing to the distribution of chemical within the glove. Since Q_u reflects the film that remains on the skin (and cannot be wiped off), a larger value should be used to reflect that the liquid volume is trapped in the glove, rather than falling from the hand. Alternatively, the product $S \times Q_u$ ($cm^2 \times mg/cm^2$-event) could be replaced by a single variable representing the mass of chemical that deposits inside the glove per event, M (mg/event):

Equation E-9

$$D_{exp} = M \times Y_{derm} \times FT$$

Garrod et al. (2001) surveyed contamination by involatile components of non-agricultural pesticide products inside gloves across different job tasks and found that protective gloves were nearly always contaminated inside. While the study does not describe the exact mechanism in which the contamination occurs (e.g. via the cuff, permeation, or penetration through imperfections in glove materials), it quantified inner glove exposure as "amount of product per unit time", with a median value of 1.36 mg product per minute, a 75th percentile value of 4.21 mg/min, and a 95th percentile value of 71.9 mg/min. It is possible to use these values to calculate the value of M, i.e. mass of chemical that deposits inside the glove, if the work activity duration is known.

Assuming an activity duration of one hour, the 50th and 95th percentile values translate to 81.6 mg and 4,314 mg of inner glove exposure. While these values may be used as default for M in Equation E-10, EPA notes the significant difference between the 50th and 95th percentile deposition, with the 95th percentile value being two times more conservative than the defaults for the EPA/OPPT 2-Hand Dermal Exposure Model (where the product $S \times Q_u$ is 2,247 mg/event). Given the significant variability in inner glove exposure and lack of information on the specific mechanism in which the inner glove contamination occurs, EPA addresses the occlusion scenario in combination with other glove contamination and permeation factors through the use of a protection factor, as described in the next section.

EPA does not expect occlusion scenarios to be a reasonable occurrence for all conditions of use. Specifically, occlusion is not expected at sites using chemicals in closed systems where the only potential of dermal exposure is during the connecting/disconnecting of hoses used for unloading/loading of bulk containers (e.g., tank trucks or rail cars) or while collecting quality control samples including manufacturing sites, repackaging sites, sites processing the chemical as a reactant, formulation sites, and other similar industrial sites. Occlusion is also not expected to occur at highly controlled sites, such as electronics and pharmaceuticals manufacturing sites, where, due to purity requirements, the use of engineering controls is expected to limit potential dermal exposures. EPA also does not expect occlusion at sites where contact with bulk liquid chemical is not expected such as aerosol degreasing sites where workers are only expected to handle the aerosol cans containing the chemical and not the actual bulk liquid chemical.

EPA expects occlusion to be a reasonable occurrence at sites where workers may come in contact with bulk liquid chemical and handle the chemical in open systems. This includes conditions of use such as vapor degreasing, cold cleaning, and dry cleaning where workers are expected to handle bulk chemical during cleanout of spent solvent and addition of fresh solvent to equipment. Similarly, occlusion may occur at coating or adhesive application sites when workers replenish application equipment with liquid coatings or adhesives.

E.5 Incorporating Glove Protection

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.

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, assigned protection factor 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.

The protection afforded by gloves can be incorporated into the EPA/OPPT model (Equation E-1) by modification of Q_u with a protection factor, PF (unitless, PF ≥ 1):

Equation E-10

$$D_{exp} = S \times \frac{Q_u}{PF} \times Y_{derm} \times FT$$

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 E-2 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 E-2. Exposure Control Efficiencies and Protection Factors for Different Dermal Protection Strategies from ECETOC TRA v3

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

E.6 Proposed Dermal Dose Equation

Accounting for all parameters above, the proposed, overall equation for estimating dermal exposure is:

Equation E-11

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

EPA presents exposure estimates for the following deterministic dermal exposure scenarios:

- Dermal exposure without the use of protective gloves (Equation E-11, PF = 1)
- Dermal exposure with the use of protective gloves (Equation E-11, PF = 5)
- Dermal exposure with the use of protective gloves and employee training (Equation E-11, PF = 20 for industrial users and PF = 10 for professional users)
- Dermal exposure with occlusion (Equation E-9)

EPA assumes the following parameter values for Equation E-12 in addition to the parameter values presented in Table E-1:

- S, the surface area of contact: 535 cm^2 (central tendency) and 1,070 cm^2 (high end), representing the total surface area of one and two hands, repectively (note that EPA has no data on actual surface area of contact for any OES).
- Q_u, the quantity remaining on the skin: 1.4 mg/cm^2-event (central tendency) and 2.1 mg/cm^2-event (high end). These are the midpoint value and high end of range default value, respectively, used in the EPA/OPPT dermal contact with liquids models (EPA, 2013).
- Y_{derm}, the weight fraction of the chemical of interest in the liquid: EPA will assess a unique value of this parameter for each occupational scenario or group of similar occupational scenarios.

- FT, the frequency of events: 1 event per day

For Equation E-10, EPA assumes the quantity of liquid occluded underneath the glove (*M*) is equal to the product of the entire surface area of contact (S = 1,070 cm^2) and the assumed quantity of liquid remaining on the skin (Q_u = 2.1 mg/cm^2-event), which is equal to 2,247 mg/event. See discussion in Section E.5.

APPENDIX F DESCRIPTION OF MODELS USED TO ESTIMATE WORKER AND ONU EXPOSURES

F.1 Brake Servicing Near-Field/Far-Field Inhalation Exposure Model Approach and Parameters

This appendix presents the modeling approach and model equations used in the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model. The model was developed through review of the literature and consideration of existing EPA/OPPT exposure models. This model uses a near-field/far-field approach (AIHA, 2009), where an aerosol application located inside the near-field generates a mist of droplets, and indoor air movements lead to the convection of the droplets between the near-field and far-field. Workers are assumed to be exposed to methylene chloride droplet concentrations in the near-field, while occupational non-users are exposed at concentrations in the far-field.

The model uses the following parameters to estimate exposure concentrations in the near-field and far-field:

- Far-field size;
- Near-field size;
- Air exchange rate;
- Indoor air speed;
- Concentration of methylene chloride in the aerosol formulation;
- Amount of degreaser used per brake job;
- Number of degreaser applications per brake job;
- Time duration of brake job;
- Operating hours per week; and
- Number of jobs per work shift.

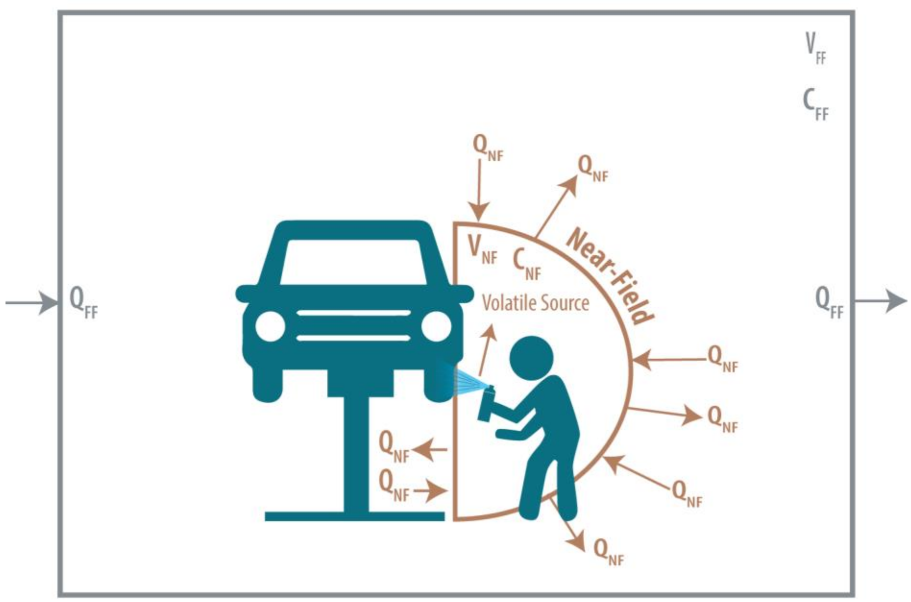
An individual model input parameter could either have a discrete value or a distribution of values. EPA assigned statistical distributions based on available literature data. A Monte Carlo simulation (a type of stochastic simulation) was conducted to capture variability in the model input parameters. The simulation was conducted using the Latin hypercube sampling method in @Risk Industrial Edition, Version 7.0.0. The Latin hypercube sampling method is a statistical method for generating a sample of possible values from a multi-dimensional distribution. Latin hypercube sampling is a stratified method, meaning it guarantees that its generated samples are representative of the probability density function (variability) defined in the model. EPA performed the model at 100,000 iterations to capture the range of possible input values (i.e., including values with low probability of occurrence).

Model results from the Monte Carlo simulation are presented as 95th and 50th percentile values. The statistics were calculated directly in @Risk. The 95th percentile value was selected to represent high-end exposure level, whereas the 50th percentile value was selected to represent central tendency exposure level. The following subsections detail the model design equations and parameters for the brake servicing model.

F.1.1 Model Design Equations

In brake servicing, the vehicle is raised on an automobile lift to a comfortable working height to allow the worker (mechanic) to remove the wheel and access the brake system. Brake servicing can include inspections, adjustments, brake pad replacements, and rotor resurfacing. These service types often involve disassembly, replacement or repair, and reassembly of the brake system. Automotive brake cleaners are used to remove oil, grease, brake fluid, brake pad dust, or dirt. Mechanics may occasionally use brake cleaners, engine degreasers, carburetor cleaners, and general purpose degreasers interchangeably (CARB, 2000). Automotive brake cleaners can come in aerosol or liquid form (CARB, 2000): this model estimates exposures from aerosol brake cleaners (degreasers).

Figure_Apx F-1 illustrates the near-field/far-field modeling approach as it was applied by EPA to brake servicing using an aerosol degreaser. The application of the aerosol degreaser immediately generates a mist of droplets in the near-field, resulting in worker exposures at a methylene chloride concentration C_{NF}. The concentration is directly proportional to the amount of aerosol degreaser applied by the worker, who is standing in the near-field-zone (i.e., the working zone). The volume of this zone is denoted by V_{NF}. The ventilation rate for the near-field zaone (Q_{NF}) determines how quickly methylene chloride dissipates into the far-field (i.e., the facility space surrounding the near-field), resulting in occupational bystander exposures to methylene chloride at a concentration C_{FF}. V_{FF} denotes the volume of the far-field space into which the methylene chloride dissipates out of the near-field. The ventilation rate for the surroundings, denoted by Q_{FF}, determines how quickly methylene chloride dissipates out of the surrounding space and into the outside air.



Figure_Apx F-1. The Near-Field/Far-Field Model as Applied to the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model

In brake servicing using an aerosol degreaser, aerosol degreaser droplets enter the near-field in non-steady "bursts," where each burst results in a sudden rise in the near-field concentration. The near-field and far-field concentrations then decay with time until the next burst causes a new rise in near-field concentration. Based on site data from automotive maintenance and repair shops obtained by CARB (2000) for brake cleaning activities and as explained in Sections F.1.2.5 and F.1.2.9 below, the model assumes a worker will perform an average of 11 applications of the degreaser product per brake job with five minutes between each application and that a worker may perform one to four brake jobs per day each taking one hour to complete. EPA modeled two scenarios: one where the brake jobs occurred back-to-back and one where brake jobs occurred one hour apart. In both scenarios, EPA assumed the worker does not perform a brake job, and does not use the aerosol degreaser, during the first hour of the day.

EPA denoted the top of each five-minute period for each hour of the day (e.g., 8:00 am, 8:05 am, 8:10 am, etc.) as $t_{m,n}$. Here, m has the values of 0, 1, 2, 3, 4, 5, 6, and 7 to indicate the top of each hour of the day (e.g., 8 am, 9 am, etc.) and n has the values of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 to indicate the top of each five-minute period within the hour. No aerosol degreaser is used, and no exposures occur, during the first hour of the day, $t_{0,0}$ to $t_{0,11}$ (e.g., 8 am to 9 am). Then, in both scenarios, the worker begins the first brake job during the second hour, $t_{1,0}$ (e.g., 9 am to 10 am). The worker applies the aerosol degreaser at the top of the second 5-minute period and each subsequent 5-minute period during the hour-long brake job (e.g., 9:05 am, 9:10 am,…9:55 am). In the first scenario, the brake jobs are performed back-to-back, if performing more than one brake job on the given day. Therefore, the second brake job begins at the top of the third hour (e.g., 10 am), and the worker applies the aerosol degreaser at the top of the second 5-minute period and each subsequent 5-minute period (e.g., 10:05 am, 10:10 am,…10:55 am). In the second scenario, the brake jobs are performed every other hour, if performing more than one brake job on the given day. Therefore, the second brake job begins at the top of the fourth hour (e.g., 11 am), and the worker applies the aerosol degreaser at the top of the second 5-minute period and each subsequent 5-minute period (e.g., 11:05 am, 11:10 am,…11:55 am).

In the first scenario, after the worker performs the last brake job, the workers and occupational non-users (ONUs) continue to be exposed as the airborne concentrations decay during the final three to six hours until the end of the day (e.g., 4 pm). In the second scenario, after the worker performs each brake job, the workers and ONUs continue to be exposed as the airborne concentrations decay during the time in which no brake jobs are occurring and then again when the next brake job is initiated. In both scenarios, the workers and ONUs are no longer exposed once they leave work.

Based on data from CARB (2000), EPA assumes each brake job requires one 14.4-oz can of aerosol brake cleaner as described in further detail below. The model determines the application rate of methylene chloride using the weight fraction of methylene chloride in the aerosol product. EPA uses a uniform distribution of weight fractions for methylene chloride based on facility data for the aerosol products in use (CARB, 2000).

The model design equations are presented below in Equation F.1-1 through Equation F.1-21.

Near-Field Mass Balance

Equation F.1-1

$$V_{NF}\frac{dC_{NF}}{dt} = C_{FF}Q_{NF} - C_{NF}Q_{NF}$$

Far-Field Mass Balance

Equation F.1-2

$$V_{FF}\frac{dC_{FF}}{dt} = C_{NF}Q_{NF} - C_{FF}Q_{NF} - C_{FF}Q_{FF}$$

Where:

V_{NF} = near-field volume;
V_{FF} = far-field volume;

Q_{NF}	=	near-field ventilation rate;
Q_{FF}	=	far-field ventilation rate;
C_{NF}	=	average near-field concentration;
C_{FF}	=	average far-field concentration; and
t	=	elapsed time.

Solving Equation F.1-1 and Equation F.1-2 in terms of the time-varying concentrations in the near-field and far-field yields Equation F.1-3 and Equation F.1-4, which EPA applied to each of the 12 five-minute increments during each hour of the day. For each five-minute increment, EPA calculated the initial near-field concentration at the top of the period ($t_{m,n}$), accounting for both the burst of methylene chloride from the degreaser application (if the five-minute increment is during a brake job) and the residual near-field concentration remaining after the previous five-minute increment ($t_{m,n-1}$; except during the first hour and $t_{m,0}$ of the first brake job, in which case there would be no residual methylene chloride from a previous application). The initial far-field concentration is equal to the residual far-field concentration remaining after the previous five-minute increment. EPA then calculated the decayed concentration in the near-field and far-field at the end of the five-minute period, just before the degreaser application at the top of the next period ($t_{m,n+1}$). EPA then calculated a 5-minute TWA exposure for the near-field and far-field, representative of the worker's and ONUs' exposures to the airborne concentrations during each five-minute increment using Equation F.1-13 and Equation F.1-14. The *k* coefficients (Equation F.1-5 through Equation F.1-8) are a function of the initial near-field and far-field concentrations, and therefore are re-calculated at the top of each five-minute period. In the equations below, where the subscript "m, n-1" is used, if the value of n-1 is less than zero, the value at "m-1, 11" is used and where the subscript "m, n+1" is used, if the value of n+1 is greater than 11, the value at "m+1, 0" is used.

Equation F.1-3

$$C_{NF,t_{m,n+1}} = \left(k_{1,t_{m,n}} e^{\lambda_1 t} + k_{2,t_{m,n}} e^{\lambda_2 t}\right)$$

Equation F.1-4

$$C_{FF,t_{m,n+1}} = \left(k_{3,t_{m,n}} e^{\lambda_1 t} - k_{4,t_{m,n}} e^{\lambda_2 t}\right)$$

Where:

Equation F.1-5

$$k_{1,t_{m,n}} = \frac{Q_{NF}\left(C_{FF,0}(t_{m,n}) - C_{NF,0}(t_{m,n})\right) - \lambda_2 V_{NF} C_{NF,0}(t_{m,n})}{V_{NF}(\lambda_1 - \lambda_2)}$$

Equation F.1-6

$$k_{2,t_{m,n}} = \frac{Q_{NF}\left(C_{NF,0}(t_{m,n}) - C_{FF,0}\,(t_{m,n})\right) + \lambda_1 V_{NF} C_{NF,0}(t_{m,n})}{V_{NF}(\lambda_1 - \lambda_2)}$$

Equation F.1-7

$$k_{3,t_{m,n}} = \frac{(Q_{NF} + \lambda_1 V_{NF})(Q_{NF}\left(C_{FF,0}(t_{m,n}) - C_{NF,0}(t_{m,n})\right) - \lambda_2 V_{NF} C_{NF,0}(t_{m,n}))}{Q_{NF} V_{NF}(\lambda_1 - \lambda_2)}$$

Equation F.1-8

$$k_{4,t_{m,n}} = \frac{(Q_{NF} + \lambda_2 V_{NF})(Q_{NF}\left(C_{NF,0}(t_{m,n}) - C_{FF,0}(t_{m,n})\right) + \lambda_1 V_{NF} C_{NF,0}(t_{m,n}))}{Q_{NF} V_{NF}(\lambda_1 - \lambda_2)}$$

Equation F.1-9

$$\lambda_1 = 0.5\left[-\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right) + \sqrt{\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right)^2 - 4\left(\frac{Q_{NF}Q_{FF}}{V_{NF}V_{FF}}\right)}\right]$$

Equation F.1-10

$$\lambda_2 = 0.5\left[-\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right) - \sqrt{\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right)^2 - 4\left(\frac{Q_{NF}Q_{FF}}{V_{NF}V_{FF}}\right)}\right]$$

Equation F.1-11

$$C_{NF,o}(t_{m,n}) = \begin{cases} 0, \ \ m = 0 \\ \frac{Amt}{V_{NF}}\left(1{,}000\frac{mg}{g}\right) + C_{NF}(t_{m,n-1}), \ \ n > 0 \ for \ all \ m \ where \ brake \ job \ occurs \end{cases}$$

Equation F.1-12

$$C_{FF,o}(t_{m,n}) = \begin{cases} 0, \ \ m = 0 \\ C_{FF}(t_{m,n-1}), \ \ for \ all \ n \ where \ m > 0 \end{cases}$$

Equation F.1-13

$$C_{NF,\text{ 5-min TWA, } t_{m,n}} = \frac{\left(\frac{k_{1,t_{m,n-1}}}{\lambda_1}e^{\lambda_1 t_2} + \frac{k_{2,t_{m,n-1}}}{\lambda_2}e^{\lambda_2 t_2}\right) - \left(\frac{k_{1,t_{m,n-1}}}{\lambda_1}e^{\lambda_1 t_1} + \frac{k_{2,t_{m,n-1}}}{\lambda_2}e^{\lambda_2 t_1}\right)}{t_2 - t_1}$$

Equation F.1-14

$$C_{FF,\text{ 5-min TWA, } t_{m,n}} = \frac{\left(\frac{k_{3,t_{m,n-1}}}{\lambda_1}e^{\lambda_1 t_2} + \frac{k_{4,t_{m,n-1}}}{\lambda_2}e^{\lambda_2 t_2}\right) - \left(\frac{k_{3,t_{m,n-1}}}{\lambda_1}e^{\lambda_1 t_1} + \frac{k_{4,t_{m,n-1}}}{\lambda_2}e^{\lambda_2 t_1}\right)}{t_2 - t_1}$$

After calculating all near-field/far-field 5-minute TWA exposures (i.e., $C_{NF,\text{ 5-min TWA, } t_{m,n}}$ and $C_{FF,\text{ 5-min TWA, } t_{m,n}}$) for each five-minute period of the work day, EPA calculated the near-field/far-field 8-hour TWA concentration and 1-hour TWA concentrations following the equations below:

Equation F.1-15

$$C_{NF,\text{ 8-hr } TWA} = \frac{\sum_{m=0}^{7}\sum_{n=0}^{11}\left[C_{NF,\text{5-min } TWA,t_{m,n}} \times 0.0833\ hr\right]}{8\ hr}$$

Equation F.1-16

$$C_{NF,\text{ 8-hr } TWA} = \frac{\sum_{m=0}^{7} \sum_{n=0}^{11} \left[C_{FF,\text{5-min } TWA, t_{m,n}} \times 0.0833\ hr \right]}{8\ hr}$$

Equation F.1-17

$$C_{NF,\text{1-hr } TWA} = \frac{\sum_{n=0}^{11} \left[C_{NF,\text{5-min } TWA, t_{m,n}} \times 0.0833\ hr \right]}{1\ hr}$$

Equation F.1-18

$$C_{FF,\text{1-hr } TWA} = \frac{\sum_{n=0}^{11} \left[C_{FF,\text{5-min } TWA, t_{m,n}} \times 0.0833\ hr \right]}{1\ hr}$$

EPA calculated rolling 1-hour TWA's throughout the workday and the model reports the maximum calculated 1-hour TWA.

To calculate the mass transfer to and from the near-field, the free surface area (FSA) is defined to be the surface area through which mass transfer can occur. The FSA is not equal to the surface area of the entire near-field. EPA defined the near-field zone to be a hemisphere with its major axis oriented vertically, against the vehicle, and aligned through the center of the wheel (see Figure_Apx F-1). The top half of the circular cross-section rests against, and is blocked by, the vehicle and is not available for mass transfer. The FSA is calculated as the entire surface area of the hemisphere's curved surface and half of the hemisphere's circular surface per Equation F.1-19, below:

Equation F.1-19

$$FSA = \left(\frac{1}{2} \times 4\pi R_{NF}^2 \right) + \left(\frac{1}{2} \times \pi R_{NF}^2 \right)$$

Where: R_{NF} is the radius of the near-field

The near-field ventilation rate, Q_{NF}, is calculated in Equation F.1-20 from the indoor wind speed, v_{NF}, and FSA, assuming half of the FSA is available for mass transfer into the near-field and half of the FSA is available for mass transfer out of the near-field:

Equation F.1-20

$$Q_{NF} = \frac{1}{2} v_{NF} FSA$$

The far-field volume, V_{FF}, and the air exchange rate, AER, is used to calculate the far-field ventilation rate, Q_{FF}, as given by Equation F.1-21:

Equation F.1-21

$$Q_{FF} = V_{FF} AER$$

Using the model inputs described in Appendix F.1.2, EPA estimated methylene chloride inhalation exposures for workers in the near-field and for occupational non-users in the far-field. EPA then conducted the Monte Carlo simulations using @Risk (Version 7.0.0). The simulations applied 100,000 iterations and the Latin Hypercube sampling method.

F.1.2 Model Parameters

Table_Apx F-1 summarizes the model parameters and their values for the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model. Each parameter is discussed in detail in the following subsections. Summary of Parameter Values and Distributions Used in the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model

Table_Apx F-1. Summary of Parameter Values and Distributions Used in the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model

Input Parameter	Symbol	Unit	Constant Model Parameter Values		Variable Model Parameter Values				Comments
			Value	Basis	Lower Bound	Upper Bound	Mode	Distribution Type	
Far-field volume	V_{FF}	m^3	—	—	206	70,679	3,769	Triangular	Distribution based on data collected by CARB (2006)
Air exchange rate	AER	hr^{-1}	—	—	1	20	3.5	Triangular	Demou et al. (2009) identifies typical AERs of 1 hr^{-1} and 3 to 20 hr^{-1} for occupational settings with and without mechanical ventilation systems, respectively. Hellweg et al. (2009) identifies average AERs for occupational settings utilizing mechanical ventilation systems to be between 3 and 20 hr^{-1}. Golsteijn et al. (2014) indicates a characteristic AER of 4 hr^{-1}. Peer reviewers of EPA's 2013 TCE draft risk assessment commented that values around 2 to 5 hr^{-1} may be more likely (SCG, 2013), in agreement with Golsteijn et al. (2014). A triangular distribution is used with the mode equal to the midpoint of the range provided by the peer reviewer (3.5 is the midpoint of the range 2 to 5 hr^{-1}).
Near-field indoor wind speed	v_{NF}	ft/hr	—	—	0	1,037	—	Lognormal	Lognormal distribution fit to commercial-type workplace data from Baldwin and Maynard (1998).
		cm/s	—	—	0	8.78	—	Lognormal	
Near-field radius	R_{NF}	m	1.5	—	—	—	—	Constant Value	Constant.
Starting time for each application period	t_1	hr	0	—	—	—	—	Constant Value	Constant.
End time for each application period	t_2	hr	0.0833	—	—	—	—	Constant Value	Assumes aerosol degreaser is applied in 5-minute increments during brake job.

Input Parameter	Symbol	Unit	Constant Model Parameter Values		Variable Model Parameter Values				Comments
			Value	Basis	Lower Bound	Upper Bound	Mode	Distribution Type	
Averaging Time	t_{avg}	hr	8	—	—	—	—	Constant Value	Constant.
Methylene chloride weight fraction	wtfrac	wt frac	—	—	0.10	0.80	—	Discrete	Discrete distribution of CHEMICAL-based aerosol product formulations based on products identified in Abt (2017). Where the weight fraction of methylene chloride in the formulation was given as a range, EPA assumed a uniform distribution within the reported range for the methylene chloride concentration in the product.
Degreaser Used per Brake Job	W_d	oz/ job	14.4	—	—	—	—	Constant Value	Based on data from CARB (2000).
Number of Applications per Job	N_A	Applications/ job	11	—	—	—	—	Constant Value	Calculated from the average of the number of applications per brake and number of brakes per job.
Amount Used per Application	Amt	g methylene chloride/ application	—	—	3.7	29.7	—	Calculated	Calculated from wtfrac, W_d, and N_A.
Operating hours per week	OHpW	hr/week	—	—	40	122.5	—	Lognormal	Lognormal distribution fit to the operating hours per week observed in CARB (2000) site visits.
Number of Brake Jobs per Work Shift	N_J	jobs/site-shift	—	—	1	4	—	—	Calculated from the average number of brake jobs per site per year, OHpW, and assuming 52 operating weeks per year and 8 hours per work shift.

F.1.2.1 Far-Field Volume

The far-field volume is based on information obtained from CARB (2000) from site visits of 137 automotive maintenance and repair shops in California. CARB (2000) indicated that shop volumes at the visited sites ranged from 200 to 70,679 m^3 with an average shop volume of 3,769 m^3. Based on this data EPA assumed a triangular distribution bound from 200 m^3 to 70,679 m^3 with a mode of 3,769 m^3 (the average of the data from CARB (2000)).

CARB measured the physical dimensions of the portion of the facility where brake service work was performed at the visited facilities. CARB did not consider other areas of the facility, such as customer waiting areas and adjacent storage rooms, if they were separated by a normally closed door. If the door was normally open, then CARB did consider those areas as part of the measured portion where brake servicing emissions could occur (CARB, 2000). CARB's methodology for measuring the physical dimensions of the visited facilities provides the appropriate physical dimensions needed to represent the far-field volume in EPA's model. Therefore, CARB's reported facility volume data are appropriate for EPA's modeling purposes.

F.1.2.2 Air Exchange Rate

The air exchange rate (AER) is based on data from Demou et al. (2009), Hellweg et al. (2009), Golsteijn et al. (2014), and information received from a peer reviewer during the development of the 2014 *TSCA Work Plan Chemical Risk Assessment Trichloroethylene: Degreasing, Spot Cleaning and Arts & Crafts Uses* (SCG, 2013). Demou et al. (2009) identifies typical AERs of 1 hr^{-1} and 3 to 20 hr^{-1} for occupational settings with and without mechanical ventilation systems, respectively. Similarly, Hellweg et al. (2009) identifies average AERs for occupational settings using mechanical ventilation systems to vary from 3 to 20 hr^{-1}. Golsteijn et al. (2014) indicates a characteristic AER of 4 hr^{-1}. The risk assessment peer reviewer comments indicated that values around 2 to 5 hr^{-1} are likely (SCG, 2013), in agreement with Golsteijn et al. (2014) and the low end reported by Demou et al. (2009) and Hellweg et al. (2009). Therefore, EPA used a triangular distribution with the mode equal to 3.5 hr^{-1}, the midpoint of the range provided by the risk assessment peer reviewer (3.5 is the midpoint of the range 2 to 5 hr^{-1}), with a minimum of 1 hr^{-1}, per Demou et al. (2009) and a maximum of 20 hr^{-1} per Demou et al. (2009) and Hellweg et al. (2009).

F.1.2.3 Near-Field Indoor Air Speed

Baldwin and Maynard (1998) measured indoor air speeds across a variety of occupational settings in the United Kingdom. Fifty-five work areas were surveyed across a variety of workplaces.

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 commercial distribution for dry cleaners (including other textile cleaning facilities that conduct spot cleaning).

EPA fit a lognormal distribution for both data sets 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. 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 from Baldwin and Maynard (1998).

EPA fit the air speed surveys representative of commercial facilities to a lognormal distribution with the following parameter values: mean of 10.853 cm/s and standard deviation of 7.883 cm/s. In the model, the lognormal distribution is truncated at 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 large.

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.

F.1.2.4 Near-Field Volume

EPA defined the near-field zone to be a hemisphere with its major axis oriented vertically, against the vehicle, and aligned through the center of the wheel (see Figure_Apx F-1). The near-field volume is calculated per Equation F.1-22. EPA defined a near-field radius (R_{NF}) of 1.5 meters, approximately 4.9 feet, as an estimate of the working height of the wheel, as measured from the floor to the center of the wheel.

Equation F.1-22

$$V_{NF} = \frac{1}{2} \times \frac{4}{3} \pi R_{NF}^3$$

F.1.2.5 Application Time

EPA assumed an average of 11 brake cleaner applications per brake job (see Section F.1.2.9). CARB observed, from their site visits, that the visited facilities did not perform more than one brake job in any given hour (CARB, 2000). Therefore, EPA assumed a brake job takes one hour to perform. Using an assumed average of 11 brake cleaner applications per brake job and one hour to perform a brake job, EPA calculates an average brake cleaner application frequency of once every five minutes (0.0833 hr). EPA models an average brake job of having no brake cleaner application during its first five minutes and then one brake cleaner application per each subsequent 5-minute period during the one-hour brake job.

F.1.2.6 Averaging Time

EPA was interested in estimating 8-hr TWAs for use in risk calculations; therefore, a constant averaging time of eight hours was used.

F.1.2.7 Methylene Chloride Weight Fraction

EPA reviewed the *Use and Market Profile for Methylene Chloride* report (Abt, 2017) for aerosol degreasers that contain methylene chloride. Abt (2017) identifies nine aerosol automotive parts cleaners that overall range in methylene chloride content from 10 to 80 weight percent. The identified aerosol automotive parts cleaners are mostly brake cleaners but also include carburetor cleaners and a gasket remover. EPA includes all of these aerosol automotive parts cleaners in the estimation of methylene chloride content as: 1) automotive maintenance and repair facilities may use different degreaser products interchangeably as observed by (CARB, 2000); and 2) EPA uses this brake servicing model as an exposure scenario representative of all commercial-type aerosol degreaser applications.

EPA used a discrete distribution to model the methylene chloride weight fraction based on the number of occurrences of each product type. For each product, the concentration of methylene chloride was reported as a range. EPA used a uniform distribution to model the methylene chloride weight fraction within the product type. Table_Apx F-2 provides a summary of the reported methylene chloride content reported in the safety data sheets identified in Abt (2017), the number of occurrences of each product type, and the fractional probability of each product type. Summary of Methylene Chloride-Based Aerosol Degreaser Formulations

Table_Apx F-2. Summary of Methylene Chloride-Based Aerosol Degreaser Formulations

Name of Aerosol Degreaser Product Identified in Abt (2017)	Methylene Chloride Weight Percent	Number of Occurrences	Fractional Probability
B-00002 BTS Brake Parts & Metal Cleaner	25-35%	1	0.10
Berryman Brake Parts Cleaner (1401, 1405, and 1455)	60-70%	1	0.10
Berryman Brake Parts Cleaner (1420)	60-70%	1	0.10
Brake & Contact Cleaner (Bulk)	30-60%	1	0.10
High Performance Brake Clean Free (80-928)	10-20%	1	0.10
Gunk Carburetor Parts Cleaner – Chlorinated (M4814H)	20-<30%	1	0.10
Gunk Brake Parts Cleaner – Chlorinated (M720)	40-<50%	1	0.10
Gunk Carb Medic Carburetor Cleaner (M4814/M4824)	60-<70%	1	0.10
Sprayway Industrial Gasket Remover No. 719	60-80%	1	0.10
American Industries, Inc.; Rapid Solv (A)	45-55%	1	0.10
Total		**10**	**1.00**

F.1.2.8 Volume of Degreaser Used per Brake Job

CARB (2000) assumed that brake jobs require 14.4 oz of aerosol product. EPA did not identify other information to estimate the volume of aerosol product per job; therefore, EPA used a constant volume of 14.4 oz per brake job based on CARB (2000).

F.1.2.9 Number of Applications per Brake Job

Workers typically apply the brake cleaner before, during, and after brake disassembly. Workers may also apply the brake cleaner after brake reassembly as a final cleaning process (CARB, 2000). Therefore, EPA assumed a worker applies a brake cleaner three or four times per wheel. Since a brake job can be performed on either one axle or two axles (CARB, 2000), EPA assumed a brake job may involve either two or four wheels. Therefore, the number of brake cleaner (aerosol degreaser) applications per brake job can range from six (3 applications/brake x 2 brakes) to 16 (4 applications/brake x 4 brakes). EPA assumed a constant number of applications per brake job based on the midpoint of this range of 11 applications per brake job.

F.1.2.10 Amount of Methylene Chloride Used per Application

EPA calculated the amount of methylene chloride used per application using Equation F.1-23. The calculated mass of methylene chloride used per application ranges from 3.7 to 29.7 grams.

Equation F.1-23

$$Amt = \frac{W_d \times wtfrac \times 28.3495 \frac{g}{oz}}{N_A}$$

Where:

Amt	=	Amount of methylene chloride used per application (g/application);
W_d	=	Weight of degreaser used per brake job (oz/job);
Wtfrac	=	Weight fraction of methylene chloride in aerosol degreaser (unitless); and
N_A	=	Number of degreaser applications per brake job (applications/job).

F.1.2.11 Operating Hours per Week

CARB (2000) collected weekly operating hour data for 54 automotive maintenance and repair facilities. The surveyed facilities included service stations (fuel retail stations), general automotive shops, car dealerships, brake repair shops, and vehicle fleet maintenance facilities. The weekly operating hours of the surveyed facilities ranged from 40 to 122.5 hr/week. EPA fit a lognormal distribution to the surveyed weekly operating hour data. The resulting lognormal distribution has a mean of 16.943 and standard deviation of 13.813, which set the shape of the lognormal distribution. EPA shifted the distribution to the right such that its minimum value is 40 hr/week and set a truncation of 122.5 hr/week (the truncation is set as 82.5 hr/week relative to the left shift of 40 hr/week).

F.1.2.12 Number of Brake Jobs per Work Shift

CARB (2000) visited 137 automotive maintenance and repair shops and collected data on the number of brake jobs performed annually at each facility. CARB calculated an average of 936 brake jobs performed per facility per year. EPA calculated the number of brake jobs per work shift using the average number of jobs per site per year, the operating hours per week, and assuming 52 weeks of operation per year and eight hours per work shift using Equation F.1-24 and rounding to the nearest integer. The calculated number of brake jobs per work shift ranges from one to four.

Equation F.1-24

$$N_J = \frac{936 \frac{jobs}{site\text{-}year} \times 8 \frac{hours}{shift}}{52 \frac{weeks}{yr} \times OHpW}$$

Where:

N_J	=	Number of brake jobs per work shift (jobs/site-shift); and
OHpW	=	Operating hours per week (hr/week).

F.2 Occupational Exposures during Vapor Degreasing and Cold Cleaning

This appendix presents the modeling approach and model equations used in the following models:

- Open-Top Vapor Degreasing Near-Field/Far-Field Inhalation Exposure Model;
- Conveyorized Degreasing Near-Field/Far-Field Inhalation Exposure Model;
- Cold Cleaning Near-Field/Far-Field Inhalation Exposure Model.

The models were developed through review of the literature and consideration of existing EPA/OPPT exposure models. These models use a near-field/far-field approach (AIHA, 2009), where a vapor generation source located inside the near-field diffuses into the surrounding environment. Workers are assumed to be exposed to methylene chloride vapor concentrations in the near-field, while occupational non-users are exposed at concentrations in the far-field.

The model uses the following parameters to estimate exposure concentrations in the near-field and far-field:

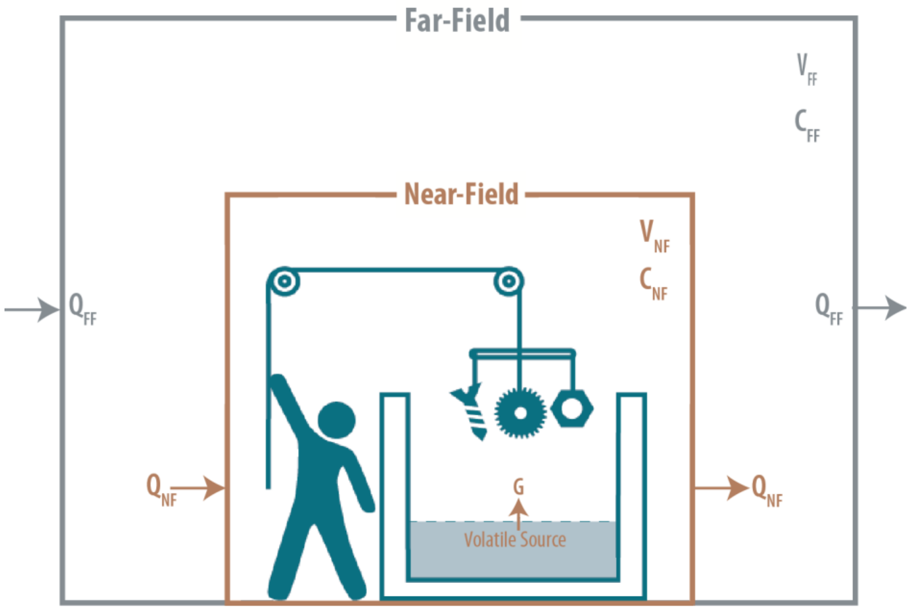
- Far-field size;
- Near-field size;
- Air exchange rate;
- Indoor air speed;
- Exposure duration;
- Vapor generation rate; and
- Operating hours per day.

An individual model input parameter could either have a discrete value or a distribution of values. EPA assigned statistical distributions based on available literature data. A Monte Carlo simulation (a type of stochastic simulation) was conducted to capture variability in the model input parameters. The simulation was conducted using the Latin hypercube sampling method in @Risk Industrial Edition, Version 7.0.0. The Latin hypercube sampling method is a statistical method for generating a sample of possible values from a multi-dimensional distribution. Latin hypercube sampling is a stratified method, meaning it guarantees that its generated samples are representative of the probability density function (variability) defined in the model. EPA performed the model at 100,000 iterations to capture the range of possible input values (i.e., including values with low probability of occurrence).

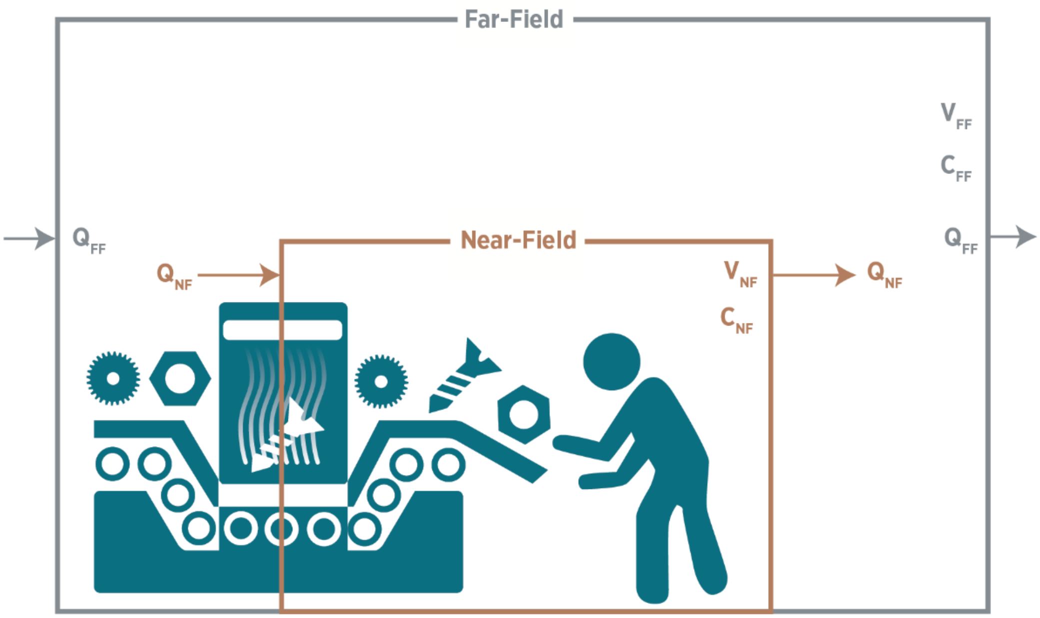
Model results from the Monte Carlo simulation are presented as 95th and 50th percentile values. The statistics were calculated directly in @Risk. The 95th percentile value was selected to represent high-end exposure level, whereas the 50th percentile value was selected to represent typical exposure level. The following subsections detail the model design equations and parameters for vapor degreasing and cold cleaning models.

F.2.1 Model Design Equations

Figure_Apx F-2 and Figure_Apx F-3 illustrate the near-field/far-field modeling approach as it was applied by EPA to each vapor degreasing and cold cleaning model. As the figures show, volatile methylene chloride vapors evaporate into the near-field, resulting in worker exposures at a methylene chloride concentration C_{NF}. The concentration is directly proportional to the evaporation rate of methylene chloride, G, into the near-field, whose volume is denoted by V_{NF}. The ventilation rate for the near-field zone (Q_{NF}) determines how quickly methylene chloride dissipates into the far-field, resulting in occupational non-user exposures to methylene chloride at a concentration C_{FF}. V_{FF} denotes the volume of the far-field space into which the methylene chloride dissipates out of the near-field. The ventilation rate for the surroundings, denoted by Q_{FF}, determines how quickly methylene chloride dissipates out of the surrounding space and into the outside air.



Figure_Apx F-2. The Near-Field/Far-Field Model as Applied to the Open-Top Vapor Degreasing Near-Field/Far-Field Inhalation Exposure Model and the Cold Cleaning Near-Field/Far-Field Inhalation Exposure Model



Figure_Apx F-3. The Near-Field/Far-Field Model as Applied to the Conveyorized Degreasing Near-Field/Far-Field Inhalation Exposure Model

The model design equations are presented below in Equation F.1-1 through Equation F.1-21. Note the design equations are the same for each of the models discussed in this appendix.

Near-Field Mass Balance

Equation F.2-25

$$V_{NF}\frac{dC_{NF}}{dt} = C_{FF}Q_{NF} - C_{NF}Q_{NF} + G$$

Far-Field Mass Balance

Equation F.2-26

$$V_{FF}\frac{dC_{FF}}{dt} = C_{NF}Q_{NF} - C_{FF}Q_{NF} - C_{FF}Q_{FF}$$

Where:

V_{NF}	=	near-field volume;
V_{FF}	=	far-field volume;
Q_{NF}	=	near-field ventilation rate;
Q_{FF}	=	far-field ventilation rate;
C_{NF}	=	average near-field concentration;
C_{FF}	=	average far-field concentration;
G	=	average vapor generation rate; and
t	=	elapsed time.

Both of the previous equations can be solved for the time-varying concentrations in the near-field and far-field as follows (AIHA, 2009):

Equation F.2-27

$$C_{NF} = G\left(k_1 + k_2e^{\lambda_1 t} - k_3e^{\lambda_2 t}\right)$$

Equation F.2-28

$$C_{FF} = G\left(\frac{1}{Q_{FF}} + k_4e^{\lambda_1 t} - k_5e^{\lambda_2 t}\right)$$

Where:

Equation F.2-29

$$k_1 = \frac{1}{\left(\frac{Q_{NF}}{Q_{NF} + Q_{FF}}\right)Q_{FF}}$$

Equation F.2-30

$$k_2 = \frac{Q_{NF}Q_{FF} + \lambda_2 V_{NF}(Q_{NF} + Q_{FF})}{Q_{NF}Q_{FF}V_{NF}(\lambda_1 - \lambda_2)}$$

Equation F.2-31

$$k_3 = \frac{Q_{NF}Q_{FF} + \lambda_1 V_{NF}(Q_{NF} + Q_{FF})}{Q_{NF}Q_{FF}V_{NF}(\lambda_1 - \lambda_2)}$$

Equation F.2-32

$$k_4 = \left(\frac{\lambda_1 V_{NF} + Q_{NF}}{Q_{NF}}\right)k_2$$

Equation F.2-33

$$k_5 = \left(\frac{\lambda_2 V_{NF} + Q_{NF}}{Q_{NF}}\right) k_3$$

Equation F.2-34

$$\lambda_1 = 0.5\left[-\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right) + \sqrt{\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right)^2 - 4\left(\frac{Q_{NF}Q_{FF}}{V_{NF}V_{FF}}\right)}\right]$$

Equation F.2-35

$$\lambda_2 = 0.5\left[-\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right) - \sqrt{\left(\frac{Q_{NF}V_{FF} + V_{NF}(Q_{NF} + Q_{FF})}{V_{NF}V_{FF}}\right)^2 - 4\left(\frac{Q_{NF}Q_{FF}}{V_{NF}V_{FF}}\right)}\right]$$

EPA calculated the hourly TWA concentrations in the near-field and far-field using Equation F.2-36 and Equation F.2-37, respectively. Note that the numerator and denominator of Equation F.2-36 and Equation F.2-37 use two different sets of time parameters. The numerator is based on operating times for the scenario (e.g., two to eight hours for OTVDs, 4 to 8 hours for conveyorized degreasers, and 1 to 24 hours for cold cleaning, see Appendix F.1.2) while the denominator is fixed to an average time span, t_avg, of eight hours (since EPA is interested in calculating 8-hr TWA exposures). Mathematically, the numerator and denominator must reflect the same amount of time. This is indeed the case since the numerator assumes exposures are zero for any hours not within the operating time. Therefore, mathematically speaking, both the numerator and the denominator reflect eight hours regardless of the values selected for t_1 and t_2.

Equation F.2-36

$$C_{NF,TWA} = \frac{\int_{t_1}^{t_2} C_{NF}dt}{\int_0^{t_{avg}} dt} = \frac{\int_{t_1}^{t_2} G\left(k_1 + k_2 e^{\lambda_1 t} - k_3 e^{\lambda_2 t}\right)dt}{t_{avg}} =$$

$$\frac{G\left(k_1 t_2 + \frac{k_2 e^{\lambda_1 t_2}}{\lambda_1} - \frac{k_3 e^{\lambda_2 t_2}}{\lambda_2}\right) - G\left(k_1 t_1 + \frac{k_2 e^{\lambda_1 t_1}}{\lambda_1} - \frac{k_3 e^{\lambda_2 t_1}}{\lambda_2}\right)}{t_{avg}}$$

Equation F.2-37

$$C_{FF,TWA} = \frac{\int_{t_1}^{t_2} C_{FF}dt}{\int_0^{t_{avg}} dt} = \frac{\int_{t_1}^{t_2} G\left(\frac{1}{Q_{FF}} + k_4 e^{\lambda_1 t} - k_5 e^{\lambda_2 t}\right)dt}{t_{avg}} =$$

$$\frac{G\left(\frac{t_2}{Q_{FF}} + \frac{k_4 e^{\lambda_1 t_2}}{\lambda_1} - \frac{k_5 e^{\lambda_2 t_2}}{\lambda_2}\right) - G\left(\frac{t_1}{Q_{FF}} + \frac{k_4 e^{\lambda_1 t_1}}{\lambda_1} - \frac{k_5 e^{\lambda_2 t_1}}{\lambda_2}\right)}{t_{avg}}$$

To calculate the mass transfer to and from the near-field, the free surface area, FSA, is defined to be the surface area through which mass transfer can occur. Note that the FSA is not equal to the surface area of the entire near-field. EPA defined the near-field zone to be a rectangular box resting on the floor; therefore, no mass transfer can occur through the near-field box's floor. FSA is calculated in Equation F.1-19, below:

Equation F.2-38

$$FSA = 2(L_{NF}H_{NF}) + 2(W_{NF}H_{NF}) + (L_{NF}W_{NF})$$

Where: L_{NF}, W_{NF}, and H_{NF} are the length, width, and height of the near-field, respectively. The near-field ventilation rate, Q_{NF}, is calculated in Equation F.1-20 from the near-field indoor wind speed, v_{NF}, and FSA, assuming half of FSA is available for mass transfer into the near-field and half of FSA is available for mass transfer out of the near-field:

Equation F.2-39

$$Q_{NF} = \frac{1}{2} v_{NF} FSA$$

The far-field volume, V_{FF}, and the air exchange rate, AER, is used to calculate the far-field ventilation rate, Q_{FF}, as given by Equation F.1-21:

Equation F.2-40

$$Q_{FF} = V_{FF} AER$$

Using the model inputs described in Appendix F.1.2, EPA estimated methylene chloride inhalation exposures for workers in the near-field and for occupational non-users in the far-field. EPA then conducted the Monte Carlo simulations using @Risk (Version 7.0.0). The simulations applied 100,000 iterations and the Latin Hypercube sampling method for each model.

F.2.2 Model Parameters

Table_Apx F-3 through
Table_Apx F-5 summarize the model parameters and their values for each of the models discussed in this Appendix. Each parameter is discussed in detail in the following subsections.

Table_Apx F-3. Summary of Parameter Values and Distributions Used in the Open-Top Vapor Degreasing Near-Field/Far-Field Inhalation Exposure Model

Input Parameter	Symbol	Unit	Constant Model Parameter Values		Variable Model Parameter Values				Comments
			Value	Basis	Lower Bound	Upper Bound	Mode	Distribution Type	
Far-field volume	V_{FF}	ft^3	—	—	10,594	70,629	17,657	Triangular	See Section F.2.2.1
Air exchange rate	AER	hr^{-1}	—	—	2	20	3.5	Triangular	See Section F.2.2.2
Near-field indoor wind speed	v_{NF}	ft/hr	—	—	—	23,882	—	Lognormal	See Section F.2.2.3
		cm/s	—	—	—	202.2	—	Lognormal	
Near-field length	L_{NF}	ft	10	—	—	—	—	Constant Value	See Section F.2.2.4
Near-field width	W_{NF}	ft	10	—	—	—	—	Constant Value	
Near-field height	H_{NF}	ft	6	—	—	—	—	Constant Value	
Starting time	t_1	hr	0	—	—	—	—	Constant Value	Constant.
Exposure Duration	t_2	hr	—	—	2	8	—	--	See Section F.2.2.5
Averaging Time	t_{avg}	hr	8	—	—	—	—	Constant Value	See Section F.2.2.6
Vapor generation rate	G	mg/hr	—	—	6.99E+03	2.72E+06	—	Discrete	See Section F.2.2.7
		lb/hr	—	—	0.015	6.00	—	Discrete	
Operating hours per day	OH	hr/day	—	—	2	8	—	Discrete	See Section F.2.2.8

Table_Apx F-4. Summary of Parameter Values and Distributions Used in the Conveyorized Degreasing Near-Field/Far-Field Inhalation Exposure Model

Input Parameter	Symbol	Unit	Constant Model Parameter Values		Variable Model Parameter Values				Comments
			Value	Basis	Lower Bound	Upper Bound	Mode	Distribution Type	
Far-field volume	V_{FF}	ft^3	—	—	10,594	70,629	17,657	Triangular	See Section F.2.2.1
Air exchange rate	AER	hr^{-1}	—	—	2	20	3.5	Triangular	See Section F.2.2.2
Near-field indoor wind speed	v_{NF}	ft/hr	—	—	—	23,882	—	Lognormal	See Section F.2.2.3
		cm/s	—	—	—	202.2	—	Lognormal	
Near-field length	L_{NF}	ft	10	—	—	—	—	Constant Value	See Section F.2.2.4
Near-field width	W_{NF}	ft	10	—	—	—	—	Constant Value	
Near-field height	H_{NF}	ft	6	—	—	—	—	Constant Value	
Starting time	t_1	hr	0	—	—	—	—	Constant Value	Constant.
Exposure Duration	t_2	hr	—	—	4	8	—	Discrete	See Section F.2.2.5
Averaging Time	t_{avg}	hr	8	—	—	—	—	Constant Value	See Section F.2.2.6
Vapor generation rate	G	mg/hr	—	—	2.20E+06	2.63E+06	—	Discrete	See Section F.2.2.7
		lb/hr	—	—	4.86	5.81	—	Discrete	
Operating hours per day	OH	hr/day	—	—	4	8	—	Discrete	See Section F.2.2.8

Table_Apx F-5. Summary of Parameter Values and Distributions Used in the Cold Cleaning Near-Field/Far-Field Inhalation Exposure Model

Input Parameter	Symbol	Unit	Constant Model Parameter Values		Variable Model Parameter Values				Comments
			Value	Basis	Lower Bound	Upper Bound	Mode	Distribution Type	
Far-field volume	V_{FF}	ft^3	—	—	10,594	70,629	17,657	Triangular	See Section F.2.2.1
Air exchange rate	AER	hr^{-1}	—	—	2	20	3.5	Triangular	See Section F.2.2.2
Near-field indoor wind speed	v_{NF}	ft/hr	—	—	—	23,882	—	Lognormal	See Section F.2.2.3
		cm/s	—	—	—	202.2	—	Lognormal	
Near-field length	L_{NF}	ft	10	—	—	—	—	Constant Value	See Section F.2.2.4
Near-field width	W_{NF}	ft	10	—	—	—	—	Constant Value	
Near-field height	H_{NF}	ft	6	—	—	—	—	Constant Value	
Starting time	t_1	hr	0	—	—	—	—	Constant Value	Constant.
Exposure Duration	t_2	hr	—	—	1	8	—	Discrete	See Section F.2.2.5
Averaging Time	t_{avg}	hr	8	—	—	—	—	Constant Value	See Section F.2.2.6
Vapor generation rate	G	mg/hr	—	—	3.08E-02	2.93E+05	—	Discrete	See Section F.2.2.7
		lb/hr	—	—	6.79E-08	0.65	—	Discrete	
Operating hours per day	OH	hr/day	—	—	1	24	—	Discrete	See Section F.2.2.8

F.2.2.1 Far-Field Volume

EPA used the same far-field volume distribution for each of the models discussed. The far-field volume is based on information obtained from von Grote et al. (2003) that indicated volumes at German metal degreasing facilities can vary from 300 to several thousand cubic meters. They noted that smaller volumes are more typical and assumed 400 and 600 m^3 (14,126 and 21,189 ft^3) in their exposure models (Von Grote et al., 2003). These are the highest and lowest values EPA identified in the literature; therefore, EPA assumes a triangular distribution bound from 300 m^3 (10,594 ft^3) to 2,000 m^3 (70,629 ft^3) with a mode of 500 m^3 (the midpoint of 400 and 600 m^3) (17,657 ft^3).

F.2.2.2 Air Exchange Rate

EPA used the same air exchange rate distribution for each of the models discussed. The air exchange rate is based on data from Hellweg et al. (2009) and information received from a peer reviewer during the development of the 2014 *TSCA Work Plan Chemical Risk Assessment Trichloroethylene: Degreasing, Spot Cleaning and Arts & Crafts Uses* (SCG, 2013). Hellweg et al. (2009) reported that average air exchange rates for occupational settings using mechanical ventilation systems vary from 3 to 20 hr^{-1}. The risk assessment peer reviewer comments indicated that values around 2 to 5 hr^{-1} are likely (SCG, 2013), in agreement with the low end reported by Hellweg et al. (2009). Therefore, EPA used a triangular distribution with the mode equal to 3.5 hr^{-1}, the midpoint of the range provided by the risk assessment peer reviewer (3.5 is the midpoint of the range 2 to 5 hr^{-1}), with a minimum of 2 hr^{-1}, per the risk assessment peer reviewer (SCG, 2013) and a maximum of 20 hr^{-1} per Hellweg et al. (2009).

F.2.2.3 Near-Field Indoor Air Speed

Baldwin and Maynard (1998) measured indoor air speeds across a variety of occupational settings in the United Kingdom. Fifty-five work areas were surveyed across a variety of workplaces.

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 facilities performing vapor degreasing and/or cold cleaning.

EPA fit a lognormal distribution for both data sets 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. 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 from Baldwin and Maynard (1998).

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 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 large.

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.

F.2.2.4 Near-Field Volume

EPA assumed a near-field of constant dimensions of 10 ft x 10 ft x 6 ft resulting in a total volume of 600 ft^3.

F.2.2.5 Exposure Duration

EPA assumed the maximum exposure duration for each model is equal to the entire work-shift (eight hours). Therefore, if the degreaser/cold cleaning machine operating time was greater than eight hours, then exposure duration was set equal to eight hours. If the operating time was less than eight hours, then exposure duration was set equal to the degreaser/cold cleaning machine operating time (see Appendix F.2.2.8 for discussion of operating hours).

F.2.2.6 Averaging Time

EPA was interested in estimating 8-hr TWAs for use in risk calculations; therefore, a constant averaging time of eight hours was used for each of the models.

F.2.2.7 Vapor Generation Rate

For the vapor generation rate from each machine type (OTVD, conveyorized, web, and cold), EPA used a discrete distribution based on the annual unit emission rates reported in the 2014 NEI (U.S. EPA, 2018a) . Annual unit emission rates were converted to hourly unit emission rates by dividing the annual reported emissions by the reported annual operating hours (see Appendix F.2.2.8). Reported annual emissions in NEI without accompanying reported annual operating hours were not included in the analysis. Emission rates reported as zero were also excluded as it is unclear if this is before or after vapor controls used by the site and if the vapor controls used would control emissions into the work area (thus reducing exposure) or only control emissions to the environment (which would not affect worker exposures). Table_Apx F-6 summarizes the data available in the 2014 NEI.

Table_Apx F-6. Summary of Methylene Chloride Vapor Degreasing and Cold Cleaning Data from the 2014 NEI

Unit Type	Total Units	Units with Zero Emissions	Units without Accompanying Operating Hours	Units Used in Analysis[a]
Open-Top Vapor Degreasers	18	1	9	8
Conveyorized Degreasers	3	0	1	2
Cold Cleaning Machines	27	4	3	21

a – Some units with zero emissions also did not include accompanying operating hours; therefore, subtracting the units with zero emissions and the units without operating hours from the total units does not equal the units in the analysis due to double counting.
Source: U.S. EPA (2018a)

Table_Apx F-7 through Table_Apx F-9 summarize the distribution of hourly unit emissions for each machine type calculated from the annual emission in the 2014 NEI.

Table_Apx F-7. Distribution of Methylene Chloride Open-Top Vapor Degreasing Unit Emissions

Count of Units	Unit Emissions (lb/unit-hr)	Fractional Probability

1	6.00	0.1250
1	4.73	0.1250
1	4.00	0.1250
1	3.69	0.1250
1	3.17	0.1250
1	3.17	0.1250
1	1.78	0.1250
1	0.02	0.1250

Table_Apx F-8. Distribution of Methylene Chloride Conveyorized Degreasing Unit Emissions

Count of Units	Unit Emissions (lb/unit-hr)	Fractional Probability
1	5.81	0.5000
1	4.86	0.5000

Table_Apx F-9. Distribution of Methylene Chloride Cold Cleaning Unit Emissions

Count of Units	Unit Emissions (lb/unit-hr)	Fractional Probability
1	0.65	0.0476
1	0.60	0.0476
1	0.58	0.0476
1	0.50	0.0476
1	0.09	0.0476
1	0.02	0.0476
1	0.02	0.0476
1	0.02	0.0476
1	0.01	0.0476
1	0.01	0.0476
1	0.01	0.0476
1	0.01	0.0476
1	0.01	0.0476
1	2.66E-04	0.0476
1	1.37E-04	0.0476
1	2.77E-05	0.0476
1	1.03E-05	0.0476
1	1.49E-06	0.0476
1	2.98E-07	0.0476
1	2.98E-07	0.0476
1	6.79E-08	0.0476
1	0.65	0.0476

F.2.2.8 Operating Hours

For the operating hours of each machine type (OTVD, conveyorized, web, and cold), EPA used a discrete distribution based on the daily operating hours reported in the 2014 NEI. It should be noted that not all units had an accompanying reported daily operating hours; therefore, the distribution for the operating hours per day is based on a subset of the reported units. Table_Apx F-10 through Table_Apx F-12 summarize the distribution of operating hours per day for each machine type.

Table_Apx F-10. Distribution of Methylene Chloride Open-Top Vapor Degreasing Operating Hours

Operating Hours (hr/day)	Fractional Probability
8	0.2000
4	0.4000
2	0.4000

Table_Apx F-11. Distribution of Methylene Chloride Conveyorized Degreasing Operating Hours

Operating Hours (hr/day)	Fractional Probability
8	0.5000
4	0.5000

Table_Apx F-12. Distribution of Methylene Chloride Cold Cleaning Operating Hours

Operating Hours (hr/day)	Fractional Probability
24	0.4583
16	0.0417
10	0.1250
8	0.3333
1	0.0417

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