

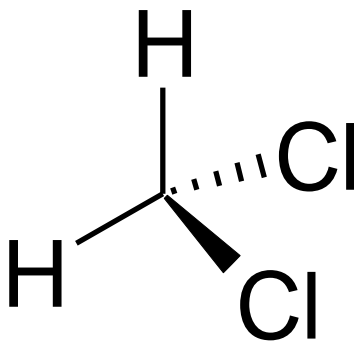


# Final Risk Evaluation for Methylene Chloride

## Supplemental File:

### Supplemental Information on Releases and Occupational Exposure Assessment

CASRN: 75-09-2



*June 2020*

# TABLE OF CONTENTS

---

<b>ABBREVIATIONS</b> .....	<b>13</b>
<b>1 INTRODUCTION</b> .....	<b>15</b>
1.1 Overview .....	15
1.2 Scope .....	15
1.3 Components of the Occupational Exposure and Environmental Release Assessment .....	22
1.4 General Approach and Methodology for Occupational Exposures and Environmental Releases 22	
1.4.1 Process Description .....	22
1.4.2 Facility Estimates and Number of Workers and Occupational Non-Users .....	22
1.4.3 Worker Activities.....	23
1.4.4 Inhalation Exposure Assessment Approach and Methodology .....	23
1.4.4.1 General Approach.....	23
1.4.4.2 Definition of Central Tendency and High End.....	24
1.4.4.3 Hierarchy of Data for Assessing Inhalation Exposures.....	25
1.4.4.4 Approach for this Risk Evaluation .....	25
1.4.4.5 Respiratory Protection .....	26
1.4.5 Dermal Exposure Assessment Approach.....	28
1.4.6 Consideration of Engineering Controls and Personal Protective Equipment .....	28
1.4.7 Water Release Assessment Approach .....	29
<b>2 ENGINEERING ASSESSMENT</b> .....	<b>30</b>
2.1 Manufacturing .....	30
2.1.1 Process Description .....	30
2.1.2 Number of Sites and Potentially Exposed Workers .....	30
2.1.3 Exposure Assessment .....	31
2.1.3.1 Worker Activities .....	31
2.1.3.2 Inhalation Exposures .....	31
2.1.4 Water Release Assessment .....	33
2.1.5 Uncertainties .....	34
2.2 Processing as a Reactant .....	34
2.2.1 Process Description .....	34
2.2.2 Number of Sites and Potentially Exposed Workers .....	34
2.2.3 Exposure Assessment .....	35
2.2.3.1 Worker Activities .....	35
2.2.3.2 Inhalation Exposures .....	36
2.2.4 Water Release Assessment .....	37
2.2.5 Uncertainties .....	37
2.3 Processing - Incorporation into Formulation, Mixture, or Reaction Product .....	37
2.3.1 Process Description .....	37
2.3.2 Number of Sites and Potentially Exposed Workers .....	38
2.3.3 Exposure Assessment .....	39
2.3.3.1 Worker Activities .....	39
2.3.3.2 Inhalation Exposures .....	39
2.3.4 Water Release Assessment .....	40
2.3.5 Uncertainties .....	41

2.4	Repackaging	41
2.4.1	Process Description	41
2.4.2	Number of Sites and Potentially Exposed Workers	42
2.4.3	Exposure Assessment	43
2.4.3.1	Worker Activities	43
2.4.3.2	Inhalation Exposures	44
2.4.4	Water Release Assessment	45
2.4.5	Uncertainties	45
2.5	Batch Open-Top Vapor Degreasing	46
2.5.1	Process Description	46
2.5.2	Number of Sites and Potentially Exposed Workers	47
2.5.3	Exposure Assessment	47
2.5.3.1	Worker Activities	47
2.5.3.2	Inhalation Exposures	47
2.5.4	Water Release Assessment	48
2.5.5	Uncertainties	48
2.6	Conveyorized Vapor Degreasing	48
2.6.1	Process Description	48
2.6.2	Number of Sites and Potentially Exposed Workers	52
2.6.3	Exposure Assessment	52
2.6.3.1	Worker Activities	52
2.6.3.2	Inhalation Exposures	52
2.6.4	Water Release Assessment	53
2.6.5	Uncertainties	53
2.7	Cold Cleaning	53
2.7.1	Process Description	53
2.7.2	Number of Sites and Potentially Exposed Workers	54
2.7.3	Exposure Assessment	54
2.7.3.1	Worker Activities	54
2.7.3.2	Inhalation Exposures	55
2.7.4	Water Release Assessment	56
2.7.5	Uncertainties	56
2.8	Commercial Aerosol Products (Aerosol Degreasing, Aerosol Lubricants, Automotive Care Products)	56
2.8.1	Process Description	56
2.8.2	Number of Sites and Potentially Exposed Workers	57
2.8.3	Exposure Assessment	59
2.8.3.1	Worker Activities	59
2.8.3.2	Inhalation Exposures	60
2.8.3.2.1	Monitoring Data	60
2.8.3.2.2	Modeled Data	61
2.8.4	Water Release Assessment	63
2.8.5	Uncertainties	63
2.9	Adhesives and Sealants	63
2.9.1	Process Description	63
2.9.2	Number of Sites and Potentially Exposed Workers	64
2.9.3	Exposure Assessment	67
2.9.3.1	Worker Activities	67

2.9.3.2	Inhalation Exposures .....	67
2.9.4	Water Release Assessment .....	69
2.9.5	Uncertainties .....	69
2.10	Paints and Coatings .....	69
2.10.1	Process Description .....	69
2.10.2	Number of Sites and Potentially Exposed Workers .....	69
2.10.3	Exposure Assessment .....	72
2.10.3.1	Worker Activities .....	72
2.10.3.2	Inhalation Exposures .....	72
2.10.4	Water Release Assessment .....	74
2.10.5	Uncertainties .....	74
2.11	Adhesive and Caulk Removers .....	75
2.11.1	Process Description .....	75
2.11.1	Number of Sites and Potentially Exposed Workers .....	76
2.11.2	Exposure Assessment .....	76
2.11.2.1	Worker Activities .....	76
2.11.2.2	Inhalation Exposures .....	76
2.11.3	Water Release Assessment .....	77
2.11.4	Uncertainties .....	78
2.12	Fabric Finishing.....	78
2.12.1	Process Description .....	78
2.12.2	Number of Sites and Potentially Exposed Workers .....	78
2.12.3	Exposure Assessment .....	79
2.12.3.1	Worker Activities .....	79
2.12.3.2	Inhalation Exposure.....	79
2.12.4	Water Release Assessment .....	80
2.12.5	Uncertainties .....	80
2.13	Spot Cleaning.....	81
2.13.1	Process Description .....	81
2.13.2	Number of Sites and Potentially Exposed Workers .....	81
2.13.3	Exposure Assessment .....	82
2.13.3.1	Worker Activities .....	82
2.13.3.2	Inhalation Exposures .....	82
2.13.4	Water Release Assessment .....	83
2.13.1	Uncertainties .....	84
2.14	Cellulose Triacetate Film Production.....	84
2.14.1	Process Description .....	84
2.14.2	Number of Sites and Potentially Exposed Workers .....	84
2.14.3	Exposure Assessment .....	84
2.14.3.1	Worker Activities .....	84
2.14.3.2	Inhalation Exposure.....	84
2.14.4	Water Release Assessment .....	85
2.14.5	Uncertainties .....	86
2.15	Flexible Polyurethane Foam Manufacturing.....	86
2.15.1	Process Description .....	86
2.15.2	Number of Sites and Potentially Exposed Workers .....	86
2.15.3	Exposure Assessment .....	87
2.15.3.1	Worker Activities .....	87

2.15.3.2	Inhalation Exposures .....	88
2.15.4	Water Release Assessment .....	89
2.15.5	Uncertainties .....	89
2.16	Laboratory Use .....	90
2.16.1	Process Description .....	90
2.16.2	Number of Sites and Potentially Exposed Workers .....	90
2.16.3	Exposure Assessment .....	90
2.16.3.1	Worker Activities .....	90
2.16.3.2	Inhalation Exposure .....	90
2.16.4	Water Release Assessment .....	93
2.16.5	Uncertainties .....	94
2.17	Plastic Product Manufacturing .....	94
2.17.1	Process Description .....	94
2.17.2	Number of Sites and Potentially Exposed Workers .....	94
2.17.3	Exposure Assessment .....	95
2.17.3.1	Worker Activities .....	95
2.17.3.2	Inhalation Exposure .....	95
2.17.4	Water Release Assessment .....	97
2.17.5	Uncertainties .....	98
2.18	Lithographic Printing Plate Cleaning .....	99
2.18.1	Process Description .....	99
2.18.2	Number of Sites and Potentially Exposed Workers .....	99
2.18.3	Exposure Assessment .....	99
2.18.3.1	Worker Activities .....	99
2.18.3.2	Inhalation Exposure .....	99
2.18.4	Water Release Assessment .....	101
2.18.5	Uncertainties .....	101
2.19	Miscellaneous Non-Aerosol Industrial and Commercial Uses .....	101
2.19.1	Process Description .....	101
2.19.2	Number of Sites and Potentially Exposed Workers .....	102
2.19.3	Exposure Assessment .....	102
2.19.3.1	Worker Activities .....	102
2.19.3.2	Inhalation Exposure .....	102
2.19.4	Water Release Assessment .....	103
2.19.5	Uncertainties .....	103
2.20	Waste Handling, Disposal, Treatment, and Recycling .....	103
2.20.1	Process Description .....	103
2.20.2	Number of Sites and Potentially Exposed Workers .....	106
2.20.3	Exposure Assessment .....	107
2.20.3.1	Worker Activities .....	107
2.20.3.2	Inhalation Exposures .....	108
2.20.4	Water Release Assessment .....	110
2.20.5	Uncertainties .....	111
2.21	Other Reported Water Releases .....	111
<b>3</b>	<b>SUMMARY OF OCCUPATIONAL EXPOSURE ASSESSMENT .....</b>	<b>115</b>
3.1	Inhalation Exposure Assessment .....	115
3.2	Dermal Exposure Assessment .....	116

<b>4</b>	<b>DISCUSSION OF UNCERTAINTIES AND LIMITATIONS.....</b>	<b>123</b>
4.1	Variability.....	123
4.2	Uncertainties and Limitations .....	123
4.2.1	Number of Workers .....	123
4.2.2	Analysis of Exposure Monitoring Data .....	124
4.2.3	OSHA Data Analysis .....	125
4.2.4	Near-Field/Far-Field Model Framework .....	126
4.2.4.1	Vapor Degreasing Models .....	127
4.2.4.2	Brake Servicing Model.....	127
4.2.5	Modeling Dermal Exposures .....	128
4.2.6	Release Estimates .....	128
	<b>APPENDICES .....</b>	<b>129</b>
	<b>Appendix A Inhalation Monitoring Data .....</b>	<b>129</b>
A.1	Manufacturing .....	129
A.2	Processing as a Reactant .....	181
A.3	Processing – Incorporation into Formulation, Mixture, or Reaction Product.....	186
A.4	Repackaging .....	192
A.5	Cold Cleaning.....	195
A.6	Aerosol Degreasing .....	197
A.7	Adhesives and Sealants .....	200
A.8	Paints and Coatings .....	244
A.9	Adhesive and Caulk Removers .....	266
A.10	Fabric Finishing.....	269
A.11	Spot Cleaning .....	274
A.12	Cellulose Triacetate Film Production.....	277
A.13	Flexible Polyurethane Foam Manufacturing.....	281
A.14	Laboratory Use .....	288
A.15	Plastic Product Manufacturing.....	299
A.16	Lithographic Printing Plate Cleaning.....	308
A.17	Non-Aerosol Industrial and Commercial Use.....	318
A.18	Waste Handling, Disposal, Treatment, and Recycling.....	326
	<b>Appendix B Approach for Estimating Number of Workers .....</b>	<b>331</b>
	<b>Appendix C Equations for Calculating Acute and Chronic Exposures for Non-Cancer and Cancer</b>	<b>336</b>
	<b>Appendix D Sample Calculations for Calculating Acute and Chronic (Non-Cancer and Cancer)</b>	
	<b>Inhalation Exposures .....</b>	<b>341</b>
D.1	Example High-End ADC and LADC.....	341
D.2	Example Central Tendency ADC and LADC .....	341
	<b>Appendix E Dermal Exposure Assessment Method .....</b>	<b>342</b>
E.1	Incorporating the Effects of Evaporation .....	342
E.1.1	Modification of EPA Models.....	342
E.2	Calculation of $f_{abs}$ .....	342
E.2.1	Small Doses (Case 1: $M_0 \leq M_{sat}$ ).....	343
E.2.2	Large Doses (Case 2: $M_0 > M_{sat}$ ).....	344

E.3	Comparison of $f_{abs}$ to Experimental Values for 1-BP.....	345
E.4	Potential for Occlusion.....	345
E.5	Incorporating Glove Protection.....	347
E.6	Proposed Dermal Dose Equation.....	348
<b>Appendix F Description of Models used to Estimate Worker and ONU Exposures.....</b>		<b>350</b>
F.1	Brake Servicing Near-Field/Far-Field Inhalation Exposure Model Approach and Parameters.....	350
F.1.1	Model Design Equations.....	350
F.1.2	Model Parameters.....	356
F.1.2.1	Far-Field Volume.....	360
F.1.2.2	Air Exchange Rate.....	360
F.1.2.3	Near-Field Indoor Air Speed.....	360
F.1.2.4	Near-Field Volume.....	361
F.1.2.5	Application Time.....	361
F.1.2.6	Averaging Time.....	361
F.1.2.7	Methylene Chloride Weight Fraction.....	361
F.1.2.8	Volume of Degreaser Used per Brake Job.....	362
F.1.2.9	Number of Applications per Brake Job.....	362
F.1.2.10	Amount of Methylene Chloride Used per Application.....	363
F.1.2.11	Operating Hours per Week.....	363
F.1.2.12	Number of Brake Jobs per Work Shift.....	363
F.1.3	Sensitivity of Model Parameters.....	363
F.2	Occupational Exposures during Vapor Degreasing and Cold Cleaning.....	364
F.2.1	Model Design Equations.....	365
F.2.2	Model Parameters.....	369
F.2.2.1	Far-Field Volume.....	373
F.2.2.2	Air Exchange Rate.....	373
F.2.2.3	Near-Field Indoor Air Speed.....	373
F.2.2.4	Near-Field Volume.....	374
F.2.2.5	Exposure Duration.....	374
F.2.2.6	Averaging Time.....	374
F.2.2.7	Vapor Generation Rate.....	374
F.2.2.8	Operating Hours.....	376
F.2.1	Sensitivity of Model Parameters.....	377
<b>Appendix G Data Integration Strategy for Occupational Exposure and Release Data/Information</b>		<b>378</b>
<b>Appendix H OSHA Data Statistical Summary.....</b>		<b>383</b>
H.1.1	Review and Pre-Treatment of OSHA Data.....	383
H.1.2	Two-Sample Test of Pre-Rule and Post-Rule Time Periods.....	385
H.1.3	Calculation and Comparison of Statistics of Pre-Rule and Post-Rule Time Periods.....	386
<b>REFERENCES.....</b>		<b>389</b>

## LIST OF TABLES

Table 1-1. Crosswalk of Conditions of Use to Occupational Exposure Scenarios Assessed in the Risk Evaluation .....	17
Table 1-2. Assigned Protection Factors for Respirators in OSHA Standard 29 CFR 1910.134 <sup>a</sup> .....	27
Table 2-1. Number of Potentially Exposed Workers at Manufacturing Facilities (2016 CDR).....	31
Table 2-2. Full-Shift Worker Exposure to Methylene Chloride During Manufacturing <sup>a</sup> .....	32
Table 2-3. Short-Term Worker Exposure to Methylene Chloride During Manufacturing.....	32
Table 2-4. Reported TRI Releases for Organic Chemical Manufacturing Facilities.....	33
Table 2-5. Number of U.S. Establishments, Workers, and ONUs for Processing as a Reactant from 2016 CDR .....	35
Table 2-6. Number of U.S. Establishments, Workers, and ONUs for Processing as a Reactant .....	35
Table 2-7. Worker Exposure to Methylene Chloride During Processing as a Reactant <sup>a</sup> .....	36
Table 2-8. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Processing as a Reactant .....	36
Table 2-9. Reported 2016 TRI and DMR Releases for Potential Processing as Reactant Facilities .....	37
Table 2-10. Number of U.S. Establishments, Workers, and ONUs for Processing – Incorporation into Formulation, Mixture, or Reaction Product from 2016 CDR.....	38
Table 2-11. Worker Exposure to Methylene Chloride During Processing – Incorporation into Formulation, Mixture, or Reaction Product <sup>a</sup> .....	40
Table 2-12. Potential Industries Conducting Methylene Chloride Processing – Incorporation into Formulation, Mixture, or Reaction Product in 2016 TRI or DMR.....	40
Table 2-13. Reported 2016 TRI and DMR Releases for Potential Processing—Incorporation into Formulation, Mixture, or Reaction Product Facilities .....	41
Table 2-14 Number of Potential Import Facilities and Exposed Workers (2016 CDR).....	42
Table 2-15. Number of U.S. Establishments, Workers, and ONUs for Processing – Repackaging from 2016 CDR .....	43
Table 2-16. Worker Exposure to Methylene Chloride During Repackaging <sup>a</sup> .....	44
Table 2-17. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Import and Repackaging.....	45
Table 2-18. Reported 2016 TRI and DMR Releases for Repackaging Facilities.....	45
Table 2-19. Statistical Summary of Methylene Chloride 8-hr TWA Exposures (ADC and LADC) for Batch Open-Top Vapor Degreasing.....	48
Table 2-20. Statistical Summary of Methylene Chloride 8-hr TWA Exposures (ADC and LADC) for Conveyorized Vapor Degreasing.....	53
Table 2-21. Exposure to Methylene Chloride During Cold Cleaning <sup>a</sup> .....	56
Table 2-22. NAICS Codes for Aerosol Degreasing and Lubricants.....	57
Table 2-23. Estimated Number of Workers Potentially Exposed to Methylene Chloride During Use of Aerosol Degreasers and Aerosol Lubricants.....	59
Table 2-24. Worker Exposure to Methylene Chloride During Aerosol Degreasing Based on Monitoring Data <sup>a</sup> .....	60
Table 2-25. Statistical Summary of Methylene Chloride 8-hr TWA Exposures (ADC and LADC) for Aerosol Products Based on Modeling.....	62
Table 2-26. US Number of Establishments and Employees for Industries Conducting Adhesive and Sealant Application.....	65
Table 2-27. Exposure to Methylene Chloride During Industrial Non-Spray Adhesives and Sealants Use <sup>a</sup> .....	68
Table 2-28. Exposure to Methylene Chloride During Industrial Spray Adhesives and Sealants Use <sup>a</sup> .....	68



Table 2-29. Exposure to Methylene Chloride During Adhesives and Sealants (Unknown Application Method) <sup>a</sup> .....	68
Table 2-30. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Industrial Adhesives and Sealants Use.....	68
Table 2-31. Number of U.S. Establishments, Workers, and ONU for Industries Performing Paint and Coating Application .....	71
Table 2-32. Exposure to Methylene Chloride During Paint/Coating Spray Application <sup>a</sup> .....	73
Table 2-33. Exposure to Methylene Chloride During Paint/Coating (Unknown Application Method) <sup>a</sup> .....	73
Table 2-34. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Paint/Coating Use .....	73
Table 2-35. Number of U.S. Establishments, Workers, and ONUs for Industries Conducting Paint Stripping.....	76
Table 2-36. Full-Shift Exposure to Methylene Chloride During Adhesive and Caulk Removal (Using Professional Contractor Paint Stripping Data as Surrogate) <sup>a</sup> .....	77
Table 2-37. Short-Term Exposure to Methylene Chloride During Adhesive and Caulk Removal (Using Professional Contractor Paint Stripping Data as Surrogate).....	77
Table 2-38. Number of U.S. Establishments, Workers, and ONUs for Fabric Finishing Sites.....	79
Table 2-39. Worker and ONU Exposure to Methylene Chloride During Fabric Finishing .....	80
Table 2-40. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Fabric Finishing .....	80
Table 2-41. SOC Codes for Worker Exposure in Dry Cleaning.....	82
Table 2-42. Number of U.S. Establishments, Workers, and ONUs for Industries Using Spot Removers at Dry Cleaners .....	82
Table 2-43. Exposure to Methylene Chloride During Spot Cleaning <sup>a</sup> .....	83
Table 2-44. Surface Water Releases of Methylene Chloride During Spot Cleaning.....	84
Table 2-45. Worker Exposure to Methylene Chloride During CTA Film Manufacturing <sup>a</sup> .....	85
Table 2-46. Reported 2016 TRI and DMR Releases for CTA Manufacturing Facilities .....	85
Table 2-47. Number of U.S. Establishments, Workers, and ONUs for Industries Conducting Polyurethane Foam Manufacturing.....	87
Table 2-48. Exposure to Methylene Chloride During Industrial Polyurethane Foam Manufacturing <sup>a</sup> ...	88
Table 2-49. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Polyurethane Foam Manufacturing.....	88
Table 2-50. Water Releases Reported in 2016 TRI for Polyurethane Foam Manufacturing .....	89
Table 2-51. Number of U.S. Establishments, Workers, and ONUs for Testing Laboratories.....	90
Table 2-52. Worker Exposure to Methylene Chloride During Laboratory Use <sup>a</sup> .....	91
Table 2-53. Worker Personal Short-Term Exposure Data for Methylene Chloride During Laboratory Use .....	92
Table 2-54. Number of U.S. Establishments, Workers, and ONUs for Testing Laboratories.....	95
Table 2-55. Worker and ONU Exposure to Methylene Chloride During Plastic Product Manufacturing.....	96
Table 2-56. Worker Short-Term Exposure Data for Methylene Chloride During Plastic Product Manufacturing.....	97
Table 2-57. Potential Industries Conducting Plastics Product Manufacturing in 2016 TRI or DMR .....	98
Table 2-58. Reported 2016 TRI and DMR Releases for Potential Plastics Product Manufacturing Facilities.....	98
Table 2-59. Number of U.S. Establishments, Workers, and ONUs for Printing .....	99
Table 2-60. Worker Exposure to Methylene Chloride During Printing Plate Cleaning <sup>a</sup> .....	100
Table 2-61. Worker Short-Term Exposure Data for Methylene Chloride During Printing Plate Cleaning .....	101

Table 2-62. Reported 2016 TRI and DMR Releases for Potential Lithographic Printing Facilities .....	101
Table 2-63. Worker Exposure to Methylene Chloride During Industrial and Commercial Non-Aerosol Use <sup>a</sup> .....	102
Table 2-64. Number of U.S. Establishments, Workers, and ONUs for Waste Handling .....	107
Table 2-65. Exposure to Methylene Chloride During Waste Handling and Disposal <sup>a</sup> .....	109
Table 2-66. Worker Short-Term Exposure Data for Methylene Chloride During Waste Handling and Disposal .....	109
Table 2-67. Potential Industries Conducting Waste Handling, Disposal, Treatment, and Recycling in 2016 TRI or DMR .....	110
Table 2-68. Reported 2016 TRI and DMR Releases for Potential Recycling/Disposal Facilities .....	110
Table 2-69. Reported 2016 DMR Releases for Wastewater Treatment Facilities .....	112
Table 2-70. Reported 2016 TRI and DMR Releases for Unclassified Facilities .....	114
Table 3-1. Summary of Acute and Chronic Inhalation Exposures to Methylene Chloride for Central and Higher-End Scenarios by Use .....	115
Table 3-2. Glove Protection Factors for Different Dermal Protection Strategies .....	117
Table 3-3. Modeled Dermal Retained Dose (mg/day) for Workers in All Conditions of Use .....	121

## LIST OF FIGURES

Figure 2-1. Open Top Vapor Degreaser .....	46
Figure 2-2. Open Top Vapor Degreaser with Enclosure .....	47
Figure 2-3. Monorail ConveyORIZED Vapor Degreasing System .....	49
Figure 2-4. Cross-Rod ConveyORIZED Vapor Degreasing System .....	50
Figure 2-5. Vibra ConveyORIZED Vapor Degreasing System .....	50
Figure 2-6. Ferris Wheel ConveyORIZED Vapor Degreasing System .....	51
Figure 2-7. Belt/Strip ConveyORIZED Vapor Degreasing System .....	52
Figure 2-8 Typical Batch-Loaded, Maintenance Cold Cleaner .....	54
Figure 2-9 Illustration for Use of Cold Cleaner in a Variety of Industries .....	55
Figure 2-10 Overview of Aerosol degreasing .....	57
Figure 2-11 Schematic of the Near-Field/Far-Field Model for Aerosol degreasing .....	62
Figure 2-12 Overview of Use of Spot Cleaning at Dry Cleaners .....	81
Figure 2-13. Typical Waste Disposal Process .....	104
Figure 2-14. Typical Industrial Incineration Process .....	106

## LIST OF APPENDIX TABLES

Table_Apx A-1. Summary of Full-Shift Inhalation Monitoring Data for Manufacturing .....	130
Table_Apx A-2. Summary of Short-Term Inhalation Monitoring Data for Manufacturing .....	163
Table_Apx A-3. Summary of Full-Shift Inhalation Monitoring Data for Processing as a Reactant .....	182
Table_Apx A-4. Summary of Short-Term Inhalation Monitoring Data for Processing as a Reactant .....	185
Table_Apx A-5. Summary of Full-Shift Inhalation Monitoring Data for Processing – Incorporation into Formulation, Mixture, or Reaction Product .....	187
Table_Apx A-6. Summary of Short-Term Inhalation Monitoring Data for Processing – Incorporation into Formulation, Mixture, or Reaction Product .....	191
Table_Apx A-7. Summary of Full-Shift Inhalation Monitoring Data for Import and Repackaging .....	193
Table_Apx A-8. Summary of Short-Term Inhalation Monitoring Data for Import and Repackaging .....	193
Table_Apx A-9. Summary of Full-Shift Inhalation Monitoring Data for Cold Cleaning .....	196
Table_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Aerosol Degreasing .....	198

Table_Apx A-11. Summary of Full-Shift Inhalation Monitoring Data for Application of Adhesives and Sealants .....	201
Table_Apx A-12. Summary of Short-Term Inhalation Monitoring Data for Application of Adhesives and Sealants .....	241
Table_Apx A-13. Summary of Full-Shift Inhalation Monitoring Data for Application of Paints and Coatings .....	245
Table_Apx A-14. Summary of Short-Term Inhalation Monitoring Data for Application of Paints and Coatings .....	264
Table_Apx A-15. Summary of Full-Shift Inhalation Monitoring Data for Paint Stripping by Professional Contractors .....	268
Table_Apx A-16. Summary of Short-Term Inhalation Monitoring Data for Paint Stripping by Professional Contractors .....	268
Table_Apx A-17. Summary of Full-Shift Inhalation Monitoring Data for Fabric Finishing .....	270
Table_Apx A-18. Summary of Short-Term Inhalation Monitoring Data for Fabric Finishing .....	272
Table_Apx A-19. Summary of Full-Shift Inhalation Monitoring Data for Spot Cleaning .....	275
Table_Apx A-20. Summary of Full-Shift Inhalation Monitoring Data for Cellulose Triacetate Film Manufacturing .....	278
Table_Apx A-21. Summary of Full-Shift Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing .....	282
Table_Apx A-22. Summary of Short-Term Inhalation Monitoring Data for Flexible Polyurethane Foam Manufacturing .....	287
Table_Apx A-23. Summary of Full-Shift Inhalation Monitoring Data for Laboratory Use .....	289
Table_Apx A-24. Summary of Short-Term Inhalation Monitoring Data for Laboratory Use .....	295
Table_Apx A-25. Summary of Full-Shift Inhalation Monitoring Data for Plastic Product Manufacturing .....	300
Table_Apx A-26. Summary of Short-Term Inhalation Monitoring Data for Plastic Product Manufacturing .....	305
Table_Apx A-27. Summary of Full-Shift Inhalation Monitoring Data for Lithographic Printing Plate Cleaning .....	309
Table_Apx A-28. Summary of Short-Term Inhalation Monitoring Data for Lithographic Printing Plate Cleaning .....	317
Table_Apx A-29. Summary of Full-Shift Inhalation Monitoring Data for Non-Aerosol Commercial Use .....	319
Table_Apx A-30. Summary of Full-Shift Inhalation Monitoring Data for Waste Handling, Disposal, Treatment, and Recycling .....	327
Table_Apx A-31. Summary of Short-Term Inhalation Monitoring Data for Waste Handling, Disposal, Treatment, and Recycling .....	328
Table_Apx B-1. SOCs with Worker and ONU Designations for All Conditions of Use Except Dry Cleaning .....	332
Table_Apx B-2. SOCs with Worker and ONU Designations for Dry Cleaning Facilities .....	332
Table_Apx B-3. Estimated Number of Potentially Exposed Workers and ONUs under NAICS 812320 .....	333
Table_Apx C-1. Parameter Values for Calculating Inhalation Exposure Estimates .....	337
Table_Apx C-2. Overview of Average Worker Tenure from U.S. Census SIPP (Age Group 50+) .....	339
Table_Apx C-3. Median Years of Tenure with Current Employer by Age Group .....	339
Table_Apx E-1. Estimated Fraction Evaporated and Absorbed (fabs) using Equation E 8 .....	345
Table_Apx E-2. Exposure Control Efficiencies and Protection Factors for Different Dermal Protection Strategies from ECETOC TRA v3 .....	348

Table_Apx F-1. Summary of Parameter Values and Distributions Used in the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model.....	357
Table_Apx F-2. Summary of Methylene Chloride-Based Aerosol Degreaser Formulations.....	362
Table_Apx F-3. Summary of Parameter Values and Distributions Used in the Open-Top Vapor Degreasing Near-Field/Far-Field Inhalation Exposure Model .....	370
Table_Apx F-4. Summary of Parameter Values and Distributions Used in the ConveyORIZED Degreasing Near-Field/Far-Field Inhalation Exposure Model .....	371
Table_Apx F-5. Summary of Parameter Values and Distributions Used in the Cold Cleaning Near-Field/Far-Field Inhalation Exposure Model.....	372
Table_Apx F-6. Summary of Methylene Chloride Vapor Degreasing and Cold Cleaning Data from the 2014 NEI.....	374
Table_Apx F-7. Distribution of Average Hourly Methylene Chloride Open-Top Vapor Degreasing Unit Emissions Based on 2014 NEI Data .....	375
Table_Apx F-8. Distribution of Average Hourly Methylene Chloride ConveyORIZED Degreasing Unit Emissions Based on 2014 NEI Data .....	375
Table_Apx F-9. Distribution of Average Hourly Methylene Chloride Cold Cleaning Unit Emissions Based on 2014 NEI Data.....	376
Table_Apx F-10. Distribution of Average Methylene Chloride Open-Top Vapor Degreasing Operating Hours Based on 2014 NEI Data.....	376
Table_Apx F-11. Distribution of Average Methylene Chloride ConveyORIZED Degreasing Operating Hours Based on 2014 NEI Data.....	377
Table_Apx F-12. Distribution of Methylene Chloride Cold Cleaning Operating Hours Based on 2014 NEI Data .....	377
Table_Apx G-1. Hierarchy guiding integration of occupational exposure data/information .....	381
Table_Apx G-2. Hierarchy guiding integration of environmental release data/information.....	382
Table_Apx H-1. Comparison of Statistics Pre- and Post-Rule Period .....	385
Table_Apx H-2. Summary of Pre- and Post-Rule Exposure Concentrations for Industries with Largest Number of Data Points.....	387
Table_Apx H-3. Summary of Pre- and Post-Rule Exposure Concentrations Mapped to Occupational Exposure Scenarios .....	387

## **LIST OF APPENDIX FIGURES**

---

Figure_Apx F-1. The Near-Field/Far-Field Model as Applied to the Brake Servicing Near-Field/Far-Field Inhalation Exposure Model.....	351
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.....	365
Figure_Apx F-3. The Near-Field/Far-Field Model as Applied to the ConveyORIZED Degreasing Near-Field/Far-Field Inhalation Exposure Model.....	366

## 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 <sup>3</sup>	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 <sub>ow</sub>	Logarithmic Octanol:Water Partition Coefficient
LPG	Liquefied Petroleum Gas
m <sup>3</sup>	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 for 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. Lithographic Printing Plate Cleaning (Section 2.18)
19. Miscellaneous Non-Aerosol Industrial and Commercial Uses (Section 2.19)
20. Waste Handling, Disposal, Treatment, and Recycling (Section 2.20)

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 <sup>a</sup>	Subcategory <sup>b</sup>	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	Incorporated into formulation, mixture, or reaction product	Solvents (for cleaning or degreasing), including manufacturing of: <ul style="list-style-type: none"> <li>• All other basic organic chemical</li> <li>• Soap, cleaning compound and toilet preparation</li> </ul>	Section 2.3 – Processing - Incorporation into Formulation, Mixture, or Reaction Product
			Solvents (which become part of product formulation or mixture), including manufacturing of: <ul style="list-style-type: none"> <li>• All other chemical product and preparation</li> <li>• Paints and coatings</li> </ul>	
			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 <sup>a</sup>	Subcategory <sup>b</sup>	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 2.20 – 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) <sup>d</sup>	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 <sup>e</sup>	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 2.19 – Miscellaneous Non-Aerosol Industrial and Commercial Uses

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

Life Cycle Stage	Category <sup>a</sup>	Subcategory <sup>b</sup>	Assessed Occupational Exposure Scenarios
	Fabric, textile and leather products not covered elsewhere	Textile finishing and impregnating/ surface treatment products e.g. water repellent	Section 2.12 – Fabric Finishing
	Automotive care products	Function fluids for air conditioners: refrigerant, treatment, leak sealer	Section 2.19 – 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)
		Degreasers – aerosol and non-aerosol degreasers and cleaners	Section 2.19 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
	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

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

Life Cycle Stage	Category <sup>a</sup>	Subcategory <sup>b</sup>	Assessed Occupational Exposure Scenarios
	Processing aid not otherwise listed	In multiple manufacturing sectors <sup>f</sup>	Section 2.14 – Cellulose Triacetate Film Production
	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 2.19 – 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 2.19 – Miscellaneous Non-Aerosol Industrial and Commercial Uses
Toys, playground, and sporting equipment - including novelty articles (toys, gifts, etc.)		Section 2.19 – Miscellaneous Non-Aerosol Industrial and Commercial Uses	
Carbon remover, lithographic printing cleaner, wood floor cleaner, brush cleaner	Section 2.18 – Lithographic Printing Plate Cleaning		
Disposal	Disposal	Industrial pre-treatment	Section 2.20 – Waste Handling, Disposal, Treatment, and Recycling
		Industrial wastewater treatment	
		Publicly owned treatment works (POTW)	
		Underground injection	
		Municipal landfill	
		Hazardous landfill	
		Other land disposal	

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

Life Cycle Stage	Category <sup>a</sup>	Subcategory <sup>b</sup>	Assessed Occupational Exposure Scenarios
		Municipal waste incinerator	
		Hazardous waste incinerator	
		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 1.4.4 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**

---

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 Appendix 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 50<sup>th</sup> and 95<sup>th</sup> 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 Appendix C.

#### **1.4.4.2 Definition of Central Tendency and High End**

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 50<sup>th</sup> 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 50<sup>th</sup> 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 90<sup>th</sup> 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 95<sup>th</sup> percentile. If the 95<sup>th</sup> percentile was not available, EPA used a different percentile greater than or equal to the 90<sup>th</sup> percentile but less than or equal to the 99.9<sup>th</sup> 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

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 50<sup>th</sup> percentile and 95<sup>th</sup> percentile. For datasets with three to five data points, central tendency exposure was calculated using the 50<sup>th</sup> 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'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 Appendix C and Appendix D, respectively.



### **1.4.4.3 Hierarchy of Data for Assessing Inhalation Exposures**

---

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])

### **1.4.4.4 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.

OSHA data are collected as part of compliance inspections at various types of facilities. Certain industries are typically targeted based on national and regional emphasis programs. Other inspections may be prompted based on complaints or referrals. These data are compiled in the Chemical Exposure Health Data (CEHD) database, available on the OSHA website, which contains the facility name, NAICS code, sampling date, sampling time, and sample result. However, EPA consulted with OSHA and discussed data needs for the risk evaluations. OSHA subsequently provided a subset of data that also included worker activity descriptions and were verified for quality and were subsequently used in the risk evaluation ([OSHA, 2019](#)). A comment from Dr. Finkel also provided an OSHA dataset originating from a Freedom of Information Act (FOIA) request. However, the metadata were not fully described and the overall data set was not verified for quality by OSHA. Additional discussion of limitations and treatment of the Finkel dataset are included in Section 4.2.3 and Appendix H, respectively. NIOSH data were primarily from Health Hazard Evaluations (HHEs) conducted at specific processing or use sites.

Data found in sources were evaluated using the evaluation strategies described 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 # EPA-HQ-OPPT-2016-0742” ([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 # EPA-HQ-OPPT-2016-0742” ([U.S. EPA, 2019a](#)). Data from sources included in the risk evaluation were found acceptable for risk assessment purposes. The Data Integration strategy is described in Appendix G.

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 assumed that inhalation exposure data were applicable for a combination of workers and nearby ONUs. Some nearby ONUs may have lower inhalation exposures than users, especially when they are further away from the source of exposure. EPA assumed that ONUs that may be in close proximity to workers handling methylene chloride usually do not directly contact the liquids containing methylene chloride.

For short-term exposures, EPA grouped exposures into 15-minute, 30-minute, 1-hour, and 4-hour TWA averaging periods, in order to evaluate with existing toxicity values for these time periods. EPA typically grouped sample points according to the closest averaging period. However, if the sample duration was more than ~30% longer than a grouping, then it was placed into the next highest grouping.

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 Appendix F.

#### **1.4.4.5 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 1-2 comply 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/m<sup>3</sup> as an 8-hr TWA, and the OSHA short-term exposure limit (STEL) is 125 ppm, or 433 mg/m<sup>3</sup> 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 of 25 ppm. EPA received a public comment that included over 12,000 samples taken during OSHA or state health inspections from 1984 to 2016 (Finkel, 2017). EPA analyzed these samples to evaluate how occupational exposures to methylene chloride changed with time; in particular, any changes after the new PEL was fully implemented (the 1997 OSHA rule required all facilities to comply with all parts of the rule no later than April 9, 2000, which was three years after the final rule's effective date of April 10, 1997) (62 FR 1494). EPA filtered

the samples to personal samples only, combined sequential samples taken on the same worker, and calculated about 3,300 8-hr TWA exposures. EPA replaced sample results of 0 ppm with the limit of detection (LOD) divided by the square root of two. The exact LOD of the sampling and analysis method used in each inspection conducted from 1984 to 2016 is not known. OSHA method 80 for methylene chloride (fully validated in 1990) reports an LOD of 0.201 ppm (OSHA, 1990). NIOSH method 1005 for methylene chloride (issued January 15, 1998) reports an LOD of 0.4 micrograms per sample, with a minimum and maximum air sample volume of 0.5 and 2.5 liters, respectively (NIOSH, 1998). EPA calculated a range in LOD for the NIOSH method of 0.046 to 0.231 ppm. For this analysis, EPA used an LOD of 0.046 ppm (the smallest of these three LOD values) and an LOD divided by the square root of two equal to 0.0326 ppm.

EPA analyzed 1,407 and 1,471 8-hr TWA exposures measured prior to April 10, 1997 (pre-rule) and after April 10, 2000 (post-rule), respectively. The arithmetic mean of the pre-rule and post-rule distributions was 27.3 ppm and 17.9 ppm, respectively, a reduction of about 34%. The median of the pre-rule and post-rule distributions was 3.7 ppm and 2.5 ppm, respectively, a reduction of about 31%, similar to the reduction in the mean. EPA calculated the percentile ranks of 25 ppm in the pre-rule and post-rule distributions: approximately 23% and 15% of the exposures exceeded 25 ppm in the pre-rule and post-rule distributions, respectively. This is a reduction of about 35%, similar to the reductions in the mean and median. While exposures in the distributions showed consistent reductions of about 30% to 35%, this followed a reduction in the PEL of 95%. Hence, a twentyfold reduction in the PEL resulted in only an approximately 1.5-fold reduction in actual exposures. Due to the small reduction in exposures relative to the reduction in PEL, EPA included the pre-rule samples in the occupational exposure assessment to provide a more robust data set. The analysis is discussed in Appendix H.

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<sup>a</sup>**

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	<b>50</b>	.....	.....
• Continuous flow mode	.....	50	<b>1,000</b>	<b>25/1,000</b>	<b>25</b>
• Pressure-demand or other positive-pressure mode	.....	50	<b>1,000</b>	.....	.....
4. Self-Contained Breathing Apparatus (SCBA)					
• Demand mode	.....	10	<b>50</b>	<b>50</b>	.....
• Pressure-demand or other positive-pressure mode	.....	.....	<b>10,000</b>	<b>10,000</b>	.....

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 Appendix E.

#### **1.4.6 Consideration of Engineering Controls and Personal Protective Equipment**

---

OSHA requires and NIOSH recommends that employers utilize the hierarchy of controls to address hazardous exposures in the workplace. The hierarchy of controls strategy outlines, in descending order of priority, the use of elimination, substitution, engineering controls, administrative controls, and lastly personal protective equipment (PPE). The hierarchy of controls prioritizes the most effective measures first which is to eliminate or substitute the harmful chemical (e.g., use a different process, substitute with a less hazardous material), thereby preventing or reducing exposure potential. Following elimination and substitution, the hierarchy recommends engineering controls to isolate employees from the hazard, followed by administrative controls, or changes in work practices to reduce exposure potential (e.g., source enclosure, local exhaust ventilation systems). Administrative controls are policies and procedures instituted and overseen by the employer to protect worker exposures. As the last means of control, the use of personal protective equipment (e.g., respirators, gloves) is recommended, when the other control measures cannot reduce workplace exposure to an acceptable level. The National Institute for Occupational Safety and Health (NIOSH) and the U.S. Department of Labor's Bureau of Labor Statistics (BLS) conducted a voluntary survey of U.S. employers regarding the use of respiratory protective devices between August 2001 and January 2002 (NIOSH, 2003). For additional information, please also refer to [*Memorandum\_NIOSH\_BLS Respirator Usage in Private Sector Firms. Docket # 1354 EPA-HQ-OPPT-2019-0500*] (U.S. EPA, 2020). EPA could not determine whether PPE or engineering controls were used for some settings where monitoring was conducted.

### 1.4.7 Water Release Assessment Approach

EPA 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 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 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 estimated annual releases, average daily releases, and number of release days per year. Where TRI and/or DMR were available, EPA 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 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 a total of 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 <sup>a</sup> 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 <sup>b</sup>
CBI	INEOS Chlor Americas Inc.	INEOS Chlor America Inc.	Wilmington	DE	CBI <sup>b</sup>
CBI	CBI	GreenChem	West Palm Beach	FL	CBI <sup>b</sup>
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Geismar	LA	CBI <sup>b</sup>
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Wichita	KS	CBI <sup>b</sup>
Withheld	FRP Services & Co. (America) Inc.	FRP Services & Co. (America) Inc.	New York	NY	Withheld <sup>b</sup>
Withheld	Solvay USA Inc	Solvay USA INC	Princeton	NJ	Withheld <sup>b</sup>
Withheld	Global Chemical Resources Inc.	Global Chemical Resources Inc.	Toledo	OH	Withheld <sup>b</sup>
Withheld	Shrieve Chemical Company	Shrieve Chemical Products, Inc.	The Woodlands	TX	Withheld <sup>b</sup>
<i>Total establishments and number of potentially exposed workers during Manufacture/Import</i>			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 Appendix A summarize the inhalation monitoring data for methylene chloride manufacturing that EPA compiled from published literature sources, including 8-hour TWA, 12-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 for a variety of worker activities ([Halogenated Solvents Industry Alliance, 2018](#)). From this monitoring data, EPA calculated the 50th and 95th percentile 8- and 12-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- and 12-hr TWA exposure concentrations for this scenario are generally one order of magnitude below the OSHA PEL value of 87 mg/m<sup>3</sup> (25 ppm).

Using these 8- and 12-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-2.

**Table 2-2. Full-Shift Worker Exposure to Methylene Chloride During Manufacturing <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
<i>8-hr TWA Results</i>			
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
<i>12-hr TWA Results</i>			
12-hr TWA Exposure Concentration	149	0.45	12
Average Daily Concentration (ADC)		0.15	4.1
Lifetime Average Daily Concentration (LADC)		0.27	9.3

Sources: [Halogenated Solvents Industry Alliance \(2018\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

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 <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
15-minute <sup>a</sup>	148	9.6	180
30-minute <sup>b</sup>	1	2.6	
1-hour	4	4.3	16

Source: [Halogenated Solvents Industry Alliance \(2018\)](#). Full results are presented in Table\_Apx A-2.

a – EPA evaluated 148 samples, with durations ranging from 15 to 22 minutes, as 15-minute exposures.

b – EPA evaluated 1 sample, with a duration of 35 minutes, as a 30-minute exposure.

c – EPA evaluated 4 samples, with durations ranging from 50 to 55 minutes, as 1-hour exposures.

Note: The OSHA Short-term exposure limit (STEL) is 433 mg/m<sup>3</sup> as a 15-min TWA. One sample of 486 mg/m<sup>3</sup> among the 148 15-min samples exceeded this limit, and the remaining 147 samples were below this limit.

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	<a href="#">U.S. EPA (2017c)</a>
EMERALD PERFORMANCE MATERIALS LLC	HENRY	IL	0.5	350	0.001	Surface Water	<a href="#">U.S. EPA (2017c)</a>
FISHER SCIENTIFIC CO LLC	FAIR LAWN	NJ	2	350	0.01	POTW	<a href="#">U.S. EPA (2017c)</a>
FISHER SCIENTIFIC CO LLC	BRIDGEWATER	NJ	2	350	0.01	POTW	<a href="#">U.S. EPA (2017c)</a>
OLIN BLUE CUBE FREEPORT TX	FREEPORT	TX	58	350	0.2	Non-POTW WWT	<a href="#">U.S. EPA (2017c)</a>
REGIS TECHNOLOGIES INC	MORTON GROVE	IL	2	350	0.01	POTW	<a href="#">U.S. EPA (2017c)</a>
SIGMA-ALDRICH MANUFACTURING LLC	SAINT LOUIS	MO	2	350	0.01	POTW	<a href="#">U.S. EPA (2017c)</a>
VANDERBILT CHEMICALS LLC-MURRAY DIV	MURRAY	KY	0.5	350	0.001	Non-POTW WWT	<a href="#">U.S. EPA (2017c)</a>
E I DUPONT DE NEMOURS - CHAMBERS WORKS	DEEPWATER	NJ	76	350	0.2	Surface Water	<a href="#">U.S. EPA (2016a)</a>
BAYER MATERIALSCIENCE BAYTOWN	BAYTOWN	TX	10	350	0.03	Surface Water	<a href="#">U.S. EPA (2016a)</a>
INSTITUTE PLANT	INSTITUTE	WV	3	350	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
MPM SILICONES LLC	FRIENDLY	WV	2	350	0.005	Surface Water	<a href="#">U.S. EPA (2016a)</a>
BASF CORPORATION	WEST MEMPHIS	AR	1	350	0.003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
ARKEMA INC	PIFFARD	NY	0.3	350	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>

EAGLE US 2 LLC - LAKE CHARLES COMPLEX	LAKE CHARLES	LA	0.2	350	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
BAYER MATERIALSCIENCE	NEW MARTINSVILLE	WV	0.2	350	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
ICL-IP AMERICA INC	GALLIPOLIS FERRY	WV	0.1	350	0.0004	Surface Water	<a href="#">(U.S. EPA, 2016a)</a>
KEESHAN AND BOST CHEMICAL CO., INC.	MANVEL	TX	0.02	350	0.00005	Surface Water	<a href="#">U.S. EPA (2016a)</a>
INDORAMA VENTURES OLEFINS, LLC	SULPHUR	LA	0.01	350	0.00003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CHEMTURA NORTH AND SOUTH PLANTS	MORGANTOWN	WV	0.01	350	0.00002	Surface Water	<a href="#">U.S. EPA (2016a)</a>

### 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 <sup>a</sup> likely to be exposed
CBI	Intermediates	<10	25 to <50
CBI	Intermediates	<10	50 to <100
<i>Total establishments and number of potentially exposed workers and ONUs =</i>		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 <sup>b</sup>	Number of ONUs per Site <sup>b</sup>
325120	Industrial Gas Manufacturing	18 <sup>a</sup>	14	7
325320	Pesticide and Other Agricultural Chemical Manufacturing		25	7
<i>Total establishments and number of potentially exposed workers and ONUs =<sup>c</sup></i>			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 Appendix 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<sup>3</sup> (15 samples) ([Halogenated Solvents Industry Alliance, 2018](#)). Finkel (2017) also submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-6 above. For the set of 14 data points, 8-hr TWA exposure concentrations ranged from 0.11 to 301 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to the use of methylene chloride as a reactant, nor to distinguish workers from ONUs. While there may be additional activities at these sites, such as use of methylene chloride as a cleaning solvent that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposure during processing as a reactant. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H.

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/m<sup>3</sup> (25 ppm), while the high-end 8-hr TWA exposure concentrations for this scenario is higher 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 Appendix B.

**Table 2-7. Worker Exposure to Methylene Chloride During Processing as a Reactant <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	29	1.6	110
Average Daily Concentration (ADC)		0.37	25
Lifetime Average Daily Concentration (LADC)		0.65	55

Sources: [Halogenated Solvents Industry Alliance \(2018\)](#); [Finkel \(2017\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

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/m <sup>3</sup> )	Exposure Duration (min)
Other Chemical Industry	<a href="#">TNO (CIVO) (1999)</a>	filter changing, charging and discharging, etc	350 (max)	10 <sup>a</sup>

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m <sup>3</sup> )	Exposure Duration (min)
Pesticides Mfg	<a href="#">Olin Corp (1979)</a>	Drumming	1,700	25 <sup>b</sup>

a – EPA evaluated as a 15-minute exposure.

b – EPA evaluated as a 30-minute exposure.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> 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.

### 2.2.4 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	<a href="#">U.S. EPA (2017c)</a>
THE DOW CHEMICAL CO	MIDLAND	MI	25	350	0.1	Surface Water	<a href="#">U.S. EPA (2017c)</a>
FMC CORPORATION	MIDDLEPORT	NY	0.1	350	0.0003	Surface Water	<a href="#">U.S. EPA (2016a)</a>

### 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 propellant 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 propellant (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 <sup>a</sup> likely to be exposed
Adhesive manufacturing	Adhesives and sealant chemicals	NKRA <sup>b</sup>	NKRA <sup>b</sup>
Adhesive manufacturing	Adhesives and sealant chemicals	<10	NKRA <sup>b</sup>
All other basic organic chemical manufacturing	Solvents (for cleaning and degreasing)	NKRA <sup>a</sup>	NKRA <sup>b</sup>
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 <sup>b</sup>	NKRA <sup>b</sup>
Paint and coating manufacturing	Solvents (which become part of product formulation or mixture)	NKRA <sup>b</sup>	NKRA <sup>b</sup>
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
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>c</sup></i>		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 Appendix 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.

Finkel ([2017](#)) submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes for Paint and Coating Manufacturing and Adhesives Manufacturing. For the set of 45 data points, 8-hr TWA exposure concentrations ranged from 0.86 to 559 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to formulation processes using methylene chloride, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use of methylene chloride as a reactant or as a cleaning solvent that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during processing methylene chloride into formulation. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. U.S. EPA

(1985) also provided exposure data for packing at paint/varnish and cleaning products sites, ranging from 52 mg/m<sup>3</sup> (mixing) to 2,223 mg/m<sup>3</sup> (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 slightly higher than the OSHA PEL value of 87 mg/m<sup>3</sup> (25 ppm), while the high-end estimate is approximately six times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix 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 <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	55	100	540
Average Daily Concentration (ADC)		23	120
Lifetime Average Daily Concentration (LADC)		40	280

Sources: [US EPA \(1985\)](#); [Finkel \(2017\)](#)

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<sup>3</sup>, but did not provide exposure duration. Therefore, this exposure concentration was not used in the assessment.

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	<a href="#">U.S. EPA (2017c)</a>
MCGEAN-ROHCO INC	LIVONIA	MI	113	300	0.4	POTW	<a href="#">U.S. EPA (2017c)</a>
WM BARR & CO INC	MEMPHIS	TN	0.5	300	0.002	POTW	<a href="#">U.S. EPA (2017c)</a>
BUCKMAN LABORATORIES INC	MEMPHIS	TN	254	300	1	POTW	<a href="#">U.S. EPA (2017c)</a>
EUROFINS MWG OPERON LLC	LOUISVILLE	KY	5,785	300	19	POTW	<a href="#">U.S. EPA (2017c)</a>
SOLVAY - HOUSTON PLANT	HOUSTON	TX	12	300	0.04	Surface Water	<a href="#">U.S. EPA (2016a)</a>
HONEYWELL INTERNATIONAL INC - GEISMAR COMPLEX	GEISMAR	LA	4	300	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
STEPAN CO MILLSDALE ROAD	ELWOOD	IL	2	300	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
ELEMENTIS SPECIALTIES, INC.	CHARLESTON	WV	0.2	300	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>

### 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 <sup>a</sup> 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 <sup>b</sup>
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 <sup>c</sup>
CBI	INEOS Chlor Americas Inc.	INEOS Chlor America Inc.	Wilmington	DE	CBI <sup>c</sup>
CBI	CBI	GreenChem	West Palm Beach	FL	CBI <sup>c</sup>
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Geismar	LA	CBI <sup>c</sup>

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

Manufacture/ Import	Company	Facility	Facility		Workers <sup>a</sup> likely to be exposed
			City	State	
CBI	Occidental Chemical Holding Corp.	Occidental Chemical Corporation	Wichita	KS	CBI <sup>c</sup>
Withheld	FRP Services & Co. (America) Inc.	FRP Services & Co. (America) Inc.	New York	NY	Withheld <sup>c</sup>
Withheld	Solvay USA Inc	Solvay USA INC	Princeton	NJ	Withheld <sup>c</sup>
Withheld	Global Chemical Resources Inc.	Global Chemical Resources Inc.	Toledo	OH	Withheld <sup>c</sup>
Withheld	Shrieve Chemical Company	Shrieve Chemical Products, Inc.	The Woodlands	TX	Withheld <sup>c</sup>
<i>Total establishments and number of potentially exposed workers during Manufacture/Import</i>			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 <sup>a</sup> likely to be exposed
Wholesale and retail trade	CBI	CBI <sup>b</sup>	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 <sup>c</sup>
CBI	Laboratory chemicals	<10	25 to <50
<i>Total establishments and number of potentially exposed workers during Repackaging</i>		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 Appendix 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<sup>3</sup> (5 data points) ([Unocal Corporation, 1986](#)).

Because only five data points were available, EPA assessed the median value of 8.8 mg/m<sup>3</sup> as the central tendency, and the maximum reported value of 137.8 mg/m<sup>3</sup> 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/m<sup>3</sup> (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 Appendix B. The results of these calculations are shown in Table 2-16.

**Table 2-16. Worker Exposure to Methylene Chloride During Repackaging <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
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 \(1986\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

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/m <sup>3</sup> )	Exposure Duration (min)
Distribution	<a href="#">Unocal Corporation (1986)</a>	Transfer loading from truck to storage tank (4,100 gallons)	0.35	30 <sup>a</sup>
		Truck loading (2,000 gal)	330	50 <sup>b</sup>
		Truck loading (800 gal)	35	30 <sup>a</sup>
		Truck loading (250 gal)	30	47 <sup>b</sup>

a – EPA evaluated two samples, with durations of 30 minutes each, as 30-minute exposures.

b – EPA evaluated two samples, with durations of 47 and 50 minutes, as 1-hr exposures.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> 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.

#### **2.4.4 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 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	<a href="#">U.S. EPA (2017c)</a>
HUBBARD-HALL INC	WATERBURY	CT	144	250	1	Non-POTW WWT	<a href="#">U.S. EPA (2017c)</a>
WEBB CHEMICAL SERVICE CORP	MUSKEGON HEIGHTS	MI	98	250	0.4	POTW	<a href="#">U.S. EPA (2017c)</a>
RESEARCH SOLUTIONS GROUP INC	PELHAM	AL	0.09	250	0.0003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
EMD MILLIPORE CORP	CINCINNATI	OH	0.03	250	0.0001	Surface Water	<a href="#">U.S. EPA (2016a)</a>

#### **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 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.

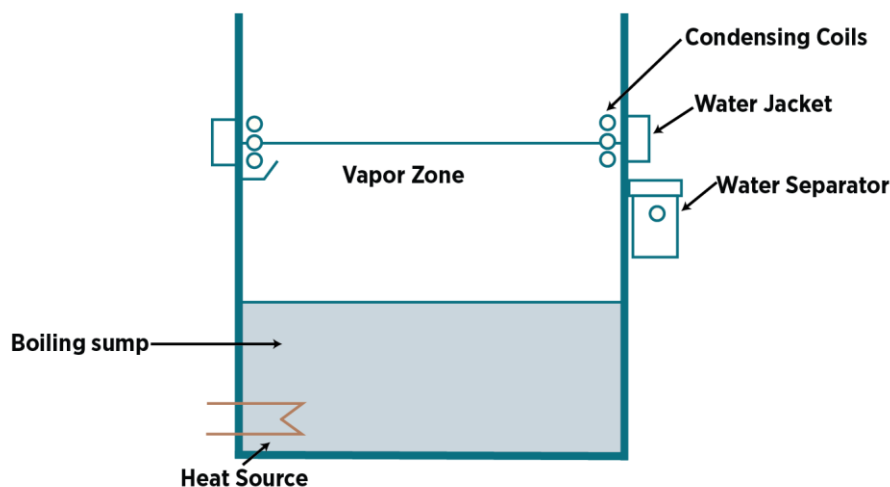
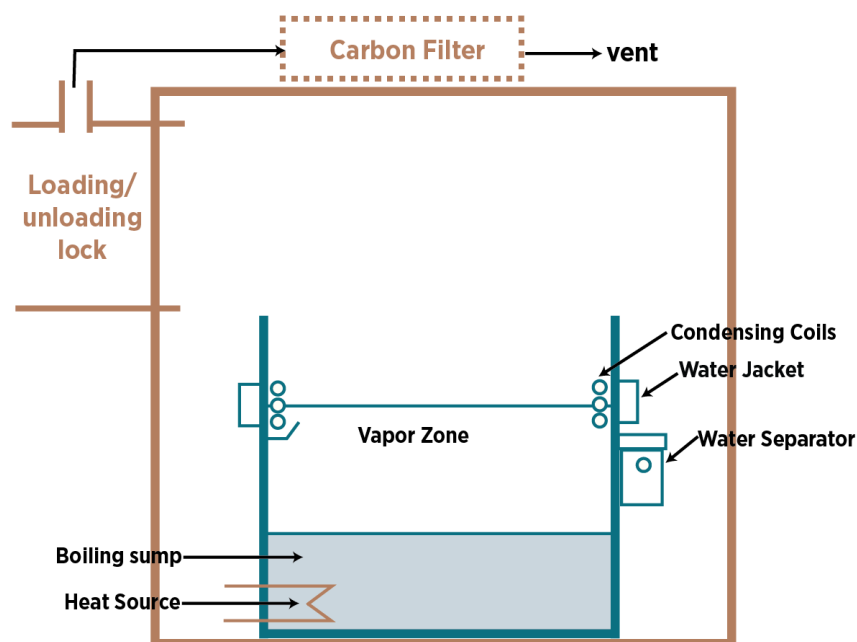


Figure 2-1. Open Top Vapor Degreaser

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, 2004](#)). 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<sup>3</sup> at the 50th percentile and 744.8 mg/m<sup>3</sup> at the 95th percentile. For occupational non-users, the modeled 8-hr TWA exposures are 86.5 mg/m<sup>3</sup> at the 50th percentile and 455.6 mg/m<sup>3</sup> 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/m<sup>3</sup> (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 C, 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/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
<b>Workers (Near-Field)</b>		
8-hr TWA Exposure Concentration	170	740
Average Daily Concentration (ADC)	38	170
Lifetime Average Daily Concentration (LADC)	67	380
<b>Occupational Non-Users (Far-Field)</b>		
8-hr TWA Exposure Concentration	86	460
Average Daily Concentration (ADC)	20	100
Lifetime Average Daily Concentration (LADC)	34	230

### 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.

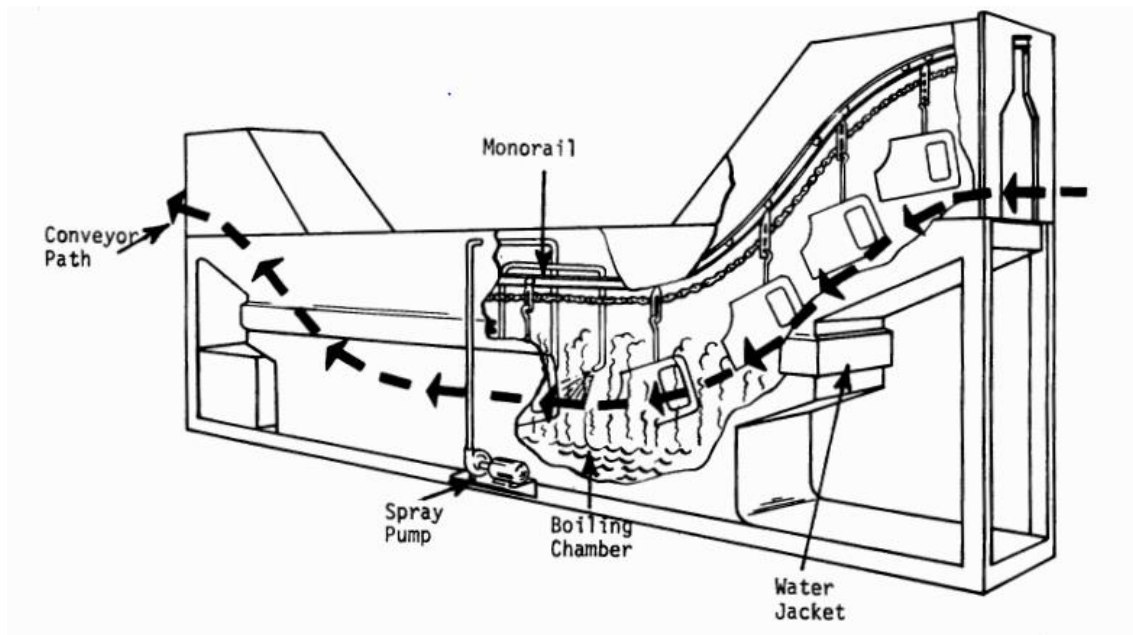
## 2.6 Conveyorized Vapor Degreasing

### 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](#)).

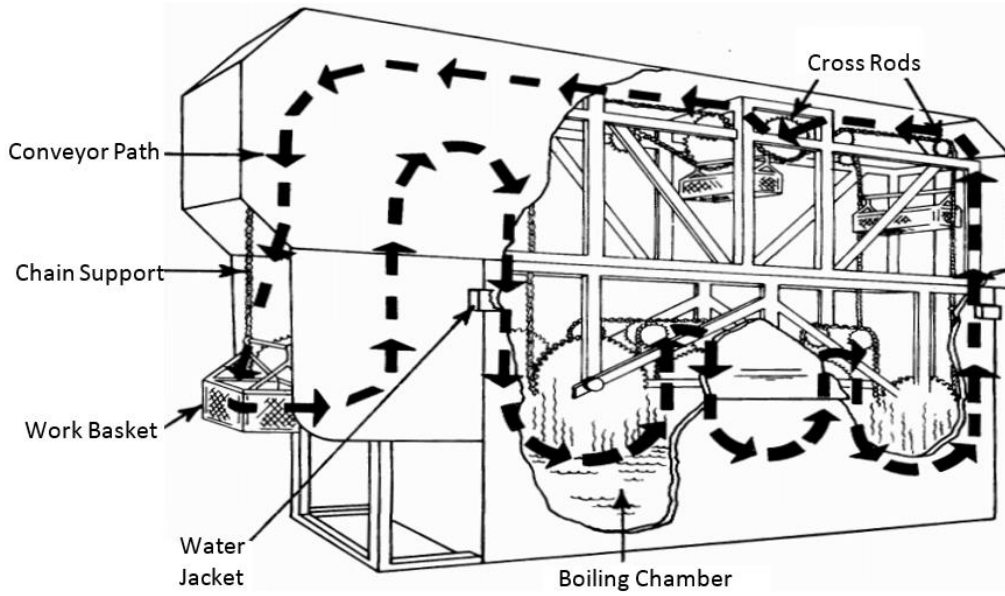
- Monorail Degreasers – Monorail degreasing systems are typically used when parts are already being transported throughout the manufacturing areas by a conveyor. They use a straight-line conveyor to transport parts into and out of the cleaning zone. The parts may enter one side and exit and the other 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.





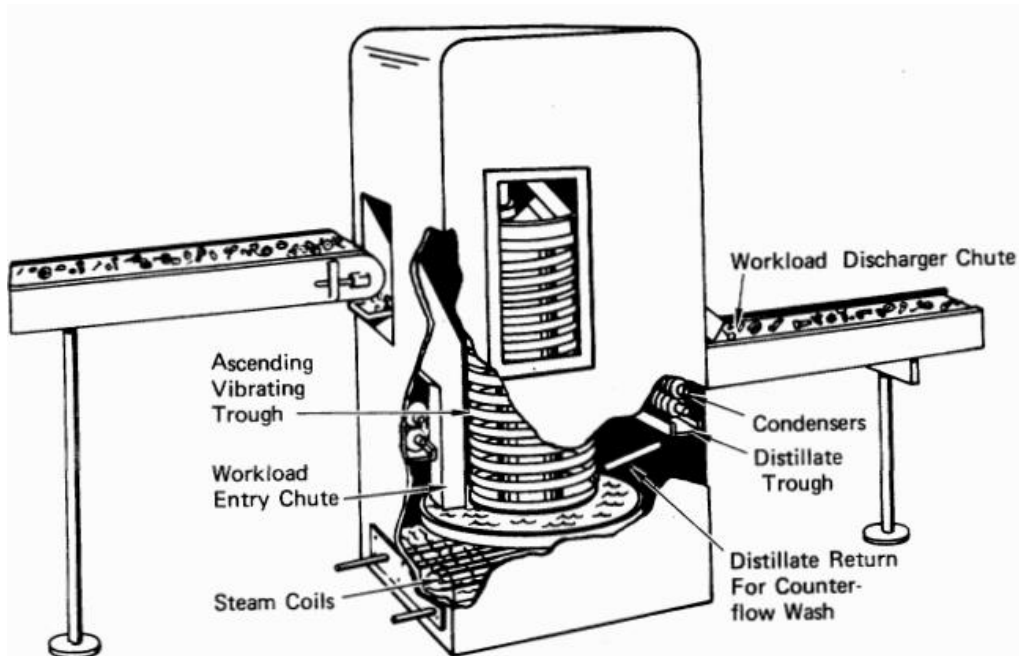
**Figure 2-3. Monorail ConveyORIZED Vapor Degreasing System ([U.S. EPA, 1977](#))**

- 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.



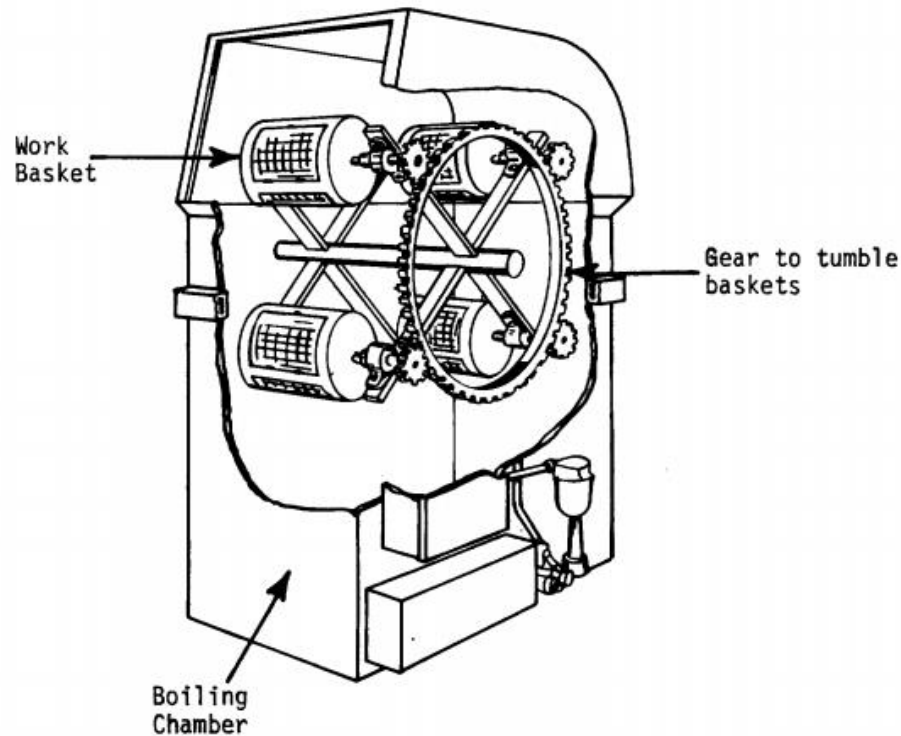
**Figure 2-4. Cross-Rod ConveyORIZED Vapor Degreasing System (U.S. EPA, 1977)**

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).



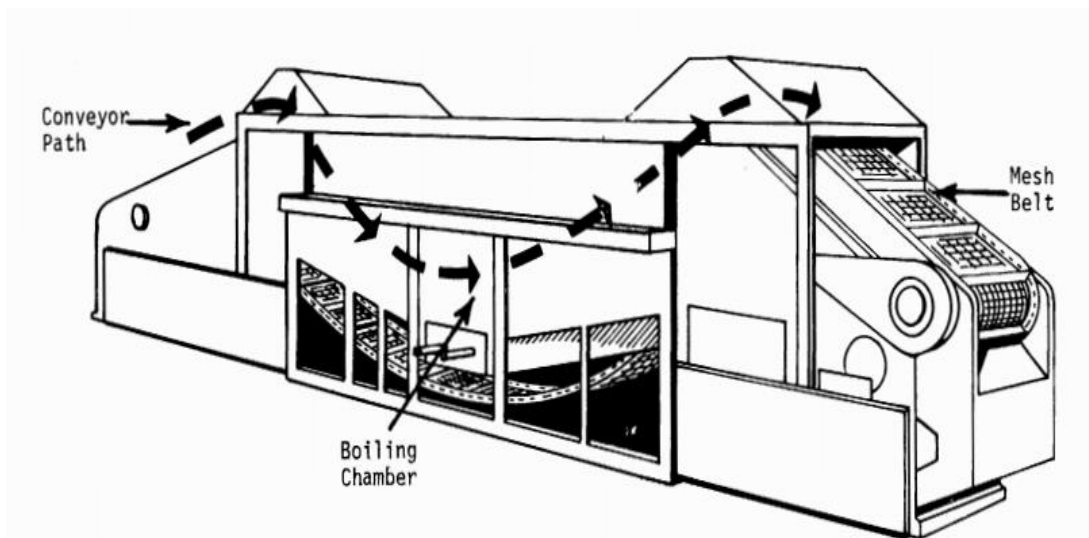
**Figure 2-5. Vibra ConveyORIZED Vapor Degreasing System (U.S. EPA, 1977)**

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<sup>3</sup> at the 50<sup>th</sup> percentile and 465.0 mg/m<sup>3</sup> at the 95<sup>th</sup> percentile. For occupational non-users, the modeled 8-hr TWA exposures are 253.0 mg/m<sup>3</sup> at the 50<sup>th</sup> percentile and 900 mg/m<sup>3</sup> at the 95<sup>th</sup> percentile. The central tendency 8-hr TWA worker exposure concentration for this scenario is approximately twice the OSHA PEL value of 87 mg/m<sup>3</sup> (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 Appendix 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 <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
<b>Workers (Near-Field)</b>		
8-hr TWA Exposure Concentration	490	1,400
Average Daily Concentration (ADC)	110	320
Lifetime Average Daily Concentration (LADC)	190	720
<b>Occupational Non-Users (Far-Field)</b>		
8-hr TWA Exposure Concentration	250	900
Average Daily Concentration (ADC)	58	210
Lifetime Average Daily Concentration (LADC)	100	460

#### 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

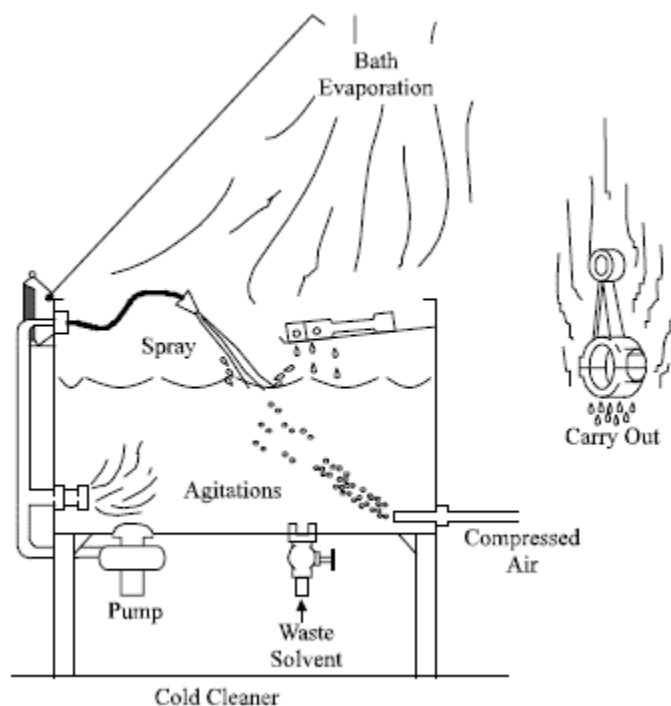
In summary, dermal and inhalation exposures are expected for this use, as well as direct or indirect water releases. EPA has not identified additional uncertainties for this use beyond those discussed in Section 4.2.

### 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](#)).

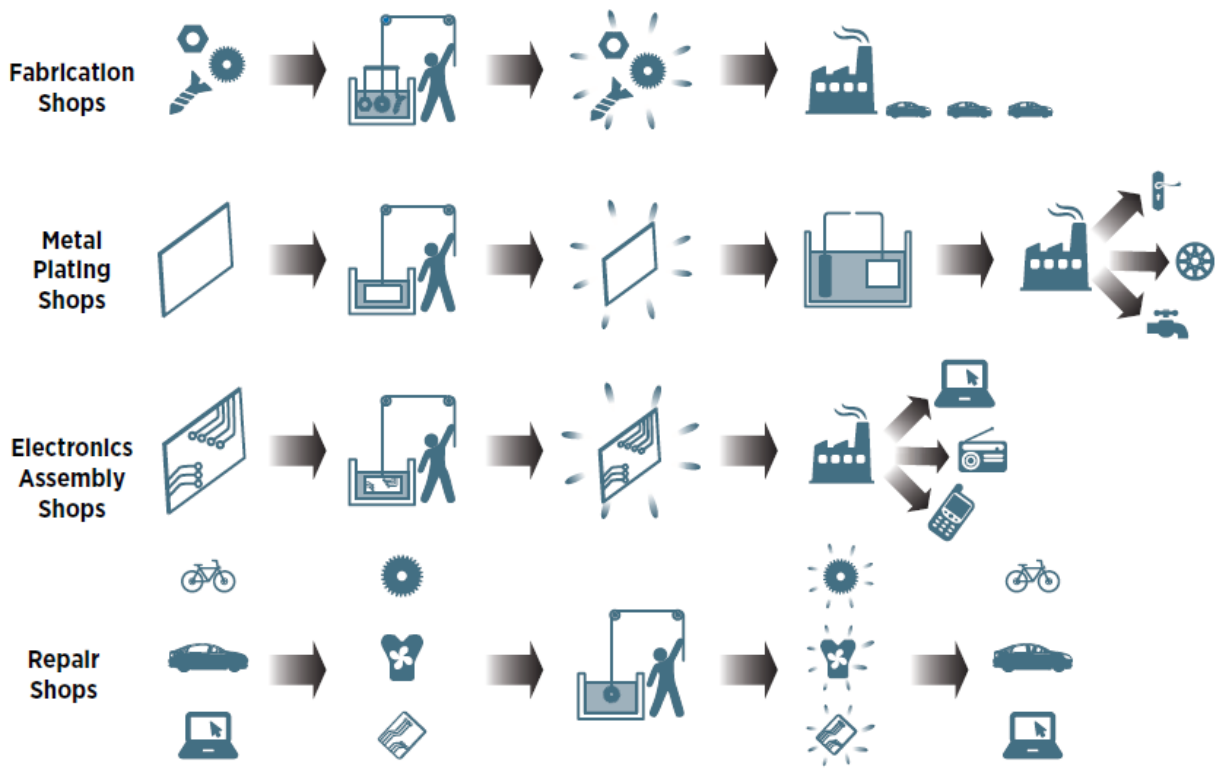
### **2.7.2 Number of Sites and Potentially Exposed Workers**

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, or 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 Appendix 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<sup>3</sup> on average, ranging from 14 to over 1,000 mg/m<sup>3</sup>. 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<sup>3</sup> as the central tendency, and the maximum reported value of 1,000 mg/m<sup>3</sup> 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/m<sup>3</sup> (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 Appendix B. The results of these calculations are shown in Table 2-21.

**Table 2-21. Exposure to Methylene Chloride During Cold Cleaning<sup>a</sup>**

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

Source: [TNO \(CIVO\) \(1999\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

b – 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/m<sup>3</sup> at the 50th percentile and 103.8 mg/m<sup>3</sup> at the 95th percentile. For ONUs, the modeled 8-hr TWA exposures are 0.5 mg/m<sup>3</sup> at the 50th percentile and 60 mg/m<sup>3</sup> at the 95th percentile.

For the risk evaluation, EPA used the available monitoring data because the monitoring data have higher weight of evidence due to higher relevance than modeling results for this use. The higher relevance of data is because monitoring data are known to be relevant to this use, and the modeled results cannot be validated and do not capture the full range of possible exposure concentrations identified by the monitoring data for this use. For example, the 95<sup>th</sup> percentile modeling results appear equal to about the 25<sup>th</sup> percentile of monitoring data. Modeling details are in Appendix F.

#### **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)**

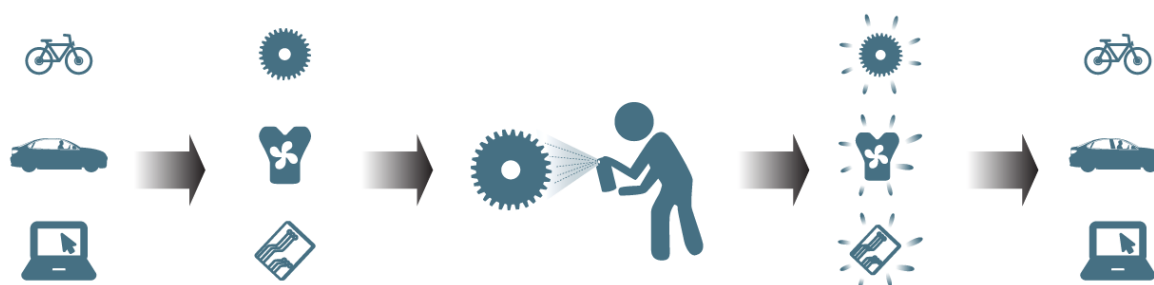
### **2.8.1 Process Description**

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 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

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

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 <sup>a</sup>	Number of Workers per Site <sup>b</sup>	Number of ONUs per Site <sup>b</sup>
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
<i>Total establishments and number of potentially exposed workers and ONUs =<sup>c</sup></i>		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

#### 2.8.3.2.1 Monitoring Data

Table\_Apx A-10 in Appendix A summarizes TWA inhalation monitoring data for use of methylene chloride 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.

Finkel (2017) submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-23 above. For the set of 21 data points, 8-hr TWA exposure concentrations ranged from 0.1 to 396.5 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to aerosol degreasing, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as application of paints and coatings, use of adhesives, and use of paint strippers that contributed to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during aerosol product application. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H.

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/m<sup>3</sup> (25 ppm), while the high-end 8-hr TWA exposure concentrations for this scenario is approximately 3 times the OSHA PEL.

Table 2-24 presents the calculated the AC, ADC, and LADC for these 8-hr TWA exposure concentrations, as described in Appendix B.

**Table 2-24. Worker Exposure to Methylene Chloride During Aerosol Degreasing Based on Monitoring Data <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	21	6.0	230
Average Daily Concentration (ADC)		1.4	52
Lifetime Average Daily Concentration (LADC)		2.4	120

Source: [Finkel \(2017\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

EPA has not identified data on potential short-term or 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.

### 2.8.3.2.2 Modeled Data

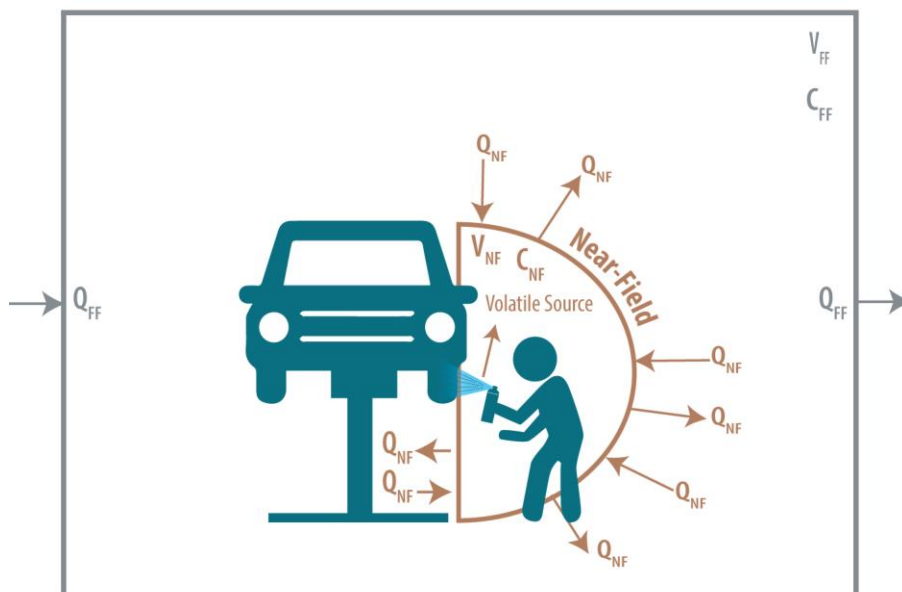
---

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 Appendix 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 Appendix 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<sup>3</sup> at the 50<sup>th</sup> percentile and 78.7 mg/m<sup>3</sup> at the 95<sup>th</sup> percentile; the modeled maximum 1-hr TWA exposures are 68.0 mg/m<sup>3</sup> at the 50<sup>th</sup> percentile and 230.3 mg/m<sup>3</sup> at the 95<sup>th</sup> percentile. For occupational non-users, the modeled 8-hr TWA exposures are 0.40 mg/m<sup>3</sup> at the 50<sup>th</sup> percentile and 3.26 mg/m<sup>3</sup> at the 95<sup>th</sup> percentile; the modeled maximum 1-hr TWA exposures are 1.2 mg/m<sup>3</sup> at the 50<sup>th</sup> percentile and 9.7 mg/m<sup>3</sup> at the 95<sup>th</sup> 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<sup>3</sup> (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 Appendix B, and are presented in Table 2-25.

**Table 2-25. Statistical Summary of Methylene Chloride 8-hr TWA Exposures (ADC and LADC) for Aerosol Products Based on Modeling**

	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
<b>Workers (Near-Field)</b>		
8-hr TWA Exposure Concentration	22	79
Average Daily Concentration (ADC)	5.0	18
Lifetime Average Daily Concentration (LADC)	8.7	40
Maximum 1-hr TWA Exposures	68	230
<b>Occupational Non-Users (Far-Field)</b>		
8-hr TWA Exposure Concentration	0.40	3.3
Average Daily Concentration (ADC)	0.09	0.74

	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
Lifetime Average Daily Concentration (LADC)	0.16	1.7
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 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 2-26. 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 2-26. 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 <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
Specialty Trade Contractors	Market Profile	238200	Building Equipment Contractors	176,142	8 <sup>b</sup>	1 <sup>b</sup>
		238330	Flooring Contractors	14,601	4	0
Wood Product Manufacturing	OSHA	321200	Veneer, Plywood, and Engineered Wood Product Manufacturing	1,407	25 <sup>d</sup>	7 <sup>d</sup>
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 <sup>b</sup>	12 <sup>b</sup>
		334200	Communications Equipment Manufacturing	1,369	13	14
		334300	Audio and Video Equipment Manufacturing	486	6 <sup>b</sup>	6 <sup>b</sup>
		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 <sup>b</sup>	6 <sup>b</sup>
		335100	Electric Lighting Equipment Manufacturing	1,104	17	5
		335200	Household Appliance Manufacturing	303	102	20
		335300	Electrical Equipment Manufacturing	2,124	28	12
Transportation Equipment Manufacturing		335900	Other Electrical Equipment and Component Manufacturing	2,140	23	8
		336100	Motor Vehicle Manufacturing	340	234 <sup>b</sup>	97 <sup>b</sup>
		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
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 <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>d</sup></i>				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-11 and Table\_Apx A-12 in Appendix 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, as well as data for unknown application methods.

8-hr TWA data are primarily from Finkel ([2017](#)) who submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-26Table 2-23 above. For the set of 468 data points, 8-hr TWA exposure concentrations ranged from 0.11 to 2,280 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to application of adhesives and sealants, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as application of paints and coatings and use of paint strippers that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during use of adhesives and sealants. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. Additional 8-hr TWA data are from a 1985 EPA Risk Assessment that compiled laminating and gluing activities in various industries, ranging from ND to 575 mg/m<sup>3</sup> (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<sup>3</sup> (12 samples) ([NIOSH, 1985](#)). Two data points from OSHA ranged from 13.2 to 15.2 (scaled up to 8-hr TWA) ([OSHA, 2019](#)).

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<sup>3</sup> (25 ppm), while worst-case estimates are between three and eight times the OSHA PEL.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-27, Table 2-28, and Table 2-29 for non-spray, spray, and unknown adhesives and sealants application, respectively.

**Table 2-27. Exposure to Methylene Chloride During Industrial Non-Spray Adhesives and Sealants Use <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	100	10	300
Average Daily Concentration (ADC)		2.4	67
Lifetime Average Daily Concentration (LADC)		4.2	150

Sources: [OSHA \(2019\)](#); [NIOSH \(1985\)](#); [US EPA \(1985\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

**Table 2-28. Exposure to Methylene Chloride During Industrial Spray Adhesives and Sealants Use<sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
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 \(1985\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

**Table 2-29. Exposure to Methylene Chloride During Adhesives and Sealants (Unknown Application Method) <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	468	27	690
Average Daily Concentration (ADC)		6.2	160
Lifetime Average Daily Concentration (LADC)		11	350

Source: [Finkel \(2017\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

Table 2-30 summarizes available short-term exposure data available from the same references and industries identified above for the 8-hr TWA data, as well as OSHA inspection data. Data range from 12 mg/m<sup>3</sup> to 720 mg/m<sup>3</sup> during adhesive/sealant application.

**Table 2-30. 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 <sup>3</sup> )	Exposure Duration (min)
Metal Window and Door Manufacturing	<a href="#">OSHA (2019)</a>	Adhesive/Sealant Sprayer	720	15 <sup>a</sup>
			580	
			140	

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m <sup>3</sup> )	Exposure Duration (min)
Wood Kitchen Cabinet and Countertop Manufacturing			480	
			160	
			360	
			100	
			280	
			12	
Flexible Circuit Board Manufacturing	<a href="#">NIOSH (1985)</a>	Operator, laminator #3 & #4, cleaning (Non-Spray)	420	10 <sup>a</sup>
		Employee mixing adhesives/sealants, Dept 12 (Non-Spray)	570	12 <sup>a</sup>
Industrial Sign Manufacturing	<a href="#">OSHA (2019)</a>	Laminator	63.4	71 <sup>b</sup>

a – EPA evaluated samples with durations ranging from 10 to 15 minutes, as 15-minute exposures.

b – EPA evaluated one sample with duration of 71 minutes as a 1-hr exposure.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> 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

The 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 2-31. 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 2-31. 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 <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
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 <sup>b</sup>	2 <sup>b</sup>
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 <sup>b</sup>	5 <sup>b</sup>
Repair and Maintenance	OSHA	811111	General Automotive Repair	80,243	2	0
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>c</sup></i>				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-13 and Table\_Apx A-14 in Appendix 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, 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.

A number of data points did not specify the method of application. Finkel ([2017](#)) submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-31. For the set of 266 data points, 8-hr TWA exposure concentrations ranged from 0.11 to 3,365 mg/m<sup>3</sup>. Worker activity information was not available; therefore it was not possible to specifically attribute the exposures to the use of paints and coatings, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use of paint strippers that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during use of paints and coatings. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. 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<sup>3</sup> (25 ppm), but the high-end estimate is approximately four times higher.

For unknown application method operations, the central tendency 8-hr TWA exposure concentration is approximately seven times lower than the OSHA PEL value of 87 mg/m<sup>3</sup> (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 Appendix B. The results of these calculations are shown in Table 2-32 and Table 2-33, respectively for spray paint/coating application and unknown application method paint/coating application.

**Table 2-32. Exposure to Methylene Chloride During Paint/Coating Spray Application <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
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 \(1985\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

**Table 2-33. Exposure to Methylene Chloride During Paint/Coating (Unknown Application Method) <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	271	12	260
Average Daily Concentration (ADC)		2.8	60
Lifetime Average Daily Concentration (LADC)		4.9	130

Sources: [DOEHRS-IH \(2018\)](#); [Finkel \(2017\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

Table 2-34 summarizes available short-term exposure data 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 2-34. 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 <sup>3</sup> )	Exposure Duration (min)
Metro Bus Maintenance Shop	<a href="#">NIOSH (1981)</a>	Painting	ND (<0.01)	40 <sup>b</sup>
		Painting	ND (<0.01)	50 <sup>c</sup>
Metal Fabrication Plant			64	32 <sup>b</sup>

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m <sup>3</sup> )	Exposure Duration (min)
	<a href="#">NIOSH (1973)</a>	Spray Painter in Aisle No. 2 (Front) Spray Booth	54	32 <sup>b</sup>
			63	27 <sup>b</sup>
			36	20 <sup>a</sup>
			74	29 <sup>b</sup>
		Spray Painter in Aisle No. 1 (Rear) Spray Booth	1.0	18 <sup>a</sup>
			3.0	23 <sup>b</sup>
Painting/Coating Operations	<a href="#">(DOEHRS-IH) (2018)</a>	Painting Operations	4.1	15 <sup>a</sup>
		Painting Operations	4.1	
		Painting Operations	4.1	
		Painting Operations	4.1	
		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	
Industrial Sign Manufacturing	<a href="#">OSHA (2019)</a>	Floor Manager, Painter	133.9	72 <sup>c</sup>

ND – not detected

a – EPA evaluated 11 samples, with durations ranging from 15 to 20 minutes, as 15-minute exposures.

b – EPA evaluated seven samples, with durations ranging from of 22 to 32 minutes, as 30-minute exposures.

c – EPA evaluated two samples, with duration of 50 to 72 minutes, as 1-hr exposure.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> 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.

#### **2.10.4 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 2-35 ([U.S. BLS, 2016](#); [U.S. Census Bureau, 2015](#)).

**Table 2-35. Number of U.S. Establishments, Workers, and ONUs for Industries Conducting Paint Stripping**

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

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-15 and Table\_Apx A-16 in 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<sup>3</sup>, and a midpoint of 1,520 mg/m<sup>3</sup>. The central tendency 8-hr TWA exposure concentration for this scenario is approximately 17 times the OSHA PEL value of 87 mg/m<sup>3</sup> (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 Appendix B. The results of these calculations are shown in Table 2-36.

**Table 2-36. Full-Shift Exposure to Methylene Chloride During Adhesive and Caulk Removal (Using Professional Contractor Paint Stripping Data as Surrogate) <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
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 \(2014\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

Table 2-37 summarizes available short-term exposure data from paint stripping using methylene chloride.

**Table 2-37. 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 <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
Professional Contractors	unknown	7,100	14,100

Note: The OSHA STEL is 433 mg/m<sup>3</sup> as a 15-min TWA.

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 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 onto 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 2-38 ([U.S. BLS, 2016](#); [U.S. Census Bureau, 2015](#)).

**Table 2-38. Number of U.S. Establishments, Workers, and ONUs for Fabric Finishing Sites**

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
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
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>b</sup></i>		<b>1,886</b>	<b>19,000</b>	<b>12,000</b>

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-17 in Appendix 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.

Finkel (2017) submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-38. For the set of 38 data points, 8-hr TWA exposure concentrations ranged from 0.11 to 331.3mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to the fabric finishing process, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use of spot cleaners or general cleaning solvents that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during fabric finishing. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. An additional two data points were provided by OSHA for a presser (0.8 mg/m<sup>3</sup> – used as worker exposure) and a finishing department supervisor (1.2 mg/m<sup>3</sup> – used as ONU exposure) (OSHA, 2019).

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 one order of magnitude less than the OSHA PEL value of 87 mg/m<sup>3</sup> (25 ppm), while the high-end estimate for workers is approximately twice the PEL value. Exposure concentrations for ONUs based on the single data point are an order of magnitude less than the PEL value.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-39 for workers and ONUs during fabric finishing.

**Table 2-39. Worker and ONU Exposure to Methylene Chloride During Fabric Finishing**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
Workers			
8-hr TWA Exposure Concentration	39	7.8	140
Average Daily Concentration (ADC)		1.8	31
Lifetime Average Daily Concentration (LADC)		3.1	70
Occupational Non-Users			
8-hr TWA Exposure Concentration	1	1.2	
Average Daily Concentration (ADC)		0.27	
Lifetime Average Daily Concentration (LADC)		0.47	0.61

Source: [OSHA \(2019\)](#); [Finkel \(2017\)](#); [TNO \(CIVO\) \(1999\)](#).

Table 2-40 summarizes available short-term exposure data available from OSHA inspections.

**Table 2-40. Summary of Personal Short-Term Exposure Data for Methylene Chloride During Fabric Finishing**

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m <sup>3</sup> )	Exposure Duration (min)
All Other Leather Good and Allied Product Manufacturing	<a href="#">OSHA (2019)</a>	Sprayer of Methylene Chloride	10	194 <sup>a</sup>

a – As there are no health comparisons for 2- or 3-hr samples, this data point is presented but not used to calculate risk.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> as a 15-min TWA

#### 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 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 2-41 presents BLS occupation codes where workers are potentially exposed to dry cleaning solvents. EPA 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 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 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 2-41. 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 2-42 ([U.S. BLS, 2016](#); [U.S. Census Bureau, 2015](#)).

**Table 2-42. 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 <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
812320	Drycleaning and Laundry Services (except Coin-Operated)	21,370	4	0.4
<i>Total establishments and number of potentially exposed workers and ONUs =<sup>b</sup></i>			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-19 in Appendix A summarizes 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.

Finkel (2017) submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes for Industrial Launderers and Drycleaning and Laundry Services (except Coin-Operated). For the set of 18 data points, 8-hr TWA exposure concentrations ranged from 0.1 to 410.4 mg/m<sup>3</sup>. Worker activity information was not available; therefore it was not possible to specifically attribute the exposures to spot cleaning, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use general cleaning solvents that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during spot cleaning. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H.

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 value was two orders of magnitude less than the OSHA PEL value of 87 mg/m<sup>3</sup> (25 ppm), while the high end value was approximately two times the OSHA PEL.

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

**Table 2-43. Exposure to Methylene Chloride During Spot Cleaning<sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	18	0.67	190
Average Daily Concentration (ADC)		0.15	42
Lifetime Average Daily Concentration (LADC)		0.26	95

Source: [Finkel \(2017\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

EPA has not identified data on short term worker exposures or 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 2-44. 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 2-44. 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	<a href="#">U.S. EPA (2016a)</a>

### **2.13.1 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.

## **2.14 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-20 in Appendix 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<sup>3</sup> (25 ppm), respectively.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-45 for CTA film manufacturing.

**Table 2-45. Worker Exposure to Methylene Chloride During CTA Film Manufacturing <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	>166 <sup>a</sup>	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 – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

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 2-46. EPA did not identify any potential CTA manufacturing facilities in the 2016 TRI that reported water releases.

**Table 2-46. 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 DIVISIO N	ROCHESTER	NY	29	250	0.1	Surface Water	<a href="#">U.S. EPA (2016a)</a>
-------------------------------	-----------	----	----	-----	-----	------------------	----------------------------------

### **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 2-47 ([U.S. BLS, 2016](#); [U.S. Census Bureau, 2015](#)).

**Table 2-47. 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 <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
326150	Urethane and Other Foam Product (except Polystyrene) Manufacturing	654	15	4
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>b</sup></i>			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-21. and Table\_Apx A-22 in Appendix A summarize the inhalation monitoring data for methylene chloride used in polyurethane foam 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. 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. Exposures varied from 0.3 mg/m<sup>3</sup> from purge operations, to 2,200.9 mg/m<sup>3</sup> during laboratory operations. Many different types worker activities were listed but the actual source of exposure to methylene chloride was unclear. There appear to be diverse uses of methylene chloride in the PU foam manufacturing industry, which may contribute to the wide range of exposure concentrations.

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<sup>3</sup> (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 Appendix B. The results of these calculations are shown in Table 2-48 for flexible polyurethane foam manufacturing.

**Table 2-48. Exposure to Methylene Chloride During Industrial Polyurethane Foam Manufacturing <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	84	190	1,000
Average Daily Concentration (ADC)		44	230
Lifetime Average Daily Concentration (LADC)		76	510

Sources: [IARC \(2016\)](#); [TNO \(CIVO\) \(1999\)](#); [\(IPCS\) \(1996\)](#); [Vulcan Chemicals \(1991\)](#); [NIOSH \(1990a\)](#); [Cone Mills \(1981\)](#); [Cone Mills \(1982\)](#); [US EPA \(1985\)](#); [Olin Chemicals \(1977\)](#); [OSHA \(2019\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

Table 2-49 summarizes available short-term exposure data.

**Table 2-49. 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 <sup>3</sup> )	Exposure Duration (min)
Polyurethane Foam Manufacturing	<a href="#">US EPA (1985)</a>	Foam Blowing	5.2	360 <sup>a</sup>
		Foam Blowing	13	360 <sup>a</sup>
		Foam Blowing	19	360 <sup>a</sup>



Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m <sup>3</sup> )	Exposure Duration (min)
		Foam Blowing	17	360 <sup>a</sup>
		Foam Blowing	5.2	360 <sup>a</sup>
		Foam Blowing	38	360 <sup>a</sup>
		Foam Blowing	11	360 <sup>a</sup>
		Nozzle Cleaning	55	30 <sup>b</sup>

a – As there are no health comparisons for 3-hr samples, these data points are presented but not used to calculate risk

b – EPA evaluated one sample, with a 30 minute duration, as a 30-minute exposure.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> 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.

#### 2.15.4 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 2-50 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 2-50. 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	<a href="#">U.S. EPA (2017c)</a>

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 2-51 (citation for BLS and Census).

**Table 2-51. Number of U.S. Establishments, Workers, and ONUs for Testing Laboratories**

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
541380	Testing Laboratories	17,511	1	9
625511	Medical Laboratories		1 <sup>b</sup>	9 <sup>b</sup>
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>c</sup></i>			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-23 and Table\_Apx A-24 in Appendix 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.

Finkel (2017) submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification

(SIC) codes in the dataset with the NAICS codes listed in Table 2-51 above. For the set of 65 data points, 8-hr TWA exposure concentrations ranged from 0.11 to 371.4 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to laboratory activities, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use cleaning solvents that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during laboratory use. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. Additional data were available from a 1989 NIOSH inspection of an analytical laboratory ([NIOSH, 1990b](#)), 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. OSHA provided an additional data point for an extractions lab tech (171.5 mg/m<sup>3</sup>) ([OSHA, 2019](#)).

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<sup>3</sup> (25 ppm), while the high-end estimate is slightly above the PEL value.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-52.

**Table 2-52. Worker Exposure to Methylene Chloride During Laboratory Use <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	76	6.0	100
Average Daily Concentration (ADC)		1.4	23
Lifetime Average Daily Concentration (LADC)		2.4	52

Sources: [OSHA \(2019\)](#); [DOEHRS-IH \(2018\)](#); [Texaco Inc \(1993\)](#); [NIOSH \(1990b\)](#); [Finkel \(2017\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

Table 2-53 summarizes available short-term exposure data available from the 1989 NIOSH inspection, DOD provided data identified above for the 8-hr TWA data, and OSHA inspection data.

**Table 2-53. 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 <sup>3</sup> )	Exposure Duration (min)
Analytical Laboratory	<a href="#">NIOSH (1990b)</a>	sample concentrating	2.7	233 <sup>d</sup>
		sample sonification	3.9	218 <sup>d</sup>
		sample sonification	4.5	218 <sup>d</sup>
		washing separatory funnels in sink near CLLE	110	10 <sup>a</sup>
		column cleaning	10	200 <sup>e</sup>
		sample concentrating	30	210 <sup>e</sup>
		sample concentrating	4.2	234 <sup>d</sup>
		sample concentrating	6.8	198 <sup>e</sup>
		transferring 100 ml MeCl into soil samples	9.8	115 <sup>e</sup>
		collecting waste chemicals & dumping into waste chemical storage	1,000	24 <sup>b</sup>
	<a href="#">(DOEHRS-IH) (2018)</a>	Miscellaneous lab operations	3.1	244 <sup>d</sup>
		Miscellaneous lab operations	3.1	238 <sup>d</sup>
		Sample extraction and analysis (3809, OCD)	34.7	180 <sup>e</sup>
		(3)GC Extraction	0.7	154 <sup>e</sup>
		134: Extraction of PCB in water samples (Rm 221 - Prep & Rm 227 - GC)	22.5	130 <sup>e</sup>
		134: Extraction of total volatiles (TCLP)(Rm 227)	64.7	130 <sup>e</sup>
		Analysis, chemical (Laboratory Operations)	1.7	59 <sup>c</sup>
		Analysis, chemical (Laboratory Operations)	2.4	48 <sup>c</sup>
		LAB ACTIVITIES	3.3	31 <sup>b</sup>
		LAB ACTIVITIES	6.4	30 <sup>b</sup>
		LAB ACTIVITIES	16.6	30 <sup>b</sup>
		LAB ACTIVITIES	3.4	30 <sup>b</sup>
		LAB ACTIVITIES	3.4	30 <sup>b</sup>
		LAB ACTIVITIES	3.4	30 <sup>b</sup>
		LAB ACTIVITIES	3.4	30 <sup>b</sup>
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	30 <sup>b</sup>
		514A Using Solvents	1830.0	25 <sup>b</sup>
		EXTRACTION OP	3.6	19 <sup>a</sup>
		EXTRACTION OP	24.8	19 <sup>a</sup>
		(3)GC Extraction	10.4	15 <sup>a</sup>
(3)GC Extraction	10.4	15 <sup>a</sup>		

Occupational Exposure Scenario	Source	Worker Activity	Methylene Chloride Short-Term Concentration (mg/m <sup>3</sup> )	Exposure Duration (min)
		Sample extraction and analysis (3809, OCD)	62.5	15 <sup>a</sup>
		Miscellaneous lab operations	6.7	15 <sup>a</sup>
		EXTRACTION OP	4.6	15 <sup>a</sup>
		EXTRACTION OP	4.6	15 <sup>a</sup>
		134: Extraction of PCB in water samples (Rm 221 - Prep & Rm 227 - GC)	5.3	15 <sup>a</sup>
		134: Extraction of total volatiles (TCLP)(Rm 227)	5.0	15 <sup>a</sup>
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	15 <sup>a</sup>
		IND-025-10 HM/HW HANDLING CLEANUP, CONTAINER SAMPLE/OPEN	6.1	15 <sup>a</sup>
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	10.9	15 <sup>a</sup>
		PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	13.2	15 <sup>a</sup>
Laboratory	<a href="#">OSHA (2019)</a>	Organic Prep Lab Tech	ND	53 <sup>f</sup>
		Organic Prep Lab Tech	ND	49 <sup>f</sup>

ND – not detected

a – EPA evaluated 15 samples, with durations ranging from 10 to 19 minutes, as 15-minute exposures.

b – EPA evaluated 10 samples, with durations ranging from 24 to 31 minutes, as 30-minute exposures.

c – EPA evaluated two samples, with durations ranging from 48 to 59 minutes, as 1-hr exposures.

d – EPA evaluated six samples, with durations ranging from 218 to 244 minutes, as 4-hr exposures.

e – As there are no health comparisons for 2- or 3-hr samples, these data points are presented but not used to calculate risk.

f – Limit of detection was not provided for these samples, so they were not used to evaluate risk.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> as a 15-min TWA.

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 2-54 ([U.S. BLS, 2016](#); [U.S. Census Bureau, 2015](#)).

**Table 2-54. Number of U.S. Establishments, Workers, and ONUs for Testing Laboratories**

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
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 <sup>b</sup>	11 <sup>b</sup>
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>c</sup></i>		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-25 and Table\_Apx A-26 in Appendix 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.

Finkel (2017) submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-54 above. For the set of 32 data points, 8-hr TWA exposure concentrations ranged from 0.1 to 1,637.3 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the

exposures to the plastic manufacturing process, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use of adhesives or cleaning solvents that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during plastics manufacturing. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. HSIA provided an additional 20 data points from 2005 through 2017, for production technicians during plastic product manufacturing. Exposure concentrations ranged from 3.9 to 134.1 mg/m<sup>3</sup> ([Halogenated Solvents Industry Alliance, 2018](#)). Additional data were found for various other sources that ranged from 9 mg/m<sup>3</sup> to 2,685.1 mg/m<sup>3</sup> (for hop area operator) ([OSHA, 2019](#); [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 ten times lower the OSHA PEL value of 87 mg/m<sup>3</sup> (25 ppm), while the high-end estimate for workers is more than two times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-55 for workers and ONUs during plastic product manufacturing.

**Table 2-55. Worker and ONU Exposure to Methylene Chloride During Plastic Product Manufacturing**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
<b>Workers</b>			
8-hr TWA Exposure Concentration	62	8.5	210
Average Daily Concentration (ADC)		1.9	47
Lifetime Average Daily Concentration (LADC)		3.4	110
<b>ONUs</b>			
8-hr TWA Exposure Concentration	2	9.7	10
Average Daily Concentration (ADC)		2.2	2.3
Lifetime Average Daily Concentration (LADC)		3.9	5.3

Sources: [OSHA \(2019\)](#); [Halogenated Solvents Industry Alliance \(2018\)](#); [Fairfax and Porter \(2006\)](#); [IPCS \(1996\)](#); [GE \(1989\)](#); [Finkel \(2017\)](#)

Table 2-56 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 2-56. 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 <sup>3</sup> )	Exposure Duration (min)
Plastic Product Manufacturing	<a href="#">OSHA (2019)</a>	Plastics Manufacturer	ND	15 <sup>a</sup>
			28	15 <sup>a</sup>
			21	20 <sup>a</sup>
Plastics Material and Resin Manufacturing	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	Operator	100	13 <sup>a</sup>
		Operator	74	18 <sup>a</sup>
		Operator	94	14 <sup>a</sup>
		Operator	66	20 <sup>a</sup>
		Operator	66	20 <sup>a</sup>
		Operator	60	22 <sup>b</sup>
		Operator	130	10 <sup>a</sup>
		Operator	66	20 <sup>a</sup>
		Operator	100	13 <sup>a</sup>
		Operator	170	8 <sup>a</sup>
		Operator	110	12 <sup>a</sup>
		Operator	83	15 <sup>a</sup>
		Product technician	120	11 <sup>a</sup>
		Product technician	69	19 <sup>a</sup>
		Product technician	83	16 <sup>a</sup>
		Product technician	63	21 <sup>a</sup>
Product technician	88	15 <sup>a</sup>		
Product technician	83	16 <sup>a</sup>		
Product technician	100	13 <sup>a</sup>		
Product technician	110	12 <sup>a</sup>		
Product technician	51	26 <sup>b</sup>		
Plastics Material and Resin Manufacturing	<a href="#">OSHA (2019)</a>	CSHO	ND	92 <sup>c</sup>
		Extruder Operator	20.4	313 <sup>d</sup>

ND – not detected

a – EPA evaluated 21 samples, with durations ranging from 8 to 21 minutes, as 15-minute exposures.

b – EPA evaluated 10 samples, with durations ranging from 22 to 26 minutes, as 30-minute exposures.

c – Limit of detection was not provided for this sample, so it was not used to evaluate risk.

d – As there are no health comparisons for ~5-hr samples, this data point is presented but not used to calculate risk.

Note: The OSHA STEL is 433 mg/m<sup>3</sup> as a 15-min TWA.

#### 2.17.4 Water Release Assessment

EPA identified facilities classified under four NAICS and SIC codes, listed in Table 2-57, that reported water releases in the 2016 TRI and 2016 DMR and may be related to plastic product manufacturing. Table 2-58 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 2-57. 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 2-58. 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	<a href="#">U.S. EPA (2017c)</a>
SABIC INNOVATIVE PLASTICS MT. VERNON, LLC	MOUNT VERNON	IN	28	250	0.1	Surface Water	<a href="#">U.S. EPA (2016a)</a>
SABIC INNOVATIVE PLASTICS US LLC	SELKIRK	NY	9	250	0.03	Surface Water	<a href="#">U.S. EPA (2016a)</a>
EQUISTAR CHEMICALS LP	LA PORTE	TX	9	250	0.03	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CHEMOURS COMPANY FC LLC	WASHINGTON	WV	7	250	0.03	Surface Water	<a href="#">U.S. EPA (2016a)</a>
SHINTECH ADDIS PLANT A	ADDIS	LA	3	250	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
STYROLUTION AMERICA LLC	CHANNAHON	IL	0.2	250	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
DOW CHEMICAL CO DALTON PLANT	DALTON	GA	0.3	250	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
PREGIS INNOVATIVE PACKAGING INC	WURLAND	KY	0.02	250	0.0001	Surface Water	<a href="#">U.S. EPA (2016a)</a>

### 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 Lithographic Printing Plate Cleaning

### 2.18.1 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 also periodically 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](#)).

### 2.18.2 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 2-59 ([U.S. BLS, 2016](#); [U.S. Census Bureau, 2015](#)).

**Table 2-59. Number of U.S. Establishments, Workers, and ONUs for Printing**

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers Site <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
323111	Commercial Printing (except Screen and Books)	18,687	2	1
<i>Total establishments and number of potentially exposed workers and ONUs = <sup>b</sup></i>			40,000	19,000

a – Rounded to the nearest worker.

b – Unrounded figures were used for total worker and ONU calculations.

### 2.18.3 Exposure Assessment

#### 2.18.3.1 Worker Activities

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

#### 2.18.3.2 Inhalation Exposure

Table\_Apx A-27 and Table\_Apx A-28 in Appendix 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 Finkel (2017), who submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-59 above. For the set of 50 data points, 8-hr TWA exposure concentrations ranged from 0.01 to 167 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to use as a lithographic printing plate cleaner, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use of inks or coatings that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during lithographic printing plate cleaning. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. An additional 44 data points were found 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) (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); (NIOSH, 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<sup>3</sup>; ND was assessed as zero). Minimum and maximum values from reported ranges were used as discrete data points, while calculated statistics such as mean values were excluded.

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/m<sup>3</sup> (25 ppm), while the high-end estimate is approximately two times higher.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-60 for workers during printing.

**Table 2-60. Worker Exposure to Methylene Chloride During Printing Plate Cleaning <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	>130 <sup>b</sup>	8.7	160
Average Daily Concentration (ADC)		2.0	37
Lifetime Average Daily Concentration (LADC)		3.5	82

Sources: [Ukai et al. \(1998\)](#); [US EPA \(1985\)](#); [NIOSH \(1980\)](#); [Finkel \(2017\)](#)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

b – One study indicated that statistics were based on 61 samples, but only provided the minimum, maximum, and mean values. The minimum and maximum values were used as discrete values in the exposure data pool (total of 48 values). Another study provided two exposure values, one of which was ND. ND was assessed as zero.

Table 2-61 summarizes the available 4-hr TWA exposure data for workers from one of the same sources identified above for the 8-hr TWA data. Data were taken in two 4-hr shifts.

**Table 2-61. 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 <sup>3</sup> )	Exposure Duration (min) <sup>a</sup>
Lithographic Printing Plate Cleaning	<a href="#">Ukai et al. (1998)</a>	Cleaning of printing rolls / solvent in production	3.5	240
			940	
			3.6	
			480	

a – EPA evaluated these samples as 4-hr exposures.

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

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.

#### 2.18.4 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 2-62. 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 2-62. 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	<a href="#">U.S. EPA (2016a)</a>

#### 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 Miscellaneous Non-Aerosol Industrial and Commercial Uses

### 2.19.1 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.

### **2.19.2 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).

### **2.19.3 Exposure Assessment**

#### **2.19.3.1 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 onto substrates (wipe, brush, roller), or engage in transferring liquids between containers.

#### **2.19.3.2 Inhalation Exposure**

EPA compiled various miscellaneous 8-hr TWA monitoring data for non-aerosol commercial settings as shown in Table\_Apx A-29 of Appendix 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<sup>3</sup> ([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/m<sup>3</sup> (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 Appendix B. The results of these calculations are shown in Table 2-63 for workers during industrial and commercial non-aerosol use.

**Table 2-63. Worker Exposure to Methylene Chloride During Industrial and Commercial Non-Aerosol Use <sup>a</sup>**

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

Sources: [US EPA \(1985\)](#).

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

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.

#### **2.19.4 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.

#### **2.19.5 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.

### **2.20 Waste Handling, Disposal, Treatment, and Recycling**

---

#### **2.20.1 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 2.19 (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:

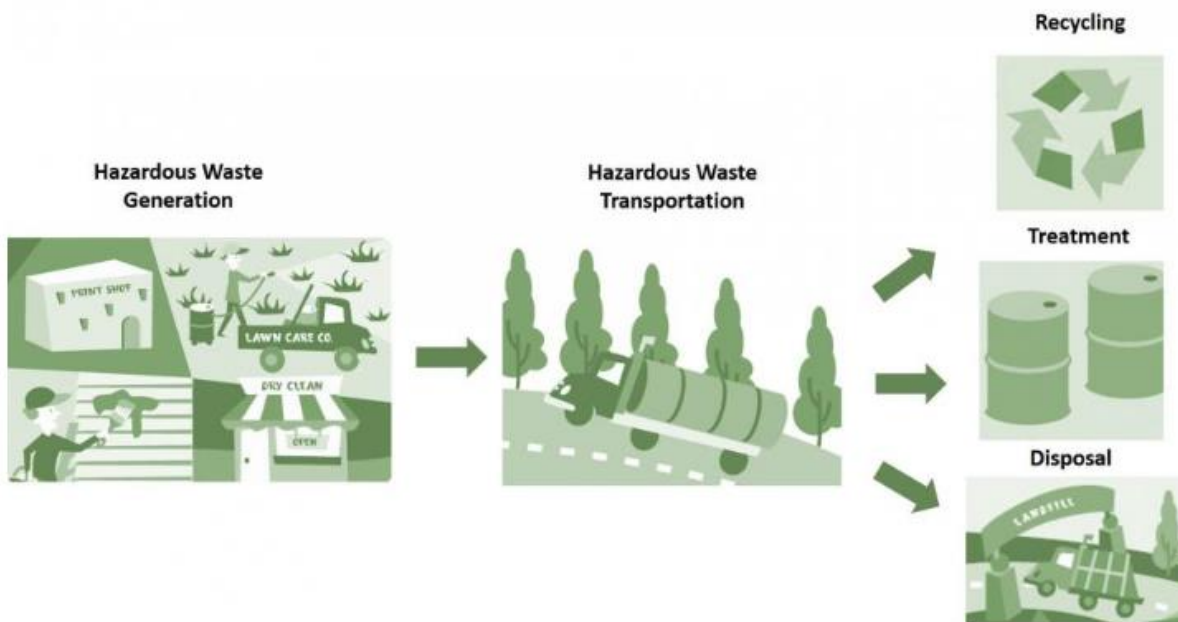
- **Wastewater:** Methylene chloride may be contained in wastewater discharged to POTW or other, non-public treatment works for treatment. Industrial wastewater containing methylene chloride discharged to a POTW may be subject to EPA or authorized NPDES state pretreatment programs. The assessment of 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 2.19.
- **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.

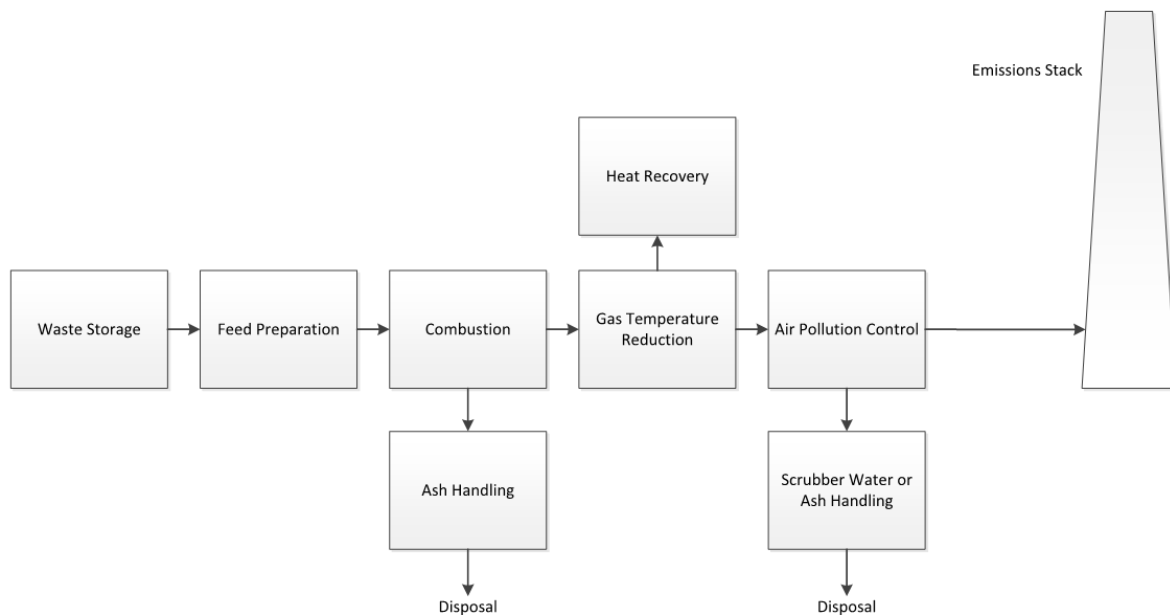
Tipping floor operations may generate dust. Air from the enclosed tipping floor, however, is continuously drawn into the combustion unit via one or more forced air fans to serve as the primary combustion air and minimize odors. Dust and lint present in the air is typically captured in filters or other 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.

#### **2.20.2 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 2-64 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 2-64. Number of U.S. Establishments, Workers, and ONUs for Waste Handling**

NAICS Codes	NAICS Description	Number of Establishments	Number of Workers per Site <sup>a</sup>	Number of ONUs per Site <sup>a</sup>
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
<i>Total establishments and number of potentially exposed workers and ONUs =<sup>bs</sup></i>		2,449	12,000	7,600

a – Rounded to the nearest worker.

b – Unrounded figures were used for total worker and ONU calculations.

## 2.20.3 Exposure Assessment

### 2.20.3.1 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](#)).

#### **2.20.3.2 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 Appendix 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.

8-hr TWA data are primarily from Finkel ([2017](#)), who submitted workplace monitoring data obtained from a FOIA request of OSHA. EPA extracted relevant monitoring data by crosswalking the Standard Industrial Classification (SIC) codes in the dataset with the NAICS codes listed in Table 2-64 above. For the set of 15 data points, 8-hr TWA exposure concentrations ranged from 0.11 to 107 mg/m<sup>3</sup>. Worker activity information was not available; therefore, it was not possible to specifically attribute the exposures to waste handling activities, nor to distinguish workers from ONUs. While additional activities are possible at these sites, such as use of cleaning solvents that contribute to methylene chloride exposures, EPA assumes that exposures are representative of worker exposures during waste handling. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all

applicable data points over 8 hours. Additional discussion of data treatment is included in Appendix H. EPA’s 1985 assessment included also three full-shift data points for solvent reclaimers at solvent recovery sites, ranging from 10.5 to 19.2 mg/m<sup>3</sup> (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<sup>3</sup> (DOEHRS-IH, 2018). EPA assessed the 50<sup>th</sup> percentile value of 18.5 mg/m<sup>3</sup> as the central tendency, and the 95% percentile value of 19.0 mg/m<sup>3</sup> 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<sup>3</sup> (25 ppm) and high-end 8-hr TWA exposure concentration is slightly lower than the PEL.

Using these 8-hr TWA exposure concentrations, EPA calculated the ADC and LADC as described in Appendix B. The results of these calculations are shown in Table 2-65.

**Table 2-65. Exposure to Methylene Chloride During Waste Handling and Disposal <sup>a</sup>**

	Number of Samples	Central Tendency (mg/m <sup>3</sup> )	High-End (mg/m <sup>3</sup> )
8-hr TWA Exposure Concentration	22	2.3	81
Average Daily Concentration (ADC)		0.54	18
Lifetime Average Daily Concentration (LADC)		0.93	41

Source: (DOEHRS-IH) (2018); US EPA (1985); Finkel (2017)

a – No data for ONUs were found; EPA assumes that ONU exposures are less than worker exposures.

Table 2-66 summarizes the available short-term exposure data for workers from the DOD data.

**Table 2-66. 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 <sup>3</sup> )	Exposure Duration (min)
Waste Handling	(DOEHRS-IH) (2018)	Transfer of solvent during waste disposal	2.9	30 <sup>a</sup>
			2.9	30 <sup>a</sup>
			1.8	144 <sup>b</sup>
			5.8	158 <sup>b</sup>
			2.7	159 <sup>b</sup>
			2.8	163 <sup>b</sup>
			0.8	173 <sup>b</sup>
			3.4	156 <sup>b</sup>

a – EPA evaluated two 30-minute samples as 30-minute exposures.

b – As there are no health comparisons for 2- or 3-hr samples, these data points are presented but not used to calculate risk

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

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.

### 2.20.4 Water Release Assessment

EPA identified facilities classified under five NAICS and SIC codes, listed in Table 2-67, that reported water releases in the 2016 TRI and 2016 DMR and may be related to recycling/disposal.

Table 2-68 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 used a default assumption of 250 days/yr of operation and averaged the annual release over the operating days.

**Table 2-67. 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 2-68. 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	<a href="#">U.S. EPA (2017c)</a>
CLEAN HARBORS	LA PORTE	TX	522	250	2	Non-POTW WWT	<a href="#">U.S. EPA (2017c)</a>

DEER PARK LLC							
CLEAN HARBORS EL DORADO LLC	EL DORADO	AR	113	250	0.5	Non-POTW WWT	<a href="#">U.S. EPA (2017c)</a>
TRADEBE TREATMENT & RECYCLING LLC	EAST CHICAGO	IN	19	250	0.1	Non-POTW WWT	<a href="#">U.S. EPA (2017c)</a>
VEOLIA ES TECHNICAL SOLUTIONS LLC	WEST CARROLLTON	OH	2	250	0.01	POTW	<a href="#">U.S. EPA (2017c)</a>
VEOLIA ES TECHNICAL SOLUTIONS LLC	AZUSA	CA	0	250	0.002	POTW	<a href="#">U.S. EPA (2017c)</a>
VEOLIA ES TECHNICAL SOLUTIONS LLC	MIDDLESEX	NJ	115,059	250	460	99.996% Non-POTW WWT 0.004% POTW	<a href="#">U.S. EPA (2017c)</a>
CHEMICAL WASTE MANAGEMENT	EMELLE	AL	4	250	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
OILTANKING HOUSTON INC	HOUSTON	TX	1	250	0.003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
HOWARD CO ALFA RIDGE LANDFILL	MARRIOTTSVILLE	MD	0.1	250	0.0002	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CLIFFORD G HIGGINS DISPOSAL SERVICE INC SLF	KINGSTON	NJ	0.02	250	0.0001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CLEAN WATER OF NEW YORK INC	STATEN ISLAND	NY	2	250	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
FORMER CARBORUNDUM COMPLEX	SANBORN	NY	0.2	250	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>

### 2.20.5 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.

## 2.21 Other Reported Water Releases

Table 2-69 lists surface water releases of methylene chloride reported in the 2016 DMR from wastewater treatment plants.

**Table 2-69. 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	<a href="#">U.S. EPA (2016a)</a>
JUANITA MILLENDER-MCDONALD CARSON REGIONAL WRP	CARSON	CA	1	365	0.002	Surface Water	<a href="#">U.S. EPA (2016a)</a>
LONDON WTP	LONDON	OH	0.4	365	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
LONG BEACH (C) WPCP	LONG BEACH	NY	2,730	365	7	Surface Water	<a href="#">U.S. EPA (2016a)</a>
MIDDLESEX COUNTY UTILITIES AUTHORITY	SAYREVILLE	NJ	1,634	365	4	Surface Water	<a href="#">U.S. EPA (2016a)</a>
JOINT WATER POLLUTION CONTROL PLANT	CARSON	CA	604	365	1.7	Surface Water	<a href="#">U.S. EPA (2016a)</a>
HYPERION TREATMENT PLANT	PLAYA DEL REY	CA	164	365	0.5	Surface Water	<a href="#">U.S. EPA (2016a)</a>
SD CITY PT LOMA WASTEWATER TREATMENT	SAN DIEGO	CA	164	365	0.5	Surface Water	<a href="#">U.S. EPA (2016a)</a>
REGIONAL SANITATION DISTRICT	ELK GROVE	CA	86	365	0.2	Surface Water	<a href="#">U.S. EPA (2016a)</a>
BERGEN POINT STP & BERGEN AVE DOCK	W BABYLON	NY	65	365	0.2	Surface Water	<a href="#">U.S. EPA (2016a)</a>
NEW ROCHELLE STP	NEW ROCHELLE	NY	15	365	0.04	Surface Water	<a href="#">U.S. EPA (2016a)</a>
SIMI VLY CNTY SANITATION	SIMI VALLEY	CA	7	365	0.02	Surface Water	<a href="#">U.S. EPA (2016a)</a>
OCEANSIDE OCEAN OUTFALL	OCEANSIDE	CA	4	365	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
SANTA CRUZ WASTEWATER TREATMENT PLANT	SANTA CRUZ	CA	2	365	0.01	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CORONA WWTP 1	CORONA	CA	2	365	0.005	Surface Water	<a href="#">U.S. EPA (2016a)</a>
BLIND BROOK SD WWTP	RYE	NY	1	365	0.003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
MCKINLEYVILL E CSD -	MCKINLEYVILL E	CA	1	365	0.003	Surface Water	<a href="#">U.S. EPA (2016a)</a>



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 PLANT							
SAN JOSE CREEK WATER RECLAMATION PLANT	WHITTIER	CA	0.4	365	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CARMEL AREA WASTEWATER DISTRICT TREATMENT FACILITY	CARMEL	CA	0.3	365	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CAMERON TRADING POST WWTP	CAMERON	AZ	0.2	365	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CITY OF RED BLUFF WASTEWATER RECLAMATION PLANT	RED BLUFF	CA	0.2	365	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
91ST AVE WASTEWATER TREATMENT PLANT	TOLLESON	AZ	31	365	0.1	Surface Water	<a href="#">U.S. EPA (2016a)</a>
EVERETT WATER POLLUTION CONTROL FACILITY	EVERETT	WA	30	365	0.1	Surface Water	<a href="#">U.S. EPA (2016a)</a>
PIMA COUNTY - INA ROAD WWTP	TUCSON	AZ	27	365	0.1	Surface Water	<a href="#">U.S. EPA (2016a)</a>
23RD AVENUE WASTEWATER TREATMENT PLANT	PHOENIX	AZ	19	365	0.1	Surface Water	<a href="#">U.S. EPA (2016a)</a>
SUNNYSIDE STP	SUNNYSIDE	WA	2	365	0.005	Surface Water	<a href="#">U.S. EPA (2016a)</a>
AGUA NUEVA WRF	TUCSON	AZ	1	365	0.003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
PORT OF SUNNYSIDE INDUSTRIAL WWTF	SUNNYSIDE	WA	1	365	0.002	Surface Water	<a href="#">U.S. EPA (2016a)</a>
APACHE JUNCTION WWTP	APACHE JUNCTION	AZ	0.1	365	0.0003	Surface Water	<a href="#">U.S. EPA (2016a)</a>

Table 2-70 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 2.20.

**Table 2-70. 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 BIOSYSTEMS LLC	PLEASANTON	CA	42	250	0.2	Non-POTW WWT	<a href="#">U.S. EPA (2017c)</a>
EMD MILLIPORE CORP	JAFFREY	NH	2	250	0.01	POTW	<a href="#">U.S. EPA (2017c)</a>
GBC METALS LLC SOMERS THIN STRIP	WATERBURY	CT	0.2	250	0.001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
HYSTER-YALE GROUP, INC	SULLIGENT	AL	0.0002	250	0.000001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
AVNET INC (FORMER IMPERIAL SCHRADER)	ELLENVILLE	NY	0.005	250	0.00002	Surface Water	<a href="#">U.S. EPA (2016a)</a>
BARGE CLEANING AND REPAIR	CHANNELVIEW	TX	0.1	250	0.0003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
AC & S INC	NITRO	WV	0.01	250	0.00005	Surface Water	<a href="#">U.S. EPA (2016a)</a>
MOOG INC - MOOG IN-SPACE PROPULSION ISP	NIAGARA FALLS	NY	0.003	250	0.00001	Surface Water	<a href="#">U.S. EPA (2016a)</a>
OILTANKING JOLIET	CHANNAHON	IL	1	250	0.003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
NIPPON DYNAWAVE PACKAGING COMPANY	LONGVIEW	WA	22	250	0.1	Surface Water	<a href="#">U.S. EPA (2016a)</a>
TREE TOP INC WENATCHEE PLANT	WENATCHEE	WA	0.01	250	0.00003	Surface Water	<a href="#">U.S. EPA (2016a)</a>
CAROUSEL CENTER	SYRACUSE	NY	0.001	250	0.000002	Surface Water	<a href="#">U.S. EPA (2016a)</a>

### 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 <sub>DCM</sub> , 8- or 12-hr TWA (mg/m <sup>3</sup> )		ADC <sub>DCM</sub> , 24-hr TWA (mg/m <sup>3</sup> )		LADC <sub>DCM</sub> , 24-hr TWA (mg/m <sup>3</sup> )	
			Central Tendency	High End	Central Tendency	High End	Central Tendency	High End
1	Manufacturing (8-hr TWA)	Worker & ONU	0.36	4.6	0.08	1.1	0.14	2.4
1	Manufacturing (12-hr TWA)	Worker & ONU	0.45	12	0.15	4.1	0.27	9.3
2	Processing as a Reactant	Worker & ONU	1.6	110	0.37	25	0.65	55
3	Processing - Incorporation into Formulation	Worker & ONU	100	540	23	120	40	280
4	Import and Repackaging	Worker & ONU	8.8	140	2.0	31	3.5	71
5	Batch Open-Top Vapor Degreasing (Modeled)	Worker	170	740	38	170	67	380
5	Batch Open-Top Vapor Degreasing (Modeled)	ONU	86	460	20	100	34	230
6	Conveyorized Vapor Degreasing (Modeled)	Worker	490	1,400	110	320	190	720
6	Conveyorized Vapor Degreasing (Modeled)	ONU	250	900	58	210	100	460
7	Cold Cleaning	Worker & ONU	280	1,000	64	230	110	510
8	Aerosol Degreasing/Lubricants (Monitoring)	Worker & ONU	6.0	230	1.4	52	2.4	120
8	Aerosol Degreasing/Lubricants (Modeled)	Worker	22	79	5.0	18	8.7	40
8	Aerosol Degreasing/Lubricants (Modeled)	ONU	0.40	3.3	0.09	0.74	0.16	1.7
9	Adhesives/Sealants (Spray)	Worker & ONU	39	560	8.9	130	16	290
9	Adhesives/Sealants (Non-Spray)	Worker & ONU	10	300	2.4	67	4.2	150

9	Adhesives/Sealants (Unknown Application)	Worker & ONU	27	690	6.2	160	11.0	350
10	Paints and Coatings (Spray)	Worker & ONU	70	360	16	83	28	190
10	Paints and Coatings (Unknown Application Method)	Worker & ONU	12	260	2.8	60	4.9	130
11	Adhesive and Caulk Removers	Worker & ONU	1,500	3,000	350	680	600	1,500
12	Fabric Finishing	Worker	7.8	140	1.8	31	3.1	70
12	Fabric Finishing	ONU	1.2		0.27		0.47	0.61
13	Spot Cleaning	Worker & ONU	0.67	190	0.15	42	0.26	95
14	CTA Manufacturing	Worker & ONU	1,000	1,400	240	320	410	560
15	Flexible PU Foam Manufacturing	Worker & ONU	190	1,000	44	230	76	510
16	Laboratory Use	Worker & ONU	6.0	100	1.4	23	2.4	52
17	Plastic Product Manufacturing	Worker	8.5	210	1.9	47	3.4	110
17	Plastic Product Manufacturing	ONU	9.7	10	2.2	2.3	3.9	5.3
18	Lithographic Printing Cleaner	Worker & ONU	8.7	160	2.0	37	3.5	82
19	Non-Aerosol Commercial Use (Cleaning Solvent)	Worker & ONU	57	930	13	210	23	480
20	Waste Handling, Disposal, Treatment, and Recycling	Worker & ONU	2.3	81	0.54	18	0.93	41

### **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 Appendix 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<sup>2</sup>; defaults: 535 cm<sup>2</sup> (central tendency); 1,070 cm<sup>2</sup> (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)); note: EPA has no data on actual surface area of contact with liquid and that the value is assumed to represent an adequate proxy for a high-end surface area of contact with liquid that may sometimes include exposures to much of the hands and also beyond the hands, such as wrists, forearms, neck, or other parts of the body, for some scenarios

Q<sub>u</sub> is the quantity remaining on the skin (mg/cm<sup>2</sup>-event; defaults: 1.4 mg/cm<sup>2</sup>-event (central tendency); 2.1 mg/cm<sup>2</sup>-event (high end))

Y<sub>derm</sub> is the weight fraction of the chemical of interest in the liquid (0 ≤ Y<sub>derm</sub> ≤ 1)

FT is the frequency of events (integer number per day; default: 1 event/day)

f<sub>abs</sub> 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<sub>abs</sub>) 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 <i>b</i> 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<sup>1</sup> 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

<sup>1</sup> The absorbed fraction (f<sub>abs</sub>) is a function of indoor air speed, which differs for industrial and commercial settings.

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 ( $Y_{\text{derm}}$ ), 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 protective 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:
  - No protective 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 protective 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 protective 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 protective 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	Fabs	Max Y <sub>derm</sub>	Non-Occluded Exposure (mg/day)				Occluded Exposure	
				No Protective Gloves (PF = 1)	Protective Gloves (PF = 5)	Protective Gloves (Commercial uses, PF = 10)	Protective Gloves (Industrial uses, PF = 20)		
Manufacturing	Bin 1 - Industrial	0.08	1.0	60 (CT) 180 (HE)	12 (CT) 36 (HE)	6 (CT) 18 (HE)	3 (CT) 9 (HE)	N/A – occlusion not expected	
Import and Repackaging									
Processing as a Reactant									
Processing - Incorporation into Formulation, Mixture, or Rxn Product									
Waste Handling, Disposal, Treatment, and Recycling									
Use of Adhesives and Sealants	Bin 2 - Industrial	0.08	1.0	60 (CT) 180 (HE)	12 (CT) 36 (HE)	6 (CT) 18 (HE)	3 (CT) 9 (HE)	2,247	
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 3 - Commercial	0.13	1.0	94 (CT) 280 (HE)	19 (CT) 57 (HE)	9 (CT) 28 (HE)	5 (CT) 14 (HE)	2,247	
Use of Adhesives and Sealants			0.95	90 (CT) 270 (HE)	18 (CT) 54 (HE)	9 (CT) 27 (HE)	4 (CT) 13 (HE)	2,135	
Fabric Finishing			0.9	85 (CT) 260 (HE)	17 (CT) 51 (HE)	9 (CT) 26 (HE)	4 (CT) 13 (HE)	2,022	
Adhesive and Caulk Removers			0.885	84 (CT) 250 (HE)	17 (CT) 50 (HE)	8 (CT) 25 (HE)	4 (CT) 13 (HE)	1,989	
Spot Cleaning			1.0						2,247
Lithographic Printing Cleaner									
Laboratory Use		0.13	1.0					2,247	

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

Occupational Exposure Scenario	Bin	Fabs	Max Y <sub>derm</sub>	Non-Occluded Exposure (mg/day)				Occluded Exposure
				No Protective Gloves (PF = 1)	Protective Gloves (PF = 5)	Protective Gloves (Commercial uses, PF = 10)	Protective Gloves (Industrial uses, PF = 20)	
Miscellaneous Non-Aerosol Commercial Uses (crafting glues and cements, novelty items)	Bin 4 – Commercial			94 (CT) 280 (HE)	19 (CT) 57 (HE)	9 (CT) 28 (HE)	5 (CT) 14 (HE)	
Miscellaneous Non-Aerosol Industrial Uses (solvents and degreasers)	Bin 4- Industrial	0.08	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	0.13	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' SUBS. 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. Additionally, there are various potential worker activities and/or sites within each OES that may have varying levels of exposures. If the exposure estimate is based on one or very few worker activities or sites within the OES, it could potentially underestimate or overestimate exposures for other workers included in the same OES.

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.

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 OSHA Data Analysis**

---

Some air concentration data comes from sources pre-dating the most recent PEL update for methylene chloride in 1997. An analysis of the pre- and post-PEL exposures is included in Appendix H. The data for this analysis originated from a docket comment from Dr. Finkel, who obtained dataset via a Freedom of Information Act (FOIA) request from OSHA ([Finkel, 2017](#)). The Finkel data only provide SIC codes, which are only sufficient to relate exposures to broad industry sectors. Within each industry, there may be worker activities that span several OES. For example, an automotive repair shop may use MC-containing paint strippers, paints and coatings, adhesives, and non-aerosol cleaning solvents. Without worker activity descriptions for each measured exposure, it was not possible to assign exposure data to specific OES or to distinguish between workers and ONUs. For the purpose of this analysis, EPA grouped NAICS codes that may be relevant to each condition of use and assumed that the exposures were representative for each OES. Sample times also varied; EPA assumed that any measurement longer than 15 minutes was done to assess compliance with the 8-hr TWA PEL, as opposed to the 15-minute STEL, and averaged all applicable data points over 8 hours. Therefore, there may be shorter-term data that do not fully represent the exposures over the full work shift, which would result in underestimated exposures when averaged over a 8-hr time period.

Note that the Finkel ([2017](#)) data were not verified for quality by OSHA. EPA separately consulted with OSHA and discussed data needs for the risk evaluations. OSHA subsequently provided a subset of data that also included worker activity descriptions and were verified for quality and were subsequently used in the risk evaluation ([OSHA, 2019](#)).

For this analysis, EPA defined the pre-rule period as prior to April 10, 1997 and the post-rule period as after April 10, 2000. Some companies may have begun implementing controls to

reduce exposure prior to the official rule date, which would result in smaller pre- to post-PEL reductions. However, it is not possible to tell when each company undertook measures to comply to the PEL.

As discussed in Section 4.2.1, EPA's judgments about which industries (represented by NAICS 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 have potential exposures is nevertheless subjective, and some industries 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 exposures.

As discussed in Section 4.2.2, OSHA data are typically obtained from inspections, which may be the result of worker complaints and may provide exposure results that are generally more conservative than the industry average. Additionally, the comparison likely does not compare pre- and post-PEL worker exposures at the same sites involved in the processes, so a direct assessment of the PEL impact is not possible.

#### **4.2.4 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.

#### **4.2.4.1 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.

#### **4.2.4.2 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.

#### 4.2.5 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.

#### 4.2.6 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 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 1.4.7 for additional details). Actual release days may vary 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 8-hr monitoring data provided by HSIA, with sampling dates between 2005 and 2017, for various worker activities at two manufacturing facilities ([Halogenated Solvents Industry Alliance, 2018](#)). HSIA indicated that samples are taken as part of the company's continuous IH monitoring program.
- 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.
- Rows 141 through 289 were 12-hr monitoring data provided by HSIA, with sampling dates between 2005 and 2018, for various worker activities at two manufacturing facilities ([Halogenated Solvents Industry Alliance, 2018](#)). HSIA indicated that samples are taken as part of the company's continuous IH monitoring program.

Table\_Apx A-2 presents short-term data:

- Rows 1 through 159 contain monitoring data provided by HSIA, taken between 2005 and 2017, with various sample times and worker activities at two manufacturing facilities ([Halogenated Solvents Industry Alliance, 2018](#)). HSIA indicated that samples are taken as part of the company's continuous IH monitoring program. Samples were grouped into the nearest exposure duration groupings: 15-minute, 30-minute, and 1-hr exposures: EPA assumed 148 sample durations, ranging from 15 to 22 minutes, as 15-minute exposures; 1 sample duration of 35 minutes as a 30-minute exposure; and 4 sample durations, ranging from 50 to 55 minutes, as 1-hour exposures.

**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 <sup>3</sup> ) <sub>a,b</sub>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
4	Manufacturing	Personal	Full-Shift - made and shot standards.	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
7	Manufacturing	Personal	Load product/locomotive and rail activities	0.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
18	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
19	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
21	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
22	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
24	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
27	Manufacturing	Personal	Performed 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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) 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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
31	Manufacturing	Personal	Full-Shift - Ran samples	0.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
33	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
36	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
37	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
39	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) 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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
44	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) 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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
51	Manufacturing	Personal	Load product/locomotive and rail activities	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
53	Manufacturing	Personal	Load product/locomotive and rail activities	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
55	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
56	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
57	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	1.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
62	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
63	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
65	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
66	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
68	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
69	Manufacturing	Personal	Perform maintenance on instrumentation	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
70	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.6	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
71	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.6	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
72	Manufacturing	Personal	Loaded 1 methyl chloride trailer, offloaded a methanol railcar; shipped a chloroform order.	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
73	Manufacturing	Personal	Vented a methyl railcar to VCRU; shipped a drum of chloroform.	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
76	Manufacturing	Personal	Prepared some drums to ship.	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
78	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	1.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
79	Manufacturing	Personal	Drumming chloroform most of shift; drummed 40 chloroform drums, sampled 1 drum, and	4.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
			dumped excess to waste solvents drum.						
80	Manufacturing	Personal	Unloaded 2 methanol railcars, topped off a methylene railcar, and vented 1 each methylene and chloroform cars; shipped 2 drum orders.	5.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
81	Manufacturing	Personal	Loaded/filled 40 drums of chloroform.	0.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
83	Manufacturing	Personal	Filled 24 drums of carbon tetrachloride.	0.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
86	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
87	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	1.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
88	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	10.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
92	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
93	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
94	Manufacturing	Personal	Load product/locomotive and rail activities	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
95	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.6	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
96	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
100	Manufacturing	Personal	Loaded 1 chloroform railcar and 1 methyl railcar; offloaded 1 methanol railcar.	0.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
101	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
102	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	0.8	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
103	Manufacturing	Personal	Transfer waste/Filter Changes/Trap Changes	10.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
104	Manufacturing	Personal	Full-Shift - routine supervision duties.	0.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
105	Manufacturing	Personal	Full-Shift - routine supervision duties.	0.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
106	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
107	Manufacturing	Personal	General 8-hour exposure	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
108	Manufacturing	Personal	Analytical work	2.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
109	Manufacturing	Personal	General 8-hour exposure	0.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
110	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
111	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
112	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
113	Manufacturing	Personal	General 8-hour exposure	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
114	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
115	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
116	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
117	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
118	Manufacturing	Personal	General 8-hour exposure	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
119	Manufacturing	Personal	General 8-hour exposure	3.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
120	Manufacturing	Personal	General 8-hour exposure	2.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
121	Manufacturing	Personal	General 8-hour exposure	0.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
122	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
123	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
124	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
125	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
126	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
127	Manufacturing	Personal	Analytical work	0.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
128	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
129	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
130	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
131	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
132	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
133	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
134	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
135	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
136	Manufacturing	Personal	General 8-hour exposure	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
137	Manufacturing	Personal	Plant and Packing Personnel	3.5	1	8-hr TWA	<a href="#">TNO (CIVO) (1999)</a>	2.3	Excluded in favor of direct monitoring data
138	Manufacturing	Personal	Plant and Packing Personnel	35.0	1	8-hr TWA	<a href="#">TNO (CIVO) (1999)</a>	2.3	Excluded in favor of direct monitoring data
139	Manufacturing	Personal	Plant and Packing Personnel-Maintenance	219.0	1	8-hr TWA	<a href="#">TNO (CIVO) (1999)</a>	2.3	Excluded in favor of direct monitoring data

**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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
140	Manufacturing	Personal	Plant and Packing Personnel-Maintenance	374.0	1	8-hr TWA	<a href="#">TNO (CIVO) (1999)</a>	2.3	Excluded in favor of direct monitoring data
141	Manufacturing	Personal	Process Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
142	Manufacturing	Personal	Process Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
143	Manufacturing	Personal	Process Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
144	Manufacturing	Personal	Process Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
145	Manufacturing	Personal	Process Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
146	Manufacturing	Personal	Process Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
147	Manufacturing	Personal	Operator	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
148	Manufacturing	Personal	Operator	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
149	Manufacturing	Personal	Tank Area	0.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
150	Manufacturing	Personal	Tank Area	10.8	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
151	Manufacturing	Personal	Tank Area	1.7	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
152	Manufacturing	Personal	CLM2 Thermal Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
153	Manufacturing	Personal	CLM2 Methyl Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
154	Manufacturing	Personal	CLM2 Thermal Technician	1.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
155	Manufacturing	Personal	CLM2 Methyl Technician	1.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
156	Manufacturing	Personal	CLM2 Thermal Technician	2.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
157	Manufacturing	Personal	Tank Area	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
158	Manufacturing	Personal	Tank Area	0.7	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
159	Manufacturing	Personal	Tank Area	0.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
160	Manufacturing	Personal	Tank Area	4.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
161	Manufacturing	Personal	Control Lab	1.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
162	Manufacturing	Personal	Control Lab	3.8	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
163	Manufacturing	Personal	CLM2 Thermal Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
164	Manufacturing	Personal	CLM2 Methyl Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
165	Manufacturing	Personal	CLM2 Methyl Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
166	Manufacturing	Personal	CLM2 Thermal Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
167	Manufacturing	Personal	CLM2 Methyl Technician	1.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
168	Manufacturing	Personal	CLM2 Thermal Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
169	Manufacturing	Personal	CLM2 Technician	1.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
170	Manufacturing	Personal	CLM2 Technician	1.7	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
171	Manufacturing	Personal	Control Lab	7.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
172	Manufacturing	Personal	Control Lab	1.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
173	Manufacturing	Personal	Control Lab	2.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
174	Manufacturing	Personal	Drum Fill Warehouse	0.8	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
175	Manufacturing	Personal	Drum Fill Warehouse	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
176	Manufacturing	Personal	Drum Fill Warehouse	20.8	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
177	Manufacturing	Personal	Tank Area	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
178	Manufacturing	Personal	CLM2 Technician	0.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
179	Manufacturing	Personal	CLM2 Thermal Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
180	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
181	Manufacturing	Personal	CLM2 Thermal Technician	0.8	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
182	Manufacturing	Personal	CLM2 Thermal Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
183	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
184	Manufacturing	Personal	CLM2 Methyl Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
185	Manufacturing	Personal	CLM2 Thermal Technician	1.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
186	Manufacturing	Personal	CLM2 Thermal Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
187	Manufacturing	Personal	CLM2 Methyl Technician	0.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
188	Manufacturing	Personal	Control Lab	0.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
189	Manufacturing	Personal	Tank Area	0.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
190	Manufacturing	Personal	Tank Area	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
191	Manufacturing	Personal	Tank Area	0.7	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
192	Manufacturing	Personal	Tank Area	7.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
193	Manufacturing	Personal	Tank Area	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
194	Manufacturing	Personal	Tank Area	0.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
195	Manufacturing	Personal	CLM2 Thermal Technician	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
196	Manufacturing	Personal	CLM2 Methyl Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
197	Manufacturing	Personal	Control Lab	1.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
198	Manufacturing	Personal	Control Lab	4.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
199	Manufacturing	Personal	Tank Area	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
200	Manufacturing	Personal	Control Lab	2.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
201	Manufacturing	Personal	Control Lab	1.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
202	Manufacturing	Personal	Tank Area	0.7	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
203	Manufacturing	Personal	CLM2 Thermal Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
204	Manufacturing	Personal	CLM2 Methyl Technician	1.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
205	Manufacturing	Personal	CLM2 Methyl Technician	2.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
206	Manufacturing	Personal	CLM2 Thermal Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
207	Manufacturing	Personal	CLM2 Methyl Technician	2.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
208	Manufacturing	Personal	Control Lab	2.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
209	Manufacturing	Personal	CLM2 Thermal Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
210	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
211	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
212	Manufacturing	Personal	CLM2 Thermal Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
213	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
214	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
215	Manufacturing	Personal	Tank Area	7.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
216	Manufacturing	Personal	Tank Area	15.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
217	Manufacturing	Personal	CLM2 Methyl Technician	2.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
218	Manufacturing	Personal	CLM2 Thermal Technician	12.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
219	Manufacturing	Personal	CLM2 Thermal Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
220	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
221	Manufacturing	Personal	Control Lab	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
222	Manufacturing	Personal	Control Lab	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
223	Manufacturing	Personal	CLM2 Methyl Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
224	Manufacturing	Personal	CLM2 Thermal Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
225	Manufacturing	Personal	CLM2 Methyl Technician	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
226	Manufacturing	Personal	CLM2 Thermal Technician	0.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
227	Manufacturing	Personal	Tank Area	41.7	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
228	Manufacturing	Personal	Tank Area	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
229	Manufacturing	Personal	Control Lab	0.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
230	Manufacturing	Personal	Control Lab	1.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
231	Manufacturing	Personal	CLM2 Thermal Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
232	Manufacturing	Personal	CLM2 Methyl Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
233	Manufacturing	Personal	CLM2 Thermal Technician	7.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
234	Manufacturing	Personal	EDC Outside Equipment Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
235	Manufacturing	Personal	EDC Outside Equipment Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
236	Manufacturing	Personal	EDC Outside Equipment Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
237	Manufacturing	Personal	EDC Outside Equipment Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
238	Manufacturing	Personal	EDC Outside Equipment Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
239	Manufacturing	Personal	Methanes Distillation Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
240	Manufacturing	Personal	Methanes Hydrochlor Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
241	Manufacturing	Personal	Lab Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
242	Manufacturing	Personal	Methanes Hydrochlor Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
243	Manufacturing	Personal	Methanes Hydrochlor Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
244	Manufacturing	Personal	EDC Outside Equipment Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
245	Manufacturing	Personal	Lab Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
246	Manufacturing	Personal	Lab Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
247	Manufacturing	Personal	Shipping Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
248	Manufacturing	Personal	Shipping Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
249	Manufacturing	Personal	Lab Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
250	Manufacturing	Personal	Lab Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
251	Manufacturing	Personal	Methanes Hydrochlor Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
252	Manufacturing	Personal	Shipping Shift Technician	0.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
253	Manufacturing	Personal	Lab Shift Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
254	Manufacturing	Personal	Methanes Hydrochlor Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
255	Manufacturing	Personal	Shipping Shift Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
256	Manufacturing	Personal	Shipping Shift Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
257	Manufacturing	Personal	Lab Shift Technician	0.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
258	Manufacturing	Personal	Methanes Distillation Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
259	Manufacturing	Personal	Methanes Distillation Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
260	Manufacturing	Personal	Methanes Hydrochlor Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
261	Manufacturing	Personal	Lab Shift Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
262	Manufacturing	Personal	Lab Shift Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
263	Manufacturing	Personal	Methanes Hydrochlor Technician	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
264	Manufacturing	Personal	Shipping Shift Technician	0.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
265	Manufacturing	Personal	Methanes Hydrochlor Technician	0.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
266	Manufacturing	Personal	Methanes Distillation Technician	1.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
267	Manufacturing	Personal	Shipping Shift Technician	1.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
268	Manufacturing	Personal	Shipping Shift Technician	1.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
269	Manufacturing	Personal	Methanes Distillation Technician	1.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sub>a,b</sub>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
270	Manufacturing	Personal	Shipping Shift Technician	1.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
271	Manufacturing	Personal	Methanes Hydrochlor Technician	1.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
272	Manufacturing	Personal	Methanes Distillation Technician	2.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
273	Manufacturing	Personal	Methanes Distillation Technician	2.3	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
274	Manufacturing	Personal	Methanes Distillation Technician	2.6	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
275	Manufacturing	Personal	Methanes Distillation Technician	2.7	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
276	Manufacturing	Personal	Shipping Shift Technician	4.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
277	Manufacturing	Personal	Operator	3.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
278	Manufacturing	Personal	Operator	35.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
279	Manufacturing	Personal	Control Lab	219.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) a,b	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
280	Manufacturing	Personal	Tank Area	374.0	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
281	Manufacturing	Personal	Tank Area	27.4	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
282	Manufacturing	Personal	Tank Area	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
283	Manufacturing	Personal	VCRU Technician	0.1	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
284	Manufacturing	Personal	Control Lab	3.8	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
285	Manufacturing	Personal	VCRU Technician	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
286	Manufacturing	Personal	Control Lab	6.9	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
287	Manufacturing	Personal	Control Lab	0.5	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
288	Manufacturing	Personal	Operator	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-Worker
289	Manufacturing	Personal	Operator	0.2	1	12-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Full-Shift TWA-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<sup>3</sup> 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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
2	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
3	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
4	Distribution lab operator	Personal	Lab - analysis	6.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
5	Outside operator	Personal	Catch samples - other	5.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
6	Logistics distribution operator	Personal	Loading/unloading – sampling and disconnect loading hose	298.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
7	Outside operator	Personal	Lab – analysis	5.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
8	Outside operator	Personal	Catch samples – other	4.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
9	Outside operator	Personal	Catch samples - other	4.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
10	Logistics distribution operator	Personal	Loading/unloading – sampling and connect loading hose	4.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
11	Outside operator	Personal	Lab - analysis	4.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
12	Logistics distribution operator	Personal	Loading/unloading – sampling and connect loading hose	2.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 30-min STEL - Worker
13	Logistics distribution operator	Personal	Loading/unloading – sampling and connect loading hose	1.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 1-hr STEL - Worker
14	Logistics distribution operator	Personal	Loading/unloading – sampling and disconnect loading hose	16.0	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 1-hr STEL - Worker
15	Logistics distribution operator	Personal	Loading/unloading – sampling and disconnect loading hose	6.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 1-hr STEL - Worker
16	Machinist	Personal	Line and equipment opening	1.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 1-hr STEL - Worker
17	VCRU Technician	Personal	Change D530 Filters	0.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
18	VCRU Technician	Personal	Change D530 Filters	0.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
19	VCRU Technician	Personal	Change D530 Filters	0.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
20	VCRU Technician	Personal	Sample D517, stabilized D518	0.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
21	CLM2 Thermal Technician	Personal	Sample Round	9.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
22	Control Lab Technician	Personal	Special Samples	11.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
23	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	6.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
24	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	6.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
25	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	14.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
26	Chloromethanes II Thermal Technician	Personal	Sample rounds	4.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
27	Chloromethanes II Thermal Technician	Personal	Sample rounds	20.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
28	VCRU Technician	Personal	Change D530 Filters	0.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
29	VCRU Technician	Personal	Change D530 Filters	0.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
30	VCRU Technician	Personal	Change D530 Filters	3.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
31	VCRU Technician	Personal	D530 Filter Change	2.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
32	VCRU Technician	Personal	D530 Filter Change	27.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
33	VCRU Technician	Personal	D530 Filter Change	2.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
34	VCRU Technician	Personal	D530 Filter Change	3.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
35	Tank Area	Personal	Sample Collection	170.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
36	VCRU Technician	Personal	Special Samples	59.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
37	Chloromethanes II Thermal Technician	Personal	Sample rounds	3.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
38	Chloromethanes II Thermal Technician	Personal	Sample rounds	4.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
39	Chloromethanes II Thermal Technician	Personal	Sample rounds	6.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
40	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	215.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
42	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	152.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
43	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	104.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
44	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	45.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
45	Control Lab Technician	Personal	Dumping Jugs	79.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
46	Control Lab Technician	Personal	Dumping Jugs	125.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
47	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	125.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
48	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	132.0	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
49	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	145.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
50	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	159.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
51	Control Lab Technician	Personal	Dumping Jugs	138.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
52	Tank Area	Personal	Sample Collection	21.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
53	Tank Area	Personal	Sample Collection	111.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
54	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	72.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
55	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	86.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
56	Control Lab Technician	Personal	Dumping Jugs	90.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
57	VCRU Technician	Personal	D530 Filter Change	0.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
58	Chloromethanes II Thermal Technician	Personal	Sample Collection	6.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
59	Chloromethanes II Thermal Technician	Personal	Sample Collection	12.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
60	Tank Area	Personal	Sample Collection	62.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
61	VCRU Technician	Personal	D530 Filter Change	5.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
62	VCRU Technician	Personal	D530 Filter Change	8.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
63	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	45.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
64	Control Lab Technician	Personal	Dumping Jugs	180.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
65	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	100.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
66	Tank Area	Personal	Sample Collection	17.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
67	Control Lab Technician	Personal	Dumping Jugs	86.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
68	Chloromethanes II Thermal Technician	Personal	Sample Collection	24.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
69	Chloromethanes II Thermal Technician	Personal	Sample Collection	2.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
70	Chloromethanes II Thermal Technician	Personal	Sample Collection	2.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
71	Control Lab Technician	Personal	Dumping Jugs	486.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
72	Control Lab Technician	Personal	Dumping Jugs	184.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
73	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	104.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
74	VCRU Technician	Personal	D530 Filter Change	2.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
75	Control Lab Technician	Personal	Dumping Jugs	198.0	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
76	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	18.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
77	VCRU Technician	Personal	D530 Filter Change	1.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
78	Chloromethanes II Thermal Technician	Personal	Sample Collection	15.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
79	Control Lab Technician	Personal	Dumping Jugs	125.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
80	Chloromethanes II Thermal Technician	Personal	Sample Collection	10.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
82	Chloromethanes II Thermal Technician	Personal	Sample Collection	9.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
83	VCRU Technician	Personal	D530 Filter Change	11.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
84	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	18.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
85	Control Lab Technician	Personal	Dumping Jugs	253.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
86	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	24.0	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
87	Chloromethanes II Thermal Technician	Personal	Sample Collection	1.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
88	Control Lab Technician	Personal	Dumping Jugs	41.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
89	VCRU Technician	Personal	D530 Filter Change	1.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
90	Tank Area	Personal	Sample Collection	59.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
91	VCRU Technician	Personal	D530 Filter Change	1.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
92	Chloromethanes II Thermal Technician	Personal	Sample Collection	121.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
93	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	24.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
94	VCRU Technician	Personal	D530 Filter Change	3.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
95	Control Lab Technician	Personal	Dumping Jugs	128.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
96	Tank Area	Personal	Sample Collection	11.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
97	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	41.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
98	VCRU Technician	Personal	D530 Filter Change	4.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
102	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	2.0	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
103	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	41.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
107	Methanes Distillation Technician	Personal	Collected process sample from DR-520	3.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
109	Methanes Distillation Technician	Personal	Collected process sample from DR-503.	3.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
110	Methanes Distillation Technician	Personal	Collected process sample from DR-503.	3.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
114	Methanes Hydrochlor Technician	Personal	Collected process sample from DR-503.	4.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
115	Methanes Distillation Technician	Personal	Collected process sample from T- 504 OH.	4.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
116	Methanes Distillation Technician	Personal	Collected process sample from DR-520.	4.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
117	Methanes Distillation Technician	Personal	Collected process sample from DR-503.	6.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
118	Methanes Distillation Technician	Personal	Collected process sample from T- 504 OH.	8.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
119	Methanes Distillation Technician	Personal	Collected process sample from DR-520.	11.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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. unsewed funnel from tote and capped the tote.	22.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
122	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	16.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
123	Drum Fill Loader	Personal	Sample Methylene Chloride Drum	48.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
124	Drum Fill Loader	Personal	Sample Methylene Chloride Railcar	48.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
129	VCRU Technician	Personal	D530 Filter Change	6.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
130	Chloromethanes II Thermal Technician	Personal	Sample Collection	10.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
133	Chloromethanes II Thermal Technician	Personal	Sample Collection	8.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
134	VCRU Technician	Personal	D530 Filter Change	26.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
135	Control Lab Technician	Personal	Dumping Jugs	26.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
136	Solvent Loader	Personal	Special Samples	8.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
137	Solvent Loader	Personal	Special Samples	32.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
138	Chloromethanes II Thermal Technician	Personal	Sample Collection	1.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
139	Control Lab Technician	Personal	Dumping Jugs	3.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
140	VCRU Technician	Personal	D530 Filter Change	194.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
141	Chloromethanes II Thermal Technician	Personal	Sample Collection	7.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
142	Control Lab Technician	Personal	Special Samples	4.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
143	Solvent Loader	Personal	Special Samples	1.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
144	Control Lab Technician	Personal	Dumping Jugs	9.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
145	VCRU Technician	Personal	D530 Filter Change	48.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
146	Solvent Loader	Personal	Special Samples	3.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
147	Control Lab Technician	Personal	Special Samples	1.0	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
148	VCRU Technician	Personal	D530 Filter Change	3.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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/m <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
149	Control Lab Technician	Personal	Special Samples	6.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
150	Chloromethanes II Thermal Technician	Personal	Sample Collection	8.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
151	Control Lab Technician	Personal	Dumping Jugs	22.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
152	Solvent Loader	Personal	Special Samples	5.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included 15-min STEL - Worker
153	Solvent Loader	Personal	Special Samples	3.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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<sup>3</sup> 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 8-hr TWA monitoring data provided by HSIA from one facility that uses methylene chloride in the manufacturing process of fluorochemicals, with sampling dates between 2010 and 2017 ([Halogenated Solvents Industry Alliance, 2018](#)). HSIA indicated that samples are taken as part of the company's continuous IH monitoring program.
- 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](#)).
- Rows 26 through 39 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data mainly come from Industrial Gas Manufacturing and Pesticide and Other Agricultural Chemical Manufacturing sites. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

Table\_Apx A-4 present short-term monitoring data:

- Row 1 provides a range of samples from "closed industrial applications" (10-minute samples) and is used as surrogate data ([TNO \(CIVO\), 1999](#)). EPA evaluated as a 15-minute exposure.
- Row 2 presents a 30-minute STEL provided by Olin Corporation during drumming operations ([Olin Corp, 1979](#)). EPA evaluated as a 30-minute exposure.

**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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Fluorochemicals Production	Personal	Maintenance	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
2	Fluorochemicals Production	Personal	Maintenance	0.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
3	Fluorochemicals Production	Personal	Maintenance	ND	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
4	Fluorochemicals Production	Personal	Chemical operator	ND	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
5	Fluorochemicals Production	Personal	Chemical operator	13.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
6	Fluorochemicals Production	Personal	Chemical operator	5.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
7	Fluorochemicals Production	Personal	Chemical operator	ND	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
8	Fluorochemicals Production	Personal	Laboratory technician	1.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
9	Fluorochemicals Production	Personal	Laboratory technician	8.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
10	Fluorochemicals Production	Personal	Maintenance	1.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
11	Fluorochemicals Production	Personal	Chemical operator	1.6	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
12	Fluorochemicals Production	Personal	Chemical operator	1.6	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
13	Fluorochemicals Production	Personal	Chemical operator	1.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
14	Fluorochemicals Production	Personal	Chemical operator	8.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
15	Fluorochemicals Production	Personal	Chemical operator	3.1	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included-Worker Full-Shift TWA
16	Fluorochemicals Production	Area	Chemical operator	0.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Excluded - used personal samples
17	Fluorochemicals Production	Area	Chemical operator	2.0	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Excluded - used personal samples
18	Fluorochemicals Production	Area	Chemical operator	1.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Excluded - used personal samples
19	Fluorochemicals Production	Area	Chemical operator	ND	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Excluded - used personal samples
20	Other Chemical Industry	Personal	Closed Industrial Applications	0 – 160 20 (mean)	unknown	8-hr TWA	<a href="#">TNO (CIVO) (1999)</a>	2.3	Excluded - used direct monitoring data instead
21	Olin Corporation – Crop Protection	Personal	Operator	10.16	1	6.5-hr TWA	<a href="#">Olin Corp (1979)</a>	2.2	Excluded – used higher quality data
22	Olin Corporation – Crop Protection	Personal	Operator	0.15	1	6.5-hr TWA	<a href="#">Olin Corp (1979)</a>	2.2	Excluded – used higher quality data
23	Olin Corporation – Crop Protection	Personal	Asst Operator	21.77	1	6.5-hr TWA	<a href="#">Olin Corp (1979)</a>	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 <sup>3</sup> ) <sup>a,b,c</sup>	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	<a href="#">Olin Corp (1979)</a>	2.2	Excluded – used higher quality data
25	Fluorochemicals Production	Personal	Not specified	CBI	Unknown	8-hr TWA	<a href="#">Bernstein (2017)</a>	1.8	Excluded – used higher quality data
26	Industrial Gas Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
27	Industrial Gas Manufacturing	Personal	unknown	21.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
28	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	3.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
29	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	4.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
30	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
31	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
32	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
33	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
34	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	61.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
35	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	134.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
36	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
37	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	68.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
38	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	300.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
39	Pesticide and Other Agricultural Chemical Manufacturing	Personal	unknown	57.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA



a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

**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 <sup>3</sup> ) <sup>a</sup>	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	<a href="#">TNO (CIVO) (1999)</a>	2.3	Included - 15-min STEL
2	Olin Corporation – Crop Protection	Personal	Drumming	1,692.7	1	25-min	<a href="#">Olin Corp (1979)</a>	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<sup>3</sup> 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<sup>3</sup> 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<sup>3</sup>, mainly during packing operations ([US EPA, 1985](#)).
- Rows 13 through 57 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data mainly come from Paint and Coating Manufacturing and Adhesive Manufacturing sites. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

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<sup>3</sup> during filling containers of methylene chloride-containing products (aerosols), as reported in a 1999 European Commission report ([TNO \(CIVO\), 1999](#)). Sample duration was not provided; therefore, this exposure concentration was not used in the assessment.

**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 <sup>3</sup> ) <sup>a,b,c</sup>	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	<a href="#">TNO (CIVO) (1999)</a>	2.3	Not used in favor of individual data points
2	Aerosol Products Manufacturing	Personal	Aerosol Filling	95 – 628	Unknown	8-hr TWA	<a href="#">(IPCS) (1996)</a>	2.3	Not used in favor of individual data points
3	Paint Manufacture	Personal	Aerosol Line Filler	101	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
4	Specialty Cleaning	Personal	Line Operator	101	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
5	Specialty Cleaning	Personal	Line Operator	349	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
6	Specialty Cleaning	Personal	Valve Dropper	171	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
7	Specialty Cleaning	Personal	Valve Dropper	454	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
8	Paint, Varnish, Etc.	Personal	Batch Mixer	52	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
9	Paint, Varnish, Etc.	Personal	Package Grinding	464	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
10	Paint, Varnish, Etc.	Personal	Tipper Operator	1260	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
11	Paint, Varnish, Etc.	Personal	Valve Dropper	2223	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
12	Paint, Varnish, Etc.	Personal	Tub Cleaner	529	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker Full-Shift TWA
13	Paint and Coating Manufacturing	Personal	unknown	246.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
14	Paint and Coating Manufacturing	Personal	unknown	44.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
15	Paint and Coating Manufacturing	Personal	unknown	111.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
16	Paint and Coating Manufacturing	Personal	unknown	462.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
17	Paint and Coating Manufacturing	Personal	unknown	214.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
18	Paint and Coating Manufacturing	Personal	unknown	176.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
19	Paint and Coating Manufacturing	Personal	unknown	309.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
20	Paint and Coating Manufacturing	Personal	unknown	6.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
21	Paint and Coating Manufacturing	Personal	unknown	161.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
22	Paint and Coating Manufacturing	Personal	unknown	0.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
23	Paint and Coating Manufacturing	Personal	unknown	80.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
24	Paint and Coating Manufacturing	Personal	unknown	486.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
25	Paint and Coating Manufacturing	Personal	unknown	39.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
26	Paint and Coating Manufacturing	Personal	unknown	104.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
27	Paint and Coating Manufacturing	Personal	unknown	22.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
28	Paint and Coating Manufacturing	Personal	unknown	149.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
29	Paint and Coating Manufacturing	Personal	unknown	559.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
30	Paint and Coating Manufacturing	Personal	unknown	58.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
31	Paint and Coating Manufacturing	Personal	unknown	19.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
32	Paint and Coating Manufacturing	Personal	unknown	3.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
33	Paint and Coating Manufacturing	Personal	unknown	236.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
34	Paint and Coating Manufacturing	Personal	unknown	15.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
35	Paint and Coating Manufacturing	Personal	unknown	4.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
36	Paint and Coating Manufacturing	Personal	unknown	14.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
37	Paint and Coating Manufacturing	Personal	unknown	73.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
38	Paint and Coating Manufacturing	Personal	unknown	253.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
39	Adhesive Manufacturing	Personal	unknown	29.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
40	Adhesive Manufacturing	Personal	unknown	20.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
41	Adhesive Manufacturing	Personal	unknown	75.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
42	Adhesive Manufacturing	Personal	unknown	105.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
43	Adhesive Manufacturing	Personal	unknown	177.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
44	Adhesive Manufacturing	Personal	unknown	274.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
45	Adhesive Manufacturing	Personal	unknown	351.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
46	Adhesive Manufacturing	Personal	unknown	140.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
47	Adhesive Manufacturing	Personal	unknown	193.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
48	Adhesive Manufacturing	Personal	unknown	44.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
49	Adhesive Manufacturing	Personal	unknown	113.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
50	Adhesive Manufacturing	Personal	unknown	26.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
51	Adhesive Manufacturing	Personal	unknown	7.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
52	Adhesive Manufacturing	Personal	unknown	101.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
53	Adhesive Manufacturing	Personal	unknown	13.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
54	Adhesive Manufacturing	Personal	unknown	11.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
55	Adhesive Manufacturing	Personal	unknown	81.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
56	Adhesive Manufacturing	Personal	unknown	64.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
57	Adhesive Manufacturing	Personal	unknown	77.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

**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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Formulation of DCM containing products (aerosols)	Personal	Filling	180	Unknown	Peak	<a href="#">TNO (CIVO) (1999)</a>	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<sup>3</sup> 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 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<sup>3</sup> ([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 <sup>3</sup> ) <sup>a</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Distribution	Personal	Filling drums / loading trucks	39.64	1	Full-shift	<a href="#">Unocal Corporation (1986)</a>	2.0	Included – Full-Shift TWA - Worker
2	Distribution	Personal	Filling drums / loading trucks	2.54	1	Full-shift	<a href="#">Unocal Corporation (1986)</a>	2.0	Included – Full-Shift TWA - Worker
3	Distribution	Personal	Filling drums / loading trucks	2.54	1	Full-shift	<a href="#">Unocal Corporation (1986)</a>	2.0	Included – Full-Shift TWA - Worker
4	Distribution	Personal	Truck loading & unloading	1.74	1	Full-shift	<a href="#">Unocal Corporation (1986)</a>	2.0	Included – Full-Shift TWA - Worker
5	Distribution	Personal	Drumming solvent	14.47	1	Full-shift	<a href="#">Unocal Corporation (1986)</a>	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 <sup>3</sup> ) <sup>a</sup>	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	<a href="#">Unocal Corporation (1986)</a>	2.0	Included – Short-Term TWA - Worker
2	Distribution	Personal	Truck loading (2,000 gal)	94	1	1-hr TWA	<a href="#">Unocal Corporation (1986)</a>	2.0	Included – Short-Term TWA - Worker
3	Distribution	Personal	Truck loading (800 gal)	10	1	0.5-hr TWA	<a href="#">Unocal Corporation (1986)</a>	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 <sup>3</sup> ) <sup>a</sup>	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	<a href="#">Unocal Corporation (1986)</a>	2.0	Included – Short-Term TWA - Worker

## A.5 Cold Cleaning

---

Table\_Apx A-9 presents 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<sup>3</sup> and a mean value of 280 mg/m<sup>3</sup> for cold degreasing activities ([TNO \(CIVO\), 1999](#)).
- Row 2 indicates that exposure levels can be kept below 124 mg/m<sup>3</sup> if stringent controls are applied; however, the specific type of degreasing is not specified for this exposure; 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 <sup>3</sup> ) <sup>a, b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Unknown	unknown	Cold degreasing	14 – 1,000 280 (mean)	Unknown	Unknown	<a href="#">TNO (CIVO) (1999)</a>	2.3	Included – Worker Full-Shift TWA
2	Unknown	unknown	Degreasing	124	Unknown	Unknown	<a href="#">TNO (CIVO) (1999)</a>	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<sup>3</sup> 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 Aerosol Degreasing**

---

Table\_Apx A-10 presents the full shift data available for sites that may potentially perform aerosol degreasing:

- Rows 1 through 21 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data mainly come from various automotive industries such as Automotive Body, Paint, and Interior Repair and Maintenance; General Automotive Repair; and New Car Dealers. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

**Table\_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Aerosol Degreasing**

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m <sup>3</sup> ) <sup>a, b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Other Automotive Mechanical and Electrical Repair and Maintenance	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
2	Other Automotive Mechanical and Electrical Repair and Maintenance	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
3	Other Automotive Mechanical and Electrical Repair and Maintenance	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
4	Other Automotive Mechanical and Electrical Repair and Maintenance	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
5	Other Automotive Mechanical and Electrical Repair and Maintenance	Personal	Unknown	7.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
6	Sporting Goods Stores	Personal	Unknown	200.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
7	New Car Dealers	Personal	Unknown	69.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
8	Automotive Body, Paint, and Interior Repair and Maintenance	Personal	Unknown	68.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
9	Sporting Goods Stores	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
10	Automotive Body, Paint, and Interior Repair and Maintenance	Personal	Unknown	227.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
11	Automotive Body, Paint, and Interior Repair and Maintenance	Personal	Unknown	396.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
12	Automotive Body, Paint, and Interior Repair and Maintenance	Personal	Unknown	12.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
13	Automotive Body, Paint, and Interior Repair and Maintenance	Personal	Unknown	6.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
14	Other Personal and Household Goods Repair and Maintenance	Personal	Unknown	58.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
15	New Car Dealers	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-10. Summary of Full-Shift Inhalation Monitoring Data for Aerosol Degreasing**

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m <sup>3</sup> ) <sup>a, b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
16	New Car Dealers	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
17	New Car Dealers	Personal	Unknown	9.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
18	General Automotive Repair	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
19	General Automotive Repair	Personal	Unknown	30.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
20	General Automotive Repair	Personal	Unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
21	General Automotive Repair	Personal	Unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1.

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 Adhesives and Sealants

---

Full-shift data are summarized in Table\_Apx A-11:

- 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.
- Rows 114 and 115 contain personal sampling data from OSHA inspections for gluers during sign manufacturing. Concentration data were scaled to 8-hr TWAs ([OSHA, 2019](#))
- Rows 116 through 583 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data come from various industries. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

Short-term data are summarized in Table\_Apx A-12:

- Rows 1 through 10 contain provided 15-min 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 11 and 12 had sample durations of 10 and 12 minutes, which were evaluated as 15-minute exposures.
- 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 ([NIOSH, 2016](#)).
- Row 20 contains a data point from an OSHA inspection for a laminator at an industrial sign manufacturing facility. The sample duration was 71 minutes and was evaluated as a 1-hr exposure ([OSHA, 2019](#)).



**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	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	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
2	Flexible Circuit Board Manufacturing	Personal	Operator, Laminator #4	250.1	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
3	Flexible Circuit Board Manufacturing	Personal	Tape Machine, Dept. 12	458.5	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
4	Flexible Circuit Board Manufacturing	Personal	Laminator #1, Dept. 14	218.8	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	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	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
6	Flexible Circuit Board Manufacturing	Personal	Laminator #1, Dept. 14	132.0	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
7	Flexible Circuit Board Manufacturing	Personal	Adhesive mixer, Dept. 14	90.3	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
8	Flexible Circuit Board Manufacturing	Personal	Tape Machine, Dept. 12	204.9	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
9	Flexible Circuit Board Manufacturing	Personal	Laminator #4, Dept. 14	114.6	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	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	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
11	Flexible Circuit Board Manufacturing	Personal	Laminator #1, Dept. 14	86.8	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
12	Flexible Circuit Board Manufacturing	Personal	36" Laminator, Dept. 12	364.7	1	8-hr TWA	<a href="#">NIOSH (1985)</a>	1.6	Included – full-shift TWA (non-spray)
13	Adhesives	Personal	Spray application	3.5 – 1,500 200 (average)	unknown	8-hr TWA	<a href="#">TNO (CIVO) (1999)</a>	2.3	Included – full-shift TWA (spray)
14	Foam Industry	Personal	Glue spraying	85 – 244	unknown	8-hr TWA	<a href="#">(IPCS) (1996)</a>	2.3	Included – full-shift TWA (spray)
15	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
16	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
17	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
18	Fiberglass Boats	Personal	Deck Lamination	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
19	Fiberglass Boats	Personal	Gel Kote	17.45	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
20	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
21	Fiberglass Boats	Personal	Lamination	1.745	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
22	Fiberglass Boats	Personal	Lamination	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
23	Fiberglass Boats	Personal	Lamination	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
24	Fiberglass Boats	Personal	Gel Kote	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
25	Fiberglass Boats	Personal	Hull Lamination	20.94	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
26	Fiberglass Boats	Personal	Hull Lamination	17.45	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
27	Fiberglass Boats	Personal	Hull Lamination	28.94	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
28	Fiberglass Boats	Personal	Hull Lamination	53.84	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
29	Fiberglass Boats	Personal	Lam Stiffening	17.45	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
30	Fiberglass Boats	Personal	Hull Lamination	17.45	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
31	Fiberglass Boats	Personal	Gel Kote	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
32	Fiberglass Boats	Personal	Mold Repair	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
33	Fiberglass Boats	Personal	Deck Lamination	26.94	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
34	Fiberglass Boats	Personal	Hull Lamination	27.92	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
35	Fiberglass Boats	Personal	Deck Lamination	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
36	Fiberglass Boats	Personal	Deck Lamination	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
37	Fiberglass Boats	Personal	Deck Lamination	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
38	Fiberglass Boats	Personal	Stiffening	13.96	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
39	Fiberglass Boats	Personal	Gel Kote	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
40	Fiberglass Boats	Personal	Hull Lamination	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
41	Fiberglass Boats	Personal	Hull Lamination	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
42	Fiberglass Boats	Personal	Hull Lamination	10.47	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
43	Fiberglass Boats	Personal	Hull Lamination	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
44	Fiberglass Boats	Personal	Hull Lamination	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
45	Fiberglass Boats	Personal	Hull Lamination	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
46	Fiberglass Boats	Personal	Stiffening	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
47	Fiberglass Boats	Personal	Stiffening	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
48	Fiberglass Boats	Personal	Gel Kote	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
49	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
50	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
51	Fiberglass Boats	Personal	Lamination	13.96	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
52	Fiberglass Boats	Personal	Gel Kote	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
53	Fiberglass Boats	Personal	Lamination	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
54	Fiberglass Boats	Personal	Lamination	30.39	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
55	Fiberglass Boats	Personal	Lamination	6.98	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
56	Fiberglass Boats	Personal	Stringer	3.49	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
57	Plastics Materials	Personal	Laminator Helper	0.073	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
58	Plastics Materials	Personal	Laminator Helper	87.25	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
59	Plastics Materials	Personal	Laminator Helper	87.25	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
60	Plastics Materials	Personal	Mold Controller	87.25	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
61	Plastics Materials	Personal	PM Laminator	48.86	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
62	Building Paper	Personal	Laborer	223.36	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
63	Building Paper	Personal	Laminator	177.99	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
64	Building Paper	Personal	Laminator Laborer	87.25	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
65	Misc. Plastic Products	Personal	Laminator	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
66	Misc. Plastic Products	Personal	Lead Man	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
67	Misc. Plastic Products	Personal	Lead Man	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
68	Misc. Plastic Products	Personal	Laminator	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
69	Wood Household Furniture	Personal	Laminator	79.118	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
70	Boat Building	Personal	Sprayer	60.028	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
71	Boat Building	Personal	Foreman	72.941	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
72	Boat Building	Personal	Foreman/Sprayer	60.796	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
73	Boat Building	Personal	Roller/Sprayer	86.23	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
74	Boat Building	Personal	Sprayer	43.555	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
75	Boat Building	Personal	Gel Coat Sprayer	34.481	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
76	Boat Building	Personal	Sprayer Helper	93.637	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
77	Boat Building	Personal	Layup Sprayer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
78	Boat Building	Personal	Layup Sprayer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
79	Boat Building	Personal	Sprayer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
80	Boat Building	Personal	Layup Sprayer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
81	Boat Building	Personal	Layup Sprayer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (spray)
82	Boat Building	Personal	Layup	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
83	Boat Building	Personal	Layup	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
84	Boat Building	Personal	Layup	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
85	Boat Building	Personal	Layup	0.14	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
86	Boat Building	Personal	Layup	4.18	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
87	Air Brake Manufacture	Personal	Gluer	205.918	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
88	Foam Products	Personal	Glue Mixing	0.007	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
89	Abrasive Products	Personal	Gluer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
90	Abrasive Products	Personal	Gluer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
91	Abrasive Products	Personal	Gluer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)



**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
92	Abrasive Products	Personal	Portable Belt Gluer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
93	Public Bldg. Furniture	Personal	Glue Gun Operator	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
94	Public Bldg. Furniture	Personal	Glue Gun Operator	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
95	Foam Products	Personal	Hot Wire Cutting	0.698	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
96	Foam Products	Personal	Hot Wire Cutting	0.698	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
97	Foam Products	Personal	Hot Wire Cutting	0.349	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
98	Foam Products	Personal	Foam Processing	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
99	Foam Products	Personal	Foam Processing	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
100	Foam Products	Personal	Adhesive Storage	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
101	Foam Products	Personal	Adhesive Storage	0.044	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
102	Abrasive Products	Personal	Presser	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
103	Plastic Materials	Personal	Medical Device Ass.	575.05	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
104	Plastic Materials	Personal	Micro Flush Assembly	206.1	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
105	Plastic Materials	Personal	Assembler	20.94	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
106	Plastic Materials	Personal	Micro Flush Assembly	397.162	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
107	Rubber & Plastic Footwear	Personal	Sock Liner	145.917	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
108	Rubber & Plastic Footwear	Personal	Lacer	77.827	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
109	Rubber & Plastic Footwear	Personal	Sock Liner	120.405	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
110	Rubber & Plastic Footwear	Personal	Sock Liner	187.364	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
111	Public Bldg. Furniture	Personal	Upholsterer	0	1	TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA (non-spray)
112	Flexible Circuit Board Manufacturing	Area	Area Sample, Laminator #4	284.8	1	TWA	<a href="#">NIOSH (1985)</a>	1.6	Excluded – prioritized personal samples
113	Cabinet Manufacturing	Area	Spray contact cement	1,042 – 1,736	unknown	TWA	<a href="#">Mahmud and Kales (1999)</a>	2.3	Excluded – prioritized personal samples

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
114	Sign Manufacturing	Personal	Gluer	15.2	1	TWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA (non-spray)
115	Sign Manufacturing	Personal	Gluer	13.2	1	TWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA (non-spray)
116	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	65.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
117	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	35.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
118	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	26.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
119	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	88.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
120	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	90.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
121	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	67.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
122	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	39.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
123	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	27.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
124	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	47.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
125	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	49.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
126	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	71.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
127	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	0.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
128	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	31.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
129	Prefabricated Metal Building and Component Manufacturing	Personal	unknown	1.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
130	Fabricated Structural Metal Manufacturing	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
131	Fabricated Structural Metal Manufacturing	Personal	unknown	7.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
132	Fabricated Structural Metal Manufacturing	Personal	unknown	43.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
133	Plate Work Manufacturing	Personal	unknown	251.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
134	Plate Work Manufacturing	Personal	unknown	31.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
135	Plate Work Manufacturing	Personal	unknown	3.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
136	Plate Work Manufacturing	Personal	unknown	588.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
137	Plate Work Manufacturing	Personal	unknown	745.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
138	Plate Work Manufacturing	Personal	unknown	411.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
139	Plate Work Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
140	Metal Window and Door Manufacturing	Personal	unknown	17.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
141	Metal Window and Door Manufacturing	Personal	unknown	118.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
142	Metal Window and Door Manufacturing	Personal	unknown	560.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
143	Metal Window and Door Manufacturing	Personal	unknown	89.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
144	Metal Window and Door Manufacturing	Personal	unknown	113.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
145	Metal Window and Door Manufacturing	Personal	unknown	544.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
146	Metal Window and Door Manufacturing	Personal	unknown	113.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
147	Metal Window and Door Manufacturing	Personal	unknown	542.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
148	Metal Window and Door Manufacturing	Personal	unknown	59.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
149	Metal Window and Door Manufacturing	Personal	unknown	510.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
150	Metal Window and Door Manufacturing	Personal	unknown	246.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
151	Metal Window and Door Manufacturing	Personal	unknown	159.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
152	Metal Window and Door Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
153	Metal Window and Door Manufacturing	Personal	unknown	671.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
154	Metal Window and Door Manufacturing	Personal	unknown	529.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
155	Metal Window and Door Manufacturing	Personal	unknown	22.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
156	Metal Window and Door Manufacturing	Personal	unknown	1227.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
157	Metal Window and Door Manufacturing	Personal	unknown	27.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
158	Metal Window and Door Manufacturing	Personal	unknown	9.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
159	Metal Window and Door Manufacturing	Personal	unknown	32.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
160	Metal Window and Door Manufacturing	Personal	unknown	0.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
161	Metal Window and Door Manufacturing	Personal	unknown	7.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
162	Metal Window and Door Manufacturing	Personal	unknown	0.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
163	Metal Window and Door Manufacturing	Personal	unknown	223.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
164	Metal Window and Door Manufacturing	Personal	unknown	64.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
165	Metal Window and Door Manufacturing	Personal	unknown	633.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
166	Metal Window and Door Manufacturing	Personal	unknown	1244.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
167	Metal Window and Door Manufacturing	Personal	unknown	514.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
168	Metal Window and Door Manufacturing	Personal	unknown	954.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
169	Metal Window and Door Manufacturing	Personal	unknown	792.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
170	Metal Window and Door Manufacturing	Personal	unknown	367.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
171	Metal Window and Door Manufacturing	Personal	unknown	61.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
172	Metal Window and Door Manufacturing	Personal	unknown	34.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
173	Metal Window and Door Manufacturing	Personal	unknown	463.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
174	Metal Window and Door Manufacturing	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
175	Metal Window and Door Manufacturing	Personal	unknown	5.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
176	Metal Window and Door Manufacturing	Personal	unknown	61.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
177	Metal Window and Door Manufacturing	Personal	unknown	7.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
178	Metal Window and Door Manufacturing	Personal	unknown	99.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
179	Metal Window and Door Manufacturing	Personal	unknown	3.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
180	Metal Window and Door Manufacturing	Personal	unknown	41.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
181	Metal Window and Door Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
182	Metal Window and Door Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
183	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	1.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
184	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	24.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
185	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	4.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
186	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	76.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
187	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	23.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
188	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	76.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
189	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	38.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
190	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	395.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
191	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	12.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
192	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	24.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
193	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	16.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
194	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
195	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
196	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	18.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
197	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	31.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
198	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	104.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
199	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	59.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
200	Measuring, Dispensing, and Other Pumping Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
201	Elevator and Moving Stairway Manufacturing	Personal	unknown	8.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
202	Elevator and Moving Stairway Manufacturing	Personal	unknown	12.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
203	Elevator and Moving Stairway Manufacturing	Personal	unknown	11.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
204	Elevator and Moving Stairway Manufacturing	Personal	unknown	447.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
205	Elevator and Moving Stairway Manufacturing	Personal	unknown	7.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
206	Elevator and Moving Stairway Manufacturing	Personal	unknown	1300.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
207	Elevator and Moving Stairway Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
208	Conveyor and Conveying Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA



**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
209	Conveyor and Conveying Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
210	Conveyor and Conveying Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
211	Industrial Truck, Tractor, Trailer, and Stacker Machinery Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
212	Welding and Soldering Equipment Manufacturing	Personal	unknown	13.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
213	Packaging Machinery Manufacturing	Personal	unknown	6.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
214	Packaging Machinery Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
215	Packaging Machinery Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
216	Industrial Process Furnace and Oven Manufacturing	Personal	unknown	80.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
217	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	10.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
218	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	37.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
219	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	172.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
220	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	289.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
221	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
222	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	102.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
223	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	89.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
224	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
225	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
226	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
227	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
228	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	257.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
229	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	124.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
230	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	129.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
231	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	Personal	unknown	165.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
232	Other Communications Equipment Manufacturing	Personal	unknown	60.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
233	Other Communications Equipment Manufacturing	Personal	unknown	123.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
234	Other Communications Equipment Manufacturing	Personal	unknown	50.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
235	Other Communications Equipment Manufacturing	Personal	unknown	206.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
236	Other Communications Equipment Manufacturing	Personal	unknown	5.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
237	Other Communications Equipment Manufacturing	Personal	unknown	415.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
238	Other Communications Equipment Manufacturing	Personal	unknown	1070.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
239	Other Communications Equipment Manufacturing	Personal	unknown	191.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
240	Other Communications Equipment Manufacturing	Personal	unknown	47.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
241	Audio and Video Equipment Manufacturing	Personal	unknown	10.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
242	Bare Printed Circuit Board Manufacturing	Personal	unknown	105.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
243	Bare Printed Circuit Board Manufacturing	Personal	unknown	94.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
244	Bare Printed Circuit Board Manufacturing	Personal	unknown	7.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
245	Semiconductor and Related Device Manufacturing	Personal	unknown	5.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
246	Semiconductor and Related Device Manufacturing	Personal	unknown	10.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
247	Semiconductor and Related Device Manufacturing	Personal	unknown	20.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
248	Semiconductor and Related Device Manufacturing	Personal	unknown	11.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
249	Semiconductor and Related Device Manufacturing	Personal	unknown	21.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
250	Semiconductor and Related Device Manufacturing	Personal	unknown	170.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
251	Semiconductor and Related Device Manufacturing	Personal	unknown	19.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
252	Electromedical and Electrotherapeutic Apparatus Manufacturing	Personal	unknown	117.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
253	Electromedical and Electrotherapeutic Apparatus Manufacturing	Personal	unknown	7.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
254	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing	Personal	unknown	2.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
255	Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables	Personal	unknown	6.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
256	Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
257	Totalizing Fluid Meter and Counting Device Manufacturing	Personal	unknown	8.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
258	Totalizing Fluid Meter and Counting Device Manufacturing	Personal	unknown	0.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
259	Totalizing Fluid Meter and Counting Device Manufacturing	Personal	unknown	6.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
260	Totalizing Fluid Meter and Counting Device Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
261	Totalizing Fluid Meter and Counting Device Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
262	Analytical Laboratory Instrument Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
263	Irradiation Apparatus Manufacturing	Personal	unknown	26.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
264	Irradiation Apparatus Manufacturing	Personal	unknown	13.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
265	Irradiation Apparatus Manufacturing	Personal	unknown	15.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
266	Irradiation Apparatus Manufacturing	Personal	unknown	10.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
267	Residential Electric Lighting Fixture Manufacturing	Personal	unknown	923.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
268	Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing	Personal	unknown	42.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
269	Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing	Personal	unknown	10.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
270	Commercial, Industrial, and Institutional Electric Lighting Fixture Manufacturing	Personal	unknown	15.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
271	Power, Distribution, and Specialty Transformer Manufacturing	Personal	unknown	6.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
272	Power, Distribution, and Specialty Transformer Manufacturing	Personal	unknown	10.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
273	Power, Distribution, and Specialty Transformer Manufacturing	Personal	unknown	10.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
274	Power, Distribution, and Specialty Transformer Manufacturing	Personal	unknown	7.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
275	Motor and Generator Manufacturing	Personal	unknown	35.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
276	Motor and Generator Manufacturing	Personal	unknown	0.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
277	Motor and Generator Manufacturing	Personal	unknown	0.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
278	Motor and Generator Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
279	Motor and Generator Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
280	Motor and Generator Manufacturing	Personal	unknown	22.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
281	Motor and Generator Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
282	Motor and Generator Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
283	Switchgear and Switchboard Apparatus Manufacturing	Personal	unknown	0.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
284	Switchgear and Switchboard Apparatus Manufacturing	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
285	Relay and Industrial Control Manufacturing	Personal	unknown	78.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
286	Relay and Industrial Control Manufacturing	Personal	unknown	71.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
287	Relay and Industrial Control Manufacturing	Personal	unknown	0.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
288	Relay and Industrial Control Manufacturing	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
289	Primary Battery Manufacturing	Personal	unknown	14.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
290	Primary Battery Manufacturing	Personal	unknown	34.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
291	All Other Miscellaneous Electrical Equipment and Component Manufacturing	Personal	unknown	4.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
292	Automobile Manufacturing	Personal	unknown	3.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
293	Automobile Manufacturing	Personal	unknown	7.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
294	Automobile Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
295	Automobile Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
296	Automobile Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
297	Automobile Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
298	Automobile Manufacturing	Personal	unknown	39.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
299	Automobile Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
300	Automobile Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
301	Automobile Manufacturing	Personal	unknown	53.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
302	Automobile Manufacturing	Personal	unknown	46.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
303	Automobile Manufacturing	Personal	unknown	1.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
304	Automobile Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
305	Automobile Manufacturing	Personal	unknown	4.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
306	Motor Vehicle Body Manufacturing	Personal	unknown	37.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
307	Motor Vehicle Body Manufacturing	Personal	unknown	23.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
308	Motor Vehicle Body Manufacturing	Personal	unknown	3.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
309	Motor Vehicle Body Manufacturing	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
310	Motor Vehicle Body Manufacturing	Personal	unknown	845.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
311	Motor Vehicle Body Manufacturing	Personal	unknown	595.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
312	Motor Vehicle Body Manufacturing	Personal	unknown	578.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
313	Motor Vehicle Body Manufacturing	Personal	unknown	1010.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
314	Motor Vehicle Body Manufacturing	Personal	unknown	626.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
315	Motor Vehicle Body Manufacturing	Personal	unknown	69.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
316	Motor Vehicle Body Manufacturing	Personal	unknown	14.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
317	Motor Vehicle Body Manufacturing	Personal	unknown	1.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
318	Motor Vehicle Body Manufacturing	Personal	unknown	6.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
319	Motor Vehicle Body Manufacturing	Personal	unknown	9.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
320	Motor Vehicle Body Manufacturing	Personal	unknown	385.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
321	Motor Vehicle Body Manufacturing	Personal	unknown	68.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
322	Motor Vehicle Body Manufacturing	Personal	unknown	0.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
323	Motor Vehicle Body Manufacturing	Personal	unknown	23.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
324	Motor Vehicle Body Manufacturing	Personal	unknown	13.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
325	Motor Vehicle Body Manufacturing	Personal	unknown	64.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
326	Motor Vehicle Body Manufacturing	Personal	unknown	18.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
327	Motor Vehicle Body Manufacturing	Personal	unknown	78.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
328	Motor Vehicle Body Manufacturing	Personal	unknown	22.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
329	Motor Vehicle Body Manufacturing	Personal	unknown	1.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
330	Motor Vehicle Body Manufacturing	Personal	unknown	4.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
331	Motor Vehicle Body Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
332	Motor Vehicle Body Manufacturing	Personal	unknown	1.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
333	Motor Vehicle Body Manufacturing	Personal	unknown	18.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
334	Motor Vehicle Body Manufacturing	Personal	unknown	15.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA



**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
335	Motor Vehicle Body Manufacturing	Personal	unknown	10.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
336	Motor Vehicle Body Manufacturing	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
337	Motor Vehicle Body Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
338	Motor Vehicle Body Manufacturing	Personal	unknown	32.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
339	Motor Vehicle Body Manufacturing	Personal	unknown	61.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
340	Motor Vehicle Body Manufacturing	Personal	unknown	0.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
341	Motor Vehicle Body Manufacturing	Personal	unknown	14.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
342	Motor Vehicle Body Manufacturing	Personal	unknown	6.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
343	Motor Vehicle Body Manufacturing	Personal	unknown	4.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
344	Motor Vehicle Body Manufacturing	Personal	unknown	321.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
345	Motor Vehicle Body Manufacturing	Personal	unknown	92.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
346	Motor Vehicle Body Manufacturing	Personal	unknown	11.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
347	Motor Vehicle Body Manufacturing	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
348	Motor Vehicle Body Manufacturing	Personal	unknown	449.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
349	Motor Vehicle Body Manufacturing	Personal	unknown	261.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
350	Motor Vehicle Body Manufacturing	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
351	Motor Vehicle Body Manufacturing	Personal	unknown	20.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
352	Motor Vehicle Body Manufacturing	Personal	unknown	7.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
353	Motor Vehicle Body Manufacturing	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
354	Motor Vehicle Body Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
355	Truck Trailer Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
356	Travel Trailer and Camper Manufacturing	Personal	unknown	6.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
357	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	Personal	unknown	160.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
358	Motor Vehicle Gasoline Engine and Engine Parts Manufacturing	Personal	unknown	148.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
359	Motor Vehicle Electrical and Electronic Equipment Manufacturing	Personal	unknown	22.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
360	Motor Vehicle Electrical and Electronic Equipment Manufacturing	Personal	unknown	32.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
361	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
362	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	1.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
363	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
364	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	64.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
365	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
366	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	2278.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
367	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	2280.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
368	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	615.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
369	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	1529.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
370	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
371	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	0.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
372	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	36.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
373	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	37.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
374	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	54.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
375	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	44.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
376	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	4.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
377	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	29.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
378	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	2.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
379	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	2.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
380	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	2.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
381	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	5.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
382	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	4.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
383	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
384	Motor Vehicle Seating and Interior Trim Manufacturing	Personal	unknown	1.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
385	Motor Vehicle Metal Stamping	Personal	unknown	121.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
386	Motor Vehicle Metal Stamping	Personal	unknown	33.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
387	Aircraft Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
388	Aircraft Manufacturing	Personal	unknown	418.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
389	Aircraft Manufacturing	Personal	unknown	191.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
390	Aircraft Manufacturing	Personal	unknown	119.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
391	Aircraft Manufacturing	Personal	unknown	119.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
392	Aircraft Manufacturing	Personal	unknown	57.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
393	Aircraft Manufacturing	Personal	unknown	44.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
394	Aircraft Manufacturing	Personal	unknown	29.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
395	Aircraft Manufacturing	Personal	unknown	13.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
396	Aircraft Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
397	Aircraft Manufacturing	Personal	unknown	11.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
398	Aircraft Manufacturing	Personal	unknown	396.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
399	Aircraft Manufacturing	Personal	unknown	121.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
400	Aircraft Manufacturing	Personal	unknown	209.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
401	Aircraft Manufacturing	Personal	unknown	253.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
402	Aircraft Manufacturing	Personal	unknown	25.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
403	Aircraft Manufacturing	Personal	unknown	264.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
404	Aircraft Manufacturing	Personal	unknown	7.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
405	Aircraft Engine and Engine Parts Manufacturing	Personal	unknown	120.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
406	Aircraft Engine and Engine Parts Manufacturing	Personal	unknown	83.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
407	Ship Building and Repairing	Personal	unknown	604.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
408	Ship Building and Repairing	Personal	unknown	119.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
409	Ship Building and Repairing	Personal	unknown	613.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
410	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
411	Boat Building	Personal	unknown	1.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
412	Boat Building	Personal	unknown	60.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
413	Boat Building	Personal	unknown	29.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
414	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
415	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
416	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
417	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
418	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
419	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
420	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
421	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
422	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
423	Boat Building	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
424	Boat Building	Personal	unknown	0.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
425	Boat Building	Personal	unknown	18.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
426	Boat Building	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
427	Boat Building	Personal	unknown	34.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
428	Boat Building	Personal	unknown	129.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
429	Boat Building	Personal	unknown	57.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
430	Boat Building	Personal	unknown	5.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
431	Motorcycle, Bicycle, and Parts Manufacturing	Personal	unknown	0.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
432	Military Armored Vehicle, Tank, and Tank Component Manufacturing	Personal	unknown	24.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
433	Reupholstery and Furniture Repair	Personal	unknown	52.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
434	Reupholstery and Furniture Repair	Personal	unknown	269.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
435	Reupholstery and Furniture Repair	Personal	unknown	312.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
436	Reupholstery and Furniture Repair	Personal	unknown	465.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
437	Reupholstery and Furniture Repair	Personal	unknown	8.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
438	Reupholstery and Furniture Repair	Personal	unknown	9.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
439	Reupholstery and Furniture Repair	Personal	unknown	484.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
440	Reupholstery and Furniture Repair	Personal	unknown	47.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
441	Reupholstery and Furniture Repair	Personal	unknown	40.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
442	Reupholstery and Furniture Repair	Personal	unknown	23.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
443	Reupholstery and Furniture Repair	Personal	unknown	2168.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
444	Reupholstery and Furniture Repair	Personal	unknown	12.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
445	Reupholstery and Furniture Repair	Personal	unknown	64.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
446	Reupholstery and Furniture Repair	Personal	unknown	316.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
447	Reupholstery and Furniture Repair	Personal	unknown	15.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
448	Reupholstery and Furniture Repair	Personal	unknown	25.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
449	Reupholstery and Furniture Repair	Personal	unknown	594.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
450	Reupholstery and Furniture Repair	Personal	unknown	6.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
451	Reupholstery and Furniture Repair	Personal	unknown	3.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
452	Reupholstery and Furniture Repair	Personal	unknown	15.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
453	Reupholstery and Furniture Repair	Personal	unknown	255.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
454	Reupholstery and Furniture Repair	Personal	unknown	10.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
455	Reupholstery and Furniture Repair	Personal	unknown	105.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
456	Reupholstery and Furniture Repair	Personal	unknown	254.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
457	Reupholstery and Furniture Repair	Personal	unknown	219.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
458	Reupholstery and Furniture Repair	Personal	unknown	82.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
459	Reupholstery and Furniture Repair	Personal	unknown	48.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
460	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
461	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
462	Reupholstery and Furniture Repair	Personal	unknown	3.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA



**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
463	Reupholstery and Furniture Repair	Personal	unknown	18.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
464	Reupholstery and Furniture Repair	Personal	unknown	117.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
465	Reupholstery and Furniture Repair	Personal	unknown	146.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
466	Reupholstery and Furniture Repair	Personal	unknown	33.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
467	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
468	Reupholstery and Furniture Repair	Personal	unknown	5.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
469	Reupholstery and Furniture Repair	Personal	unknown	10.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
470	Reupholstery and Furniture Repair	Personal	unknown	66.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
471	Reupholstery and Furniture Repair	Personal	unknown	143.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
472	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
473	Reupholstery and Furniture Repair	Personal	unknown	51.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
474	Reupholstery and Furniture Repair	Personal	unknown	1.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
475	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
476	Reupholstery and Furniture Repair	Personal	unknown	124.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
477	Reupholstery and Furniture Repair	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
478	Reupholstery and Furniture Repair	Personal	unknown	53.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
479	Reupholstery and Furniture Repair	Personal	unknown	1032.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
480	Reupholstery and Furniture Repair	Personal	unknown	131.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
481	Reupholstery and Furniture Repair	Personal	unknown	30.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
482	Reupholstery and Furniture Repair	Personal	unknown	2.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
483	Reupholstery and Furniture Repair	Personal	unknown	368.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
484	Reupholstery and Furniture Repair	Personal	unknown	12.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
485	Reupholstery and Furniture Repair	Personal	unknown	181.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
486	Reupholstery and Furniture Repair	Personal	unknown	5.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
487	Reupholstery and Furniture Repair	Personal	unknown	7.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
488	Reupholstery and Furniture Repair	Personal	unknown	566.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
489	Reupholstery and Furniture Repair	Personal	unknown	100.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
490	Reupholstery and Furniture Repair	Personal	unknown	17.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
491	Reupholstery and Furniture Repair	Personal	unknown	4.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
492	Reupholstery and Furniture Repair	Personal	unknown	4.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
493	Reupholstery and Furniture Repair	Personal	unknown	461.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
494	Reupholstery and Furniture Repair	Personal	unknown	5.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
495	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
496	Reupholstery and Furniture Repair	Personal	unknown	239.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
497	Reupholstery and Furniture Repair	Personal	unknown	7.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
498	Reupholstery and Furniture Repair	Personal	unknown	292.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
499	Reupholstery and Furniture Repair	Personal	unknown	1260.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
500	Reupholstery and Furniture Repair	Personal	unknown	375.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
501	Reupholstery and Furniture Repair	Personal	unknown	1409.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
502	Reupholstery and Furniture Repair	Personal	unknown	0.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
503	Reupholstery and Furniture Repair	Personal	unknown	7.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
504	Reupholstery and Furniture Repair	Personal	unknown	348.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
505	Reupholstery and Furniture Repair	Personal	unknown	129.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
506	Reupholstery and Furniture Repair	Personal	unknown	28.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
507	Reupholstery and Furniture Repair	Personal	unknown	100.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
508	Reupholstery and Furniture Repair	Personal	unknown	698.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
509	Reupholstery and Furniture Repair	Personal	unknown	117.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
510	Reupholstery and Furniture Repair	Personal	unknown	137.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
511	Reupholstery and Furniture Repair	Personal	unknown	1204.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
512	Reupholstery and Furniture Repair	Personal	unknown	133.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
513	Reupholstery and Furniture Repair	Personal	unknown	4.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
514	Reupholstery and Furniture Repair	Personal	unknown	3.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
515	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
516	Reupholstery and Furniture Repair	Personal	unknown	129.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
517	Reupholstery and Furniture Repair	Personal	unknown	803.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
518	Reupholstery and Furniture Repair	Personal	unknown	75.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
519	Reupholstery and Furniture Repair	Personal	unknown	29.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
520	Reupholstery and Furniture Repair	Personal	unknown	176.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
521	Reupholstery and Furniture Repair	Personal	unknown	10.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
522	Reupholstery and Furniture Repair	Personal	unknown	117.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
523	Reupholstery and Furniture Repair	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
524	Reupholstery and Furniture Repair	Personal	unknown	1.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
525	Reupholstery and Furniture Repair	Personal	unknown	206.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
526	Reupholstery and Furniture Repair	Personal	unknown	212.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
527	Reupholstery and Furniture Repair	Personal	unknown	166.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
528	Reupholstery and Furniture Repair	Personal	unknown	75.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
529	Reupholstery and Furniture Repair	Personal	unknown	39.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
530	Reupholstery and Furniture Repair	Personal	unknown	82.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
531	Reupholstery and Furniture Repair	Personal	unknown	110.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
532	Reupholstery and Furniture Repair	Personal	unknown	6.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
533	Reupholstery and Furniture Repair	Personal	unknown	559.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
534	Reupholstery and Furniture Repair	Personal	unknown	699.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
535	Reupholstery and Furniture Repair	Personal	unknown	258.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
536	Reupholstery and Furniture Repair	Personal	unknown	1166.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
537	Reupholstery and Furniture Repair	Personal	unknown	60.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
538	Reupholstery and Furniture Repair	Personal	unknown	17.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
539	Reupholstery and Furniture Repair	Personal	unknown	40.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
540	Reupholstery and Furniture Repair	Personal	unknown	85.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
541	Reupholstery and Furniture Repair	Personal	unknown	10.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
542	Reupholstery and Furniture Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
543	Reupholstery and Furniture Repair	Personal	unknown	54.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
544	Reupholstery and Furniture Repair	Personal	unknown	171.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
545	Reupholstery and Furniture Repair	Personal	unknown	98.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
546	Reupholstery and Furniture Repair	Personal	unknown	312.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
547	Reupholstery and Furniture Repair	Personal	unknown	63.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
548	Reupholstery and Furniture Repair	Personal	unknown	17.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
549	Reupholstery and Furniture Repair	Personal	unknown	21.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
550	Reupholstery and Furniture Repair	Personal	unknown	161.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
551	Reupholstery and Furniture Repair	Personal	unknown	7.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
552	Reupholstery and Furniture Repair	Personal	unknown	590.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
553	Reupholstery and Furniture Repair	Personal	unknown	19.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
554	Reupholstery and Furniture Repair	Personal	unknown	51.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
555	Reupholstery and Furniture Repair	Personal	unknown	11.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
556	Reupholstery and Furniture Repair	Personal	unknown	326.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
557	Reupholstery and Furniture Repair	Personal	unknown	376.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
558	Reupholstery and Furniture Repair	Personal	unknown	306.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
559	Reupholstery and Furniture Repair	Personal	unknown	143.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
560	Reupholstery and Furniture Repair	Personal	unknown	7.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
561	Reupholstery and Furniture Repair	Personal	unknown	77.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
562	Reupholstery and Furniture Repair	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
563	Reupholstery and Furniture Repair	Personal	unknown	5.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
564	Reupholstery and Furniture Repair	Personal	unknown	80.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
565	Reupholstery and Furniture Repair	Personal	unknown	14.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
566	Reupholstery and Furniture Repair	Personal	unknown	17.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
567	Reupholstery and Furniture Repair	Personal	unknown	50.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
568	Reupholstery and Furniture Repair	Personal	unknown	890.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
569	Reupholstery and Furniture Repair	Personal	unknown	33.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
570	Reupholstery and Furniture Repair	Personal	unknown	666.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
571	Reupholstery and Furniture Repair	Personal	unknown	441.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
572	Reupholstery and Furniture Repair	Personal	unknown	214.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
573	Reupholstery and Furniture Repair	Personal	unknown	283.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
574	Reupholstery and Furniture Repair	Personal	unknown	10.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-11. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
575	Reupholstery and Furniture Repair	Personal	unknown	1.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
576	Reupholstery and Furniture Repair	Personal	unknown	713.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
577	Reupholstery and Furniture Repair	Personal	unknown	586.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
578	Reupholstery and Furniture Repair	Personal	unknown	511.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
579	Reupholstery and Furniture Repair	Personal	unknown	188.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
580	Reupholstery and Furniture Repair	Personal	unknown	14.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
581	Reupholstery and Furniture Repair	Personal	unknown	69.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
582	Reupholstery and Furniture Repair	Personal	unknown	58.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
583	Reupholstery and Furniture Repair	Personal	unknown	4.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.



**Table\_Apx A-12. 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 <sup>3</sup> ) <sup>a,b</sup>	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-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
2	Metal Window and Door Manufacturing	Personal	Adhesive Sprayer	576.6	1	15-min-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
3	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	142.4	1	15-min-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
4	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	225.8	1	6-min-STEEL	<a href="#">OSHA (2019)</a>	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-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
6	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	159.8	1	15-min-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
7	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	361.3	1	15-min-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
8	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	100.7	1	15-min-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
9	Wood Kitchen Cabinet and	Personal	Adhesive Sprayer	284.8	1	15-min-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray

**Table\_Apx A-12. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
	Countertop Manufacturing								
10	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	Adhesive Sprayer	12.2	1	15-min-STEEL	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 15-min STEEL - Spray
11	Flexible Circuit Board Manufacturing	Personal	Operator, laminator #3 & #4, cleaning	423.8	1	10-min	<a href="#">NIOSH (1985)</a>	1.6	Included – Industrial 15-min STEEL - Non-Spray
12	Flexible Circuit Board Manufacturing	Personal	Employee mixing adhesives, Dept 12	569.7	1	12-min	<a href="#">NIOSH (1985)</a>	1.6	Included – Industrial 15-min STEEL - Non-Spray
13	Flexible Circuit Board Manufacturing	Personal	Employee cleaning parts in room with no ventilation	6085.8	1	Short Term	<a href="#">NIOSH (1985)</a>	1.6	Excluded – cleaning operations
14	Flexible Circuit Board Manufacturing	Personal	Operator cleaning 39 inch laminator, Dept 12	2539.2	1	Short Term	<a href="#">NIOSH (1985)</a>	1.6	Excluded – cleaning operations
15	Flexible Circuit Board Manufacturing	Personal	Operator cleaning tape machine, Dept 12	1754.2	1	Short Term	<a href="#">NIOSH (1985)</a>	1.6	Excluded – cleaning operations
16	Flexible Circuit Board Manufacturing	Personal	Employee cleaning "tunnel" of laminator #10, Dept 14	1545.8	1	Short Term	<a href="#">NIOSH (1985)</a>	1.6	Excluded – cleaning operations
17	Flexible Circuit Board Manufacturing	Personal	Employee cleaning "tunnel" of laminator #10, Dept 14	930.9	1	Short Term	<a href="#">NIOSH (1985)</a>	1.6	Excluded – cleaning operations
18	Federal Crime Lab	Personal	Pouring MeCl into secondary container (2 min)	ND (<69.5)	1	Short Term	<a href="#">NIOSH (2016)</a>	2.3	Excluded – Not typical scale of industrial/commercial applications.
19	Federal Crime Lab	Personal	Using MeCl to connect pieces of plastic in the shop (few seconds)	ND (<69.5)	1	Short Term	<a href="#">NIOSH (2016)</a>	2.3	Excluded – Not typical scale of

**Table\_Apx A-12. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
									industrial/commercial applications.
20	Industrial Sign Manufacturing	Personal	Laminator	63.4	1	Short-Term	<a href="#">OSHA (2019)</a>	1.3	Included – Industrial 1-hr STEL – Non-Spray

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<sup>3</sup> 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 Paints and Coatings

---

Full-shift monitoring data for paints and coatings are presented in Table\_Apx A-13:

- 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<sup>3</sup>, 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<sup>3</sup> ([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](#)).
- Rows 33 through 298 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data come from various industries, such as "Commercial Screen Printing," "Wood Kitchen Cabinet and Countertop Manufacturing," "Upholstered Household Furniture Manufacturing," "Nonupholstered Wood Household Furniture Manufacturing," "Institutional Furniture Manufacturing," and "General Automotive Repair." However, worker activities for these exposure data points are not known. Sample times vary - however, exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

Short-term monitoring data are presented in Table\_Apx A-14:

- 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 ([NIOSH, 1981](#)). EPA assessed the 40-minute sample using a 30-minute exposure period, and assessed the 50-minute sample over a 1-hr exposure period.
- 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<sup>3</sup> during spray painting activities, sampled over 18 to 32 minutes ([NIOSH, 1973](#)). EPA evaluated samples with durations 15 to 20 minutes as 15-minute exposures and samples with durations ranging from of 22 to 32 minutes, as 30-minute exposures.
- 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](#)). EPA evaluated samples with durations 15 to 20 minutes as 15-minute exposures.
- Row 12 contains a data point from an OSHA inspection for a Floor Manager / Painter, sampled over 72 minutes. EPA evaluated this sample as a 1-hr exposure ([OSHA, 2019](#))

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Unknown	Personal	Paint Sprayer	14.2	1	8-hr TWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
2	Unknown	Personal	Paint Sprayer	222.3	1	8-hr TWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
3	Sporting Goods	Personal	Spray Painter	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
4	Sporting Goods	Personal	Spray Painter	76.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
5	Sporting Goods	Personal	Spray Painter	270.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
6	Sporting Goods	Personal	Spray Painter	35.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
7	Metal Products	Personal	Spray Painter	22.5	1	6-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
8	Metal Products	Personal	Spray Painter	377.3	1	6-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
9	Metal Products	Personal	Spray Painter	313.5	1	6-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
10	A/C Equipment	Personal	Spray Painter	64.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
11	A/C Equipment	Personal	Spray Painter	54.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
12	A/C Equipment	Personal	Spray Painter	63.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
13	A/C Equipment	Personal	Spray Painter	36.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
14	A/C Equipment	Personal	Spray Painter	74.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
15	A/C Equipment	Personal	Spray Painter	0.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
16	A/C Equipment	Personal	Spray Painter	3.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
17	A/C Equipment	Personal	Spray Painter	4.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
18	Fabr. Rubber Products NEC	Personal	Spray Painter	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
19	Public Bldg. Furniture	Personal	Spray Painter	65.6	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
20	A/C & Heating Equipment	Personal	Spray Painter	87.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
21	A/C & Heating Equipment	Personal	Spray Painter	87.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
22	Airports	Personal	Spray Painter	69.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
23	Surgical Instruments	Personal	Spray Painter	42.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
24	Misc. Plastic Products	Personal	Spray Painter	156.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
25	Misc. Plastic Products	Personal	Spray Painter	439.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
26	Misc. Plastic Products	Personal	Spray Painter	255.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
27	Misc. Plastic Products	Personal	Spray Painter	264.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
28	DOD	Personal	009A-5, STRUCTURAL REPAIR, PAINTING OPS	0.9	1	2-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included – full-shift TWA (averaged over 8-hr )

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
31	DOD	Personal	009A-5, STRUCTURAL REPAIR, PAINTING OPS	7.1	1	2-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included – full-shift TWA (averaged over 8-hr )
33	Commercial Screen Printing	Personal	unknown	456.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
34	Commercial Screen Printing	Personal	unknown	1.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
35	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
36	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
37	Commercial Screen Printing	Personal	unknown	24.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
38	Commercial Screen Printing	Personal	unknown	7.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
39	Commercial Screen Printing	Personal	unknown	3.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
40	Commercial Screen Printing	Personal	unknown	97.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
41	Commercial Screen Printing	Personal	unknown	8.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
42	Commercial Screen Printing	Personal	unknown	1.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
43	Commercial Screen Printing	Personal	unknown	19.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
44	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
45	Commercial Screen Printing	Personal	unknown	63.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
46	Commercial Screen Printing	Personal	unknown	3.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
47	Commercial Screen Printing	Personal	unknown	61.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
48	Commercial Screen Printing	Personal	unknown	76.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
49	Commercial Screen Printing	Personal	unknown	3.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
50	Commercial Screen Printing	Personal	unknown	1.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
51	Commercial Screen Printing	Personal	unknown	70.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
52	Commercial Screen Printing	Personal	unknown	211.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
53	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
54	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
55	Commercial Screen Printing	Personal	unknown	227.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
56	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
57	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
58	Commercial Screen Printing	Personal	unknown	142.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
59	Commercial Screen Printing	Personal	unknown	3364.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
60	Commercial Screen Printing	Personal	unknown	5.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
61	Commercial Screen Printing	Personal	unknown	32.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA



**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
62	Commercial Screen Printing	Personal	unknown	9.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
63	Commercial Screen Printing	Personal	unknown	5.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
64	Commercial Screen Printing	Personal	unknown	38.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
65	Commercial Screen Printing	Personal	unknown	2.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
66	Commercial Screen Printing	Personal	unknown	2.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
67	Commercial Screen Printing	Personal	unknown	3.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
68	Commercial Screen Printing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
69	Commercial Screen Printing	Personal	unknown	1.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
70	Commercial Screen Printing	Personal	unknown	11.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
71	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	8.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
72	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	31.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
73	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	16.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
74	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	6.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
75	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	1.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
76	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
77	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	42.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
78	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	10.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
79	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	3.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
80	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	41.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
81	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	254.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
82	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	57.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
83	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	26.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
84	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	3.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
85	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	74.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
86	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
87	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
88	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
89	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	26.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
90	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	54.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
91	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	105.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
92	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	142.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
93	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	132.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
94	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	3.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
95	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	6.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
96	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	226.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
97	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	47.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
98	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	9.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
99	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
100	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
101	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
102	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
103	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
104	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
105	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
106	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	48.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
107	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	7.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
108	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
109	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
110	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	64.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
111	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	15.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
112	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	292.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
113	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	19.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
114	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	16.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
115	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	12.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
116	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	2.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
117	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	109.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
118	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	85.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
119	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	150.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
120	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	26.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
121	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
122	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	11.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
123	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	12.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
124	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	26.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
125	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	19.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
126	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	11.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
127	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
128	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
129	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
130	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
131	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
132	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	40.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
133	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	73.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
134	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	38.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
135	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	59.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
136	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	66.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
137	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	5.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
138	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	43.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
139	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	57.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
140	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	6.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
141	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	32.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
142	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
143	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	29.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
144	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	137.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
145	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	1.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
146	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
147	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	1.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
148	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	44.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
149	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	37.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
150	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	185.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
151	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	130.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
152	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	215.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
153	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	52.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
154	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	50.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
155	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
156	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
157	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	4.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
158	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	20.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
159	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	6.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
160	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	59.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
161	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	63.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
162	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	6.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
163	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	24.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
164	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
165	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
166	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
167	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	55.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
168	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	1.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
169	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	1.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
170	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	8.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
171	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	36.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
172	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	8.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
173	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	2.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
174	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	4.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
175	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	8.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
176	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	7.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
177	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	16.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
178	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	30.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
179	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
180	Wood Kitchen Cabinet and Countertop Manufacturing	Personal	unknown	23.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
181	Upholstered Household Furniture Manufacturing	Personal	unknown	1516.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
182	Upholstered Household Furniture Manufacturing	Personal	unknown	79.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
183	Upholstered Household Furniture Manufacturing	Personal	unknown	0.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
184	Upholstered Household Furniture Manufacturing	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
185	Upholstered Household Furniture Manufacturing	Personal	unknown	617.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
186	Upholstered Household Furniture Manufacturing	Personal	unknown	267.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
187	Upholstered Household Furniture Manufacturing	Personal	unknown	1.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
188	Upholstered Household Furniture Manufacturing	Personal	unknown	16.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
189	Upholstered Household Furniture Manufacturing	Personal	unknown	979.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA



**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
190	Upholstered Household Furniture Manufacturing	Personal	unknown	8.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
191	Upholstered Household Furniture Manufacturing	Personal	unknown	986.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
192	Upholstered Household Furniture Manufacturing	Personal	unknown	944.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
193	Upholstered Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
194	Upholstered Household Furniture Manufacturing	Personal	unknown	319.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
195	Upholstered Household Furniture Manufacturing	Personal	unknown	8.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
196	Upholstered Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
197	Upholstered Household Furniture Manufacturing	Personal	unknown	977.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
198	Upholstered Household Furniture Manufacturing	Personal	unknown	7.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
199	Upholstered Household Furniture Manufacturing	Personal	unknown	3.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
200	Upholstered Household Furniture Manufacturing	Personal	unknown	17.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
201	Upholstered Household Furniture Manufacturing	Personal	unknown	23.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
202	Upholstered Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
203	Upholstered Household Furniture Manufacturing	Personal	unknown	19.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
204	Upholstered Household Furniture Manufacturing	Personal	unknown	169.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
205	Upholstered Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
206	Upholstered Household Furniture Manufacturing	Personal	unknown	22.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
207	Upholstered Household Furniture Manufacturing	Personal	unknown	4.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
208	Upholstered Household Furniture Manufacturing	Personal	unknown	3.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
209	Upholstered Household Furniture Manufacturing	Personal	unknown	11.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
210	Upholstered Household Furniture Manufacturing	Personal	unknown	212.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
211	Upholstered Household Furniture Manufacturing	Personal	unknown	49.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
212	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	43.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
213	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	11.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
214	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	4.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
215	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
216	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	30.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
217	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	26.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
218	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	14.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
219	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	22.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
220	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	6.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
221	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	3.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
222	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	35.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
223	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	93.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
224	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	4.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
225	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	55.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
226	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
227	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
228	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
229	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	70.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
230	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	78.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
231	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
232	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	112.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
233	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
234	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	59.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
235	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	36.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
236	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	27.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
237	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
238	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
239	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	61.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
240	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	118.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
241	Nonupholstered Wood Household Furniture Manufacturing	Personal	unknown	100.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
242	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
243	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	115.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
244	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	1.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
245	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	17.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
246	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	52.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
247	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	4.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
248	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	179.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
249	Household Furniture (except Wood and Metal) Manufacturing	Personal	unknown	112.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
250	Institutional Furniture Manufacturing	Personal	unknown	31.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
251	Institutional Furniture Manufacturing	Personal	unknown	114.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
252	Institutional Furniture Manufacturing	Personal	unknown	141.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
253	Institutional Furniture Manufacturing	Personal	unknown	414.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
254	Institutional Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
255	Institutional Furniture Manufacturing	Personal	unknown	90.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
256	Institutional Furniture Manufacturing	Personal	unknown	14.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
257	Institutional Furniture Manufacturing	Personal	unknown	6.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
258	Institutional Furniture Manufacturing	Personal	unknown	239.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
259	Institutional Furniture Manufacturing	Personal	unknown	4.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
260	Institutional Furniture Manufacturing	Personal	unknown	1.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
261	Institutional Furniture Manufacturing	Personal	unknown	44.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
262	Institutional Furniture Manufacturing	Personal	unknown	3.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
263	Institutional Furniture Manufacturing	Personal	unknown	4.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
264	Institutional Furniture Manufacturing	Personal	unknown	17.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
265	Institutional Furniture Manufacturing	Personal	unknown	14.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
266	Institutional Furniture Manufacturing	Personal	unknown	6.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
267	Institutional Furniture Manufacturing	Personal	unknown	10.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
268	Institutional Furniture Manufacturing	Personal	unknown	10.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
269	Institutional Furniture Manufacturing	Personal	unknown	106.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
270	Institutional Furniture Manufacturing	Personal	unknown	86.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
271	Institutional Furniture Manufacturing	Personal	unknown	352.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
272	Institutional Furniture Manufacturing	Personal	unknown	11.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
273	Institutional Furniture Manufacturing	Personal	unknown	17.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
274	Institutional Furniture Manufacturing	Personal	unknown	0.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
275	Institutional Furniture Manufacturing	Personal	unknown	7.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
276	Institutional Furniture Manufacturing	Personal	unknown	10.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
277	Institutional Furniture Manufacturing	Personal	unknown	12.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
278	Institutional Furniture Manufacturing	Personal	unknown	57.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
279	Institutional Furniture Manufacturing	Personal	unknown	52.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
280	Institutional Furniture Manufacturing	Personal	unknown	13.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
281	Institutional Furniture Manufacturing	Personal	unknown	43.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
282	Institutional Furniture Manufacturing	Personal	unknown	73.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
283	Institutional Furniture Manufacturing	Personal	unknown	37.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
284	Institutional Furniture Manufacturing	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
285	Institutional Furniture Manufacturing	Personal	unknown	20.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-13. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
286	Institutional Furniture Manufacturing	Personal	unknown	12.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
287	Institutional Furniture Manufacturing	Personal	unknown	42.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
288	Institutional Furniture Manufacturing	Personal	unknown	54.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
289	Institutional Furniture Manufacturing	Personal	unknown	11.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
290	Institutional Furniture Manufacturing	Personal	unknown	11.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
291	Institutional Furniture Manufacturing	Personal	unknown	41.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
292	Institutional Furniture Manufacturing	Personal	unknown	432.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
293	Institutional Furniture Manufacturing	Personal	unknown	2.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
294	Institutional Furniture Manufacturing	Personal	unknown	34.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
295	General Automotive Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
296	General Automotive Repair	Personal	unknown	30.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
297	General Automotive Repair	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
298	General Automotive Repair	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

**Table\_Apx A-14. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Metro Bus maintenance shop	Personal	Painting	ND (<0.01)	1	STEL	<a href="#">NIOSH (1981)</a>	1.8	Worker 30-min STEL
2	Metro Bus maintenance shop	Personal	Painting	ND (<0.01)	1	STEL	<a href="#">NIOSH (1981)</a>	1.8	Worker 1-hr STEL
3	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	64.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 30-min STEL
4	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	54.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 30-min STEL
5	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	63.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 30-min STEL
6	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	36.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 15-min STEL
7	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 2 (Front) Spray Booth	74.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 30-min STEL
8	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 1 (Rear) Spray Booth	1.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 15-min STEL
9	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 1 (Rear) Spray Booth	3.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 30-min STEL
10	Metal Fabrication Plant	Personal	Spray Painter in Aisle No. 1 (Rear) Spray Booth	4.0	1	STEL	<a href="#">NIOSH (1973)</a>	1.7	Worker 30-min STEL
11	DOD	Personal	Painting Operations	4.1	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
12	DOD	Personal	Painting Operations	4.1	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
13	DOD	Personal	Painting Operations	4.1	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
14	DOD	Personal	Painting Operations	4.1	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
15	DOD	Personal	Priming Operations	5.2	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL



**Table\_Apx A-14. 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 <sup>3</sup> ) <sup>a,b</sup>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
17	DOD	Personal	IND-006-00 Coating Operations, Multiple Operations	1.9	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
18	DOD	Personal	IND-006-00 Coating Operations, Multiple Operations	1.9	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
19	DOD	Personal	NPS ECE aerosol can painting	13.5	1	STEL	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Worker 15-min STEL
20	Industrial Sign Manufacturing	Personal	Floor Manager, Painter	133.9	1	STEL	<a href="#">OSHA (2019)</a>	1.3	Worker 1-hr 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<sup>3</sup> 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.9 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 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<sup>3</sup> (10 ppm) to a few short-term exposures of over 14,100 mg/m<sup>3</sup> (4,063 ppm)<sup>2</sup>. The majority of the exposures were below 1,770 mg/m<sup>3</sup> (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<sup>3</sup> (83.3 ppm), but the ventilation rate or air change rate was not specified. The peak exposure during application was 460 mg/m<sup>3</sup> (133 ppm). The peak exposure during scrape-off ranged from 710 to 1,410 mg/m<sup>3</sup> (205 to 406 ppm), and the observed maximum during the study was 3,530 mg/m<sup>3</sup> (1,017 ppm). When no ventilation was used, the worst-case exposure exceeded 14,000 mg/m<sup>3</sup> (4,035 ppm). Based on the solvent manufacturer, 8-hr TWA exposures under supplier-recommended ventilation would be 187 to 226 mg/m<sup>3</sup> (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<sup>3</sup> (240 to 790 ppm) in an unventilated room, and 129.5 to 948 mg/m<sup>3</sup> (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<sup>3</sup> (133 to 859 ppm)<sup>3</sup> in unventilated rooms and 60 to 400 mg/m<sup>3</sup> (17 to 115 ppm) ventilated rooms ([TNO \(CIVO\), 1999](#)).

---

<sup>2</sup> The short-term exposure of over 14,100 mg/m<sup>3</sup> (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-15 ([TNO \(CIVO\), 1999](#)). EPA/OPPT calculated the midpoint values from the high-end values reported by the study authors.

<sup>3</sup> The methylene chloride air concentrations of 60 mg/m<sup>3</sup> (17 ppm) and 2,980 mg/m<sup>3</sup> (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-15 ([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<sup>3</sup> (52 ppm), ranging from 21 to 318 mg/m<sup>3</sup> (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<sup>3</sup> (25 ppm) ([EU, 2007](#)).
- Another case study observed an average personal methylene chloride exposure of 710 mg/m<sup>3</sup> (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<sup>3</sup> (115 ppm) and a minimum of zero mg/m<sup>3</sup>.<sup>4</sup> The average of all of the reported means was approximately 62 mg/m<sup>3</sup> (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<sup>3</sup> (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<sup>3</sup> (836 to 1,037 ppm). The stationary, 8-hr TWA concentration ranged from 1,700 to 2,000 mg/m<sup>3</sup> (490 to 576 ppm) ([U.S. EPA, 2014](#)).
- MRI reported breathing zone concentrations of 380 and 430 mg/m<sup>3</sup> (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<sup>3</sup> (86 to 141 ppm). The stationary, 8-hr TWA concentration ranged from 230 to 270 mg/m<sup>3</sup> (66 to 78 ppm) ([U.S. EPA, 2014](#)).

Table\_Apx A-15 and Table\_Apx A-16 present a summary of exposure data.

---

<sup>4</sup> The short-term exposure of 0 mg/m<sup>3</sup> 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-15 ([TNO \(CIVO\), 1999](#)).

**Table\_Apx A-15. 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 <sup>3</sup> ) <sup>a, b</sup>				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	<a href="#">U.S. EPA (2014)</a>	1.1	Included as best available data source (surrogate)

**Table\_Apx A-16. 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 <sup>3</sup> ) <sup>a, b</sup>				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	<a href="#">U.S. EPA (2014)</a>	1.1	Included as best available data source (surrogate)

## A.10 Fabric Finishing

---

Table\_Apx A-17 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 and 3 contain data provided by OSHA during apparel manufacturing for a presser and a finishing department supervisor (assumed as ONU). Sample times vary - however, exposures were adjusted to 8-hr TWAs ([OSHA, 2019](#)).
- Rows 4 through 41 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data come from textile and fabric industries, such as “Textile and Fabric Finishing Mills” and “Fabric and Coating Mills.” However, worker activities for these exposure data points are not known. Sample times vary - however, exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

Table\_Apx A-17 presents short-term monitoring data for fabric finishing.

- Row 1 contains data provided by OSHA during methylene chloride spraying. The exposure data presented is for a 194-minute sample time. As there are no health comparisons for 3-hr samples, this data point is presented but not used to calculate risk ([OSHA, 2019](#)).

**Table\_Apx A-17. 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 <sup>3</sup> ) <sup>a, b, c</sup>	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	<a href="#">TNO (CIVO) (1999)</a>	2.3	Excluded – Used direct monitoring data
2	Women’s, Girls’, and Infants’ Cut and Sew Apparel Manufacturing	Personal	Presser	0.8	1	Worker 8-hr TWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
3	Women’s, Girls’, and Infants’ Cut and Sew Apparel Manufacturing	Personal	Supervisor - Finishing Dept	1.2	1	ONU 8-hr TWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA (ONU)
4	Textile and Fabric Finishing Mills	Personal	unknown	30.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
5	Textile and Fabric Finishing Mills	Personal	unknown	24.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
6	Textile and Fabric Finishing Mills	Personal	unknown	2.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
7	Textile and Fabric Finishing Mills	Personal	unknown	11.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
8	Textile and Fabric Finishing Mills	Personal	unknown	7.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
9	Textile and Fabric Finishing Mills	Personal	unknown	7.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
10	Textile and Fabric Finishing Mills	Personal	unknown	216.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
11	Textile and Fabric Finishing Mills	Personal	unknown	34.0	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
12	Textile and Fabric Finishing Mills	Personal	unknown	24.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
13	Textile and Fabric Finishing Mills	Personal	unknown	64.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
14	Textile and Fabric Finishing Mills	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-17. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
15	Textile and Fabric Finishing Mills	Personal	unknown	5.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
16	Textile and Fabric Finishing Mills	Personal	unknown	6.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
17	Textile and Fabric Finishing Mills	Personal	unknown	331.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
18	Textile and Fabric Finishing Mills	Personal	unknown	2.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
19	Textile and Fabric Finishing Mills	Personal	unknown	7.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
20	Fabric Coating Mills	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
21	Fabric Coating Mills	Personal	unknown	99.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
22	Fabric Coating Mills	Personal	unknown	23.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
23	Fabric Coating Mills	Personal	unknown	6.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
24	Fabric Coating Mills	Personal	unknown	1.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
25	Fabric Coating Mills	Personal	unknown	1.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
26	Fabric Coating Mills	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
27	Fabric Coating Mills	Personal	unknown	5.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
28	Fabric Coating Mills	Personal	unknown	11.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
29	Fabric Coating Mills	Personal	unknown	12.5	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
30	Fabric Coating Mills	Personal	unknown	4.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-17. 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 <sup>3</sup> ) <sup>a, b, c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
31	Fabric Coating Mills	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
32	Fabric Coating Mills	Personal	unknown	124.1	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
33	Fabric Coating Mills	Personal	unknown	7.2	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
34	Fabric Coating Mills	Personal	unknown	91.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
35	Fabric Coating Mills	Personal	unknown	11.4	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
36	Fabric Coating Mills	Personal	unknown	11.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
37	Fabric Coating Mills	Personal	unknown	3.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
38	Fabric Coating Mills	Personal	unknown	126.7	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
39	Fabric Coating Mills	Personal	unknown	2.9	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
40	Fabric Coating Mills	Personal	unknown	82.6	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
41	Fabric Coating Mills	Personal	unknown	8.8	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

**Table\_Apx A-18. Summary of Short-Term Inhalation Monitoring Data for Fabric Finishing**

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m <sup>3</sup> ) <sup>a, b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	All Other Leather Good and Allied Product Manufacturing	Personal	Sprayer of Methylene Chloride	10	1	194-min sample	<a href="#">OSHA (2019)</a>	2.3	No short-term health comparisons



**Table\_Apx A-18. Summary of Short-Term Inhalation Monitoring Data for Fabric Finishing**

Row	Industry	Type of Sample	Worker Activity or Sampling Location	Methylene Chloride Airborne Concentration (mg/m <sup>3</sup> ) <sup>a, b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
									for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.

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<sup>3</sup> 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 Spot Cleaning**

---

Table\_Apx A-19 presents full-shift inhalation monitoring data for the use of methylene chloride for at industrial launderers:

- Rows 1 through 18 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data mainly come from Industrial Launderer and Drycleaning and Laundry Services (except Coin-Operated) sites. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

**Table Apx A-19. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Drycleaning and Laundry Services (except Coin-Operated)	Personal	unknown	0.11	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
2	Drycleaning and Laundry Services (except Coin-Operated)	Personal	unknown	0.11	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
3	Drycleaning and Laundry Services (except Coin-Operated)	Personal	unknown	0.11	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
4	Drycleaning and Laundry Services (except Coin-Operated)	Personal	unknown	0.11	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
5	Drycleaning and Laundry Services (except Coin-Operated)	Personal	unknown	0.11	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
6	Drycleaning and Laundry Services (except Coin-Operated)	Personal	unknown	0.11	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
7	Drycleaning and Laundry Services (except Coin-Operated)	Personal	unknown	0.11	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
8	Industrial Launderers	Personal	unknown	0.60	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
9	Industrial Launderers	Personal	unknown	118.03	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
10	Industrial Launderers	Personal	unknown	7.29	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
11	Industrial Launderers	Personal	unknown	2.44	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
12	Industrial Launderers	Personal	unknown	0.73	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
13	Industrial Launderers	Personal	unknown	410.35	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
14	Industrial Launderers	Personal	unknown	0.19	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
15	Industrial Launderers	Personal	unknown	1.64	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
16	Industrial Launderers	Personal	unknown	3.03	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-19. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
17	Industrial Launderers	Personal	unknown	2.66	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
18	Industrial Launderers	Personal	unknown	145.82	1	TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

## A.12 Cellulose Triacetate Film Production

---

Table\_Apx A-20 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<sup>3</sup> ([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<sup>3</sup> ([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<sup>3</sup>; 20 mg/m<sup>3</sup> (mean).
  - An IPCS study reported 8-hr TWA exposures up to 350 mg/m<sup>3</sup>

**Table\_Apx A-20. 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 <sup>3</sup> ) <sup>a,b</sup>			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	<a href="#">Ott et al. (1983)</a>	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	<a href="#">Ott et al. (1983)</a>	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	<a href="#">Ott et al. (1983)</a>	2.2	Included – full-shift TWA
4	CTA Film Manufacturing	Personal	Cellulose Triacetate - Preparation Area	17.37	1,319.98	-	26	8-hr TWA	<a href="#">Ott et al. (1983)</a>	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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA

**Table\_Apx A-20. 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 <sup>3</sup> ) <sup>a,b</sup>			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	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
15	CTA Film Manufacturing	Personal	CTA film-base production / extrusion & preparation areas	DL	5905.15	-	-	8-hr TWA	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
17	CTA Film Manufacturing	Personal	CTA film-base production / Dope section	-	-	253.57	47	8-hr TWA	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
18	CTA Film Manufacturing	Personal	CTA film-base production / Operator (D block)	-	-	305.68	47	8-hr TWA	<a href="#">Dell et al. (1999)</a>	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	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
20	CTA Film Manufacturing	Personal	CTA film-base production / Solvent Recovery	-	-	93.79	47	8-hr TWA	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
21	CTA Film Manufacturing	Personal	CTA film-base production / Cleaning	-	-	86.84	47	8-hr TWA	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
22	CTA Film Manufacturing	Personal	CTA film-base production / Subwash operator	-	-	34.74	47	8-hr TWA	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
23	CTA Film Manufacturing	Personal	CTA film-base production / Laboratory	-	-	24.32	47	8-hr TWA	<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
24	CTA Film Manufacturing	Personal	CTA film-base production / Polyester film worker and electroplater				21		<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
25	CTA Film Manufacturing	Personal	CTA film-base production / MeCl work area, not otherwise spec				30		<a href="#">Dell et al. (1999)</a>	2.1	Included – full-shift TWA
26	CTA Film Manufacturing	Personal	CTA production	0	60 3650	20	unknown		<a href="#">TNO (CIVO) (1999)</a>	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  $\text{mg}/\text{m}^3$  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 Flexible Polyurethane Foam Manufacturing

---

Table\_Apx A-21 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<sup>3</sup>) and during miscellaneous tasks in PU foam production (7 – 700 mg/m<sup>3</sup>, mean 231 mg/m<sup>3</sup>) ([TNO \(CIVO\), 1999](#)).
- Row 3 presents an 8-hr TWA data exposure concentration of 27.8 mg/m<sup>3</sup> 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<sup>3</sup> ([NIOSH, 1990a](#)).
- 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<sup>3</sup>. 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<sup>3</sup> ([Cone Mills, 1982](#)).
- 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<sup>3</sup> ([Cone Mills, 1981](#)).
- Rows 29 through 31 present exposures from a 1989 monitoring study a Vulcan Chemicals facility, which used MeCl as an auxiliary 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<sup>3</sup> ([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<sup>3</sup> ([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<sup>3</sup> ([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-22 presents the short-term data:

- Rows 1 through 8 contain 30-min 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/mg3 (30-min TWA) and 5.5 to 38.0 mg/m3 (3-hr TWA) ([US EPA, 1985](#)). Because there are no short-term health comparisons for 3-hr TWA data, EPA presents the data point, but is not used to calculate risk.

**Table Apx A-21. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Foam Industry	Personal	Blowing Agent	13 - 570	1	8-hr TWA	<a href="#">TNO (CIVO) (1999)</a>	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	<a href="#">TNO (CIVO) (1999)</a>	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	<a href="#">IARC (2016)</a>	1.9	Included – full-shift TWA
4	Tractor Trailer Construction	Personal	Foam Operator	4.5	1	8-hr TWA	<a href="#">NIOSH (1990a)</a>	1.7	Included – full-shift TWA
5	Tractor Trailer Construction	Personal	Foam Operator	17.4	1	8-hr TWA	<a href="#">NIOSH (1990a)</a>	1.7	Included – full-shift TWA
6	Tractor Trailer Construction	Personal	Foam Operator	10.8	1	8-hr TWA	<a href="#">NIOSH (1990a)</a>	1.7	Included – full-shift TWA
7	Tractor Trailer Construction	Personal	Foam Operator	17.7	1	8-hr TWA	<a href="#">NIOSH (1990a)</a>	1.7	Included – full-shift TWA
8	Tractor Trailer Construction	Personal	Foam Operator	15.6	1	8-hr TWA	<a href="#">NIOSH (1990a)</a>	1.7	Included – full-shift TWA
9	Foam industry	Personal	Moulding	88-1,090	unknown	8-hr TWA	<a href="#">(IPCS) (1996)</a>	2.3	Included – full-shift TWA
10	Foam industry	Personal	Moulding	<247	unknown	8-hr TWA	<a href="#">(IPCS) (1996)</a>	2.3	Included – full-shift TWA
11	Foam industry	Personal	Unknown	7.1-- 251	unknown	8-hr TWA	<a href="#">(IPCS) (1996)</a>	2.3	Included – full-shift TWA
12	Foam industry	Personal	Various jobs	18 -- 580	unknown	8-hr TWA	<a href="#">(IPCS) (1996)</a>	2.3	Included – full-shift TWA
13	Cone Mills Corporation-Corporate Medical Department	Personal	Spraying	111.2	1	8-hr TWA	<a href="#">Cone Mills (1982)</a>	1.7	Included – full-shift TWA
14	Cone Mills Corporation-Corporate Medical Department	Personal	Spraying	114.6	1	8-hr TWA	<a href="#">Cone Mills (1982)</a>	1.7	Included – full-shift TWA
15	Cone Mills Corporation-Corporate Medical Department	Personal	Spraying	86.8	1	8-hr TWA	<a href="#">Cone Mills (1982)</a>	1.7	Included – full-shift TWA
16	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	13.9	1	8-hr TWA	<a href="#">Cone Mills (1981)</a>	1.7	Included – full-shift TWA
17	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	38.2	1	8-hr TWA	<a href="#">Cone Mills (1981)</a>	1.7	Included – full-shift TWA
18	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	243.2	1	8-hr TWA	<a href="#">Cone Mills (1981)</a>	1.7	Included – full-shift TWA
19	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Line Operator	625.3	1	8-hr TWA	<a href="#">Cone Mills (1981)</a>	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	<a href="#">Cone Mills (1981)</a>	1.7	Included – full-shift TWA

**Table Apx A-21. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
21	Cone Mills Corporation-Corporate Medical Department	Personal	Cut-Off Saw Operator in Foam Storage Removal	521.0	1	8-hr TWA	<a href="#">Cone Mills (1981)</a>	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	<a href="#">Cone Mills (1981)</a>	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	<a href="#">Cone Mills (1981)</a>	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	<a href="#">Cone Mills (1981)</a>	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	<a href="#">Cone Mills (1981)</a>	1.7	Included – full-shift TWA
26	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Storage Crane Operators	486.3	1	8-hr TWA	<a href="#">Cone Mills (1981)</a>	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	<a href="#">Cone Mills (1981)</a>	1.7	Included – full-shift TWA
28	Cone Mills Corporation-Corporate Medical Department	Personal	Foam Storage Crane Operators	521.0	1	8-hr TWA	<a href="#">Cone Mills (1981)</a>	1.7	Included – full-shift TWA
29	Vulcan Chemicals	Personal	Saw Operator	654.5	1	8-hr TWA	<a href="#">Vulcan Chemicals (1991)</a>	1.9	Included – full-shift TWA
30	Vulcan Chemicals	Personal	Quality Control Operator	773.1	1	8-hr TWA	<a href="#">Vulcan Chemicals (1991)</a>	1.9	Included – full-shift TWA
31	Vulcan Chemicals	Personal	Flat Top Operator	682.9	1	8-hr TWA	<a href="#">Vulcan Chemicals (1991)</a>	1.9	Included – full-shift TWA
32	Olin Chemicals	Personal	Batch operations	91.0	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
33	Olin Chemicals	Personal	Batch operations	167.1	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
34	Olin Chemicals	Personal	Drumming	94.1	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
35	Olin Chemicals	Personal	Drumming	377.2	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA

**Table Apx A-21. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
36	Olin Chemicals	Personal	Purge Operations	110.8	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
37	Olin Chemicals	Personal	Purge Operations	0.3	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
38	Olin Chemicals	Personal	Cylinder cleaning	620.0	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
39	Olin Chemicals	Personal	Cylinder cleaning	515.1	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
40	Olin Chemicals	Personal	Blending	112.9	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
41	Olin Chemicals	Personal	Blending	38.9	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
42	Olin Chemicals	Personal	Blending	225.1	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
43	Olin Chemicals	Personal	Laboratory Operations	2200.9	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
44	Olin Chemicals	Personal	Laboratory Operations	1039.3	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
45	Olin Chemicals	Personal	Batch operations	336.2	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
46	Olin Chemicals	Personal	Batch operations	242.1	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
47	Olin Chemicals	Personal	Laboratory Operations	266.1	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
48	Olin Chemicals	Personal	Laboratory Operations	323.0	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
49	Olin Chemicals	Personal	Filter cleaning, MDA tank	1400.6	1	8-hr TWA	<a href="#">Olin Chemicals (1977)</a>	1.9	Included – full-shift TWA
50	Plastic Products	Personal	Foam Gun Operator	558.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
51	Plastic Products	Personal	Foam Gun Operator	942.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
52	Plastic Products	Personal	Foam Gun Operator	767.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
53	Plastic Products	Personal	Foam Gun Operator	698	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA

**Table Apx A-21. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
54	Plastic Products	Personal	Inj. Mold Operator	24.43	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
55	Plastic Products	Personal	Inj. Mold Operator	34.98	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
56	Household Refrigerators	Personal	Foam Operator	173.104	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
57	Household Refrigerators	Personal	Foam Operator	169.265	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
58	Household Refrigerators	Personal	Foam Operator	87.25	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
59	Prefab Metal Buildings	Personal	Foamline Operator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA; assumed zero value
60	Food Product Machinery	Personal	Foam Injecting	111.331	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
61	Plastic Products	Personal	Crusher	296.63	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
62	Plastic Products	Personal	Crusher	17.45	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
63	Plastic Products	Personal	Crusher	146.58	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
64	Plastic Products	Personal	Skin Layer	523.58	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
65	Plastic Products	Personal	Skin Layer	272.22	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
66	Plastic Products	Personal	Skin Layer	122.15	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
67	Plastic Products	Personal	Beaders	1001.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
68	Plastic Products	Personal	Beaders	418.88	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
69	Plastic Products	Personal	Beaders	383.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
70	Plastic Products	Personal	Beaders	97.72	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
71	Plastic Products	Personal	Waxer	558.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
72	Plastic Products	Personal	Waxer	872.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
73	Plastic Products	Personal	Vacuum Former	216.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
74	Plastic Products	Personal	Crimper	6.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
75	Plastic Products	Personal	Mold Opener	254.77	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
76	Plastic Products	Personal	Mold Opener	167.52	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – full-shift TWA
77	Plastic Products	Personal	Shearing Machine	17.45	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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<sup>3</sup> 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-22. 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/m <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Appliance Manufacturing	Personal	Foam Blowing	5.2	1	STEL	<a href="#">US EPA (1985)</a>	1.4	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
2	Appliance Manufacturing	Personal	Foam Blowing	13.1	1	STEL	<a href="#">US EPA (1985)</a>	1.4	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
3	Appliance Manufacturing	Personal	Foam Blowing	18.5	1	STEL	<a href="#">US EPA (1985)</a>	1.4	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
4	Appliance Manufacturing	Personal	Foam Blowing	17.0	1	STEL	<a href="#">US EPA (1985)</a>	1.4	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
5	Appliance Manufacturing	Personal	Foam Blowing	5.2	1	STEL	<a href="#">US EPA (1985)</a>	1.4	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
6	Appliance Manufacturing	Personal	Foam Blowing	38.0	1	STEL	<a href="#">US EPA (1985)</a>	1.4	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
7	Appliance Manufacturing	Personal	Foam Blowing	10.5	1	STEL	<a href="#">US EPA (1985)</a>	1.4	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
8	Toys	Personal	Nozzle Cleaning	54.5	1	STEL	<a href="#">US EPA (1985)</a>	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<sup>3</sup> 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 Laboratory Use

---

Table\_Apx A-23 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<sup>3</sup> ([NIOSH, 1990b](#)).
- 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<sup>3</sup>) ([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<sup>3</sup> ([\(DOEHRS-IH\), 2018](#)).
- Row 12 contains data provided by OSHA for an extractions lab tech. Sample was taken over 13.3 hours. EPA assumed this value as an 8-hr TWA value ([OSHA, 2019](#)).
- Rows 13 through 77 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data mainly come from Medical Laboratories and Testing Laboratories. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

Table\_Apx A-24 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 ([NIOSH, 1990b](#))
- Row 13 presents a data point from IARC that indicated short-term exposures less than 3.5 mg/m<sup>3</sup>, 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<sup>3</sup> (various sample times) ([\(DOEHRS-IH\), 2018](#)).
- From rows 1 through 12 and 14 through 44, EPA evaluated 15 samples with durations ranging from 10 to 19 minutes, as 15-minute exposures; 10 samples with durations ranging from 24 to 31 minutes, as 30-minute exposures, two samples with durations ranging from 48 to 59 minutes, as 1-hr exposures, and six samples with durations ranging from 218 to 244 minutes, as 4-hr exposures. For eight samples, as there are no health comparisons for 2- or 3-hr samples, these data points are presented but not used to calculate risk.
- Rows 45 and 46 contain data from OSHA inspections for organic preparation lab techs. Sample durations were 49 to 53 minutes and resulted in ND. However, the limit of detection was not provided; therefore these values were not used to calculate risk ([OSHA, 2019](#)).



**Table\_Apx A-23. 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 <sup>3</sup> ) <sup>a,b,c</sup>	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 <sup>a</sup>	1	TWA	<a href="#">NIOSH (1990a)</a>	1.8	Included – full-shift TWA
2	Analytical Laboratory	Personal	Transferring sample from 250-ml beakers, load on steam bath	3.3 <sup>a</sup>	1	TWA	<a href="#">NIOSH (1990a)</a>	1.8	Included – full-shift TWA
3	Analytical Laboratory	Personal	Sample concentrating	2.8 <sup>a</sup>	1	TWA	<a href="#">NIOSH (1990a)</a>	1.8	Included – full-shift TWA
4	Laboratory	Personal	Research lab staff	3.5	1	TWA	<a href="#">Texaco Inc (1993)</a>	1.9	Included – full-shift TWA
5	Laboratory	Personal	Research lab staff	3.5	1	TWA	<a href="#">Texaco Inc (1993)</a>	1.9	Included – full-shift TWA
6	Laboratory	Personal	Pro lab Staff	3.5	1	TWA	<a href="#">Texaco Inc (1993)</a>	1.9	Included – full-shift TWA
7	Laboratory	Personal	Research lab staff	3.5	1	TWA	<a href="#">Texaco Inc (1993)</a>	1.9	Excluded – repeat of above data
8	DOD Laboratory	Personal	INSTRUMENT ANALYSIS	4.9	1	TWA	<a href="#">((DOEHRS-IH), 2018)</a> .	1.3	Included – full-shift TWA
9	DOD Laboratory	Personal	LAB SAMPLE PREPARATION	6.4	1	TWA	<a href="#">((DOEHRS-IH), 2018)</a> .	1.3	Included – full-shift TWA
10	DOD Laboratory	Personal	LAB SAMPLE PREPARATION	3.3	1	TWA	<a href="#">((DOEHRS-IH), 2018)</a> .	1.3	Included – full-shift TWA
11	DOD Laboratory	Personal	LAB SAMPLE PREPARATION	16.6	1	TWA	<a href="#">((DOEHRS-IH), 2018)</a> .	1.3	Included – full-shift TWA
12	Laboratory	Personal	Extractions Lab Tech	49.36	1	TWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
13	Testing Laboratories	Personal	unknown	94.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
14	Testing Laboratories	Personal	unknown	4.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-23. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
15	Testing Laboratories	Personal	unknown	11.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
16	Testing Laboratories	Personal	unknown	25.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
17	Testing Laboratories	Personal	unknown	371.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
18	Testing Laboratories	Personal	unknown	27.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
19	Testing Laboratories	Personal	unknown	61.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
20	Testing Laboratories	Personal	unknown	45.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
21	Testing Laboratories	Personal	unknown	23.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
22	Testing Laboratories	Personal	unknown	3.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
23	Testing Laboratories	Personal	unknown	32.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
24	Testing Laboratories	Personal	unknown	18.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
25	Testing Laboratories	Personal	unknown	13.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
26	Testing Laboratories	Personal	unknown	1.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
27	Testing Laboratories	Personal	unknown	1.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
28	Testing Laboratories	Personal	unknown	21.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
29	Testing Laboratories	Personal	unknown	25.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
30	Testing Laboratories	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-23. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
31	Testing Laboratories	Personal	unknown	9.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
32	Testing Laboratories	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
33	Testing Laboratories	Personal	unknown	24.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
34	Testing Laboratories	Personal	unknown	1.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
35	Testing Laboratories	Personal	unknown	14.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
36	Testing Laboratories	Personal	unknown	6.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
37	Testing Laboratories	Personal	unknown	8.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
38	Testing Laboratories	Personal	unknown	180.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
39	Testing Laboratories	Personal	unknown	0.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
40	Testing Laboratories	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
41	Testing Laboratories	Personal	unknown	47.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
42	Testing Laboratories	Personal	unknown	10.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
43	Testing Laboratories	Personal	unknown	7.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
44	Testing Laboratories	Personal	unknown	13.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
45	Testing Laboratories	Personal	unknown	21.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
46	Testing Laboratories	Personal	unknown	2.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-23. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
47	Testing Laboratories	Personal	unknown	3.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
48	Testing Laboratories	Personal	unknown	6.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
49	Testing Laboratories	Personal	unknown	10.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
50	Testing Laboratories	Personal	unknown	9.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
51	Testing Laboratories	Personal	unknown	0.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
52	Testing Laboratories	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
53	Testing Laboratories	Personal	unknown	4.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
54	Testing Laboratories	Personal	unknown	6.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
55	Testing Laboratories	Personal	unknown	3.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
56	Testing Laboratories	Personal	unknown	1.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
57	Testing Laboratories	Personal	unknown	11.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
58	Testing Laboratories	Personal	unknown	4.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
59	Testing Laboratories	Personal	unknown	16.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
60	Testing Laboratories	Personal	unknown	18.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
61	Testing Laboratories	Personal	unknown	3.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
62	Testing Laboratories	Personal	unknown	3.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-23. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
63	Testing Laboratories	Personal	unknown	2.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
64	Testing Laboratories	Personal	unknown	5.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
65	Testing Laboratories	Personal	unknown	7.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
66	Testing Laboratories	Personal	unknown	1.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
67	Testing Laboratories	Personal	unknown	11.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
68	Testing Laboratories	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
69	Medical Laboratories	Personal	unknown	4.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
70	Medical Laboratories	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
71	Medical Laboratories	Personal	unknown	125.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
72	Medical Laboratories	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
73	Medical Laboratories	Personal	unknown	1.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
74	Medical Laboratories	Personal	unknown	8.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
75	Medical Laboratories	Personal	unknown	4.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
76	Medical Laboratories	Personal	unknown	82.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
77	Medical Laboratories	Personal	unknown	4.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

**Table\_Apx A-24. 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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Analytical Laboratory	Personal	sample concentrating	2.7	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Included - Worker 4-hr TWA
2	Analytical Laboratory	Personal	sample sonification	3.9	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Included - Worker 4-hr TWA
3	Analytical Laboratory	Personal	sample sonification	4.5	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Included - Worker 4-hr TWA
4	Analytical Laboratory	Personal	washing separatory funnels in sink near CLLE	113.0	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Included - Worker 15-min STEL
5	Analytical Laboratory	Personal	column cleaning	10.0	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
6	Analytical Laboratory	Personal	sample concentrating	30.0	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
7	Analytical Laboratory	Personal	sample concentrating	4.2	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Included - Worker 4-hr TWA
8	Analytical Laboratory	Personal	sample concentrating	6.8	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
9	Analytical Laboratory	Personal	transferring 100 ml MeCl into soil samples	9.8	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
10	Analytical Laboratory	Personal	collecting waste chemicals & dumping into waste chemical storage	995.0	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Included - Worker 30-min TWA
11	Analytical Laboratory	Personal	above refrigerator #G in organic lab storage	17.0	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Excluded - Personal Samples Prioritized
12	Analytical Laboratory	Personal	on top of refrigerator #F in organics lab storage	11.0	1	STEL	<a href="#">NIOSH (1990b)</a>	1.8	Excluded - Personal Samples Prioritized

**Table\_Apx A-24. 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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
13	Analytical Laboratory	Personal	Laboratory worker	3.5	1	STEL	<a href="#">IARC (2016)</a>	2.2	Excluded - no info on type of sampling
14	DOD Laboratory	Personal	Miscellaneous lab operations	3.1	1	4-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 4-hr TWA
15	DOD Laboratory	Personal	Miscellaneous lab operations	3.1	1	4-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 4-hr TWA
16	DOD Laboratory	Personal	Sample extraction and analysis (3809, OCD)	34.7	1	3-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.
17	DOD Laboratory	Personal	(3)GC Extraction	0.7	1	2.5-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 1-hr TWA
21	DOD Laboratory	Personal	Analysis, chemical (Laboratory Operations)	2.4	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 1-hr TWA
22	DOD Laboratory	Personal	LAB ACTIVITIES	3.3	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
23	DOD Laboratory	Personal	LAB ACTIVITIES	6.4	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
24	DOD Laboratory	Personal	LAB ACTIVITIES	16.6	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA



**Table\_Apx A-24. 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) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
25	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
26	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
27	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
28	DOD Laboratory	Personal	LAB ACTIVITIES	3.4	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
29	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	1	30-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
30	DOD Laboratory	Personal	514A Using Solvents	1830.0	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
31	DOD Laboratory	Personal	EXTRACTION OP	3.6	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
32	DOD Laboratory	Personal	EXTRACTION OP	24.8	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 30-min TWA
33	DOD Laboratory	Personal	(3)GC Extraction	10.4	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
34	DOD Laboratory	Personal	(3)GC Extraction	10.4	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
35	DOD Laboratory	Personal	Sample extraction and analysis (3809, OCD)	62.5	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
36	DOD Laboratory	Personal	Miscellaneous lab operations	6.7	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
37	DOD Laboratory	Personal	EXTRACTION OP	4.6	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
38	DOD Laboratory	Personal	EXTRACTION OP	4.6	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA

**Table\_Apx A-24. 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/m <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
41	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	5.4	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
43	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	10.9	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
44	DOD Laboratory	Personal	PRO-001-01 LABORATORY CHEMICAL ANALYSIS/SAMPLING	13.2	1	15-min TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 15-min TWA
45	Laboratory	Personal	Organic Prep Lab Tech	ND	1	1-hr TWA	<a href="#">OSHA (2019)</a>	1.3	Not Included – Limit of Detection not provided
46	Laboratory	Personal	Organic Prep Lab Tech	ND	1	1-hr TWA	<a href="#">OSHA (2019)</a>	1.3	Not Included – Limit of Detection 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<sup>3</sup> 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.15 Plastic Product Manufacturing

---

Table\_Apx A-25 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<sup>3</sup>. Specific worker activities were not specified ([OSHA, 2019](#)).
- Row 6 presents an 8-hr TWA of 28.5 mg/m<sup>3</sup> 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<sup>3</sup> from fabrication of rubber products ([IPCS, 1996](#)).
- Rows 8 through 27 contain monitoring data provided by HSIA, with sampling dates between 2005 and 2017 at one facility, for production technicians during plastic product manufacturing. Exposure concentrations ranged from 3.9 to 134.1 mg/m<sup>3</sup> ([Halogenated Solvents Industry Alliance, 2018](#)). HSIA indicated that samples are taken as part of the company's continuous IH monitoring program.
- 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<sup>3</sup> ([GE, 1989](#)).
- Row 31 contains data provided by OSHA for an assistant supervisor. Sample was taken over 423 minutes and scaled to an 8-hr TWA value ([OSHA, 2019](#)).
- Rows 32 through 63 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data mainly come from Plastics Material and Resin Manufacturing and Synthetic Rubber Manufacturing facilities. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

Table\_Apx A-26 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<sup>3</sup> over 15 to 20 minute sampling times. Specific worker activities were not specified. ([OSHA, 2019](#)). EPA these samples as 15-minute exposures.
- Rows 4 through 24 contain monitoring data provided by HSIA, with sampling dates between 2005 and 2017 at one facility, for operators and production technicians during plastic product manufacturing. Exposure concentrations ranged from 50.7 to 166.7mg/m<sup>3</sup> over 8 to 26 minute sampling times ([Halogenated Solvents Industry Alliance, 2018](#)). HSIA indicated that samples are taken as part of the company's continuous IH monitoring program. EPA evaluated samples with durations ranging from 8 to 21 minutes as 15-minute exposures and samples with durations ranging from 22 to 26 minutes as 30-minute exposures.
- Rows 24 and 25 contain OSHA inspection data for a CSHO and an extruder operator. The CSHO sample was taken over 92 minutes and reported ND; however, the limit of detection was not provided. The extruder operator sample was taken over 313 minutes; however, there are no health comparisons available for 5-hr TWA. Both data points are presented but are not used to calculate risk. ([OSHA, 2019](#)).

**Table\_Apx A-25. 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 <sup>3</sup> ) <sup>a,b</sup>	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	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
2	All Other Plastics Product Manufacturing	Personal	Hop Area Operator	11.5	1	8-hrTWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
3	All Other Plastics Product Manufacturing	Personal	Hop Area Operator	2674.7	1	8-hrTWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
4	All Other Plastics Product Manufacturing	Personal	Injection Molding Operator	35.8	1	8-hrTWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
5	All Other Plastics Product Manufacturing	Personal	Injection Molding Operator	32.7	1	8-hrTWA	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA
6	Polyurethane Part Manufacturing (Casting)	Personal	Mix and heat ingredients in oven	28.5	1	8-hr TWA	<a href="#">Fairfax and Porter (2006)</a>	1.6	Included – full-shift TWA
7	Rubber Products	Personal	Fabrication	208 – 304	Unknown	8-hr TWA	<a href="#">(IPCS) (1996)</a>	2.3	Included – full-shift TWA
8	Plastics material and resin manufacturing	Personal	Production technician	5.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
9	Plastics material and resin manufacturing	Personal	Production technician	5.2	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
10	Plastics material and resin manufacturing	Personal	Production technician	25.5	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
11	Plastics material and resin manufacturing	Personal	Production technician	31.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
12	Plastics material and resin manufacturing	Personal	Production technician	4.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
13	Plastics material and resin manufacturing	Personal	Production technician	7.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA

**Table\_Apx A-25. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
14	Plastics material and resin manufacturing	Personal	Production technician	3.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
15	Plastics material and resin manufacturing	Personal	Production technician	3.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
16	Plastics material and resin manufacturing	Personal	Production technician	6.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
17	Plastics material and resin manufacturing	Personal	Production technician	3.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
18	Plastics material and resin manufacturing	Personal	Production technician	3.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
19	Plastics material and resin manufacturing	Personal	Production technician	14.9	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
20	Plastics material and resin manufacturing	Personal	Production technician	134.1	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
21	Plastics material and resin manufacturing	Personal	Production technician	16.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
22	Plastics material and resin manufacturing	Personal	Production technician	7.7	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
23	Plastics material and resin manufacturing	Personal	Production technician	20.3	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
24	Plastics material and resin manufacturing	Personal	Production technician	11.4	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA

**Table\_Apx A-25. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
25	Plastics material and resin manufacturing	Personal	Production technician	12.8	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
26	Plastics material and resin manufacturing	Personal	Production technician	5.1	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
27	Plastics material and resin manufacturing	Personal	Production technician	17.1	1	8-hr TWA	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Included – full-shift TWA
28	Plastic Polymer Plant	Personal	Operators	170.2	1	8-hr TWA	<a href="#">GE (1989)</a>	2.0	Included – full-shift TWA
29	Plastic Polymer Plant	Personal	Operators/Maintenance/Lab technicians	37.9	1	8-hr TWA	<a href="#">GE (1989)</a>	2.0	Included – full-shift TWA
30	Plastic Polymer Plant	Personal	Shift leaders/lab technicians	11.5	1	8-hr TWA	<a href="#">GE (1989)</a>	2.0	Included – full-shift TWA
31	Plastics Manufacturing	Personal	Assistant Supervisors	10.3	1	8-hr TWA (ONU)	<a href="#">OSHA (2019)</a>	1.3	Included – full-shift TWA (ONU)
32	Plastics Material and Resin Manufacturing	Personal	Unknown	48.9	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
33	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
34	Plastics Material and Resin Manufacturing	Personal	Unknown	9.0	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
35	Plastics Material and Resin Manufacturing	Personal	Unknown	31.7	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
36	Plastics Material and Resin Manufacturing	Personal	Unknown	6.4	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
37	Plastics Material and Resin Manufacturing	Personal	Unknown	6.2	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
38	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-25. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
39	Plastics Material and Resin Manufacturing	Personal	Unknown	3.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
40	Plastics Material and Resin Manufacturing	Personal	Unknown	0.9	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
41	Plastics Material and Resin Manufacturing	Personal	Unknown	30.6	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
42	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
43	Plastics Material and Resin Manufacturing	Personal	Unknown	7.6	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
44	Plastics Material and Resin Manufacturing	Personal	Unknown	7.0	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
45	Plastics Material and Resin Manufacturing	Personal	Unknown	5.9	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
46	Plastics Material and Resin Manufacturing	Personal	Unknown	2.4	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
47	Plastics Material and Resin Manufacturing	Personal	Unknown	1637.3	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
48	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
49	Plastics Material and Resin Manufacturing	Personal	Unknown	8.8	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
50	Plastics Material and Resin Manufacturing	Personal	Unknown	1.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
51	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
52	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
53	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
54	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

**Table\_Apx A-25. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
55	Plastics Material and Resin Manufacturing	Personal	Unknown	42.7	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
56	Plastics Material and Resin Manufacturing	Personal	Unknown	50.8	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
57	Plastics Material and Resin Manufacturing	Personal	Unknown	39.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
58	Plastics Material and Resin Manufacturing	Personal	Unknown	8.8	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
59	Plastics Material and Resin Manufacturing	Personal	Unknown	8.2	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
60	Plastics Material and Resin Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
61	Plastics Material and Resin Manufacturing	Personal	Unknown	33.8	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
62	Synthetic Rubber Manufacturing	Personal	Unknown	29.5	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA
63	Synthetic Rubber Manufacturing	Personal	Unknown	0.1	1	8-hr TWA	<a href="#">Finkel (2017)</a>	2.0	Included – Worker Full-Shift TWA

a – Statistics provided by the cited source. Concentration values from [Finkel \(2017\)](#) were converted to 8-hr TWA as discussed in Appendix H.1.1.

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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-26. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	All Other Plastics Product Manufacturing	Personal	Plastics Manufacturer	ND	1	STEL	<a href="#">OSHA (2019)</a>	1.3	Excluded – Did not include ND from OSHA data. <sup>c</sup>
2	All Other Plastics Product Manufacturing	Personal	Plastics Manufacturer	27.8	1	STEL	<a href="#">OSHA (2019)</a>	1.3	Worker - 15-min STEL
3	All Other Plastics Product Manufacturing	Personal	Plastics Manufacturer	20.8	1	STEL	<a href="#">OSHA (2019)</a>	1.3	Worker - 15-min STEL
4	Plastics material and resin manufacturing	Personal	Operator	102.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
5	Plastics material and resin manufacturing	Personal	Operator	73.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
6	Plastics material and resin manufacturing	Personal	Operator	94.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
7	Plastics material and resin manufacturing	Personal	Operator	65.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
8	Plastics material and resin manufacturing	Personal	Operator	65.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
9	Plastics material and resin manufacturing	Personal	Operator	60.2	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
10	Plastics material and resin manufacturing	Personal	Operator	131.6	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
11	Plastics material and resin manufacturing	Personal	Operator	65.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL

**Table\_Apx A-26. 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
12	Plastics material and resin manufacturing	Personal	Operator	102.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
13	Plastics material and resin manufacturing	Personal	Operator	166.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
14	Plastics material and resin manufacturing	Personal	Operator	111.1	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
15	Plastics material and resin manufacturing	Personal	Operator	83.3	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
16	Plastics material and resin manufacturing	Personal	Product technician	119.9	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
17	Plastics material and resin manufacturing	Personal	Product technician	69.4	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
18	Plastics material and resin manufacturing	Personal	Product technician	82.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
29	Plastics material and resin manufacturing	Personal	Product technician	62.8	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
20	Plastics material and resin manufacturing	Personal	Product technician	88.0	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
21	Plastics material and resin manufacturing	Personal	Product technician	82.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
22	Plastics material and resin manufacturing	Personal	Product technician	101.5	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL

**Table\_Apx A-26. 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 <sup>3</sup> ) <sup>a,b</sup>	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	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 15-min STEL
24	Plastics material and resin manufacturing	Personal	Product technician	50.7	1	STEL	<a href="#">Halogenated Solvents Industry Alliance (2018)</a>	1.6	Worker - 30-min STEL
25	Plastics material and resin manufacturing	Personal	CSHO	ND	1	STEL	<a href="#">OSHA (2019)</a>	1.3	Not included – Limit of detection not provided
26	Plastics material and resin manufacturing	Personal	Extruder Operator	20.4	1	STEL	<a href="#">OSHA (2019)</a>	1.3	No health comparisons for 5-hr TWA. Presented data point, but not used to calculate risk.

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<sup>3</sup> 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.16 Lithographic Printing Plate Cleaning

---

Table\_Apx A-27 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<sup>3</sup>, with a mean of 34.4 mg/m<sup>3</sup> ([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<sup>3</sup> ([NIOSH, 1980](#)).
- Row 4 presents a data point from IARC (2016) that indicated exposure of 24.3 mg/m<sup>3</sup> 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<sup>3</sup>; 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<sup>3</sup> ([US EPA, 1985](#)).
- Rows 51 through 132 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data mainly come from Commercial Printing (except Screen and Books) sites. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

Table\_Apx A-28 presents short-term data.

- Row 1 presents the 4-hr TWA exposure concentrations as described in Row 1 of Table\_Apx A-27. Worker exposures ranged from 3.5 to 937.9 mg/m<sup>3</sup> as 4-hr TWAs ([Ukai et al., 1998](#)).

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	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	<a href="#">Ukai et al. (1998)</a>	2.1	Included – 8-hr TWA-Monitoring Study
2	Printing	Personal	Platemaking Employees - Cleaning step and repeat machine	ND	1	Full-Shift	<a href="#">NIOSH (1980)</a>	1.7	Included – full-shift TWA-NIOSH HHE
3	Printing	Personal	Platemaking Employees - Cleaning step and repeat machine	17	1	Full-Shift	<a href="#">NIOSH (1980)</a>	1.7	Included – full-shift TWA-NIOSH HHE
4	Printing	Personal	Cleaning Presses	24.31	1	Full-Shift	<a href="#">IARC (2016)</a>	1.9	Excluded-Used actual monitoring data
5	Printing	Personal	Printing/Ink Cleaning (modeled)	0 – 521.04	n/a	Full-Shift (modeled)	<a href="#">Yamada et al. (2015)</a>	4.0	Excluded-Used actual monitoring data
6	Printing	Personal	Printing/Ink Cleaning (modeled)	69.47 – 1,632.6	n/a	Full-Shift (modeled)	<a href="#">Yamada et al. (2015)</a>	4.0	Excluded-Used actual monitoring data
7	Graphic Arts	Personal	Multilith Operator	62.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
8	Screen Printing	Personal	Printing	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
9	Screen Printing	Personal	Printing	10.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
10	Screen Printing	Personal	Printing	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
11	Screen Printing	Personal	Printing	17.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
12	Department Stores	Personal	Asst. Printer	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
13	Department Stores	Personal	Sign Maker	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
14	Department Stores	Personal	Printing Shop	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
15	Department Stores	Personal	Printer	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
16	Department Stores	Personal	Printer	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
17	Direct Selling Est.	Personal	Virkotype Printer	3.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
18	Direct Selling Est.	Personal	Offset Printer	3.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
19	Government	Personal	Printer	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
20	Newspapers	Personal	Pressman	77.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
21	Newspapers	Personal	Pressman	152.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
22	Newspapers	Personal	Pressman	76.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
23	Newspapers	Personal	Pressman	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
24	Lithographic Printing	Personal	Pressman	3.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
25	Lithographic Printing	Personal	Printing Press	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
26	Lithographic Printing	Personal	First Feeder	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
27	Lithographic Printing	Personal	Printing Press	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
28	Lithographic Printing	Personal	Pressman	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
29	Lithographic Platemaking	Personal	Proof Press Operator	139.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
30	Industrial Controls	Personal	Screen Washer	76.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
31	Industrial Controls	Personal	Silk Screen Oper.	179.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
32	Fabr. Textile Products NEW	Personal	Screen Washer	36.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
33	Fabr. Textile Products NEW	Personal	Screen Washer	18.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
34	Stationery Products	Personal	Platemaker	17.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
35	Stationery Products	Personal	Platemaker	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
36	Graphic Arts	Personal	Platemaker	19.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
37	Graphic Arts	Personal	Platemaker	30.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
38	Graphic Arts	Personal	Plate Cleaner	221.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
39	Lithographic Printing	Personal	Helper	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
40	Lithographic Platemaking	Personal	Etcher Operator	296.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
41	Graphic Arts	Personal	Mat Preparation	62.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
42	Graphic Arts	Personal	Film Processor	22.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
43	Screen Printing	Personal	Image Making	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
44	Screen Printing	Personal	Chopping	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
45	Screen Printing	Personal	Trimming	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
46	Screen Printing	Personal	Cutting	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
47	Screen Printing	Personal	Sewing	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
48	Graphic Arts	Personal	Stripper	24.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
49	Commercial Letterpress	Personal	Clean-up Man	157.1	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
50	Commercial Letterpress	Personal	Screen Maker	547.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included – Worker 8-hr TWA
51	Commercial Printing (except Screen and Books)	Personal	unknown	76.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
52	Commercial Printing (except Screen and Books)	Personal	unknown	58.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
53	Commercial Printing (except Screen and Books)	Personal	unknown	55.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
54	Commercial Printing (except Screen and Books)	Personal	unknown	0.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
55	Commercial Printing (except Screen and Books)	Personal	unknown	2.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
56	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
57	Commercial Printing (except Screen and Books)	Personal	unknown	12.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
58	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
59	Commercial Printing (except Screen and Books)	Personal	unknown	26.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
60	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
61	Commercial Printing (except Screen and Books)	Personal	unknown	71.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA



**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
62	Commercial Printing (except Screen and Books)	Personal	unknown	18.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
63	Commercial Printing (except Screen and Books)	Personal	unknown	6.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
64	Commercial Printing (except Screen and Books)	Personal	unknown	2.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
65	Commercial Printing (except Screen and Books)	Personal	unknown	37.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
66	Commercial Printing (except Screen and Books)	Personal	unknown	65.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
67	Commercial Printing (except Screen and Books)	Personal	unknown	7.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
68	Commercial Printing (except Screen and Books)	Personal	unknown	54.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
69	Commercial Printing (except Screen and Books)	Personal	unknown	75.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
70	Commercial Printing (except Screen and Books)	Personal	unknown	162.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
71	Commercial Printing (except Screen and Books)	Personal	unknown	98.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
72	Commercial Printing (except Screen and Books)	Personal	unknown	20.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
73	Commercial Printing (except Screen and Books)	Personal	unknown	25.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
74	Commercial Printing (except Screen and Books)	Personal	unknown	147.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
75	Commercial Printing (except Screen and Books)	Personal	unknown	93.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
76	Commercial Printing (except Screen and Books)	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
77	Commercial Printing (except Screen and Books)	Personal	unknown	0.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
78	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
79	Commercial Printing (except Screen and Books)	Personal	unknown	13.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
80	Commercial Printing (except Screen and Books)	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
81	Commercial Printing (except Screen and Books)	Personal	unknown	1.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
82	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
83	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
84	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
85	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
86	Commercial Printing (except Screen and Books)	Personal	unknown	97.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
87	Commercial Printing (except Screen and Books)	Personal	unknown	77.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
88	Commercial Printing (except Screen and Books)	Personal	unknown	44.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
89	Commercial Printing (except Screen and Books)	Personal	unknown	96.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
90	Commercial Printing (except Screen and Books)	Personal	unknown	81.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
91	Commercial Printing (except Screen and Books)	Personal	unknown	58.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
92	Commercial Printing (except Screen and Books)	Personal	unknown	21.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
93	Commercial Printing (except Screen and Books)	Personal	unknown	86.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
94	Commercial Printing (except Screen and Books)	Personal	unknown	10.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
95	Commercial Printing (except Screen and Books)	Personal	unknown	9.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
96	Commercial Printing (except Screen and Books)	Personal	unknown	2.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
97	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
98	Commercial Printing (except Screen and Books)	Personal	unknown	151.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
99	Commercial Printing (except Screen and Books)	Personal	unknown	29.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
100	Commercial Printing (except Screen and Books)	Personal	unknown	5.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
101	Commercial Printing (except Screen and Books)	Personal	unknown	10.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
102	Commercial Printing (except Screen and Books)	Personal	unknown	65.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
103	Commercial Printing (except Screen and Books)	Personal	unknown	6.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
104	Commercial Printing (except Screen and Books)	Personal	unknown	48.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
105	Commercial Printing (except Screen and Books)	Personal	unknown	62.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
106	Commercial Printing (except Screen and Books)	Personal	unknown	14.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
107	Commercial Printing (except Screen and Books)	Personal	unknown	2.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
108	Commercial Printing (except Screen and Books)	Personal	unknown	2.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
109	Commercial Printing (except Screen and Books)	Personal	unknown	0.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
110	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
111	Commercial Printing (except Screen and Books)	Personal	unknown	4.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
112	Commercial Printing (except Screen and Books)	Personal	unknown	8.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
113	Commercial Printing (except Screen and Books)	Personal	unknown	9.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
114	Commercial Printing (except Screen and Books)	Personal	unknown	1.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
115	Commercial Printing (except Screen and Books)	Personal	unknown	17.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
116	Commercial Printing (except Screen and Books)	Personal	unknown	7.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
117	Commercial Printing (except Screen and Books)	Personal	unknown	26.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
118	Commercial Printing (except Screen and Books)	Personal	unknown	22.9	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
119	Commercial Printing (except Screen and Books)	Personal	unknown	0.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
120	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
121	Commercial Printing (except Screen and Books)	Personal	unknown	0.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
122	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
123	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
124	Commercial Printing (except Screen and Books)	Personal	unknown	167.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
125	Commercial Printing (except Screen and Books)	Personal	unknown	1.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**Table\_Apx A-27. 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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
126	Commercial Printing (except Screen and Books)	Personal	unknown	0.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
127	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
128	Commercial Printing (except Screen and Books)	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
129	Commercial Printing (except Screen and Books)	Personal	unknown	2.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
130	Commercial Printing (except Screen and Books)	Personal	unknown	2.8	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
131	Commercial Printing (except Screen and Books)	Personal	unknown	4.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
132	Commercial Printing (except Screen and Books)	Personal	unknown	9.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

**Table\_Apx A-28. 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/m <sup>3</sup> ) <sup>a,b</sup>	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	<a href="#">Ukai et al. (1998)</a>	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	<a href="#">Ukai et al. (1998)</a>	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/m<sup>3</sup> 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<sup>3</sup> ([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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Air Transport	Personal	Maintenance Utility	423.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
2	Air Transport	Personal	Maintenance Utility	313.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
3	Air Transport	Personal	Maintenance Utility	491.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
4	Air Transport	Personal	Maintenance Utility	197.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
5	Alkalies & Chlorine	Personal	Maintenance Man	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
6	Colleges	Personal	Janitorial	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
7	Colleges	Personal	Janitorial	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
8	Consulting Services	Personal	Maintenance Man	65.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
9	Consulting Services	Personal	Maintenance Man	39.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
10	Sporting Goods	Personal	Paint Operator	65.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
11	Totalizing Fluid Meters	Personal	Painter	70.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
12	Nonferrous Foundries NEC	Personal	Painter	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
13	Nonferrous Foundries NEC	Personal	Painter	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
14	Electronic Components	Personal	Pour Head Operator	101.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
15	Electronic Components	Personal	Pour Head Operator	167.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
16	Sporting Goods	Personal	Rim Operator	43.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
17	Sporting Goods	Personal	Rim Operator	59.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
18	Sporting Goods	Personal	Rim Operator	31.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
19	Sporting Goods	Personal	Rim Operator	2.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
20	Sporting Goods	Personal	Rim Operator	2.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
21	Sporting Goods	Personal	Sole Operator	72.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
22	Sporting Goods	Personal	Sole Operator	104.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
23	Sporting Goods	Personal	Glue Operator	12.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
24	Sporting Goods	Personal	Glue Operator	62.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
25	Sporting Goods	Personal	Clean-Up Operator	64.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
26	Sporting Goods	Personal	Glue Operator	69.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
27	Sporting Goods	Personal	Glue Operator	131.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
28	Sporting Goods	Personal	Glue Operator	28.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
29	Sporting Goods	Personal	Tongue Ass. Oper	15.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
30	Sporting Goods	Personal	Tongue Ass. Oper	16.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
31	Sporting Goods	Personal	Cuff Glue Oper.	29.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
32	Sporting Goods	Personal	Hot Max Oper.	22.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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 <sup>3</sup> ) <sup>a,b</sup>	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	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
34	Mineral Wool	Personal	Utility Operator	84.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
35	Mineral Wool	Personal	Pt. Applicator	94.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
36	Mineral Wool	Personal	Dyken Operator	84.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
37	Mineral Wool	Personal	Pt. Operator	84.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
38	Aluminum Foundries	Personal	Core Machine Operator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
39	Brass Foundries	Personal	Griner	0.6	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
40	Misc Plastic Products	Personal	Equipment Operator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
41	Misc Plastic Products	Personal	Equipment Operator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
42	Pumping Equipment	Personal	Inpres. Operator	83.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
43	Wholesale Comm. Machines	Personal	DCR Operator	127.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
44	Motor Vehicle Parts	Personal	Micell. Mach. Oper.	20.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
45	Motor Vehicle Parts	Personal	Micell. Mach. Oper.	41.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
46	Special Dies & Tools	Personal	Press Operator	87.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
47	A/C & Heating	Personal	Machine Operator	174.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
48	U.S. Postal Service	Personal	Mail Process Eqpt.	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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 <sup>3</sup> ) <sup>a,b</sup>	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	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
50	Hand & Edge Tools	Personal	Induction Machine	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
51	Hand & Edge Tools	Personal	Unassigned Machine	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
52	Coating & Engraving	Personal	Machine Operator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
53	Coating & Engraving	Personal	Asst. Machine Oper.	232.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
54	Industrial Controls	Personal	Machine Operator	966.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
55	Petroleum Refining	Personal	Machinist	10.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
56	Electric Repair	Personal	Assembler	1294.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
57	Electric Repair	Personal	Assembler	621.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
58	Electric Repair	Personal	Assembler	1294.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
59	Electric Repair	Personal	Assembler	621.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
60	Service Ind. Machines NEC	Personal	Assembler	1017.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
61	Service Ind. Machines NEC	Personal	Assembler	205.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
62	Service Ind. Machines NEC	Personal	Assembler	764.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
63	Service Ind. Machines NEC	Personal	Assembler	862.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
64	Sporting Goods	Personal	Mold Cleaner	40.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
65	Sporting Goods	Personal	Mold Cleaner	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
66	Sporting Goods	Personal	Mold Cleaner	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
67	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
68	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
69	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
70	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
71	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
72	Plastic Products	Personal	Fabricator	59.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
73	Plastic Products	Personal	Fabricator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
74	Plastic Products	Personal	Helper	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
75	Plastic Products	Personal	Helper	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
76	Plastic Products	Personal	Helper	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
77	Sporting Goods	Personal	Lead Lady	81.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
78	Sporting Goods	Personal	Lead Lady	319.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
79	Sporting Goods	Personal	Riveter	15.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
80	Soaps & Detergents	Personal	Supervisor	376.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
81	Soaps & Detergents	Personal	Mixer	150.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
82	Aluminum Products	Personal	Inspector	54.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
83	Brass Foundries	Personal	Art Chase	2.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
84	U.S. Postal Service	Personal	Electronics Technician	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
85	Cleaning Services	Personal	Asst. Supervisor	468.7	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
86	Misc. Plastic Products	Personal	Mixer	137.9	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
87	Transportation Eqpt. NEC	Personal	Mechanic	311.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
88	Oil Field Machinery	Personal	Helper	188.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
89	Machine Tools	Personal	Snipper	90.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
90	A/C & Heating Eqpt.	Personal	Disassembler Steam	323.0	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
91	Metal Doors	Personal	Sealer	87.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
92	Auto Repair	Personal	Installer	51.1	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
93	Metal Household Furniture	Personal	Set-up Man	1129.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
94	Measurement Instruments	Personal	Washer	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
95	Photographic Equipment	Personal	Transport Cleaner	76.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
96	Photographic Equipment	Personal	Transport Cleaner	76.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
97	Photographic Equipment	Personal	Transport Cleaner	76.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
98	Electroplating	Personal	Watch Band Cleaner	61.6	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
99	Electroplating	Personal	Compounder	1092.4	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
100	Coating & Engraving	Personal	Line Helper	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
101	Small Arms Ammo	Personal	Applier	59.3	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
102	Small Arms Ammo	Personal	Applier	247.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
103	Motors & Generators	Personal	Grinder Washer	23.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
104	Petroleum Refining	Personal	Ketone Operator	46.8	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
105	Refuse Systems	Personal	Foreman	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
106	Refuse Systems	Personal	Drum Cutter	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
107	Refuse Systems	Personal	Operator	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
108	Refuse Systems	Personal	General Laborer	ND	1	8-hr TWA	<a href="#">US EPA (1985)</a>	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<sup>3</sup> 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<sup>3</sup> ([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<sup>3</sup> (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.
- Rows 8 through 22 contain OSHA data submitted in a public comment ([Finkel, 2017](#)). The exposure data come from Hazardous Waste Treatment and Disposal sites. However, worker activities for these exposure data points are not known. Sample times vary; exposures were adjusted to 8-hr TWAs. Additional discussion of this dataset is included in Section 4.2.3 and Appendix H.

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<sup>3</sup> (various sample times) ([DOEHRS-IH, 2018](#)). EPA evaluated two 30-minute samples as 30-minute exposures. As there are no health comparisons for 2- or 3-hr samples, the remaining data points are presented but not used to calculate risk

**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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
1	Solvent Recovery	Personal	Solvent Reclaimer	19.2	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
2	Solvent Recovery	Personal	Solvent Reclaimer	18.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
3	Solvent Recovery	Personal	Solvent Reclaimer	10.5	1	8-hr TWA	<a href="#">US EPA (1985)</a>	1.4	Included - Worker 8-hr TWA
4	DOD Waste Disposal and Sludge Handling	Personal	Waste Disposal	0.4	1	8-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 8-hr TWA
5	DOD Waste Disposal and Sludge Handling	Personal	313A Sludge Operations	2.3	1	8-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 8-hr TWA
6	DOD Waste Disposal and Sludge Handling	Personal	313A Sludge Operations	2.3	1	8-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 8-hr TWA
7	DOD Waste Disposal and Sludge Handling	Personal	313A Sludge Operations	2.3	1	8-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included - Worker 8-hr TWA
8	Hazardous Waste Treatment and Disposal	Personal	unknown	0.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
9	Hazardous Waste Treatment and Disposal	Personal	unknown	106.7	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
10	Hazardous Waste Treatment and Disposal	Personal	unknown	7.2	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
11	Hazardous Waste Treatment and Disposal	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
12	Hazardous Waste Treatment and Disposal	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
13	Hazardous Waste Treatment and Disposal	Personal	unknown	0.1	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
14	Hazardous Waste Treatment and Disposal	Personal	unknown	0.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
15	Hazardous Waste Treatment and Disposal	Personal	unknown	38.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
16	Hazardous Waste Treatment and Disposal	Personal	unknown	82.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

**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 <sup>3</sup> ) <sup>a,b,c</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
17	Hazardous Waste Treatment and Disposal	Personal	unknown	0.6	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
18	Hazardous Waste Treatment and Disposal	Personal	unknown	2.0	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
19	Hazardous Waste Treatment and Disposal	Personal	unknown	4.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
20	Hazardous Waste Treatment and Disposal	Personal	unknown	0.5	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
21	Hazardous Waste Treatment and Disposal	Personal	unknown	20.3	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA
22	Hazardous Waste Treatment and Disposal	Personal	unknown	48.4	1	TWA	<a href="#">Finkel (2017)</a>	2	Included – Worker Full-Shift TWA

a – Concentration values were converted to 8-hr TWA as discussed in Appendix H.1.1

b – Values provided in ppm were converted to mg/m<sup>3</sup> 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 converted data to 8-hr TWAs assuming zero concentrations outside sampling time.

**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 <sup>3</sup> ) <sup>a,b</sup>	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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	Included – Worker 30-min 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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
3	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	1.8	1	2.5-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	No health comparisons for 2- 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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	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	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.

**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 <sup>3</sup> ) <sup>a,b</sup>	Number of Samples	Type of Measurement	Source	Score	Rationale for Inclusion / Exclusion
8	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	3.4	1	2.5-hr TWA	<a href="#">((DOEHRS-IH), 2018)</a>	1.3	No health comparisons for 2- or 3-hr TWA. Presented data point, but not used to calculate risk.

## APPENDIX B APPROACH FOR ESTIMATING NUMBER OF WORKERS

---

This appendix summarizes the methods that EPA 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 identified NAICS industry codes associated with each condition of use. EPA generally identified NAICS industry codes for a condition of use by:

- Querying the [U.S. Census Bureau's NAICS Search tool](#) using keywords associated with each condition of use to identify NAICS codes with descriptions that match the condition of use.
- Referencing EPA Generic Scenarios (GS's) and Organisation for Economic Co-operation and Development (OECD) Emission Scenario Documents (ESDs) for a condition of use to identify NAICS codes cited by the GS or ESD.
- Reviewing 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 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 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 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 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
51-6020	Pressers, Textile, Garment, and Related Materials	W
51-6030	Sewing Machine Operators	O
51-6040	Shoe and Leather Workers	O

SOC	Occupation	Designation
51-6050	Tailors, Dressmakers, and Sewers	O
51-6090	Miscellaneous Textile, Apparel, and Furnishings Workers	O

W = worker designation

O = ONU designation

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

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

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

The third step in EPA's methodology was to further refine the employment estimates by using total employment data in the U.S. Census Bureau'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 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-digit NAICS level	% of Total Employment	Estimated Employment by SOC at 6-digit NAICS level
8123	41-2000	Retail Sales Workers	O	44,500	46.0%	20,459

8123	49-9040	Industrial Machinery Installation, Repair, and Maintenance Workers	W	1,790	46.0%	823
8123	49-9070	Maintenance and Repair Workers, General	W	3,260	46.0%	1,499
8123	49-9090	Miscellaneous Installation, Maintenance, and Repair Workers	W	1,080	46.0%	497
8123	51-6010	Laundry and Dry-Cleaning Workers	W	110,640	46.0%	50,867
8123	51-6020	Pressers, Textile, Garment, and Related Materials	W	40,250	46.0%	18,505
8123	51-6030	Sewing Machine Operators	O	1,660	46.0%	763
8123	51-6040	Shoe and Leather Workers	O	Not Reported for this NAICS Code		
8123	51-6050	Tailors, Dressmakers, and Sewers	O	2,890	46.0%	1,329
8123	51-6090	Miscellaneous Textile, Apparel, and Furnishings Workers	O	0	46.0%	0
<b>Total Potentially Exposed Employees</b>				<b>206,070</b>		<b>94,740</b>
<b>Total Workers</b>						<b>72,190</b>
<b>Total Occupational Non-Users</b>						<b>22,551</b>

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 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 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 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 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):

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

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

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

## **Step 6: Estimating the Number of Workers and Sites for a Condition of Use**

EPA estimated the number of workers and occupational non-users potentially exposed to 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- or 12-hr time weighted averages (TWA). The 8- or 12-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-or 12-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 or 12 hr/day)
- AT<sub>acute</sub> = acute averaging time (8 or 12 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

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

Where:

- ADC = average daily concentration used for chronic non-cancer risk calculations
- LADC = lifetime average daily concentration used for chronic cancer risk calculations
- C = contaminant concentration in air (8- or 12-hr TWA)
- ED = exposure duration (8 or 12 hr/day depending on TWA of C)
- EF = exposure frequency (250 days/yr for 8 hr/day ED or 167 days/yr for 12 hr/day ED)
- WY = exposed working years per lifetime (50<sup>th</sup> percentile = 31; 95<sup>th</sup> percentile = 40)
- AT = averaging time, non-cancer risks (WY × 365 days/yr × 24 hr/day)
- AT<sub>c</sub> = averaging time, cancer risks (lifetime (LT) × 250 days/year × 8 hr/day for 8 hr/day ED or 167 days/yr for 12 hr/day for 12 hr/day ED; 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 or 12	hr/day
Exposure Frequency	EF	250 for (8-hr TWA) 167 for (12-hrTWA)	days/year
Working Years	WY	31 (50 <sup>th</sup> percentile) 40 (95 <sup>th</sup> percentile)	years
Lifetime, cancer	LT	78	years
Averaging Time, non-cancer	AT	271,560 (CT) <sup>a</sup> 350,400 (HE) <sup>b</sup>	hr
Averaging Time, cancer	AT <sub>c</sub>	156,000	hr

<sup>a</sup> Calculated using the 50<sup>th</sup> percentile value for working years (WY)

<sup>b</sup> Calculated using the 95<sup>th</sup> percentile value for working years (WY)

### **Exposure Duration (ED)**

EPA generally uses an exposure duration of 8 hours per day for averaging full-shift exposures, with one exception for manufacturing monitoring data that were provided in both 8- and 12-hr TWA data. EPA used an ED of 8 hours for the 8-hr TWA data and 12 hours for the 12-hr TWA data.

### **Exposure Frequency (EF)**

EPA uses an exposure frequency of 250 days per year for 8-hr TWA data and 167 days per year for 12-hr TWA data. 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 50<sup>th</sup> 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 50<sup>th</sup> percentile value of 228 days per year. 250 days per year is approximately the 75<sup>th</sup> 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 50<sup>th</sup> 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 50<sup>th</sup> percentile value of 31 years and a 95<sup>th</sup> 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.<sup>5</sup> Census household surveys use different industry codes than the NAICS codes used in its firm surveys, so these were converted to NAICS using a published crosswalk ([U.S. Census Bureau, 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 50<sup>th</sup> and 95<sup>th</sup> 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	50 <sup>th</sup> Percentile	95 <sup>th</sup> 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
<b>16 years and over</b>	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
<b>25 years and over</b>	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
<b>65 years and over</b>	10.2	9.9	10.3	10.3

Source: [U.S. BLS \(2014\)](#)

<sup>5</sup> 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).

## **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 C.

### D.1 Example High-End ADC and LADC

---

Calculate  $ADC_{HE}$ :

$$ADC_{HE} = \frac{C_{HE} \times ED \times EF \times WY_{HE}}{AT_{HE}}$$
$$ADC_{HE} = \frac{4.6 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 250 \frac{days}{year} \times 40 \text{ years}}{350,400 \text{ hours}} = 1.1 \frac{mg}{m^3}$$

Calculate  $LADC_{HE}$ :

$$LADC_{HE} = \frac{C_{HE} \times ED \times EF \times WY_{HE}}{AT_C}$$
$$LADC_{HE} = \frac{4.6 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 250 \frac{days}{year} \times 40 \text{ years}}{156,000 \text{ hours}} = 2.4 \frac{mg}{m^3}$$

### D.2 Example Central Tendency ADC and LADC

---

Calculate  $ADC_{CT}$ :

$$ADC_{CT} = \frac{C_{CT} \times ED \times EF \times WY_{CT}}{AT_{CT}}$$
$$ADC_{CT} = \frac{0.36 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 250 \frac{days}{year} \times 31 \text{ years}}{271,560 \text{ hours}} = 0.1 \frac{mg}{m^3}$$

Calculate  $LADC_{CT}$ :

$$LADC_{CT} = \frac{C_{CT} \times ED \times EF \times WY_{CT}}{AT_C}$$
$$LADC_{CT} = \frac{0.36 \frac{mg}{m^3} \times 8 \frac{hr}{day} \times 250 \frac{days}{year} \times 31 \text{ years}}{156,000 \text{ hours}} = 0.14 \frac{mg}{m^3}$$

## APPENDIX E DERMAL EXPOSURE ASSESSMENT METHOD

---

This method was developed through review of relevant literature and consideration of existing exposure models, such as EPA 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 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, 2015](#)):

#### Equation E-1

$$D_{exp} = S \times Q_u \times Y_{derm} \times FT$$

Where:

$S$  is the surface area of contact ( $\text{cm}^2$ ; defaults:  $535 \text{ cm}^2$  (central tendency);  $1,070 \text{ cm}^2$  (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); note: EPA has no data on actual surface area of contact with liquid and that the value is assumed to represent an adequate proxy for a high-end surface area of contact with liquid that may sometimes include exposures to much of the hands and also beyond the hands, such as wrists, forearms, neck, or other parts of the body, for some scenarios

$Q_u$  is the quantity remaining on the skin ( $\text{mg}/\text{cm}^2$ -event; defaults:  $1.4 \text{ mg}/\text{cm}^2$ -event (central tendency);  $2.1 \text{ mg}/\text{cm}^2$ -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 part of the model, Kasting and Miller define a ratio of the liquid evaporation to absorption,  $\chi$ . They derive the following definition of  $\chi$  (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 ( $\mu\text{g}/\text{cm}^3$ )

$P_{vp}$  is the vapor pressure (torr)

Chemicals for which  $\chi \gg 1$  will largely evaporate from the skin surface, while chemicals for which  $\chi \ll 1$  will be largely absorbed;  $\chi = 1$  represents a balance between evaporation and absorption. Equation E-3 is applicable to chemicals having a log octanol/water partition coefficient less than or equal to three ( $\log K_{ow} \leq 3$ )<sup>6</sup>. 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)

$\chi$  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

---

<sup>6</sup> 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  $\log K_{ow} \leq 3$ .

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).

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  $\tau$  ( $Dt/h^2$ ), as shown in Equation E-6:

**Equation E-6**

$$f_{abs} = \frac{m_{abs}}{M_0} = 2 \sum_{n=1}^{\infty} \frac{1}{\lambda_n} (1 - e^{-\lambda_n^2 \tau}) \left( \frac{\chi^2 + \lambda_n^2}{\chi^2 + \lambda_n^2 + \chi} \right) \cdot \left( \frac{\cos(1 - f) \lambda_n - \cos \lambda_n}{f \cdot \lambda_n} \right)$$

where the eigenvalues  $\lambda_n$  are the positive roots of the equation:

**Equation E-7**

$$\lambda_n \cdot \cot(\lambda_n) + \chi = 0$$

Equation E-6 and Equation E-7 must be solved analytically. It should be noted that the dimensionless time  $\tau$  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 (f<sub>abs</sub>) using Equation E 8**

Chemical Name	Methylene Chloride
CASRN	75-09-2
Molecular Formula	CH <sub>2</sub> Cl <sub>2</sub>
Molecular Weight (g/mol)	84.93
P <sub>VP</sub> (torr)	435
Universal gas constant, R (L*atm/K*mol)	0.0821
Temperature, T (K)	303
Log K <sub>ow</sub>	1.25
K <sub>oct</sub>	17.8
S <sub>w</sub> (g/L)	13
S <sub>w</sub> (µg/cm <sup>3</sup> )	13,000
<b><i>Industrial Setting</i></b>	
u (m/s) <sup>a</sup>	0.1674
Evaporative Flux, $\chi$	11.46
<i>Fraction Evaporated</i>	0.92
<b><i>Fraction Absorbed</i></b>	<b>0.08</b>
<b><i>Commercial Setting</i></b>	
u (m/s) <sup>a</sup>	0.0878
Evaporative Flux, $\chi$	6.93
<i>Fraction Evaporated</i>	0.87
<b><i>Fraction Absorbed</i></b>	<b>0.13</b>

<sup>a</sup> EPA used air speeds from Baldwin and Maynard (1998): the 50<sup>th</sup> percentile of industrial occupational environments of 16.74 cm/s is used for industrial settings and the 50<sup>th</sup> percentile of commercial occupational environments of 8.78 cm/s is used for commercial settings.

### E.3 Comparison of f<sub>abs</sub> to Experimental Values for 1-BP

Sections E.2 and E.3 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  $S \times Q_u$  ( $\text{cm}^2 \times \text{mg}/\text{cm}^2\text{-event}$ ) could be replaced by a single variable representing the mass of chemical that deposits inside the glove per event,  $M$  ( $\text{mg}/\text{event}$ ):

#### 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 75<sup>th</sup> percentile value of 4.21 mg/min, and a 95<sup>th</sup> 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 50<sup>th</sup> and 95<sup>th</sup> 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 50<sup>th</sup> and 95<sup>th</sup> percentile deposition, with the 95<sup>th</sup> 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 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 through the hands while wearing gloves: this protection factor is driven by flux, and thus varies with time. The ECETOC TRA model represents the protection factor of gloves as a fixed, 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,  $PF \geq 1$ ):

### **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 <i>b</i> 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<sup>2</sup> (central tendency) and 1,070 cm<sup>2</sup> (high end), representing the total surface area of one and two hands, respectively (note: EPA has no data on actual surface area of contact with liquid and that the value is assumed to represent an adequate proxy for a high-end surface area of contact with liquid that may sometimes include exposures to much of the hands and also beyond the hands, such as wrists, forearms, neck, or other parts of the body, for some scenarios).
- *Q<sub>u</sub>*, the quantity remaining on the skin: 1.4 mg/cm<sup>2</sup>-event (central tendency) and 2.1 mg/cm<sup>2</sup>-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).

- $Y_{\text{derm}}$ , 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 ( $S = 1,070 \text{ cm}^2$ ) and the assumed quantity of liquid remaining on the skin ( $Q_u = 2.1 \text{ mg/cm}^2\text{-event}$ ), which is equal to 2,247 mg/event. See discussion in Section E.4.

## 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 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 95<sup>th</sup> and 50<sup>th</sup> percentile values. The statistics were calculated directly in [@Risk](#). The 95<sup>th</sup> percentile value was selected to represent high-end exposure level, whereas the 50<sup>th</sup> 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.

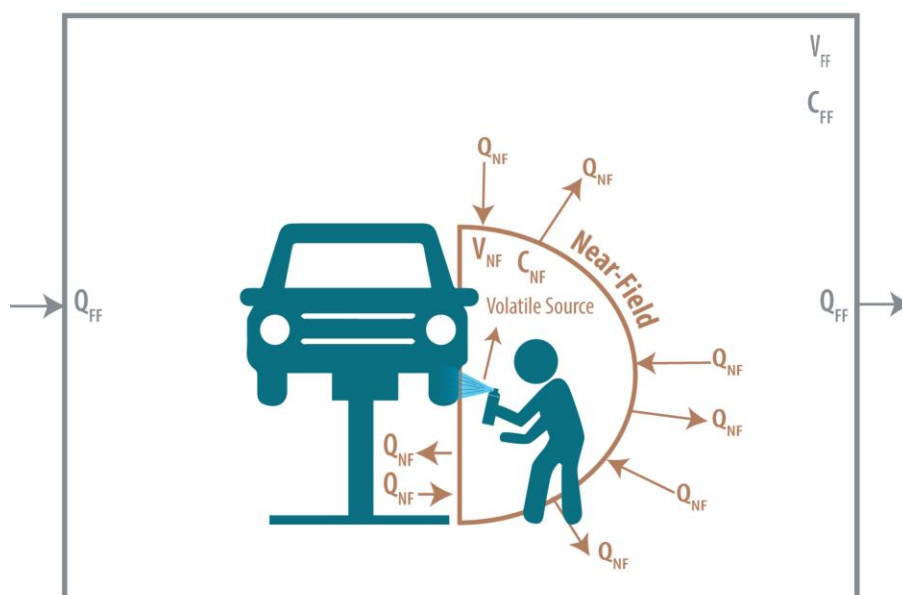
#### F.1.1 Model Design Equations

---

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 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 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**

$$C_{NF,t_{m,n+1}} = (k_{1,t_{m,n}} e^{\lambda_1 t} + k_{2,t_{m,n}} e^{\lambda_2 t})$$

**Equation F.1-4**

$$C_{FF,t_{m,n+1}} = (k_{3,t_{m,n}} e^{\lambda_1 t} - k_{4,t_{m,n}} e^{\lambda_2 t})$$

Where:

**Equation F.1-5**

$$k_{1,t_{m,n}} = \frac{Q_{NF} (C_{FF,0}(t_{m,n}) - C_{NF,0}(t_{m,n})) - \lambda_2 V_{NF} C_{NF,0}(t_{m,n})}{V_{NF}(\lambda_1 - \lambda_2)}$$

**Equation F.1-6**

$$k_{2,t_{m,n}} = \frac{Q_{NF} (C_{NF,0}(t_{m,n}) - C_{FF,0}(t_{m,n})) + \lambda_1 V_{NF} C_{NF,0}(t_{m,n})}{V_{NF}(\lambda_1 - \lambda_2)}$$

**Equation F.1-7**

$$k_{3,t_{m,n}} = \frac{(Q_{NF} + \lambda_1 V_{NF})(Q_{NF} (C_{FF,0}(t_{m,n}) - C_{NF,0}(t_{m,n})) - \lambda_2 V_{NF} C_{NF,0}(t_{m,n}))}{Q_{NF} V_{NF}(\lambda_1 - \lambda_2)}$$

**Equation F.1-8**

$$k_{4,t_{m,n}} = \frac{(Q_{NF} + \lambda_2 V_{NF})(Q_{NF} (C_{NF,0}(t_{m,n}) - C_{FF,0}(t_{m,n})) + \lambda_1 V_{NF} C_{NF,0}(t_{m,n}))}{Q_{NF} V_{NF}(\lambda_1 - \lambda_2)}$$

**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**

$$C_{NF,o}(t_{m,n}) = \begin{cases} 0, & m = 0 \\ \frac{Amt}{V_{NF}} \left( 1,000 \frac{mg}{g} \right) + C_{NF}(t_{m,n-1}), & n > 0 \text{ for all } m \text{ where brake job occurs} \end{cases}$$

**Equation F.1-12**

$$C_{FF,o}(t_{m,n}) = \begin{cases} 0, & m = 0 \\ C_{FF}(t_{m,n-1}), & \text{for all } n \text{ where } m > 0 \end{cases}$$

**Equation F.1-13**

$$C_{NF, 5\text{-min TWA}, t_{m,n}} = \frac{\left( \frac{k_{1,t_{m,n-1}}}{\lambda_1} e^{\lambda_1 t_2} + \frac{k_{2,t_{m,n-1}}}{\lambda_2} e^{\lambda_2 t_2} \right) - \left( \frac{k_{1,t_{m,n-1}}}{\lambda_1} e^{\lambda_1 t_1} + \frac{k_{2,t_{m,n-1}}}{\lambda_2} e^{\lambda_2 t_1} \right)}{t_2 - t_1}$$

**Equation F.1-14**

$$C_{FF, 5\text{-min TWA}, t_{m,n}} = \frac{\left( \frac{k_{3,t_{m,n-1}}}{\lambda_1} e^{\lambda_1 t_2} + \frac{k_{4,t_{m,n-1}}}{\lambda_2} e^{\lambda_2 t_2} \right) - \left( \frac{k_{3,t_{m,n-1}}}{\lambda_1} e^{\lambda_1 t_1} + \frac{k_{4,t_{m,n-1}}}{\lambda_2} e^{\lambda_2 t_1} \right)}{t_2 - t_1}$$

After calculating all near-field/far-field 5-minute TWA exposures (i.e.,  $C_{NF, 5\text{-min TWA}, t_{m,n}}$  and  $C_{FF, 5\text{-min TWA}, t_{m,n}}$ ) for each five-minute (0.0833 hr) 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**

$$C_{NF, 8\text{-hr TWA}} = \frac{\sum_{m=0}^7 \sum_{n=0}^{11} [C_{NF, 5\text{-min TWA}, t_{m,n}} \times 0.0833 \text{ hr}]}{8 \text{ hr}}$$

**Equation F.1-16**

$$C_{FF, 8\text{-hr TWA}} = \frac{\sum_{m=0}^7 \sum_{n=0}^{11} [C_{FF, 5\text{-min TWA}, t_{m,n}} \times 0.0833 \text{ hr}]}{8 \text{ hr}}$$

**Equation F.1-17**

$$C_{NF,1\text{-hr TWA}} = \frac{\sum_{n=0}^{11} [C_{NF,5\text{-min TWA},t_{m,n}} \times 0.0833 \text{ hr}]}{1 \text{ hr}}$$

**Equation F.1-18**

$$C_{FF,1\text{-hr TWA}} = \frac{\sum_{n=0}^{11} [C_{FF,5\text{-min TWA},t_{m,n}} \times 0.0833 \text{ hr}]}{1 \text{ hr}}$$

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.

The specificity of more complex distributions (e.g. triangular, lognormal) to characterize a model parameter value requires adequate data to demonstrate the distribution; if only an overall range is known, then a uniform distribution is the only possible distribution to use. There may be cases where a uniform distribution is appropriate if data indicate it as such, but generally, uniform distributions were used because no data were found to demonstrate a more sophisticated distribution.

Model parameters kept as constants were generally cases where data to describe variability or uncertainty of the parameter value were unknown. Additionally, some model parameters were kept as constants by choice (i.e. temperature and pressure are constant as the model is isothermal and isobaric), and some were kept as constants appropriately (i.e. molecular weight kept appropriately constant).

**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 <sub>FF</sub>	m <sup>3</sup>	—	—	206	70,679	3,769	Triangular	Distribution based on data collected by CARB ( <a href="#">2006</a> )
Air exchange rate	AER	hr <sup>-1</sup>	—	—	1	20	3.5	Triangular	Demou et al. ( <a href="#">2009</a> ) identifies typical AERs of 1 hr <sup>-1</sup> and 3 to 20 hr <sup>-1</sup> for occupational settings with and without mechanical ventilation systems, respectively. Hellweg et al. ( <a href="#">2009</a> ) identifies average AERs for occupational settings utilizing mechanical ventilation systems to be between 3 and 20 hr <sup>-1</sup> . Golsteijn et al. ( <a href="#">2014</a> ) indicates a characteristic AER of 4 hr <sup>-1</sup> . Peer reviewers of EPA’s 2013 TCE draft risk assessment commented that values around 2 to 5 hr <sup>-1</sup> may be more likely ( <a href="#">SCG, 2013</a> ), in agreement with Golsteijn et al. ( <a href="#">2014</a> ). 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 <sup>-1</sup> ).
Near-field indoor wind speed	V <sub>NF</sub>	ft/hr	—	—	—	—	—	Lognormal	Lognormal distribution fit to commercial-type workplace data from Baldwin and Maynard ( <a href="#">1998</a> ). Mean of 10.853 cm/s and standard deviation of 7.883 cm/s.
		cm/s	—	—	—	—	—	Lognormal	
Near-field radius	R <sub>NF</sub>	m	1.5	—	—	—	—	Constant Value	Constant.
Starting time for each application period	t <sub>1</sub>	hr	0	—	—	—	—	Constant Value	Constant.

Input Parameter	Symbol	Unit	Constant Model Parameter Values		Variable Model Parameter Values				Comments
			Value	Basis	Lower Bound	Upper Bound	Mode	Distribution Type	
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.
Averaging Time	$t_{avg}$	hr	8	—	—	—	—	Constant Value	Constant.
Methylene chloride weight fraction	wfrac	wt frac	—	—	0.10	0.80	—	Discrete	Discrete distribution of methylene chloride-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. See Section F.1.2.7 for further discussion.
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 wfrac, $W_d$ , and $N_A$ .
Operating hours per week	OHpW	hr/week	—	—	—	—	—	Lognormal	Lognormal distribution fit to the operating hours per week observed in CARB (2000) site visits. 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

Input Parameter	Symbol	Unit	Constant Model Parameter Values		Variable Model Parameter Values				Comments
			Value	Basis	Lower Bound	Upper Bound	Mode	Distribution Type	
Number of Brake Jobs per Work Shift	N <sub>J</sub>	jobs/site-shift	—	—	1	4	—	Calculated	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<sup>3</sup> with an average shop volume of 3,769 m<sup>3</sup>. Based on this data EPA assumed a triangular distribution bound from 200 m<sup>3</sup> to 70,679 m<sup>3</sup> with a mode of 3,769 m<sup>3</sup> (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<sup>-1</sup> and 3 to 20 hr<sup>-1</sup> 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<sup>-1</sup>. Golsteijn et al. (2014) indicates a characteristic AER of 4 hr<sup>-1</sup>. The risk assessment peer reviewer comments indicated that values around 2 to 5 hr<sup>-1</sup> 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<sup>-1</sup>, the midpoint of the range provided by the risk assessment peer reviewer (3.5 is the midpoint of the range 2 to 5 hr<sup>-1</sup>), with a minimum of 1 hr<sup>-1</sup>, per Demou et al. (2009) and a maximum of 20 hr<sup>-1</sup> 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 ten 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 two-dimensional sampling technique to model the methylene chloride weight fraction. A discrete distribution is used to model the frequency of occurrence 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 each product type. On each iteration of the simulation, the model executes each product's weight fraction distribution and the product frequency distribution. The model then reads the product selected from the product frequency

distribution and selects the weight fraction that was generated from the corresponding product's weight fraction distribution. 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**

<b>Name of Aerosol Degreaser Product Identified in Abt (2017)</b>	<b>Methylene Chloride Weight Percent</b>	<b>Number of Occurrences</b>	<b>Fractional Probability</b>
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
<b>Total</b>		<b>10</b>	<b>1.00</b>

#### **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 (varies according to lognormal distribution, see Table\_Apx F-1/Section F.1.2.11 for discussion), 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

$$N_j = \frac{936 \frac{jobs}{site-year} \times 8 \frac{hours}{shift}}{52 \frac{weeks}{yr} \times OHpW}$$

Where:

$N_j$	=	Number of brake jobs per work shift (jobs/site-shift); and
OHpW	=	Operating hours per week (hr/week).

### F.1.3 Sensitivity of Model Parameters

---

The far-field volume, AER, and near-field indoor air speed exhibit inverse relationships with the calculated NF and FF 8-hr TWA concentrations, with concentrations increasing exponentially at progressively lower  $V_{FF}$  and AER values. EPA used triangular distributions for the far-field volume and AER, and a lognormal distribution for the near-field indoor air speed, as discussed in Sections F.1.2.1,

F.1.2.2, and F.1.2.3, respectively. Generally, the AER value has a greater impact on exposure concentration than the far-field volume and indoor air speed.

Near-field volume also exhibits an inverse relationship with near-field (worker) exposure concentrations. However, this parameter was fixed as a single value within the model framework, based on the available data. Similarly to far-field volume, AER and near-field indoor air speed, smaller near-field volume values would result in calculated exposure concentrations increasing exponentially, while larger values would result in relatively small reductions in near-field exposure concentrations. Far-field exposure concentrations are largely unaffected.

The amount of methylene chloride, which is based on the methylene chloride weight fraction and the amount of degreaser used, has a linear relationship with both the NF and FF 8-hr TWA concentrations. The amount of degreaser used was fixed, based on the available data, while the methylene chloride weight fractions were varied based on a distribution as discussed in Section F.1.2.7.

## **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; and
- Cold Cleaning Near-Field/Far-Field Inhalation Exposure Model.

The models were developed through review of the literature and consideration of existing EPA 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.

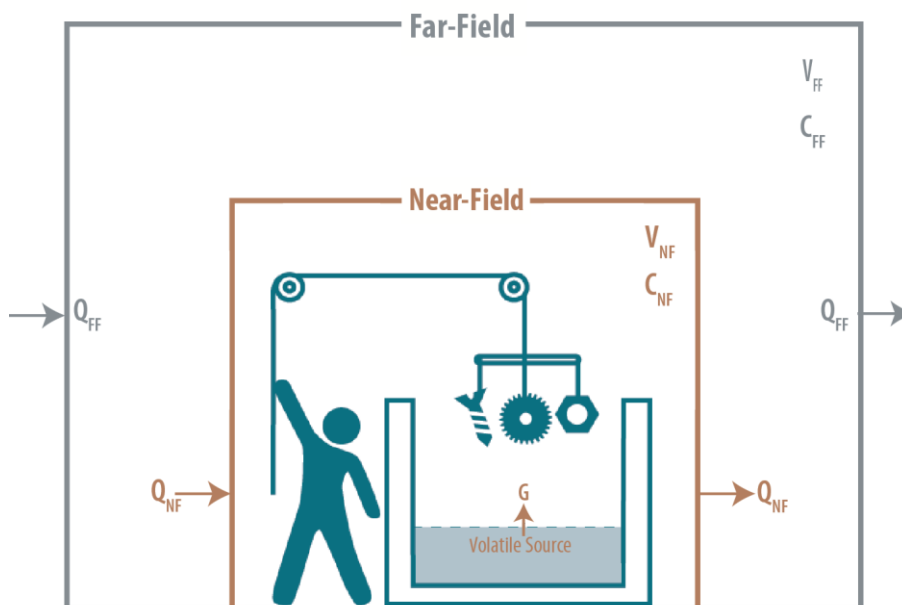
An individual model input parameter could either have a discrete value or a distribution of values. EPA assigned statistical distributions based on available literature data. A Monte Carlo simulation (a type of stochastic simulation) was conducted to capture variability in the model input parameters. 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).

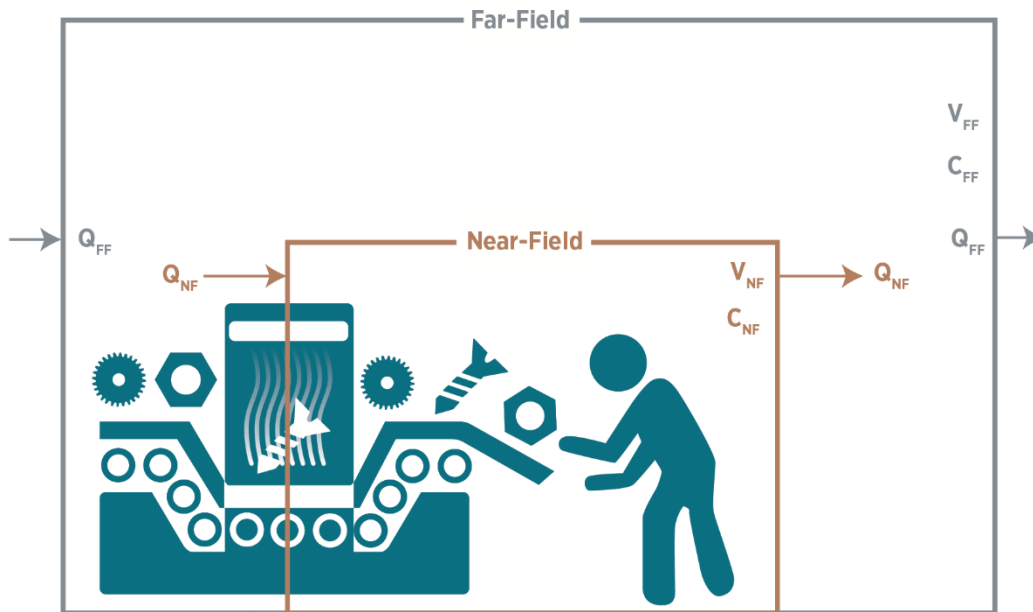
Model results from the Monte Carlo simulation are presented as 95<sup>th</sup> and 50<sup>th</sup> percentile values. The statistics were calculated directly in @Risk. The 95<sup>th</sup> percentile value was selected to represent high-end exposure level, whereas the 50<sup>th</sup> percentile value 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.2-25 through Equation F.2-40. 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**

$$C_{NF} = G(k_1 + k_2e^{\lambda_1 t} - k_3e^{\lambda_2 t})$$

**Equation F.2-28**

$$C_{FF} = G \left( \frac{1}{Q_{FF}} + k_4 e^{\lambda_1 t} - k_5 e^{\lambda_2 t} \right)$$

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**

$$C_{NF,TWA} = \frac{\int_{t_1}^{t_2} C_{NF} dt}{\int_0^{t_{avg}} dt} = \frac{\int_{t_1}^{t_2} G(k_1 + k_2 e^{\lambda_1 t} - k_3 e^{\lambda_2 t}) dt}{t_{avg}} =$$

$$\frac{G\left(k_1 t_2 + \frac{k_2 e^{\lambda_1 t_2}}{\lambda_1} - \frac{k_3 e^{\lambda_2 t_2}}{\lambda_2}\right) - G\left(k_1 t_1 + \frac{k_2 e^{\lambda_1 t_1}}{\lambda_1} - \frac{k_3 e^{\lambda_2 t_1}}{\lambda_2}\right)}{t_{avg}}$$

**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.2-38

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.2-39

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.2-40

:

**Equation F.2-40**

$$Q_{FF} = V_{FF} AER$$

Using the model inputs described in Appendix F.2.2, 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 <sub>FF</sub>	ft <sup>3</sup>	—	—	10,594	70,629	17,657	Triangular	See Section F.2.2.1
Air exchange rate	AER	hr <sup>-1</sup>	—	—	2	20	3.5	Triangular	See Section F.2.2.2
Near-field indoor wind speed	V <sub>NF</sub>	ft/hr	—	—	—	23,882	—	Lognormal	See Section F.2.2.3
		cm/s	—	—	—	202.2	—	Lognormal	
Near-field length	L <sub>NF</sub>	ft	10	—	—	—	—	Constant Value	See Section F.2.2.4
Near-field width	W <sub>NF</sub>	ft	10	—	—	—	—	Constant Value	
Near-field height	H <sub>NF</sub>	ft	6	—	—	—	—	Constant Value	
Starting time	t <sub>1</sub>	hr	0	—	—	—	—	Constant Value	Constant.
Exposure Duration	t <sub>2</sub>	hr	—	—	2	8	—	Discrete	See Section F.2.2.5. Calculated based on Operating Hours per Day
Averaging Time	t <sub>avg</sub>	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 <sub>FF</sub>	ft <sup>3</sup>	—	—	10,594	70,629	17,657	Triangular	See Section F.2.2.1
Air exchange rate	AER	hr <sup>-1</sup>	—	—	2	20	3.5	Triangular	See Section F.2.2.2
Near-field indoor wind speed	V <sub>NF</sub>	ft/hr	—	—	—	23,882	—	Lognormal	See Section F.2.2.3
		cm/s	—	—	—	202.2	—	Lognormal	
Near-field length	L <sub>NF</sub>	ft	10	—	—	—	—	Constant Value	See Section F.2.2.4
Near-field width	W <sub>NF</sub>	ft	10	—	—	—	—	Constant Value	
Near-field height	H <sub>NF</sub>	ft	6	—	—	—	—	Constant Value	
Starting time	t <sub>1</sub>	hr	0	—	—	—	—	Constant Value	Constant.
Exposure Duration	t <sub>2</sub>	hr	—	—	4	8	—	Discrete	See Section F.2.2.5. Calculated based on Operating Hours per Day
Averaging Time	t <sub>avg</sub>	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 <sub>FF</sub>	ft <sup>3</sup>	—	—	10,594	70,629	17,657	Triangular	See Section F.2.2.1
Air exchange rate	AER	hr <sup>-1</sup>	—	—	2	20	3.5	Triangular	See Section F.2.2.2
Near-field indoor wind speed	V <sub>NF</sub>	ft/hr	—	—	—	23,882	—	Lognormal	See Section F.2.2.3
		cm/s	—	—	—	202.2	—	Lognormal	
Near-field length	L <sub>NF</sub>	ft	10	—	—	—	—	Constant Value	See Section F.2.2.4
Near-field width	W <sub>NF</sub>	ft	10	—	—	—	—	Constant Value	
Near-field height	H <sub>NF</sub>	ft	6	—	—	—	—	Constant Value	
Starting time	t <sub>1</sub>	hr	0	—	—	—	—	Constant Value	Constant.
Exposure Duration	t <sub>2</sub>	hr	—	—	1	8	—	Discrete	See Section F.2.2.5. Calculated based on Operating Hours per Day
Averaging Time	t <sub>avg</sub>	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<sup>3</sup> (14,126 and 21,189 ft<sup>3</sup>) 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<sup>3</sup> (10,594 ft<sup>3</sup>) to 2,000 m<sup>3</sup> (70,629 ft<sup>3</sup>) with a mode of 500 m<sup>3</sup> (the midpoint of 400 and 600 m<sup>3</sup>) (17,657 ft<sup>3</sup>).

### **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<sup>-1</sup>. The risk assessment peer reviewer comments indicated that values around 2 to 5 hr<sup>-1</sup> 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<sup>-1</sup>, the midpoint of the range provided by the risk assessment peer reviewer (3.5 is the midpoint of the range 2 to 5 hr<sup>-1</sup>), with a minimum of 2 hr<sup>-1</sup>, per the risk assessment peer reviewer (SCG, 2013) and a maximum of 20 hr<sup>-1</sup> 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<sup>3</sup>.

#### 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 <sup>a</sup>
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 average hourly unit emissions for each machine type calculated from the annual emissions and number of operating hours reported in the 2014 NEI.

**Table\_Apx F-7. Distribution of Average Hourly Methylene Chloride Open-Top Vapor Degreasing Unit Emissions Based on 2014 NEI Data**

<b>Count of Units</b>	<b>Unit Emissions (lb/unit-hr)</b>	<b>Fractional Probability</b>
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	0.015	0.1250

**Table\_Apx F-8. Distribution of Average Hourly Methylene Chloride ConveyORIZED Degreasing Unit Emissions Based on 2014 NEI Data**

<b>Count of Units</b>	<b>Unit Emissions (lb/unit-hr)</b>	<b>Fractional Probability</b>
1	5.81	0.5000
1	4.86	0.5000

**Table\_Apx F-9. Distribution of Average Hourly Methylene Chloride Cold Cleaning Unit Emissions Based on 2014 NEI Data**

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	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 Average Methylene Chloride Open-Top Vapor Degreasing Operating Hours Based on 2014 NEI Data**

Operating Hours (hr/day)	Fractional Probability
8	0.2000
4	0.4000
2	0.4000



**Table\_Apx F-11. Distribution of Average Methylene Chloride ConveyORIZED Degreasing Operating Hours Based on 2014 NEI Data**

<b>Operating Hours (hr/day)</b>	<b>Fractional Probability</b>
8	0.5000
4	0.5000

**Table\_Apx F-12. Distribution of Methylene Chloride Cold Cleaning Operating Hours Based on 2014 NEI Data**

<b>Operating Hours (hr/day)</b>	<b>Fractional Probability</b>
24	0.4583
16	0.0417
10	0.1250
8	0.3333
1	0.0417

### **F.2.1 Sensitivity of Model Parameters**

The far-field volume, AER, and near-field indoor air speed exhibit inverse relationships with the calculated NF and FF 8-hr TWA concentrations, with the concentrations increasing exponentially at progressively lower far-field volumes and AER values. EPA used triangular distributions for the far-field volume and AER, as discussed in Sections F.2.2.1 and F.2.2.2, respectively, and used a lognormal distribution for near-field indoor air speed as discussed in Section F.2.2.3. Far-field volume and AER have a similar relative impact on exposure concentrations, but less effect than the near-field indoor air speed.

The near-field volume also exhibits an inverse relationship with near-field (worker) exposure concentrations. These parameters were fixed within the model framework, based on the available data. Similarly to far-field volume, AER, and near-field indoor air speed, using lower near-field volume values would result in exposure concentrations increasing exponentially, while higher values would result in relatively small reductions in near-field exposure concentrations. Far-field exposure concentrations are largely unaffected.

The vapor generation rate follows a linear relationship with both the NF and FF 8-hr TWA concentrations. A distribution of potential emissions rates was based on NEI data, as discussed in Section F.2.2.7.

# APPENDIX G DATA INTEGRATION STRATEGY FOR OCCUPATIONAL EXPOSURE AND RELEASE DATA/INFORMATION

---

## General Approach

Data integration is the stage following the data extraction and evaluation step discussed in the *Application of Systematic Review in TSCA Risk Evaluations* ([U.S. EPA, 2018b](#)). Data integration is where the analysis, synthesis and integration of data/ information takes place. For integration of occupational exposure and environmental release data/information, EPA will normally use the highest rated quality data among the higher level of the hierarchy of preferences as described below. Tables 1 and 2 below present the hierarchy of preferences among the primary types of data/ information to be analyzed, synthesized and integrated for the occupational exposure and release assessments in the TSCA risk evaluations. EPA will provide rationale when deviations from the hierarchy occur.

### *Selection of Data and Approaches*

EPA will select data for use from the data extraction and evaluation phase of systematic review. EPA will only use data/information rated as High, Medium, or Low in the environmental release and occupational exposure assessments; data/ information rated as unacceptable will not be used. If need be, data of lower rated quality or approaches in lower levels of the hierarchy may be used to supplement the analysis. For example, data/ information of high quality could be determined to be sufficient such that lower quality data may not be included or integrated with the higher quality data. Also, data/ information of high quality could be determined to be sufficient such that approaches assigned lower preference levels in the hierarchy may not be pursued even if they are available and possible. In many cases EPA does not have robust and or representative monitoring data and will augment such data with modeled estimates of exposure.

### *Assessment Data and Results*

EPA will provide occupational exposure and environmental release data and results representative of *central tendency* conditions and *high-end* conditions. A central tendency is assumed to be representative of occupational exposures and environmental releases in the center of the distribution for a given condition of use. For risk evaluation, EPA may use the 50<sup>th</sup> percentile (median), mean (arithmetic or geometric), mode, or midpoint values of a distribution as representative of the central tendency scenario. EPA's preference is to provide the 50<sup>th</sup> percentile of the distribution. However, if the full distribution is not known, EPA may assume that the mean, mode, or midpoint of the distribution represents the central tendency depending on the statistics available for the distribution.

A high-end is assumed to be representative of occupational exposures and environmental releases that occur at probabilities above the 90<sup>th</sup> percentile but below the exposure of the individual with the highest exposure (U.S. EPA, 1992) or the highest release. For risk evaluation, EPA plans to provide high-end results at the 95<sup>th</sup> percentile. If the 95<sup>th</sup> percentile is not available, EPA may use a different percentile greater than or equal to the 90<sup>th</sup> percentile but less than or equal to the 99.9<sup>th</sup> percentile, depending on the statistics available for the distribution. If the full distribution is not known and the preferred statistics are not available, EPA may estimate a maximum or bounding estimate in lieu of the high-end.

EPA has defined occupational exposure and environmental release scenarios (OEERS) as the most granular level that EPA will generate results within each condition of use. For some conditions of use, EPA may define only a single OEERS (e.g., a manufacturing condition of use for multiple manufacturing sites may be defined by a single manufacturing OEERS). Other conditions of use have multiple OEERS (e.g., the use of chemical X in vapor degreasing has OEERS for open-top batch vapor degreasing, conveyORIZED degreasing, web degreasing, and closed-system degreasing). EPA will attempt to provide a single set of results (central tendency and high-end) for each release or exposure assessed for an OEERS.

### *Integration of Data Sets*

To provide the occupational and environmental release results at the central tendency and high-end descriptors, EPA may integrate data sets representative of different sites, job descriptions, or process conditions to develop a distribution representative of the entire population of workers and sites involved in the given OEERS in the United States. Ideally, the distribution would account for inter-site variability (variability in operations among different sites) and intra-site variability (variability in operations within a single site).

To integrate data sets together, EPA will review the available metadata for each data set to ensure the data sets are representative of the same OEERS. EPA will document any uncertainties in the metadata or if EPA used a data set of a similar scenario as surrogate for the OEERS being assessed.

### *Integration of Data for Modeling and Calculations*

For occupational exposures, EPA may use measured or estimated air concentrations to calculate exposure concentration metrics required for risk assessment, such as average daily concentration and lifetime average daily concentration. These calculations require additional parameter inputs, such as years of exposure, exposure duration and frequency, and lifetime years. EPA may estimate exposure concentrations from monitoring data, modeling, or occupational exposure limits, as identified in Table 1 and use each of these in its evidence integration to assess the strength of the evidence.

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 50<sup>th</sup> percentile or 95<sup>th</sup> percentile) or a *full distribution*. EPA will consider three general approaches for estimating the final exposure result metrics:

- **Deterministic calculations:** EPA will use combinations of point estimates of each parameter to estimate a central tendency and high-end for each final exposure metric result. EPA will document the method and rationale for selecting parametric combinations to be representative of central tendency and high-end.
- **Probabilistic (stochastic) calculations:** EPA will pursue Monte Carlo simulations using the full distribution of each parameter to calculate a full distribution of the final exposure metric results and selecting the 50<sup>th</sup> and 95<sup>th</sup> percentiles of this resulting distribution as the central tendency and high-end, respectively.
- **Combination of deterministic and probabilistic calculations:** EPA may have full distributions for some parameters but point estimates of the remaining parameters. For example, EPA may pursue Monte Carlo modeling to estimate exposure concentrations, but only have point estimates of working years of exposure, exposure duration and frequency, and lifetime years. In this case,

EPA will document the approach and rationale for combining point estimates with distribution results for estimating central tendency and high-end results.

- Probabilistic approaches can also supplement and complement monitoring estimates by providing sensitivity analysis of parameters for certain conditions and thus provide greater certainty about the strength of the evidence.

### *Overall Confidence Statements*

For each use, EPA considered the assessment approach, the quality of the data and models, and uncertainties in assessment results to determine an overall level of confidence for the full shift (8-hr and 12-hr TWA) data and modeled estimates and for dermal potential dose estimates.

For the inhalation air concentration monitoring data, strength of confidence is improved by the following factors:

- higher approaches in the inhalation approach hierarchy
- larger number of sites monitored
- larger broadness of worker population groups included in monitoring
- higher systematic review data quality ratings.

Strength of confidence in monitoring data is reduced by:

- having a portion of a use's monitoring data that had been sampled before the OSHA PEL for methylene chloride was reduced (effective after transition in 2000)
- uncertainty of the representativeness of these data toward the true distribution of inhalation concentrations for the industries and sites covered by the use.

For modeled air concentrations, strength of confidence is improved by the following factors:

- higher approaches in the inhalation approach hierarchy
- model validation
- full distributions of input parameters.

Strength of confidence in modeled air concentration estimates is reduced by:

- uncertainty of the representativeness of the model or parameter inputs toward the true distribution of inhalation concentrations for the industries and sites covered by the use.


For dermal dose rate estimates, strength of confidence is improved by the following factors:

- use of actual data rather than assumptions for input parameters

Strength of confidence in dermal potential dose rates is reduced by:


- uncertainty of the representativeness of the of the model or parameter inputs toward the true distribution of dermal doses for the industries and sites covered by the use.

**Table\_Apx G-1. Hierarchy guiding integration of occupational exposure data/information**

<p>For occupational exposures, the generic hierarchy of preferences, listed from highest to lowest levels, is as follows (and may be modified based on the assessment):</p>	
<p>Highest Preferred</p>  <p>Lowest Preferred</p>	<p>1. Monitoring data:</p> <ul style="list-style-type: none"> <li>a. Personal and directly applicable</li> <li>b. Area and directly applicable</li> <li>c. Personal and potentially applicable or similar</li> <li>d. Area and potentially applicable or similar</li> </ul>
	<p>2. Modeling approaches:</p> <ul style="list-style-type: none"> <li>a. Surrogate monitoring data: Modeling exposure for chemical “X” and condition of use “A” based on observed monitoring data for chemical “Y” and condition of use “A”, assuming a known relationship (e.g., a linear relationship) between observed exposure and physical property (e.g., vapor pressure).</li> <li>b. Fundamental modeling approaches: Modeling exposure for chemical “X” for condition of use “A” based on fundamental mass transfer, thermodynamic, and kinetic phenomena for chemical “X” and data for condition of use “A”</li> <li>c. Fundamental modeling approaches (with surrogacy): A modeling approach following item 2.b, but using surrogate data in the model, such as data for condition of use “B” judged to be similar to condition of use “A”</li> <li>d. Statistical regression modeling approaches: Modeling exposure for chemical “X” in condition of use “A” using a statistical regression model developed based on: <ul style="list-style-type: none"> <li>i. Observed monitoring data for chemical “X” statistically correlated with observed data specific for condition of use “B” judged to be similar to condition of use “A” such that replacement of input values in the model can extrapolate exposure results to condition of use “A”</li> <li>ii. Observed monitoring data for chemical “Y” statistically correlated with physical properties and/or molecular structure such that an exposure prediction for chemical “X” can be made (e.g., QSAR techniques)</li> </ul> </li> </ul>
	<p>3. Occupational exposure limits (OELs):</p> <ul style="list-style-type: none"> <li>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)</li> <li>b. OSHA PEL</li> <li>c. Voluntary limits (ACGIH TLV, NIOSH REL, OARS WEEL [formerly by AIHA])</li> </ul>

**Table\_Apx G-2. Hierarchy guiding integration of environmental release data/information**

For environmental releases, the generic hierarchy of preferences, listed from highest to lowest levels, is as follows (and may be modified based on the assessment):

<p>Highest Preferred</p> 	<ol style="list-style-type: none"> <li>1. Monitoring and measured data:             <ol style="list-style-type: none"> <li>a. Releases calculated from site-specific concentration in medium and flow rate data (e.g., concentration in and flow rate of wastewater effluent discharged through outfall)</li> <li>b. Releases calculated from mass balances or emission factor methods using site-specific measured data (e.g., process flow rates and concentrations)</li> </ol> </li> </ol>
	<ol style="list-style-type: none"> <li>2. Modeling approaches:             <ol style="list-style-type: none"> <li>a. Surrogate monitoring data: Modeling release for chemical “X” and condition of use “A” based on observed monitoring data for chemical “Y” and condition of use “A”, assuming a known relationship (e.g., a linear relationship) between observed release and physical property (e.g., vapor pressure).</li> <li>b. Fundamental modeling approaches: Modeling release for chemical “X” for condition of use “A” based on fundamental mass transfer, thermodynamic, and kinetic phenomena for chemical “X” and data for condition of use “A”</li> <li>c. Fundamental modeling approaches (with surrogacy): A modeling approach following item 2.b, but using surrogate data in the model, such as data for condition of use “B” judged to be similar to condition of use “A”</li> <li>d. Statistical regression modeling approaches: Modeling release for chemical “X” in condition of use “A” using a statistical regression model developed based on:                 <ol style="list-style-type: none"> <li>iii. Observed monitoring data for chemical “X” statistically correlated with observed data specific for condition of use “B” judged to be similar to condition of use “A” such that replacement of input values in the model can extrapolate exposure results to condition of use “A”</li> <li>iv. Observed monitoring data for chemical “Y” statistically correlated with physical properties and/or molecular structure such that a release prediction for chemical “X” can be made (e.g., QSAR techniques)</li> </ol> </li> </ol> </li> </ol>
<p>Lowest Preferred</p>	<ol style="list-style-type: none"> <li>3. Release limits:             <ol style="list-style-type: none"> <li>a. Company-specific limits (for site-specific exposure assessments, e.g., there is only one manufacturer who provides to EPA their internal limits (e.g., point-source permits) but does not provide monitoring data)</li> <li>b. NESHAP or effluent limitations/ requirements</li> </ol> </li> </ol>

## APPENDIX H OSHA DATA STATISTICAL SUMMARY

This appendix describes the statistical analysis EPA conducted on the OSHA data provided in the public comment Finkel (2017).

### H.1.1 Review and Pre-Treatment of OSHA Data

EPA reviewed the OSHA data provided in the public comment and conducted a pre-treatment of the data prior to conducting the statistical analysis. The following steps outline EPA’s pre-treatment of the OSHA data.

1. The initial OSHA data set provided in the public comment included 12,151 data entries, which ranged in sample date from June 1, 1984 to January 22, 2016. The data set contained the fields summarized in the table below. A definition of each field was not provided. The following table provides EPA’s understanding of the definition of each field.

OSHA Data Set Field	EPA’s Understanding of the Definition of the Field
inspecnum	The identification number of the inspection.
samplenum	The identification number of the sample. EPA understands “sample” in this context to mean the collection of <i>field samples</i> taken on a single worker during a given work shift.
imis	The IMIS identification number for the chemical.
ctime	The duration of the <i>field sample</i> measured in minutes.
office	The code of the OSHA regional office or state health agency that performed the inspection.
type	The type of sample taken: <ul style="list-style-type: none"> <li>• P = Personal breathing zone sample</li> <li>• A = Area air sample</li> <li>• B = Bulk sample (e.g., a sample of a chemical formulation used at the facility)</li> <li>• S = EPA suspects this may mean a serology (blood) sample</li> </ul>
cresult	The analytical result of the field sample.
sic	The SIC code of the inspected facility.
cdate_sampled	The date the field sample was taken.
blank	A “yes” (Y) or “no” (N) indicating whether the field sample taken was a field blank.

OSHA Data Set Field	EPA's Understanding of the Definition of the Field
cair_volume	The air volume of the field sample.
uom	The unit of measure of the analytical result: <ul style="list-style-type: none"> <li>• P = parts per million (ppm)</li> <li>• X = percent</li> <li>• O = other</li> <li>• X = micrograms</li> </ul>
street	The street address of the inspected facility.
city	The city of the inspected facility.
st	The state of the inspected facility.
establishment	The name of the inspected facility.
zip	The zip code of the inspected facility.

- EPA filtered the data set to only include data entries marked as personal breathing zone samples (type = P) and unit of measures reported in ppm (uom = P), and EPA excluded data entries marked as being field blanks (blank = Y).
- EPA observed some samples with the same sample identification number and with the exact same sample duration and sample result. EPA suspected these may be duplicate field samples or a single field sample entered into the database twice. EPA removed data entries where the sample identification number, the sample duration, and the sample result were identical.
- EPA assumed the remaining data entries were all unique field samples. EPA then combined all field samples with the same sample identification number, assuming these were multiple field samples taken on the same worker during a single work shift. EPA combined these field samples by summing the product of sample duration and sample result (min x ppm) for all samples of the same sample identification number.
- EPA then calculated the product of sample duration and sample result (min x ppm) for all remaining samples (cases where only a single field sample result is reported for a given sample identification number).
- EPA then calculated 8-hr TWA exposures by dividing each sample's calculated result from Steps 4 and 5 by 480 minutes (8 hours). For any samples where the sum total of the field sample durations was greater than 480 minutes, EPA divided the summed products of sample duration and sample result (min x ppm) by the sum total of field sample durations instead of 480 minutes. This calculates an extended-shift TWA exposure, which EPA assumes is equal to the 8-hr TWA exposure. This assumes a worker is exposed at the same rate during the hours beyond 8 hours as they were exposed during the 8 hours. This yielded 3,305 8-hr TWA exposure values.
- For any calculated 8-hr TWA exposures that were equal to zero, EPA replaced this value with the limit of detection (LOD) divided by the square root of two. The exact LOD of the sampling and analysis method used in each inspection conducted from 1984 to 2016 is not known. OSHA method 80 for methylene chloride (fully validated in 1990) reports an LOD of 0.201 ppm ([OSHA, 1990](#)). NIOSH method 1005 for methylene chloride (issued January 15, 1998) reports an



LOD of 0.4 micrograms per sample, with a minimum and maximum air sample volume of 0.5 and 2.5 liters, respectively (NIOSH, 1998). EPA calculated a range in LOD for the NIOSH method of 0.046 to 0.231 ppm. For this analysis, EPA used an LOD of 0.046 ppm (the smallest of these three LOD values) and an LOD divided by the square root of two of 0.0326 ppm.

8. EPA divided the 8-hr TWA exposures into three groups: a pre-rule period; a transition period; and a post-rule period. OSHA published their final rule to change the methylene chloride PEL from 500 ppm to 25 ppm on April 10, 1997. The rule had multiple requirements for different industry groups with different deadlines for compliance with each requirement. The longest compliance period was three years after the final rule’s effective date, which equates to April 10, 2000. Therefore, EPA divided the three periods as: a pre-rule period of prior to April 10, 1997; a transition period of April 10, 1997 until April 10, 2000; and a post-rule period of after April 10, 2000.

### H.1.2 Two-Sample Test of Pre-Rule and Post-Rule Time Periods

EPA first conducted a two-sample statistical test to evaluate if the pre-rule period and post-rule period samples could be viewed as coming from the same population, meaning the change in PEL did not result in a statistically significant change to the overall population of exposures. EPA used Welch’s t-test for unequal variances to conduct this statistical inference test.

A two-sample statistical inference is conducted by defining a test and the corresponding null and alternate hypotheses. EPA is interested in whether the mean of the post-rule population is less than the mean of the pre-rule population (i.e., did exposures decrease after the rule). EPA defines the corresponding hypotheses as:

$$\begin{aligned} \text{Null Hypothesis (H}_0\text{): } & \mu_1 = \mu_2 \\ \text{Alternate Hypothesis (H}_a\text{): } & \mu_1 - \mu_2 > 0 \end{aligned}$$

EPA first calculated the following statistics for the pre-rule and post-rule periods.

**Table\_Apx H-1. Comparison of Statistics Pre- and Post-Rule Period**

	Pre-Rule Period (1)	Post-Rule Period (2)
Arithmetic Mean (ppm) ( $\bar{x}$ )	27.26	17.86
Sample Size (N)	1,407	1,471
Standard Deviation (ppm) (s)	68.17	79.69
Degrees of Freedom (v)	1,406	1,470

EPA next calculated the pooled degrees of freedom for the two samples (the pre-rule period and the post-rule period) using the Welch-Satterthwaite equation.

$$v_p = \frac{\left[ \frac{s_1^2}{N_1} + \frac{s_2^2}{N_2} \right]^2}{\frac{s_1^4}{N_1^2 v_1} + \frac{s_2^4}{N_2^2 v_2}} \quad \text{Eqn. H-1}$$

Where:

- $v_p$  = The pooled degrees of freedom
- $s_1$  = The standard deviation of sample 1 (pre-rule period)
- $s_2$  = The standard deviation of sample 2 (post-rule period)
- $N_1$  = The sample size of sample 1 (pre-rule period)

$N_2$	=	The sample size of sample 2 (post-rule period)
$v_1$	=	The degrees of freedom of sample 1 (pre-rule period)
$v_2$	=	The degrees of freedom of sample 2 (post-rule period)

EPA calculated a pooled degrees of freedom of 2,841.

The t-statistic is defined by:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}} \quad \text{Eqn. H-2}$$

Where:

$\bar{x}_1$	=	The arithmetic mean of sample 1 (pre-rule period)
$\bar{x}_2$	=	The arithmetic mean of sample 2 (post-rule period)

A critical t-statistic ( $t^*$ ) is defined as the t-statistic value at a selected confidence level. EPA selected a confidence level of 95%, which equates to a value of  $\alpha$  of 0.05 ( $0.05 = 1 - 0.95$ ). Using an  $\alpha$  value of 0.05 and a pooled degrees of freedom of 2,841, the critical two-tailed t-statistic from the t-distribution is 1.96.

EPA then calculated the t-statistic from the two samples using Equation H-2 and the calculated values in Table\_Apx H-1, which results in a t-statistic of 3.41. The corresponding two-tailed probability for a t-statistic of 3.41 and a pooled degrees of freedom of 2,841 from the t-distribution is 6.7E-4 (~0.07%). Since the two-tailed probability (6.7E-4) is less than the  $\alpha$  value of 0.05 for a confidence level of 95%, and the calculated t-statistic of 3.41 is greater than the critical two-tailed t-statistic of 1.96, the null hypothesis must be rejected. Therefore, it cannot be assumed at a 95% confidence level that the pre-rule and post-rule samples were drawn from the same population.

### **H.1.3 Calculation and Comparison of Statistics of Pre-Rule and Post-Rule Time Periods**

EPA analyzed 1,407 and 1,471 8-hr TWA exposures measured prior to April 10, 1997 (pre-rule period) and after April 10, 2000 (post-rule period). The arithmetic mean of the pre-rule and post-rule distributions was 27.3 ppm and 17.9 ppm, respectively, a reduction of about 34%. The median of the pre-rule and post-rule distributions was 3.7 ppm and 2.5 ppm, respectively, a reduction of about 31%, similar to the reduction in the mean. EPA calculated the percentile ranks of 25 ppm in the pre-rule and post-rule distributions: approximately 23% and 15% of the exposures exceeded 25 ppm in the pre-rule and post-rule distributions, respectively. This is a reduction of about 35%, similar to the reductions in the mean and median. While exposures in the distributions showed consistent reductions of about 30% to 35%, this followed a reduction in the PEL of 95%. Hence, a twentyfold reduction in the PEL resulted in only an approximately 1.5-fold reduction in actual exposures. Due to the small reduction in exposures relative to the reduction in PEL, EPA included the pre-rule samples in the occupational exposure assessment to provide a more robust data set.

In addition to analyzing the entire distributions, EPA crosswalked reported SIC codes to 2017 NAICS codes and analyzed exposures in certain industry sectors. Table\_Apx H-2 summarizes an analysis of industry codes representing the larger shares of the data set, while Table\_Apx H-3 summarizes an analyses by OES (using the same NAICS codes used for the Number of Workers analyses discussed Section 1.4.2). The summaries generally show a range in exposure reductions across

the industry sectors. The largest OES decreases were for spot cleaning (94.5%) and fabric finishing (93.4%). On the other hand, exposures increased for plastics manufacturing (617%) and aerosol degreasing (130%).

**Table\_Apx H-2. Summary of Pre- and Post-Rule Exposure Concentrations for Industries with Largest Number of Data Points**

NAICS Code	NAICS Description	Pre-Rule Update (prior to April 10, 1997)			Post-Rule Update, after all requirements in effect (after April 10, 2000)			Percent Reduction in Mean (%)
		Number of Samples	Arithmetic Mean (ppm)	Percent of Samples Above 25 ppm	Number of Samples	Arithmetic Mean (ppm)	Percent of Samples Above 25 ppm	
811420	Reupholstery and Furniture Repair	36	98.73	53.8%	121	29.38	30.8%	70.2%
337110	Wood Kitchen Cabinet and Countertop Manufacturing	35	9.91	11.7%	80	6.96	4.7%	29.8%
326121	Unlaminated Plastics Profile Shape Manufacturing	76	35.00	30.2%	78	14.24	11.5%	59.3%
326140	Polystyrene Foam Product Manufacturing	12	19.27	31.9%	15	11.44	12.0%	40.6%
336211	Motor Vehicle Body Manufacturing	32	50.69	30.3%	6	3.04	N/A <sup>a</sup>	94.0%
323111	Commercial Printing (except Screen and Books)	55	9.54	11.1%	28	5.02	5.8%	47.4%
541380	Testing Laboratories	16	2.43	N/A <sup>a</sup>	29	3.65	2.2%	-50.6% <sup>b</sup>
316110	Leather and Hide Tanning and Finishing	10	8.14	5.8%	40	8.90	12.9%	-9.4% <sup>b</sup>
All NAICS Codes Together		1,407	27.26	23.0%	1,471	17.86	15.0%	34%

a – N/A: Not applicable. There are no exposures above 25 ppm.

b – A negative reduction means the mean exposure increased from the pre-rule to post-rule periods.

**Table\_Apx H-3. Summary of Pre- and Post-Rule Exposure Concentrations Mapped to Occupational Exposure Scenarios**

OES	Potential NAICS	Pre-Rule Update (prior to April 10, 1997)			Post-Rule Update, after all requirements in effect (after April 10, 2000)			Percent Reduction in Mean (%)
		Number of Samples	Arithmetic Mean (ppm)	Percent of Samples Above 25 ppm	Number of Samples	Arithmetic Mean (ppm)	Percent of Samples Above 25 ppm	
Processing as a Reactant	325120, 325320	12	15.2	16.7%	0	N/A <sup>a</sup>	N/A <sup>a</sup>	N/A <sup>a</sup>

Processing - Incorporation into Formulation	325510, 325520, 325998	23	46.2	52.2%	17	28.1	47.1%	39.3%
Aerosol degreasing	811111, 811112, 811113, 811118, 811121, 811122, 811191, 811198, 811211, 811212, 811213, 811219, 811310, 811411, 811490, 451110, 441100	13	6.6	7.7%	15	15.1	13.3%	-129.7%
Adhesives and Sealants	326150, 332300, 333900, 334100, 334200, 334300, 334400, 334500, 334600, 335100, 335200, 335300, 335900, 336100, 336200, 336300, 336400, 336500, 336600, 337100, 811420	256	44.8	32.0%	230	24.4	24.4%	45.5%
Paints and Coatings	238320, 323113, 332000, 337100, 448100, 713100, 811111	78	23.5	19.2%	169	12.3	7.7%	47.8%
Fabric Finishing	313210, 313220, 313230, 313240, 313310, 313320	27	15.3	18.5%	6	1.0	0.0%	93.4%
Spot Cleaning	812320, 812332	14	14.1	21.4%	3	0.8	0.0%	94.5%
Laboratory Use	541380, 621511	19	5.2	5.3%	36	3.2	2.8%	38.9%
Plastic Product Mfg	325211, 325212, 325220, 325991, 326199	14	3.6	0.0%	20	26.1	5.0%	-616.9%
Lithographic Printing Plate Cleaning	323111	55	9.5	10.9%	28	5.0	7.1%	47.4%
Waste Handling, Disposal, Treatment, and Recycling	562211, 562213, 562920	15	6.0	6.7%	0	N/A <sup>a</sup>	N/A <sup>a</sup>	N/A <sup>a</sup>

a – N/A: Not applicable. Insufficient data points available.

b – N/A: Not applicable. There are no exposures above 25 ppm.

c – A negative reduction means the mean exposure increased from the pre-rule to post-rule periods. EPA does not have reasonably available information to indicate possible reasons for increases.

## REFERENCES

- 
- (CARB), CARB. (2006). California Dry Cleaning Industry Technical Assessment Report. Stationary Source Division, Emissions Assessment Branch.  
<https://www.arb.ca.gov/toxics/dryclean/finaldrycleantechreport.pdf>
- (DOEHRS-IH), DOaEHRS-IH. (2018). Email between DOD and EPA: RE: [Non-DoD Source] Update: DoD exposure data for EPA risk evaluation - EPA request for additional information [Personal Communication]. Washington, D.C.: U.S. Department of Defense.
- (IPCS), IPoCS. (1996). Environmental Health Criteria 164. Methylene Chloride Second Edition. Geneva, Switzerland: International Programme on Chemical Safety (IPCS).  
<http://www.inchem.org/documents/ehc/ehc/ehc164.htm>
- (IRTA), TifRaTA. (2006). Protecting the health of lithographic printers - Safer alternatives to toxic cleanup solvents [Fact Sheet]. The Institute for Research and Technical Assistance (IRTA).
- (NIOSH), NIOSaH. (2002a). In-depth survey report: control of perchloroethylene (PCE) in vapor degreasing operations, site #1. (EPHB 256-19b). Cincinnati, Ohio: National Institute for Occupational Safety and Health (NIOSH).
- (NIOSH), NIOSaH. (2002b). In-depth survey report: control of perchloroethylene (PCE) in vapor degreasing operations, site #4. (EPHB 256-18b). Cincinnati, Ohio: National Institute for Occupational Safety and Health (NIOSH).
- (OSHA), OSHA. (1998). Methylene Chloride Facts No. 9 - Suggested Work Practices for Cold Degreasing and Other Cold Cleaning Operations. Washington D.C.: Occupational Safety and Health Administration (OSHA).  
<https://www.osha.gov/SLTC/methylenechloride/factsheets/mcfsno9.html>
- Abt (Abt Associates Inc). (2017). Draft use and market profile for methylene chloride and NMP. (Contract # EP-W-16-009, WA #1-01). Bethesda, MD.
- AIHA (American Industrial Hygiene Association). (2009). Mathematical models for estimating occupational exposure to chemicals. In CB Keil; CE Simmons; TR Anthony (Eds.), (2nd ed.). Fairfax, VA: AIHA Press. [https://online-ams.aiha.org/amssa/ecsshop.show\\_product\\_detail?p\\_mode=detail&p\\_product\\_serno=889](https://online-ams.aiha.org/amssa/ecsshop.show_product_detail?p_mode=detail&p_product_serno=889)
- Baldwin, PE; Maynard, AD. (1998). A survey of wind speed in indoor workplaces. Ann Occup Hyg 42: 303-313. [http://dx.doi.org/10.1016/S0003-4878\(98\)00031-3](http://dx.doi.org/10.1016/S0003-4878(98)00031-3)
- Bernstein, A, . (2017). Arkema Inc. Comments to Inform EPA's Rulemaking on the Problem Formulations for the Risk Evaluations for Certain of the First Ten Chemical Substances under the Lautenberg Chemical Safety Act (LCSA). (EPA-HQ-OPPT-2016-0742-0079). Washington, D.C.: Bernstein, A. <https://www.regulations.gov/document?D=EPA-HQ-OPPT-2016-0742-0079>
- CalRecycle (California Department of Resources Recycling and Recovery). (2018). Beyond 2000: California's Continuing Need for Landfills. Available online at <https://www.calrecycle.ca.gov/SWFacilities/Landfills/NeedFor>
- CARB (California Air Resources Board). (2000). Initial statement of reasons for the proposed airborne toxic control measure for emissions of chlorinated toxic air contaminants from automotive maintenance and repair activities.
- Center, ETCHWR. (2018). High Temperature Incineration. Washington D.C.: Environmental Technology Council Hazardous Waste Resources Center. <http://etc.org/advanced-technologies/high-temperature-incineration.aspx>

- [Cherrie, JW; Semple, S; Brouwer, D.](#) (2004). Gloves and Dermal Exposure to Chemicals: Proposals for Evaluating Workplace Effectiveness. *Ann Occup Hyg* 48: 607-615.  
<http://dx.doi.org/10.1093/annhyg/meh060>
- [Cone Mills](#) (Cone Mills Corporation). (1981). Survey results of personal exposure monitoring with cover letter [TSCA Submission]. (OTS: OTS0205909; 8EHQ Num: NA; DCN: 878210294; TSCATS RefID: 16734; CIS: NA). Cone Mills Corp.
- [Cone Mills](#) (Cone Mills Corporation). (1982). Health & safety study report (EPA 40 CFR part 716) [TSCA Submission]. (OTS: OTS0205907; 8EHQ Num: NA; DCN: 878210299; TSCATS RefID: 16553; CIS: NA). Greensboro, NC.  
<https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/OTS0205907.xhtml>
- [Dancik, Y; Bigliardi, PL; Bigliardi-Qi, M, ei.](#) (2015). What happens in the skin? Integrating skin permeation kinetics into studies of developmental and reproductive toxicity following topical exposure. *Reprod Toxicol* 58: 252-281. <http://dx.doi.org/10.1016/j.reprotox.2015.10.001>
- [Dell, LD; Mundt, KA; Mcdonald, M; Tritschler, JP; Mundt, DJ.](#) (1999). Critical review of the epidemiology literature on the potential cancer risks of methylene chloride [Review]. *Int Arch Occup Environ Health* 72: 429-442. <http://dx.doi.org/10.1007/s004200050396>
- [Demou, E; Hellweg, S; Wilson, MP; Hammond, SK; Mckone, TE.](#) (2009). Evaluating indoor exposure modeling alternatives for LCA: A case study in the vehicle repair industry. *Environ Sci Technol* 43: 5804-5810. <http://dx.doi.org/10.1021/es803551y>
- [Durkee, J.](#) (2014). Cleaning with solvents: Methods and machinery. In *Cleaning with solvents: Methods and machinery*. Oxford, UK: Elsevier Inc.  
<https://www.sciencedirect.com/book/9780323225205/cleaning-with-solvents-methods-and-machinery>
- [EPA, USEPAUS.](#) (1994). Guidelines for Statistical Analysis of Occupational Exposure Data: Final. United States Environmental Protection Agency :: U.S. EPA.
- [EU](#) (European Union). (2007). Impact assessment of potential restrictions on the marketing and use of dichloromethane in paint strippers. Revised final report-Annexes. Brussels, Belgium: European Commission, Directorate-General Enterprise and Industry. <http://docplayer.net/35027991-Impact-assessment-of-potential-restrictions-on-the-marketing-and-use-of-dichloromethane-in-paint-strippers-revised-final-report-annexes.html>
- [Fairfax, R; Porter, E.](#) (2006). OSHA compliance issues - Evaluation of worker exposure to TDI, MOCA, and methylene chloride. *J Occup Environ Hyg* 3: D50-D53.  
<http://dx.doi.org/10.1080/15459620600671688>
- [FH, F.](#) (2012). Dermal Absorption of Finite doses of Volatile Compounds. *J Pharm Sci* 101: 2616-2619.  
<http://dx.doi.org/10.1080/15287394>
- [Finkel, A, .M.](#) (2017). [Comment letter of Adam M. Finkel regarding Docket ID No. EPA-HQ-OPPT-2016-0231-0536. Available online at <https://www.regulations.gov/document?D=EPA-HQ-OPPT-2016-0231-0536>
- [Frasch, HF; Bunge, AL.](#) (2015). The transient dermal exposure II: post-exposure absorption and evaporation of volatile compounds. *J Pharm Sci* 104: 1499-1507.  
<http://dx.doi.org/10.1002/jps.24334>
- [Frasch, HF; Dotson, GS; Barbero, AM.](#) (2011). In vitro human epidermal penetration of 1-bromopropane. *J Toxicol Environ Health A* 74: 1249-1260.  
<http://dx.doi.org/10.1080/15287394.2011.595666>
- [Garrod, AN; Phillips, AM; Pemberton, JA.](#) (2001). Potential exposure of hands inside protective glovesa summary of data from non-agricultural pesticide surveys. *Ann Occup Hyg* 45: 55-60.  
[http://dx.doi.org/10.1016/S0003-4878\(00\)00013-2](http://dx.doi.org/10.1016/S0003-4878(00)00013-2)
- [GE](#) (General Electric Company). (1989). MORBIDITY STUDY OF OCCUPATIONAL EXPOSURE TO METHYLENE CHLORIDE USING A COMPUTERIZED SURVEILLANCE SYSTEM

(FINAL REPORT) WITH COVER LETTER DATED 073189. (OTS: OTS0521036; 8EHQ Num: NA; DCN: 86-890001420; TSCATS RefID: 404504; CIS: NA). General Electric Co. [Gilbert, D; Goyer, M; Lyman, W; Magil, G; Walker, P; Wallace, D; Wechsler, A; Yee, J.](#) (1982). An exposure and risk assessment for tetrachloroethylene. (EPA-440/4-85-015). Washington, DC: U.S. Environmental Protection Agency, Office of Water Regulations and Standards. <http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000LLOH.txt>

[Golsteijn, L; Huizer, D; Hauck, M; van Zelm, R; Huijbregts, MA.](#) (2014). Including exposure variability in the life cycle impact assessment of indoor chemical emissions: the case of metal degreasing. *Environ Int* 71: 36-45. <http://dx.doi.org/10.1016/j.envint.2014.06.003>

[Group, ESI.](#) (2019). Industrial - solvent-borne (formulation and (re)packaging of substances and mixtures). Available online at <https://www.esig.org/reach-ges/environment/>

[Halogenated Solvents Industry Alliance, Inc., .](#) (2018). [Comment letter of Halogenated Solvents Industry Alliance, Inc. (HSIA) regarding Docket ID No. EPA-HQ-OPPT-2016-0742-0103]. Available online at <https://www.regulations.gov/document?D=EPA-HQ-OPPT-2016-0742-0103>

[Hellweg, S; Demou, E; Bruzzi, R; Meijer, A; Rosenbaum, RK; Huijbregts, MA; Mckone, TE.](#) (2009). Integrating human indoor air pollutant exposure within Life Cycle Impact Assessment [Review]. *Environ Sci Technol* 43: 1670-1679. <http://dx.doi.org/10.1021/es8018176>

[Heritage.](#) (2018). Heritage website. Retrieved from <https://www.heritage-enviro.com/services/incineration/>

[Holbrook, MT.](#) (2003). Methylene chloride. In *Kirk-Othmer Encyclopedia of Chemical Technology* (4th ed.). New York, NY: John Wiley & Sons. <http://dx.doi.org/10.1002/0471238961.1305200808151202.a02.pub2>

[IARC](#) (International Agency for Research on Cancer). (2016). Dichloromethane [IARC Monograph]. In *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. Lyon, France. <http://monographs.iarc.fr/ENG/Monographs/vol110/mono110-04.pdf>

[Kanegsberg, B; Kanegsberg, E.](#) (2011). *Handbook for critical cleaning, cleaning agents and systems* (2nd ed.). Boca Raton, FL: CRC Press.

[Kasting, BG; Miller, MA.](#) (2006). Kinetics of finite dose absorption through skin 2: Volatile compounds. *J Pharm Sci* 95: 268-280. <http://dx.doi.org/10.1002/jps.20497>

[Kitto, J., B., S., tultz, S., C., .](#) (1992). *Steam: Its Generation and Use*. In *JBSSC Kitto* (Ed.), (40th ed.). Barberton, Ohio: The Babcock & Wilcox Company.

[Mahmud, M; Kales, SN.](#) (1999). Methylene chloride poisoning in a cabinet worker. *Environ Health Perspect* 107: 769-772.

[Marquart, H; Franken, R; Goede, H; Fransman, W; Schinkel, J.](#) (2017). Validation of the dermal exposure model in ECETOC TRA. *Ann Work Expo Health* 61: 854-871. <http://dx.doi.org/10.1093/annweh/wxx059>

[Marshall, KA; Pottenger, LH.](#) (2004). Chlorocarbons and chlorohydrocarbons.

[Miller, MA; Bhatt, V; Kasting, GB.](#) (2005). Dose and airflow dependence of benzyl alcohol disposition on skin. *J Pharm Sci* 95: 281-291. <http://dx.doi.org/10.1002/jps.20513>

[NEWMOA](#) (Northeast Waste Management Officials' Association). (2001). *Pollution prevention technology profile - Closed loop vapor degreasing*. Boston, MA. <http://www.newmoa.org/prevention/p2tech/ProfileVaporDegreasing.pdf>

[NIOSH](#) (National Institute for Occupational Safety and Health). (1973). Health Hazard Evaluation report no. HHE 72-84-31, Dunham-Bush, Incorporated, West Hartford, Connecticut, Part 2. (HHE 72-84-31). Washington, DC: U.S. Department of Health and Human Services.

[NIOSH](#) (National Institute for Occupational Safety and Health). (1980). Health Hazard Evaluation report no. HHE 80-18-691, Looart Press Incorporate, Colorado Springs, Colorado. (HHE 80-18-691). Washington, DC: U.S. Department of Health and Human Services.

- [NIOSH](#) (National Institute for Occupational Safety and Health). (1981). Health Hazard Evaluation report no. HETA 81-065-938, METRO Bus Maintenance Shop, Washington, DC. (HETA 81-065-938). Washington, DC: U.S. Department of Health and Human Services.  
<https://www.cdc.gov/niosh/hhe/reports/pdfs/81-65-938.pdf>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (1985). Health hazard evaluation report no. HETA-84-214-1633, Sheldahl, Inc., Northfield, Minnesota. (HETA- 84-214-1633). Cincinnati, OH. <https://www.cdc.gov/niosh/hhe/reports/pdfs/1984-0214-1633.pdf>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (1990a). Health Hazard Evaluation report no. HETA 87-350-2084, Trailmobile, Inc., Charleston, Illinois. (HETA 87-350-2084). Washington, DC: U.S. Department of Health and Human Services.
- [NIOSH](#) (National Institute for Occupational Safety and Health). (1990b). Health Hazard Evaluation report no. HETA 89-199-2033, Enseco, Inc., Rocky Mountain Analytical Laboratory, Arvada, Colorado. (HETA 89-199-2033). Washington, DC: U.S. Department of Health and Human Services.
- [NIOSH](#) (National Institute for Occupational Safety and Health). (1997). Control of health and safety hazards in commercial drycleaners: chemical exposures, fire hazards, and ergonomic risk factors. In Education and Information Division. (DHHS (NIOSH) Publication Number 97-150). Atlanta, GA. <http://www.cdc.gov/niosh/docs/97-150/>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (1998). Methylene Chloride: Method 1005, Issue 3. <https://www.cdc.gov/niosh/docs/2003-154/pdfs/1005.pdf>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (2001). Evaluation of Solvent Exposures from the Degreaser. Trilthic Inc., IN. In Hazard Evaluation Technical Assistance Branch. (HETA 2000-0233-2845). NIOSH Publishing Office: National Institute for Occupational Safety and Health. <http://www.cdc.gov/niosh/hhe/reports/pdfs/2000-0233-2845.pdf>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (2002a). In-depth survey report: Control of perchloroethylene (PCE) in vapor degreasing operations, site #2. (EPHB 256-16b). CDC. <https://www.cdc.gov/niosh/surveyreports/pdfs/256-16b.pdf>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (2002b). In-depth survey report: Control of perchloroethylene exposure (PCE) in vapor degreasing operations, site #3. (EPHB 256-17b). CDC. <https://www.cdc.gov/niosh/surveyreports/pdfs/ECTB-256-17b.pdf>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (2003). Respirator Usage in Private Sector Firms. Washington D.C.: United States Department of Labor, Bureau of Labor Statistics and National Institute for Occupational Safety and Health.  
<https://www.cdc.gov/niosh/docs/respsurv/>
- [NIOSH](#) (National Institute for Occupational Safety and Health). (2016). Health Hazard Evaluation report no. HHE-2012-0238-3257, August 2016: Evaluation of forensic crime lab employees' chemical exposures, job stress, and work-related health concerns. (HHE-2012-0238-3257). Washington, DC: U.S. Department of Health and Human Services.  
<https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0238-3257.pdf>
- [OECD](#) (Organisation for Economic Co-operation and Development). (2004). Emission scenario document on lubricants and lubricant additives. In OECD Series On Emission Scenario Documents. (JT00174617). Paris, France.  
[http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono\(2004\)21&doclanguage=en](http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2004)21&doclanguage=en)
- [OECD](#) (Organisation for Economic Co-operation and Development). (2009a). Emission scenario document on adhesive formulation. (JT03263583). Paris, France.
- [OECD](#) (Organisation for Economic Co-operation and Development). (2009b). Emission scenario documents on coating industry (paints, lacquers and varnishes). (JT03267833). Paris, France.



- [http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env%20/jm/mono\(2009\)24&doclanguage=en](http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env%20/jm/mono(2009)24&doclanguage=en)
- OECD** (Organisation for Economic Co-operation and Development). (2015). Emission scenario document on use of adhesives. (Number 34). Paris, France.  
[http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO\(2015\)4&doclanguage=en](http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/JM/MONO(2015)4&doclanguage=en)
- Olin Chemicals**. (1977). ENVIRONMENTAL HYGIENE SURVEY OF THE OLIN CHEMICALS BROOK PARK, OHIO PLANT. (OTS: OTS0515276; 8EHQ Num: NA; DCN: 86-870000838; TSCATS RefID: 308130; CIS: NA).
- Olin Corp** (Olin Corporation). (1979). INDUSTRIAL HYGIENE SURVEY CORP PROTECTION AREA WITH COVER LETTER & MEMO. (OTS: OTS0215011; 8EHQ Num: NA; DCN: 878220192; TSCATS RefID: 18805; CIS: NA).
- OSHA** (Occupational Safety & Health Administration). (1990). Methylene Chloride: Method 80. Available online at <https://www.osha.gov/dts/sltc/methods/organic/org080/org080.html>
- OSHA** (Occupational Safety & Health Administration). (1991). Proposed rules: Occupational exposure to methylene chloride. Washington, DC: Occupational Safety and Health Administration.  
[https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=FEDERAL\\_REGISTER&p\\_id=13194](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&p_id=13194)
- OSHA** (Occupational Safety & Health Administration). (2019). Dichloromethane Sampling Results, 2012-2016 [Database].
- Ott, MG; Skory, LK; Holder, BB; Bronson, JM; Williams, PR**. (1983). Health evaluation of employees occupationally exposed to methylene chloride: metabolism data and oxygen half-saturation pressures. *Scand J Work Environ Health* 9: 1-38.
- Products, IAfSDaM**. (2012). AISE SPERC fact sheet - wide dispersive use of cleaning and maintenance products. International Association for Soaps Detergents and Maintenance Products.  
<https://www.aise.eu/our-activities/regulatory-context/reach/environmental-exposure-assessment.aspx>
- SCG** (Scientific Consulting Group, Inc.). (2013). Final peer review comments for the OPPT trichloroethylene (TCE) draft risk assessment. Available online at [https://www.epa.gov/sites/production/files/2017-06/documents/tce\\_consolidated\\_peer\\_review\\_comments\\_september\\_5\\_2013.pdf](https://www.epa.gov/sites/production/files/2017-06/documents/tce_consolidated_peer_review_comments_september_5_2013.pdf)
- Technology, K-OEOC**. (2011). Bromine, Organic Compounds. 4: 341-365.  
<http://dx.doi.org/10.1002/0471238961.0218151325150606.a01.pub2>
- Texaco Inc**. (1993). I.h. monit. for pentane, ethyl ether, chloroform, acetone, t-butyl alcohol, carbon tetrachloride, total hydrocarbons, gasoline, isooctane, hexane, methylene chloride & toluene. (OTS: OTS0537774; 8EHQ Num: NA; DCN: 86-930000338; TSCATS RefID: 423786; CIS: NA).
- TNO** (CIVO) (TNO Central Institute for Nutrition and Food Research). (1999). Methylene chloride: Advantages and Drawbacks of Possible Market Restrictions in the EU. In Methylene chloride: Advantages and drawbacks of possible market restrictions in the EU STB-99-53 Final. Brussels, Belgium: European Commission. TNO-STB.  
<http://ec.europa.eu/DocsRoom/documents/13039/attachments/1/translations/en/renditions/native>
- Tomer, A; Kane, J**. (2015). The great port mismatch. U.S. goods trade and international transportation. The Global Cities Initiative. A joint project of Brookings and JPMorgan Chase.  
<https://www.brookings.edu/wp-content/uploads/2015/06/brgkssrvygcifreightnetworks.pdf>
- U.S. BLS** (U.S. Bureau of Labor Statistics). (2014). Employee Tenure News Release. Available online at [http://www.bls.gov/news.release/archives/tenure\\_09182014.htm](http://www.bls.gov/news.release/archives/tenure_09182014.htm)
- U.S. BLS** (U.S. Bureau of Labor Statistics). (2015). Hours and Employment by Industry Tables - August 3, 2017. Available online at <http://www.bls.gov/lpc/tables.htm>

- [U.S. BLS](http://www.bls.gov/oes/tables.htm) (U.S. Bureau of Labor Statistics). (2016). May 2016 Occupational Employment and Wage Estimates: National Industry-Specific Estimates. Available online at <http://www.bls.gov/oes/tables.htm>
- [U.S. Census Bureau](https://www.census.gov/topics/employment/industry-occupation/guidance/code-lists.html). (2013). Census 2012 Detailed Industry Code List [Database]. Retrieved from <https://www.census.gov/topics/employment/industry-occupation/guidance/code-lists.html>
- [U.S. Census Bureau](https://www.census.gov/data/tables/2015/econ/susb/2015-susb-annual.html). (2015). Statistics of U.S. Businesses (SUSB). <https://www.census.gov/data/tables/2015/econ/susb/2015-susb-annual.html>
- [U.S. Census Bureau](https://www.census.gov/programs-surveys/sipp/data/datasets/2008-panel/wave-1.html). (2019a). Survey of Income and Program Participation data. Available online at <https://www.census.gov/programs-surveys/sipp/data/datasets/2008-panel/wave-1.html> (accessed May 16, 2019).
- [U.S. Census Bureau](https://www.census.gov/programs-surveys/sipp/about/sipp-introduction-history.html). (2019b). Survey of Income and Program Participation: SIPP introduction and history. Washington, DC. <https://www.census.gov/programs-surveys/sipp/about/sipp-introduction-history.html>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (1977). Control of volatile organic emissions from solvent metal cleaning [EPA Report]. (EPA-450/2-77-022). Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards.
- [U.S. EPA](http://www3.epa.gov/ttn/chief/ap42/ch04/final/c4s06.pdf) (U.S. Environmental Protection Agency). (1981). AP-42. Compilation of air pollutant emission factors. Chapter 4.6: Solvent degreasing. Washington, DC. <http://www3.epa.gov/ttn/chief/ap42/ch04/final/c4s06.pdf>
- [U.S. EPA](http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=15263) (U.S. Environmental Protection Agency). (1992). Guidelines for exposure assessment. Federal Register 57(104):22888-22938 [EPA Report]. In Risk Assessment Forum. (EPA/600/Z-92/001). Washington, DC. <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=15263>
- [U.S. EPA](http://www3.epa.gov/ttnchie1/eiip/techreport/volume03/iii06fin.pdf) (U.S. Environmental Protection Agency). (1997). Solvent Cleaning. Volume III, Chapter 6. pp. 6.2.1. Washington, DC. <http://www3.epa.gov/ttnchie1/eiip/techreport/volume03/iii06fin.pdf>
- [U.S. EPA](https://www.regulations.gov/document?D=EPA-HQ-OAR-2002-0009-0022) (U.S. Environmental Protection Agency). (2006). Risk assessment for the halogenated solvent cleaning source category [EPA Report]. (EPA Contract No. 68-D-01-052). Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. <https://www.regulations.gov/document?D=EPA-HQ-OAR-2002-0009-0022>
- [U.S. EPA](http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=236252) (U.S. Environmental Protection Agency). (2011). Exposure factors handbook: 2011 edition [EPA Report]. (EPA/600/R-090/052F). Washington, DC. <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=236252>
- [U.S. EPA](https://www.epa.gov/sites/production/files/2015-09/documents/dcm_opptworkplanra_final.pdf) (U.S. Environmental Protection Agency). (2014). TSCA work plan chemical risk assessment methylene chloride: Paint stripping use CASRN: 75-09-2. (740-R1-4003). Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention. [https://www.epa.gov/sites/production/files/2015-09/documents/dcm\\_opptworkplanra\\_final.pdf](https://www.epa.gov/sites/production/files/2015-09/documents/dcm_opptworkplanra_final.pdf)
- [U.S. EPA](https://www.epa.gov/sites/production/files/2015-05/documents/user_guide.pdf) (U.S. Environmental Protection Agency). (2015). ChemSTEER user guide - Chemical screening tool for exposures and environmental releases. Washington, D.C. [https://www.epa.gov/sites/production/files/2015-05/documents/user\\_guide.pdf](https://www.epa.gov/sites/production/files/2015-05/documents/user_guide.pdf)
- [U.S. EPA](https://echo.epa.gov/trends/loading-tool/water-pollution-search) (U.S. Environmental Protection Agency). (2016a). Discharge monitoring report (DMR) [data]. Retrieved from <https://echo.epa.gov/trends/loading-tool/water-pollution-search>
- [U.S. EPA](https://www.epa.gov/chemical-data-reporting) (U.S. Environmental Protection Agency). (2016b). Public database 2016 chemical data reporting (May 2017 release). Washington, DC: US Environmental Protection Agency, Office of Pollution Prevention and Toxics. <https://www.epa.gov/chemical-data-reporting>
- [U.S. EPA](https://www.epa.gov/sites/production/files/2016-03/documents/1-bp_report_and_appendices_final.pdf) (U.S. Environmental Protection Agency). (2016c). TSCA work plan chemical risk assessment: Peer review draft 1-bromopropane: (n-Propyl bromide) spray adhesives, dry cleaning, and degreasing uses CASRN: 106-94-5 [EPA Report]. (EPA 740-R1-5001). Washington, DC. [https://www.epa.gov/sites/production/files/2016-03/documents/1-bp\\_report\\_and\\_appendices\\_final.pdf](https://www.epa.gov/sites/production/files/2016-03/documents/1-bp_report_and_appendices_final.pdf)

- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2017a). Learn the Basics of Hazardous Waste. Available online at <https://www.epa.gov/hw/learn-basics-hazardous-waste>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2017b). Preliminary Information on Manufacturing, Processing, Distribution, Use, and Disposal: Methylene Chloride. Available online at <https://www.regulations.gov/document?D=EPA-HQ-OPPT-2016-0742-0003>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2017c). Toxics release inventory [Database]. Washington, DC: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. Retrieved from <https://www.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2018a). 2014 National Emissions Inventory Report. <https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2018b). Application of systematic review in TSCA risk evaluations. (740-P1-8001). Washington, DC: U.S. Environmental Protection Agency, Office of Chemical Safety and Pollution Prevention. [https://www.epa.gov/sites/production/files/2018-06/documents/final\\_application\\_of\\_sr\\_in\\_tsc\\_a\\_05-31-18.pdf](https://www.epa.gov/sites/production/files/2018-06/documents/final_application_of_sr_in_tsc_a_05-31-18.pdf)
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2018c). Hazardous Waste Management Facilities and Units. Available online at <https://www.epa.gov/hwpermitting/hazardous-waste-management-facilities-and-units>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2018d). Problem formulation of the risk evaluation for methylene chloride (dichloromethane, DCM). (EPA-740-R1-7016). Washington, DC: Office of Chemical Safety and Pollution Prevention, United States Environmental Protection Agency. [https://www.epa.gov/sites/production/files/2018-06/documents/mecl\\_problem\\_formulation\\_05-31-18.pdf](https://www.epa.gov/sites/production/files/2018-06/documents/mecl_problem_formulation_05-31-18.pdf)
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2019a). Risk evaluation for methylene chloride (dichloromethane, DCM): Systematic review supplemental file: Data quality evaluation of environmental releases and occupational exposure common sources . Docket # EPA-HQ-OPPT-2016-0742. Washington, DC.
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2019b). Risk evaluation for methylene chloride (dichloromethane, DCM): Systematic review supplemental file: Data quality evaluation of environmental releases and occupational exposure data. Docket # EPA-HQ-OPPT-2016-0742. Washington, DC.
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2020). Memorandum: NIOSH/BLS Respirator Usage in Private Sector Firms. Available online at <https://www.regulations.gov/document?D=EPA-HQ-OPPT-2019-0500-0029>
- [U.S. EPA; ICF Consulting](#). (2004). The U.S. solvent cleaning industry and the transition to non ozone depleting substances. <https://www.epa.gov/sites/production/files/2014-11/documents/epasolventmarketreport.pdf>
- [Ukai, H; Okamoto, S; Takada, S; Inui, S; Kawai, T; Higashikawa, K; Ikeda, M.](#) (1998). Monitoring of occupational exposure to dichloromethane by diffusive vapor sampling and urinalysis. *Int Arch Occup Environ Health* 71: 397-404. <http://dx.doi.org/10.1007/s004200050298>
- [Unocal Corporation](#). (1986). MEMORANDUM REGARDING UNOCAL TEMPORARY OCCUPATIONAL EXPOSURE LIMIT (TOEL) FOR DICHLOROMETHANE WITH ATTACHMENTS AND COVER LETTER DATED 110987. (OTS: OTS0513971; 8EHQ Num: NA; DCN: 86-880000080; TSCATS RefID: 304976; CIS: NA).
- [US EPA](#). (1985). OCCUPATIONAL EXPOSURE AND ENVIRONMENTAL RELEASE ASSESSMENT OF METHYLENE CHLORIDE CONTRACT NO 68-02-3935. (OTS:

OTS0505611; 8EHQ Num: 48503 B2-10; DCN: 45-8503010; TSCATS RefID: 30192; CIS: NA).

Von Grote, J; Hurlimann, JC; Scheringer, M; Hungerbuhler, K. (2003). Reduction of Occupational Exposure to Perchloroethylene and Trichloroethylene in Metal Degreasing over the Last 30 years: Influence of Technology Innovation and Legislation. J Expo Anal Environ Epidemiol 13: 325-340. <http://dx.doi.org/10.1038/sj.jea.7500288>

Vulcan Chemicals (Vulcan Chemicals Inc.). (1991). LETTER FROM VULCAN CHEMICALS TO USEPA SUBMITTING ENCLOSED INDUSTRIAL HYGIENE MONITORING REPORT ON METHYLENE CHLORIDE WITH ATTACHMENT. (OTS: OTS0529788; 8EHQ Num: NA; DCN: 86-910000869; TSCATS RefID: 417033; CIS: NA).

Yamada, K; Kumagai, S; Kubo, S; Endo, G. (2015). Chemical exposure levels in printing and coating workers with cholangiocarcinoma (third report). J Occup Health 57: 565-571. <http://dx.doi.org/10.1539/joh.15-0170-OA>

Yamada, K; Kumagai, S; Nagoya, T; Endo, G. (2014). Chemical exposure levels in printing workers with cholangiocarcinoma. J Occup Health 56: 332-338. <http://dx.doi.org/10.1539/joh.14-0073-OA>

Young, ML. (2012). Pre-spotting step toward better cleaning. Available online at <https://americandrycleaner.com/articles/pre-spotting-step-toward-better-cleaning>

---