

Child-Specific Exposure Factors Handbook (External Review Draft)



DISCLAIMER

This document is a draft edition that has not been fully reviewed by EPA. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TABLE OF CONTENTS

1. INTRODUCTION	1-1
1.1 BACKGROUND	1-1
1.2 PURPOSE	1-4
1.3 INTENDED AUDIENCE	1-5
1.4 SELECTION OF STUDIES FOR THE HANDBOOK	1-5
1.5 APPROACH USED TO DEVELOP RECOMMENDATIONS FOR EXPOSURE FACTORS	1-8
1.6 CHARACTERIZING VARIABILITY	1-11
1.7 USING THE HANDBOOK IN AN EXPOSURE ASSESSMENT	1-12
1.8 THE USE OF AGE GROUPINGS WHEN ASSESSING EXPOSURE	1-14
1.9 CONSIDERING LIFESTAGE WHEN CALCULATING EXPOSURE AND RISK	1-16
1.10 GENERAL EQUATIONS FOR CALCULATING DOSE	1-17
1.11 CUMULATIVE RISK	1-22
1.12 RESEARCH NEEDS	1-22
1.13 ORGANIZATION	1-23
1.14 REFERENCES FOR CHAPTER 1	1-25
2. BREAST MILK INTAKE	2-1
2.1 INTRODUCTION	2-1
2.2 STUDIES ON BREAST MILK INTAKE	2-2
2.2.1 Pao et al., 1980	2-2
2.2.2 Dewey and Lönnerdal, 1983	2-2
2.2.3 Butte et al., 1984	2-3
2.2.4 Neville et al., 1988	2-4
2.2.5 Dewey et al., 1991a, b	2-4
2.3 STUDIES ON LIPID CONTENT AND FAT INTAKE FROM BREAST MILK	2-5
2.4 OTHER FACTORS	2-7
2.4.1 Population of Nursing Infants	2-7
2.4.2 Intake Rates Based on Nutritional Status	2-8
2.5 RECOMMENDATIONS	2-9
2.5.1 Breast Milk Intake	2-9
2.5.2 Lipid Content and Lipid Intake	2-10
2.6 REFERENCES FOR CHAPTER 2	2-11
3. FOOD INTAKE	3-1
3.1 INTRODUCTION	3-1
3.2 INTAKE RATE DISTRIBUTIONS FOR VARIOUS FOOD TYPES	3-4
3.2.1 USDA, 1999	3-4
3.2.2 U.S. EPA, 2003	3-6

3.3	FISH INTAKE RATES	3-9
3.3.1	General Population Studies	3-9
3.3.1.1.	U.S. EPA, 2002	3-9
3.3.1.2.	Tsang and Klepeis, 1996	3-10
3.3.2	Freshwater Recreational Study	3-11
3.3.3	Native American Subsistence Studies	3-13
3.3.3.1	Columbia River Inter-Tribal Fish Commission (CRITFC), 1994	3-13
3.3.3.2.	Toy et al., 1996	3-15
3.3.3.3.	The Suquamish Tribe, 2000	3-16
3.3.4	Multi-State Study	3-17
3.4	FAT INTAKE	3-18
3.4.1.	Bogalusa Heart Study	3-18
3.4.2.	U.S. EPA 2006	3-19
3.5	TOTAL DIETARY INTAKE AND CONTRIBUTIONS TO DIETARY INTAKE	3-19
3.6	INTAKE OF HOME-PRODUCED FOODS	3-22
3.7	SERVING SIZE STUDY BASED ON THE USDA NFCS	3-27
3.8	CONVERSION BETWEEN “AS CONSUMED” AND DRY WEIGHT INTAKE RATES	3-28
3.9	FAT CONTENT OF MEAT AND DAIRY PRODUCTS	3-29
3.10	RECOMMENDATIONS	3-30
3.11	REFERENCES FOR CHAPTER 3	3-32
APPENDIX 3A	Calculations Used in the 1994-96 CSFII Analysis to Correct for Mixtures	
APPENDIX 3B	Food Codes and Definitions Used in Analysis of the 1994-96 USDA CSFII Data	
APPENDIX 3C	Sample Calculation of Mean Daily Fat Intake Based On CDC (1994) Data	
APPENDIX 3D	Food Codes and Definitions Used in Analysis of the 1987-88 USDA NFCS Data	
APPENDIX 3E	Statistical Notes	
4.	DRINKING WATER INGESTION	4-1
4.1	INTRODUCTION	4-1
4.2	DRINKING WATER INGESTION STUDIES	4-2
4.2.1	U.S. EPA, 2004	4-2
4.2.2.	EPA Analysis of CSFII (USDA, 1998)	4-3
4.3	RECOMMENDATIONS	4-4
4.4	REFERENCES FOR CHAPTER 4	4-6
5.	SOIL INGESTION AND PICA	5-1
5.1	INTRODUCTION	5-1
5.2	SOIL INTAKE STUDIES	5-3
5.2.1	Key Studies of Primary Analysis	5-3

5.2.1.1	Davis <i>et al.</i> , 1990	5-3
5.2.1.2	Calabrese <i>et al.</i> , 1997a	5-5
5.2.1.3	Davis and Mirick, 2006	5-7
5.2.2	Relevant Studies of Primary Analysis	5-8
5.2.2.1	Binder <i>et al.</i> , 1986	5-8
5.2.2.2	Clausing <i>et al.</i> , 1987	5-10
5.2.2.3	Calabrese <i>et al.</i> , 1989	5-11
5.2.2.4	Van Wijnen <i>et al.</i> , 1990	5-13
5.2.2.5	Calabrese <i>et al.</i> , 1996	5-14
5.2.2.6	Calabrese <i>et al.</i> , 1999	5-15
5.2.2.7	Stanek and Calabrese, 2000	5-15
5.2.2.8	Stanek <i>et al.</i> , 2001b	5-15
5.2.3	Key Studies of Secondary Analysis	5-16
5.2.3.1	Stanek and Calabrese, 1995a	5-16
5.2.3.2	Stanek and Calabrese, 1995b	5-18
5.2.4	Relevant Studies of Secondary Analysis	5-19
5.2.4.1	Thompson and Burmaster, 1991	5-19
5.2.4.2	Calabrese and Stanek, 1992a	5-20
5.2.4.3	Sedman and Mahmood, 1994	5-21
5.2.4.4	Calabrese and Stanek, 1995	5-22
5.2.4.5	Stanek <i>et al.</i> , 2001a	5-23
5.2.4.6	Zartarian <i>et al.</i> , 2005	5-24
5.3	PICA	5-25
5.3.1	Prevalence	5-25
5.3.1.1	General Pica	5-25
5.3.1.2	Soil Pica	5-25
5.3.2	Soil Pica Among Children	5-26
5.3.2.1	Calabrese <i>et al.</i> , 1991	5-26
5.3.2.2	Calabrese and Stanek, 1992b	5-27
5.3.2.3	Calabrese and Stanek, 1993	5-27
5.3.2.4	Zartarian <i>et al.</i> , 2005	5-29
5.4	RECOMMENDATIONS	5-29
5.5	REFERENCES FOR CHAPTER 5	5-33
6.	OTHER NON-DIETARY INGESTION FACTORS	6-1
6.1	INTRODUCTION	6-1
6.2	STUDIES RELATED TO NON-DIETARY INGESTION	6-2
6.2.1	Davis, 1995	6-2
6.2.2	Groot <i>et al.</i> , 1998	6-5
6.2.3	Reed <i>et al.</i> , 1999	6-6
6.2.4	Zartarian <i>et al.</i> , 1997 and 1998	6-7
6.2.5	Stanek <i>et al.</i> , 1998	6-8
6.2.6	Freeman <i>et al.</i> , 2001	6-10
6.2.7	Juberg <i>et al.</i> , 2001	6-11

6.2.8	Greene, 2002	6-12
6.2.9	Tulve et al., 2002	6-13
6.2.10	Smith and Norris, 2003	6-14
6.2.11	AuYeung et al., 2004	6-15
6.2.12	Black et al., 2005	6-16
6.3	RECOMMENDATIONS	6-17
6.4	REFERENCES FOR CHAPTER 6	6-19
7.	INHALATION ROUTE	7-1
7.1	INTRODUCTION	7-1
7.2	INHALATION RATE STUDIES	7-1
7.2.1	Linn et al., 1992	7-1
7.2.2	Spier et al., 1992	7-2
7.2.3	Adams, 1993	7-4
7.2.4	Layton, 1993	7-5
7.2.5	Rusconi et al., 1994	7-7
7.2.6	Lordo et al., 2006	7-9
7.3	RECOMMENDATIONS	7-11
7.4	REFERENCES FOR CHAPTER 7	7-12
	APPENDIX 7A: VENTILATION DATA	7-38
8.	DERMAL ROUTE	8-1
8.1	INTRODUCTION	8-1
8.2	SURFACE AREA	8-2
8.2.1.	Background	8-2
8.2.2.	Measurement Techniques	8-2
8.2.3.	Body Surface Area Studies	8-3
8.2.3.1.	Costeff, 1966	8-3
8.2.3.2.	U.S. EPA, 1985	8-4
8.2.3.3.	Phillips et al., 1993	8-5
8.2.3.4.	Wong et al. (2000)	8-6
8.2.3.5.	U.S. EPA Analysis of NHANES III Data	8-6
8.2.4.	Application of Body Surface Area Data	8-7
8.3	ADHERENCE OF SOLIDS TO SKIN	8-8
8.3.1.	Background	8-8
8.3.2.	Adherence of Solids to Skin Studies	8-8
8.3.2.1.	Kissel et al., 1996a	8-8
8.3.2.2.	Kissel et al., 1996b	8-8
8.3.2.3.	Holmes et al., 1999	8-9
8.3.2.4.	Kissel et al., 1998	8-10
8.4	RECOMMENDATIONS	8-12
8.4.1.	Body Surface Area	8-12
8.5	REFERENCES FOR CHAPTER 8	8-15

APPENDIX 8A - Formulas for Total Body Surface Area	8A-1
9. ACTIVITY FACTORS	9-1
9.1 INTRODUCTION	9-1
9.2 ACTIVITY PATTERNS	9-1
9.2.1 Timmer et al., 1985	9-2
9.2.2 Robinson and Thomas, 1991	9-3
9.2.3 Wiley et al., 1991	9-4
9.2.4 U.S. EPA, 1992 and U.S. EPA, 2004	9-5
9.2.5 Tsang and Klepeis, 1996	9-5
9.2.6 Funk et al., 1998	9-9
9.2.7 Hubal et al., 2000	9-10
9.2.8 Wong et al., 2000	9-11
9.3 RECOMMENDATIONS	9-13
.....	9-13
10. CONSUMER PRODUCTS	10-1
10.1 BACKGROUND	10-1
10.2 CONSUMER PRODUCTS USE STUDIES	10-1
10.3 RECOMMENDATIONS	10-2
10.4 REFERENCES FOR CHAPTER 10	10-3
11. BODY WEIGHT STUDIES	11-1
11.1 INTRODUCTION	11-1
11.2 BODY WEIGHT STUDIES	11-1
11.2.1 Hamill et al., 1979	11-1
11.2.2. National Center for Health Statistics, 1987	11-1
11.2.3. Burmaster and Crouch, 1997	11-2
11.2.4 U.S. EPA, 2000	11-3
11.2.5 Ogden et al., 2004	11-3
11.2.6 EPA Analysis of NHANES III Data	11-4
11.3 RECOMMENDATIONS	11-5
11.4 REFERENCES FOR CHAPTER 11	11-5

LIST OF TABLES

Table 1-1. Considerations Used to Rate Confidence in Recommended Values	1-21
Table 1-2. Summary of Exposure Factor References and Confidence Ratings	1-29
Table 1-3. Characterization of Variability in Exposure Factors	1-30
Table 1-4. Integrating EPA's <i>Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants</i> with EPA's <i>Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens</i> For Those Contaminants Which Act Via a Mutagenic Mode of Action	1-31
Table 2-1. Daily Intakes of Breast Milk	2-12
Table 2-2. Breast Milk	2-12
Table 2-3. Breast Milk Intake among Exclusively Breast-fed Infants During the First 4 Months of Life	2-13
Table 2-4. Breast Milk Intake During a 24-hour Period	2-14
Table 2-5. Breast Milk Intake Estimated by the DARLING Study	2-15
Table 2-6. Lipid Content of Human Milk and Estimated Lipid Intake among Exclusively Breast-fed Infants	2-15
Table 2-7. Percentage of Mothers Breast-feeding Newborn Infants in the Hospital and Infants at 5 or 6 Months Of Age in the United States in 1989 and 1995, by Ethnic Background and Selected Demographic Variables	2-16
Table 2-8. Confidence in Breast Milk Intake Recommendations	2-17
Table 2-9. Breast Milk Intake Rates Derived from Key Studies	2-18
Table 2-10. Lipid Intake Rates Derived from Key Studies	2-19
Table 2-11. Summary of Recommended Breast Milk And Lipid Intake Rates	2-20
Table 3-1. Grain Products: Mean Quantities consumed daily by sex and age, per capita	3-35
Table 3-2. Grain Products: Percentage of individuals consuming, by sex and age	3-36
Table 3-3. Vegetables: Mean Quantities consumed daily by sex and age, per capita	3-37
Table 3-4. Vegetables: Percentage of individuals consuming, by sex and age	3-38
Table 3-5. Fruits: Mean Quantities consumed daily by sex and age	3-39
Table 3-6. Fruits: Percentage of individuals consuming, by sex and age	3-40
Table 3-7. Milk and Milk Products: Mean Quantities consumed daily by sex and age, per capita	3-41
Table 3-8. Milk and Milk Products: Percentage of individuals consuming, by sex and age ..	3-42
Table 3-9. Meat, Poultry, and Fish: Mean Quantities consumed daily by sex and age	3-43
Table 3-10. Meat, Poultry, and Fish: Percentage of individuals consuming, by sex and age .	3-44
Table 3-11. Eggs, Legumes, Nuts and Seeds, Fats and Oils, Sugars and Sweets: Mean Quantities consumed daily by sex and age	3-45
Table 3-12. Eggs, Legumes, Nuts and Seeds, Fats and Oils, Sugars and Sweets: Percentage of individuals consuming, by sex and age	3-46
Table 3-13. Beverages: Mean Quantities consumed daily by sex and age	3-47
Table 3-14. Beverages: Percentage of individuals consuming, by sex and age	3-48
Table 3-15. Unweighted Number of Observations, 1994/96 CSFII Analysis	3-49
Table 3-16. Per Capita Intake of the Major Food Groups (g/kg-day as consumed)	3-50

Table 3-17. Per Capita Intake of Individual Foods (g/kg-day as consumed)	3-52
Table 3-18. Per Capita Intake of USDA Categories of Vegetables and Fruits (g/kg-day as consumed)	3-56
Table 3-19. Per Capita Intake of Exposed/Protected Fruit and Vegetable Categories (g/kg-day as consumed)	3-58
Table 3-20. Per Capita Distribution of Fish (Finfish and Shellfish) Intake by Age and Gender - As Consumed	3-60
Table 3-21. Consumers Only Distribution of Fish (Finfish and Shellfish) Intake by Age and Gender - As Consumed	3-61
Table 3-22. Per Capita Distribution of Fish (Finfish and Shellfish) Intake by Age and Gender - Uncooked Fish Weight	3-62
Table 3-23. Consumers Only Distribution of Fish (Finfish and Shellfish) Intake by Age and Gender - Uncooked Fish Weight	3-63
Table 3-24. Number of Respondents Reporting Consumption of a Specified Number of Servings of Seafood in 1 Month and Source of Seafood Eaten	3-64
Table 3-25. Mean Fish Intake Among Individuals Who Eat Fish and Reside in Households With Recreational Fish Consumption	3-65
Table 3-26. Fish Consumption Rates among Native American Children (age 5 years and under)	3-66
Table 3-27. Mean, 50th, and 90th Percentiles of Consumption Rates for Native American Children Age Birth to Five Years (g/kg/day)	3-67
Table 3-28. Native American Children's Consumption Rate (g/kg/day): Individual Finfish and Shellfish and Fish Groups	3-68
Table 3-29. Native American Children's Consumption Rate (g/kg/day) for Consumers Only: Individual Finfish and Shellfish and Fish Groups	3-69
Table 3-30. Mean Fish Consumption, per capita, g/day and g/kg/day As Consumed, in Four States	3-70
Table 3-31. Mean Fish Consumption, Consumers Only, g/day and g/kg/day As Consumed, in Four States	3-71
Table 3-32. Mean Fish Consumption, Consumers Only, g/day and g/kg/day As Consumed, by Caught or Bought Status	3-72
Table 3-33. Fat Intake Among Children Based on Data from the Bogalusa Heart Study, 1973-1982 (g/day)	3-73
Table 3-34. Fat Intake Among Children Based on Data from the Bogalusa Heart Study, 1973-1982 (g/kg/day)	3-74
Table 3-35. Mean Total Daily Dietary Fat Intake (g/day) Grouped by Age and Gender	3-75
Table 3-36. Total Fat Intake for the Whole Population and for the Top 10% of Animal Fat Consumers by Consumers Only (g/kg-day)	3-76
Table 3-37. Per Capita Total Dietary Intake	3-77
Table 3-38. Per Capita Intake of Major Food Groups (g/day, as consumed)	3-78
Table 3-39. Per Capita Intake of Major Food Groups (g/kg/day, as consumed)	3-82
Table 3-40. Per Capita Intake of Total Foods and Major Food Groups, and Percent of Total Food Intake for Individuals with Low-end, Mid-range, and High-end Total Food Intake	3-85

Table 3-41. Per Capita Intake of Total Foods and Major Food Groups, and Percent of Total Food Intake for Individuals with Low-end, Mid-range, and High-end Total Meat Intake	3-88
Table 3-42. Per Capita Intake of Total Foods and Major Food Groups, and Percent of Total Food Intake for Individuals with Low-end, Mid-range, and High-end Total Meat and Dairy Intake	3-91
Table 3-43. Per Capita Intake of Total Foods and Major Food Groups, and Percent of Total Food Intake for Individuals with Low-end, Mid-range, and High-end Total Fish Intake	3-94
Table 3-44. Per Capita Intake of Total Foods and Major Food Groups, and Percent of Total Food Intake for Individuals with Low-end, Mid-range, and High-end Total Fruit and Vegetable Intake	3-97
Table 3-45. Per Capita Intake of Total Foods and Major Food Groups, and Percent of Total Food Intake for Individuals with Low-end, Mid-range, and High-end Total Dairy Intake	3-100
Table 3-46. Weighted and Unweighted Number of Observations (Individuals) for NFCS Data Used in Analysis of Food Intake	3-103
Table 3-47. Consumer Only Intake of Homegrown Foods (g/kg-day) ^a - All Regions Combined	3-104
Table 3-48. Percent Weight Losses from Food Preparation	3-105
Table 3-49. Quantity (as consumed) of Food Groups Consumed Per Eating Occasion and the Percentage of Individuals Using These Foods Over a Three-Day Period in a 1977-1978 Survey	3-106
Table 3-50. Mean Moisture Content of Selected Food Groups Expressed as Percentages of Edible Portions	3-108
Table 3-51. Percent Moisture Content for Selected Fish Species ^a	3-113
Table 3-52. Percentage Lipid Content (Expressed as Percentages of 100 Grams of Edible Portions) of Selected Meat, Dairy, and Fish Products ^a	3-116
Table 3-53. Fat Content of Meat Products	3-120
Table 3-54. Summary of Recommended Values for Per Capita Intake of Foods, As Consumed	3-121
Table 3-55. Confidence Intake Recommendations for Various Foods, Including Fish (General Population)	3-123
Table 3-56. Confidence Intake Recommendations for Fish Consumption - Recreational Freshwater Angler Population	3-124
Table 3-57. Summary of Fish Intake Rates Among Native American Children (Consumers Only)	3-125
Table 3-58. Confidence Intake Recommendations for Fish Consumption - Native American Subsistence Population	3-126
Table 3A-1. Fraction of Grain and Meat Mixture Intake Represented by Various Food Items/groups	3A-2
Table 3B-1. Food Codes and Definitions Used in Analysis of the 1994-96 USDA CSFII Data	3B-1
Table 3D-1. Food Codes and Definitions Used in Analysis of the 1987-88 USDA NFCS Data	3D-1
Table 4-1. Estimated Direct and Indirect Water Ingestion for Selected Age Categories Derived from CSFII Data	4-7

Table 4-2. Estimated Direct and Indirect Community Water Ingestion By Source for Entire U.S. Population (All Ages) ^a	4-8
Table 4-3. Estimated Direct and Indirect Water Ingestion, All Sources By Age Category for U.S. Children	4-9
Table 4-4. Estimated Direct and Indirect Community Water Ingestion By Age Category for U.S. Children	4-10
Table 4-5. Estimated Direct and Indirect Bottled Water Ingestion By Age Category for U.S. Children	4-11
Table 4-6. Estimated Direct and Indirect Other Water Ingestion By Age Category for U.S. Children	4-12
Table 4-7. Summary of Recommended Community Drinking Water Ingestion Rates	4-13
Table 4-8. Confidence in Water Ingestion Recommendations	4-14
Table 5-1. Average Daily Soil Ingestion Values Based on Aluminum, Silicon, and Titanium as Tracer Elements	5-37
Table 5-2. Soil Ingestion Estimates for the Median of Best Four Trace Elements Based on Food/Soil Ratios for 64 Anaconda Children (mg/day) Using Al, Si, Ti, Y, and Zr ..	5-37
Table 5-3. Dust Ingestion Estimates for the Median of Best Four Trace Elements Based on Food/Dust Ratios for 64 Anaconda Children (mg/day) Using Al, Si, Ti, Y, and Zr ..	5-38
Table 5-4. Mean and Median Soil Ingestion (mg/day) by Family Member	5-38
Table 5-5. Estimated Daily Soil Ingestion Based on Aluminum, Silicon, and Titanium Concentrations	5-39
Table 5-6. Calculated Soil Ingestion by Nursery School Children	5-40
Table 5-7. Calculated Soil Ingestion by Hospitalized, Bedridden Children	5-41
Table 5-8. Mean and Standard Deviation Percentage Recovery of Eight Tracer Elements ..	5-41
Table 5-9. Soil and Dust Ingestion Estimates for Children Ages 1-4 Years	5-42
Table 5-10. Geometric Mean (GM) and Standard Deviation (GSD) LTM Values for Children at Daycare Centers and Campgrounds	5-43
Table 5-11. Estimated Geometric Mean Ltm Values of Children Attending Daycare Centers According to Age, Weather Category, and Sampling Period	5-44
Table 5-12. Distribution of Average (Mean) Daily Soil Ingestion Estimates per Child for 64 Children (mg/day)	5-45
Table 5-13. Estimated Distribution of Individual Mean Daily Soil Ingestion Based on Data for 64 Subjects Projected over 365 Days	5-45
Table 5-14. Summary Statistics and Parameters for Distributions of Estimated Soil Ingestion by Tracer Element ^a	5-46
Table 5-15. Positive/negative Error (Bias) in Soil Ingestion Estimates in the Calabrese <i>et al.</i> (1989) Mass-balance Study: Effect on Mean Soil Ingestion Estimate (mg/day)	5-47
Table 5-16. Daily Soil Ingestion Estimation in a Soil-Pica Child by Tracer and by Week (mg/day)	5-48
Table 5-17. Ratios of Soil, Dust, and Residual Fecal Samples in the Soil Pica Child	5-49
Table 5-18. Daily Variation of Soil Ingestion by Children Displaying Soil Pica in Wong (1988)	5-50
Table 5-19. Key Studies Used to Derive Recommendations	5-51

Table 5- 20 . Summary of Estimates of Incidental Soil and Dust Ingestion by Children (1-7 years old) from Key Studies (mg/day)	5-52
Table 5-21. Summary of Recommended Values for Soil Ingestion	5-53
Table 5-22. Confidence in Soil Intake Recommendation	5-54
Table 6-1. Extrapolated Total Mouthing Times Minutes per Day (time awake)	6-21
Table 6-2. Frequency of Contact (Contacts per Hour)	6-22
Table 6-3. Prevalence of Non-Food Ingestion/Mouthing Behaviors by Child’s Age: Percent of Children Whose Parents Reports the Behavior in the Past Month	6-23
Table 6-4 Percent of Children with Reported Behaviors From the Telephone Survey Conducted in the MNCPEs (n = 168)	6-26
Table 6-5. Median (Mean) Observed Activity Rate (Hand Contacts Per Hour) Based on 4 Hours of Observation Per Person.	6-26
Table 6-6. Comparison of Observed Activities for Boys and Girls (Mean).	6-27
Table 6-7. Mouthing times for Pacifiers and Other Objects, by Age Category	6-27
Table 6-8 . Average Mouthing Time by Object Category and Age (min/hr)	6-28
Table 6-9. Mouthing Time Statistics for Various Objects (min/hr)	6-29
Table 6-10. Estimated Daily Mouthing Times for Various Objects (min/day)	6-31
Table 6-11. Variability in Objects Mouthed for Different Age Groups.	6-32
Table 6-12. Mouthing Duration by Age Group for Pacifiers, Fingers, Toys, and Other Objects	6-33
Table 6-13. Indoor Mouthing Frequency (Contacts/Hour)	6-34
Table 6-14. Outdoor Mouthing Frequency (Contacts/Hour)	6-35
Table 6-15. Indoor Mouthing Contact Duration (Minutes/Hour)	6-36
Table 6-16. Outdoor Mouthing Contact Duration (Minutes/Hour)	6-37
Table 6-17. Videotaped Mouthing and Food-handling Activity as Median Hourly Frequency (Contacts/Hour) and Median Duration (% of Tape Time) (Mean ± SD)	6-38
Table 6-18. Summary of Studies on Mouthing Behavior	6-39
Table 6-19. Summary of Mouthing Frequency Data	6-40
Table 6-20. Summary of Recommended Values for Total Mouthing Time (minutes per day)	6-42
Table 6-21. Summary of Recommended Values for Mouthing Frequency (contacts per hour)	6-43
Table 6-22. Confidence in Mouthing Behavior Recommendations	6-44
Table 7-1. Calibration And Field Protocols For Self-monitoring of Activities Grouped by Subject Panels	7-13
Table 7-2. Subject Panel Inhalation Rates by Mean VR, Upper Percentiles, And Self-estimated Breathing Rates	7-13
Table 7-3. Distribution of Predicted Intake Rates by Location And Activity Levels For Elementary And High School Students	7-14
Table 7-4. Average Hours Spent Per Day in a Given Location and Activity Level For Elementary and High School Students	7-14
Table 7-5. Distribution Patterns of Daily Inhalation Rates For Elementary (EL) And High School (HS) Students Grouped by Activity Level	7-15

Table 7-6. Summary of Average Inhalation Rates (m ³ /hr) by Age Group And Activity Levels for Laboratory Protocols	7-16
Table 7-7. Summary of Average Inhalation Rates (m ³ /hr) by Age Group And Activity Levels in Field Protocols	7-17
Table 7-8. Comparisons of Estimated Basal Metabolic Rates (BMR) With Average Food-energy Intakes (EFD) For Individuals Sampled in The 1977-78 NFCS	7-18
Table 7-9. Daily Inhalation Rates Calculated From Food-energy Intakes	7-19
Table 7-10. Daily Inhalation Rates Obtained From The Ratios Of Total Energy Expenditure to Basal Metabolic Rate (BMR)	7-20
Table 7-11. Inhalation Rates For Short-term Exposures	7-21
Table 7-12. Mean, Median, and SD of Respiratory Rate According to Waking or Sleeping in 618 Infants and Children Grouped in Classes of Age	7-22
Table 7-13. Descriptive Statistics for Daily Average Ventilation Rate (L/min) in <u>Males</u> , by Age Category	7-24
Table 7-14. Descriptive Statistics for Daily Average Ventilation Rate (L/min) in <u>Females</u> , by Age Category	7-25
Table 7-15. Average Time Spent Per Day Performing Activities Within Specified Intensity Categories, and Average Ventilation Rates Associated With These Activity Categories, for <u>Males</u> According to Age Category	7-26
Table 7-16. Average Time Spent Per Day Performing Activities Within Specified Intensity Categories, and Average Ventilation Rates Associated With These Activity Categories, for <u>Females</u> According to Age Category	7-29
Table 7-17. Descriptive Statistics for Daily Average Ventilation Rate (m ³ /day) in <u>Males</u> , by Age Category	7-32
Table 7-18. Descriptive Statistics for Daily Average Ventilation Rate (m ³ /day) in <u>Females</u> , by Age Category	7-33
Table 7-19. Descriptive Statistics for Duration of Time (hr/day) Spent Performing Activities Within the Specified Activity Category, by Age and Gender Categories	7-34
Table 7-20. Confidence in Inhalation Rate Recommendations	7-36
Table 7-21. Summary of Recommended Values For Inhalation	7-37
Table 8-1. Total Body Surface Area of Male Children in Square Meters ^a	8-17
Table 8-2. Total Body Surface Area of Female Children in Square Meters ^a	8-18
Table 8-3. Percentage of Total Body Surface Area by Body Part For Children	8-19
Table 8-4. Descriptive Statistics For Surface Area/body Weight (SA/BW) Ratios (m ² /kg) ..	8-20
Table 8-6. Mean and Percentile Skin Surface Area (m ²) Derived from EPA Analysis of NHANES III (All Children)	8-21
Table 8-7. Mean and Percentile Skin Surface Area (m ²) Derived from EPA Analysis of NHANES III (Male Children)	8-22
Table 8-8. Mean and Percentile Skin Surface Area (m ²) Derived from EPA Analysis of NHANES III (Female Children)	8-23
Table 8-9. Summary of Field Studies	8-24
Table 8-10. Geometric Mean and Geometric Standard Deviations of Solids Adherence by Activity and Body Region	8-25

Table 8-11. Summary of Groups Assayed in Round 2 of Field Measurements	8-26
Table 8-12. Attire for Individuals within Children’s Groups Studied	8-27
Table 8-13. Geometric Means (Geometric Standard Deviations) of Round 2 Post-activity Loadings	8-28
Table 8-14. Summary of Controlled Green House Trials - Children Playing	8-29
Table 8-15. Preactivity Loadings Recovered from Greenhouse Trial Children Volunteers	8-30
Table 8-19. Confidence in Solids Adherence to Skin Recommendations	8-32
Table 8A-1. Estimated Parameter Values for Different Age Intervals	8A-4
Table 8A-2. Summary of Surface Area Parameter Values for the Dubois and Dubois Model	8A-5
Table 9-1. Mean Time Spent (minutes) Performing Major Activities Grouped by Age, Sex and Type of Day	9-16
Table 9-2. Mean Time Spent (minutes) in Major Activities Grouped by Type of Day for Five Different Age Groups	9-17
Table 9-3. Mean Time Spent Indoors and Outdoors Grouped by Age and Day of the Week	9-18
Table 9-4. Mean Time Spent at Three Locations for both CARB and National Studies (ages 12 years and older)	9-19
Table 9-5. Mean Time Spent (minutes/day) in Various Microenvironments Grouped by Total Population and Gender (12 years and over) in the National and CARB Data	9-20
Table 9-6. Mean Time Spent (minutes/day) in Various Microenvironments by Type of Day for the California and National Surveys	9-21
Table 9-7. Mean Time Spent (minutes/day) in Various Microenvironments by Age Groups for the National and California Surveys	9-22
Table 9-8. Mean Time (minutes/day) Children Ages 12 Years and Under Spent in Ten Major Activity Categories for All Respondents	9-23
Table 9-9. Mean Time Children Spent in Ten Major Activity Categories by Age a	9-24
Table 9-10. Mean Time Children Ages 12 Years and Under Spent in Ten Major Activity Categories Grouped by Seasons and Regions	9-25
Table 9-11. Mean Time Children Ages 12 Years and Under Spent in Six Major Location Categories for All Respondents (minutes/day)	9-26
Table 9-12. Mean Time Children Spent in Six Location Categories Grouped by Age and Gender	9-27
Table 9-14. Mean Time Children Spent in Proximity to Two Potential Exposures Grouped by All Respondents, Age, and Gender	9-29
Table 9-15. Mean Time Spent Indoors and Outdoors Grouped by Age	9-30
Table 9-16. Water and Soil Contact Exposure Factors	9-31
Table 9-17. Number of Showers Taken Per Day	9-31
Table 9-18. Time (minutes) Spent Taking a Shower and Spent in the Shower Room After Taking a Shower by the Number of Respondents	9-32
Table 9-19. Time Spent Taking a Shower and Spent in the Shower Room Immediately After Showering	9-32
Table 9-20. Time spent bathing, showering, and in bathroom after bathing and showering (distribution)	9-33

Table 9-21. Time spent bathing, showering, and in bathroom after bathing and showering (percentiles)	9-34
Table 9-22. Range of Number of Times Washing the Hands at Specified Daily Frequencies by the Number of Respondents	9-35
Table 9-23. Number of Minutes Spent Working or Being Near Excessive Dust in the Air (minutes/day)	9-35
Table 9-24. Range of Number of Times per Day a Motor Vehicle was Started in a Garage or Carport and Started with the Garage Door Closed	9-36
Table 9-25. Number of Minutes Spent Playing on Dirt, Grass	9-37
Table 9-26. Number of Minutes Spent Playing on Dirt, Sand/Gravel, or Grass (minutes/day)	9-38
Table 9-27. Number of Times Swimming in a Month in Freshwater Swimming Pool by the Number of Respondents	9-39
Table 9-28. Number of Minutes Spent Swimming in a Month in Freshwater Swimming Pool (minutes/month)	9-39
Table 9-29. Time Spent Sleeping/Napping: Whole Population and Doers Only: Percentile Values	9-40
Table 9-30. Time Spent Attending School Full-Time: Whole Population and Doers Only: Percentile Values	9-40
Table 9-31. Time Spent in Active Sports: Whole Population and Doers Only: Percentile Values	9-41
Table 9-32. Time Spent on Exercise: Whole Population and Doers Only: Percentile Values	9-41
Table 9-33. Time Spent on Outdoor Recreation: Whole Population and Doers Only: Percentile Values	9-42
Table 9-34. Time Spent on Walking: Whole Population and Doers Only: Percentile Values	9-42
Table 9-35. Time Spent Bathing: Whole Population and Doers Only: Percentile Values ...	9-43
Table 9-36. Time Spent Eating: Whole Population and Doers Only: Percentile Values ...	9-43
Table 9-37. Time Spent at Restaurants: Whole Population and Doers Only: Percentile Values	9-44
Table 9-38. Time Spent Indoors at School: Whole Population and Doers Only: Percentile Values	9-44
Table 9-39. Time Spent on School Grounds/Playgrounds: Whole Population and Doers Only: Percentile Values	9-45
Table 9-40. Time Spent at Home in Kitchen: Whole Population and Doers Only: Percentile Values	9-46
Table 9-41. Time Spent at Home in Living Room/Family Room/Den: Whole Population and Doers Only: Percentile Values	9-46
Table 9-42. Time Spent at Home in Dining Room: Whole Population and Doers Only: Percentile Values	9-47
Table 9-43. Time Spent at Home in Bathroom: Whole Population and Doers Only: Percentile Values	9-47

Table 9-44. Time Spent at Home in Bedroom: Whole Population and Doers Only: Percentile Values	9-48
Table 9-45. Time Spent at Home in Study/Office: Whole Population and Doers Only: Percentile Values	9-48
Table 9-46. Time Spent at Home in Garage: Whole Population and Doers Only: Percentile Values	9-49
Table 9-47. Time Spent at Home: All Rooms Combined: Whole Population and Doers Only: Percentile Values	9-49
Table 9-48. Time Spent in an Car: Whole Population and Doers Only: Percentile Values ..	9-50
Table 9-49. Time Spent in a Truck (Pickup or Van): Whole Population and Doers Only: Percentile Values	9-50
Table 9-50. Time Spent in a Truck (Not Pickup or Van): Whole Population and Doers Only: Percentile Values	9-51
Table 9-51. Time Spent on a Bus: Whole Population and Doers Only: Percentile Values ...	9-51
Table 9-52. Time Spent on a Train: Whole Population and Doers Only: Percentile Values ..	9-52
Table 9-53. Time Spent on an Airplane: Whole Population and Doers Only: Percentile Values	9-52
Table 9-54. Time Spent on a Boat: Whole Population and Doers Only: Percentile Values ..	9-53
Table 9-55. Total Time Spent Inside Vehicles: Whole Population and Doers Only: Percentile Values	9-53
Table 9-56. Time Spent Inside Grocery/Convenience Stores, Other Stores, and Malls: Whole Population and Doers Only: Percentile Values	9-54
Table 9-57. Average Time Spent Inside and Outside, By Age Category	9-54
Table 9-58. Statistics for 24-hour Cumulative Number of Minutes Spent with Smokers Present	9-55
Table 9-59. Gender and Age Groups	9-56
Table 9-60. Assignment of At-Home Activities to Ventilation Levels for Children	9-57
Table 9-61. Aggregate Time Spent (minutes/day) At-Home in Activity Groups by Adolescents and Children ^a	9-58
Table 9-62. Comparison of Mean Time (minutes/day) Spent At-Home by Gender ^a (Adolescents)	9-58
Table 9-63. Comparison of Mean Time (minutes/day) Spent At-Home by Gender and Age for Children ^a	9-58
Table 9-64. Number of Person-Days/Individuals ^a for Children in CHAD ^a Database	9-59
Table 9-65. Number of Hours Per Day Children Spend in Various Microenvironments by Age	9-60
Table 9-66. Average Number of Hours Per Day Children Spend Doing Various Macroactivities <i>While Indoors at Home</i>	9-61
Table 9-67. Number of Hours Per Day Children Spend in Various Microenvironments by Age - Recast Into New Standard Age Categories	9-62
Table 9-68. Number of Hours Per Day Children Spend in Various Macroactivities <i>While Indoors at Home</i> - Recast Into New Standard Age Categories	9-63
Table 9-69. Number and percentage of respondents with children and those reporting outdoor play ^a activities in both warm and cold weather	9-64

Table 9-70. Play frequency and duration for all child players (from SCS-II data)	9-64
Table 9-71. Hand washing and bathing frequency for all child players (from SCS-II data) .	9-65
Table 9-72. NHAPS and SCS-II play duration ^a comparison	9-65
Table 9-73. NHAPS and SCS-II hand wash frequency comparison	9-66
Table 9-77. Confidence in Activity Patterns Recommendations	9-70
Table 10-1. Consumer Products Commonly Found in Some U.S. Households ^a	10-4
Table 10-2. Number of Minutes Spent in Activities Working with or Near Household Cleaning Agents Such as Scouring Powders or Ammonia (minutes/day)	10-7
Table 10-3. Number of Minutes Spent Using Any Microwave Oven (minutes/day)	10-7
Table 10-4. Number of Respondents Using a Humidifier at Home	10-8
Table 10-5. Number of Respondents Indicating that Pesticides Were Applied by a Professional at Home to Eradicate Insects, Rodents, or Other Pests at Specified Frequencies	10-9
Table 10-6. Number of Respondents Reporting Pesticides Applied by the Consumer at Home To Eradicate Insects, Rodents, or Other Pests at Specified Frequencies	10-9
Table 11-1. Smoothed Percentiles of Weight (In Kg) by Sex And Age: Statistics From NCHS And Data From Fels Research Institute, Birth to 36 Months	11-7
Table 11-2. Weight in Kilograms For Males 2 Months-19 Years of Age– Number Examined, Mean, and Selected Percentiles, by Age Category: United States, 1976-1980 ^a	11-8
Table 11-3. Weight in Kilograms For Females 6 Months-19 Years of Age– Number Examined, Mean, and Selected Percentiles, by Age Category: United States, 1976-1980 ^a	11-9
Table 11-4. Statistics for Probability Plot Regression Analyses: Natural Log of Body Weights 6 Months to 20 Years of Age	11-10
Table 11-5. Body Weight Estimates (in kilograms) by Age and Gender, U.S. Population 1988-94	11-11
Table 11-6. Body Weight Estimates (in kilograms) by Age, U.S. Population 1988-94	11-12
Table 11-7. Mean Body Weight (kilograms) by Age and Gender Across Multiple Surveys	11-13
Table 11-8. Mean and Percentile Body Weights (kg) Derived from NHANES III (All Children)	11-14
Table 11-9 Mean and Percentile Body Weights (kg) Derived from NHANES III (Male Children)	11-14
Table 11-10. Mean and Percentile Body Weights (kg) Derived from NHANES III (Female Children)	11-15
Table 11-11. Summary of Recommended Values for Body Weight	11-15
Table 11-12. Confidence in Body Weight Recommendations	11-16

LIST OF FIGURES

Figure 1-1. Schematic of Dose and Exposure: Oral Route	1-17
Figure 7-1. 5th, 10th, 25th, 50th, 75th, 90th, and 95th Smoothed Centiles by Age in Awake Subjects	7-23
Figure 7-2. 5th, 10th, 25th, 50th, 75th, 90th, and 95th Smoothed Centiles by Age in Asleep Subjects	7-23
Figure 8-1. Schematic of Dose and Exposure: Dermal Route	8-2

Figure 8-2. Skin Coverage as Determined by Fluorescence vs. Body Part for Adults Transplanting Plants and for Children Playing in Wet Soils	8-33
Figure 8-3. Gravimetric Loading vs. Body Part for Adult Transplanting Plants in Wet Soil and for Children Playing in Wet and Dry Soils	8-33
Figure 11-1. Weight by Age percentiles for Girls Aged Birth-36 Months	11-17
Figure 11-2. Weight by Age Percentiles for Boys Aged Birth-36 Months	11-18
Figure 11-3. Mean Body Weight Estimates, U.S. Population, 1988-94	11-19
Figure 11-4. Median Body Weights Estimates, U.S. Population, 1988-94	11-20

PREFACE

The Exposure Factors Program of the of the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development (ORD) has three main goals: (1) provide updates to the *Exposure Factors Handbook* and the *Child-Specific Exposure Factors Handbook*; (2) identify exposure factors data gaps and needs in consultation with clients; and (3) develop companion documents to assist clients in the use of exposure factors data. The activities under each goal are supported by and respond to the needs of the various program offices.

The National Center for Environmental Assessment (NCEA) of EPA's Office of Research and Development (ORD) has prepared this handbook to address factors commonly used in exposure assessments for children. Children may be more heavily exposed to environmental toxicants than adults. They consume more of certain foods and water and have higher inhalation rates per pound of body weight than adults. Young children play close to the ground and come into contact with contaminated soil outdoors and with contaminated dust on surfaces and carpets indoors. As another example, exposure to chemicals in breast milk affects infants and young children.

The National Center for Environmental Assessment has published the *Exposure Factors Handbook* in 1997. This document includes exposure factors and related data on children, as well as adults. However, the EPA Program Offices identified the need to prepare a document specifically for children's exposure factors. The goal of the Child-Specific Exposure Factors Handbook is to fulfill this need.

This Handbook was first offered to the public in 2002. Since that time, EPA has developed a standardized set of age categories to be used for children's exposure assessment. The use of a standard set of age categories is intended to permit easier comparison of data among multiple sources and to allow consistency between different types of exposure factors.

EXECUTIVE SUMMARY

This *Child-Specific Exposure Factors Handbook* has been prepared to focus on various factors used in assessing exposure, specifically for children ages 0 - 21 years old. This handbook provides nonchemical-specific data on exposure factors for the EPA recommended set of childhood age groups in the following areas:

- breast milk ingestion (chapter 2);
- food ingestion, including homegrown foods and other dietary-related data (chapter 3);
- drinking water ingestion (chapter 4);
- soil ingestion (chapter 5);
- hand-to-mouth and object-to-mouth activity (chapter 6);
- dermal exposure factors such as surface areas and soil adherence (chapter 7);
- inhalation rates (chapter 8);
- duration and frequency in different locations and various microenvironments (chapter 9);
- duration and frequency of consumer product use (chapter 10); and
- body weight data (chapter 11)

The handbook was first published in 2002. Subsequently, recognizing that exposures among infants, toddlers, adolescents, and teenagers can vary significantly, the U.S. Environmental Protection Agency (EPA) published its “*Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005a).” To the extent possible, source data for the independent studies cited in the earlier version of this Handbook were obtained and re-analyzed to conform to the standard age categories. This update and revision of the 2002 interim final *Child-specific Exposure Factors Handbook* is designed specifically to complement EPA’s recommended set of childhood age groups:

- ▶ Less than 12 months old: birth to <1 month, 1 to <3 months, 3 to <6 months, and 6 to <12 months.
- ▶ Greater than 12 months old: 1 to <2 years, 2 to <3 years, 3 to <6 years, 6 to <11 years, 11 to <16 years, and 16 to <21 years.

The data presented in this handbook have been compiled from various sources, which include EPA’s *Exposure Factor Handbook* (U.S. EPA, 1997b), government reports, and information presented in the scientific literature. The data presented are the result of analyses by the individual study authors. However, in some cases EPA has conducted analysis of published primary data to present results for the recommended age groups. Studies presented in this handbook were chosen because they were seen as useful and appropriate for estimating exposure factors based on the following considerations: level of peer review, accessibility, reproducibility, focus on exposure factor of interest, pertinence of data to the U.S., primary data, currency of

1 information, adequacy of data collection period, validity of approach, representativeness of the
2 population, variability in the population, minimal (or defined) bias in study design, and minimal
3 (or defined) uncertainty in the data. Overall confidence ratings of high, medium, or low were
4 derived for the various exposure factors based on the evaluation of the elements described above.
5

6 Many scientific studies were reviewed for possible inclusion in this handbook. The
7 handbook contains summaries of selected studies published through June 2006. Generally,
8 studies were designated as “key” or “relevant” studies. Key studies were considered the most
9 useful for deriving recommendations; while relevant studies provided applicable or pertinent
10 data, but not necessarily the most important for a variety of reasons (e.g., data were outdated,
11 limitations in study design). The recommended values for exposure factors are based on the
12 results of key studies. EPA’s procedure for developing recommendations was as follows:
13

- 14 1. Key studies were evaluated in terms of both quality and relevance to specific populations
15 (general U. S. population, age groups, gender, etc.). The criteria for assessing the quality
16 of studies are described in Section 1.4.
17
- 18 2. If only one study was classified as key for a particular factor, the mean value from that
19 study was selected as the recommended central tendency value for that population. If
20 multiple key studies with reasonably equal quality, relevance, and study design
21 information were available, a weighted mean (if appropriate, considering sample size and
22 other statistical factors) of the studies was chosen as the recommended mean value. If
23 the key studies were judged to be unequal in quality, relevance, or study design, the range
24 of means is presented and the user of this handbook should employ judgment in selecting
25 the most appropriate value for the lifestage or local population of interest.
26
- 27 3. The variability of the factor across the lifestage was discussed. This document attempts
28 to characterize the variability of each of the factors. Variability refers to true
29 heterogeneity or diversity in a population. Differences among individuals in a population
30 are referred to as inter-individual variability, differences for one individual over time is
31 referred to as intra-individual variability. Since most of the studies used to derive
32 exposure factors data are short term in nature, they present the variability in short term
33 exposures across a population sample and often do not allow analysis of either inter-
34 temporal variability within individuals nor inter-individual variability of long term
35 average exposures. Inter-individual variability in this handbook is characterized in one
36 or more of the following ways: (1) as a table with various percentiles or ranges of values;
37 (2) as analytical distributions with specified parameters; and/or (3) as a qualitative
38 discussion.
39
- 40 4. Uncertainties were discussed in terms of data limitations, the range of circumstances over
41 which the estimates were (or were not) applicable, possible biases in the values
42 themselves, a statement about parameter uncertainties (measurement error, sampling
43 error) and model or scenario uncertainties if models or scenarios were used to derive the
44 recommended value.

1 5. Finally, EPA assigned a confidence rating of low, medium or high to each recommended
2 value. This rating is not intended to represent an uncertainty analysis; rather, it
3 represents EPA's judgment on the quality of the underlying data used to derive the
4 recommendation.

5 Most of the data presented in this handbook are derived from studies that target (1) the
6 general population (e.g., USDA food consumption surveys) or (2) a sample population from a
7 specific area or group (e.g., Davis et al. (1990) soil ingestion study using children from the three-
8 city area in southeastern Washington State). The decision as to whether to use site-specific or
9 national values for an assessment may depend on the quality of the competing data sets as well
10 as on the purpose of the specific assessment.

11
12 It is important to note that the recommended values were derived solely from EPA's
13 interpretation of the available data. Different values may be appropriate for the user in
14 consideration of policy, precedent, strategy, or other factors (e.g., more up-to-date data of better
15 quality and more representative of the population of concern).
16
17

1 **AUTHORS, CONTRIBUTORS, AND REVIEWERS**

2
3 The National Center for Environmental Assessment (NCEA), Office of Research and
4 Development was responsible for the preparation of this handbook. The 2001 edition was
5 prepared by the Exposure Assessment Division of Versar Inc. in Springfield, Virginia, under
6 EPA Contract No. 68-W-99-041. The 2005 revision was produced by the same group under EPA
7 Contract No. EP-W-04-035. Jacqueline Moya served as Work Assignment Manager for both the
8 original and the revision, providing overall direction, technical assistance, and serving as
9 contributing author.

10
11 **AUTHORS**

WORD PROCESSING

12 Versar, Inc.

Versar, Inc.

13 Christopher Greene

Susan Perry

14 Linda Phillips

Valerie Schwartz

15 Patricia Wood

16 Kathleen Saunders-Coon

17 Marit Espevik

18 Todd Perryman

19 Clarkson Meredith

20 Diane Sinkowski

21 Nica Mostaghim

22
23 U.S. EPA

24 Jacqueline Moya

25 Laurie Schuda

26 John Schaum

27
28 The following EPA individuals reviewed an earlier draft of this document and provided
29 valuable comments:

30
31 Marcia Bailey, U.S. EPA, Region X

32 Gary Bangs, U.S. EPA, Risk Assessment Forum, Office of Research and Development

33 Denis R. Borum, U.S. EPA, Office of Water, Health and Ecological Criteria Division

34 Dave Crawford, U.S. EPA, Office of Solid Waste

35 Becky Cuthbertson, U.S. EPA, Office of Solid Waste

36 Michael Dellarco, U.S. EPA, National Center for Environmental Assessment

37 Lynn Delpire, U.S. EPA, Office of Prevention, Pesticides, and Toxic Substances

38 Jeff Evans, U.S. EPA, Office of Pesticide Programs

39 Cathy Fehrenbacher, U.S. EPA, Office of Prevention, Pesticides, and Toxic Substances

40 Michael Firestone, U.S. EPA, Office of Children's Health Protection

41 Brenda Foos, U.S. EPA, Office of Children's Health Protection

1 Henry Kahn, U.S. EPA, National Center for Environmental Assessment
2 Youngmoo Kim, U.S. EPA, Region VI
3 Steve Kroner, U.S. EPA, Office of Solid Waste
4 Tom McCurdy, U.S. EPA, National Exposure Research Laboratory
5 David Miller, U.S. EPA Office of Pesticide Programs
6 Deirdre Murphy, U.S. EPA, Office of Air Quality Planning and Standards
7 Steve Nako, U.S. EPA, Office of Pesticide Programs
8 Marian Olsen, U.S. EPA, Region II
9 Glenn Rice, U.S. EPA, National Center for Environmental Assessment
10 Harvey Richmond, U.S. EPA, Office of Air Quality Planning and Standards
11 David Riley, U.S. EPA Region VI
12 Marybeth Smuts, U.S. EPA, Region I
13 Marc Stifelman, U.S. EPA, Region X
14 Valerie Zartarian, U.S. EPA, National Exposure Research Laboratory
15

16 In addition, the National Exposure Research Laboratory (NERL) of the Office of Research and
17 Development made an important contribution to this handbook by conducting additional
18 analyses of mouthing behavior data from the Davis 1995 study. Data analyses were conducted
19 by Nicole Tulve.
20

21
22 This document was reviewed by an external panel of experts. The panel was composed of the
23 following individuals:
24

25 [to be added upon review]
26
27
28
29
30
31
32