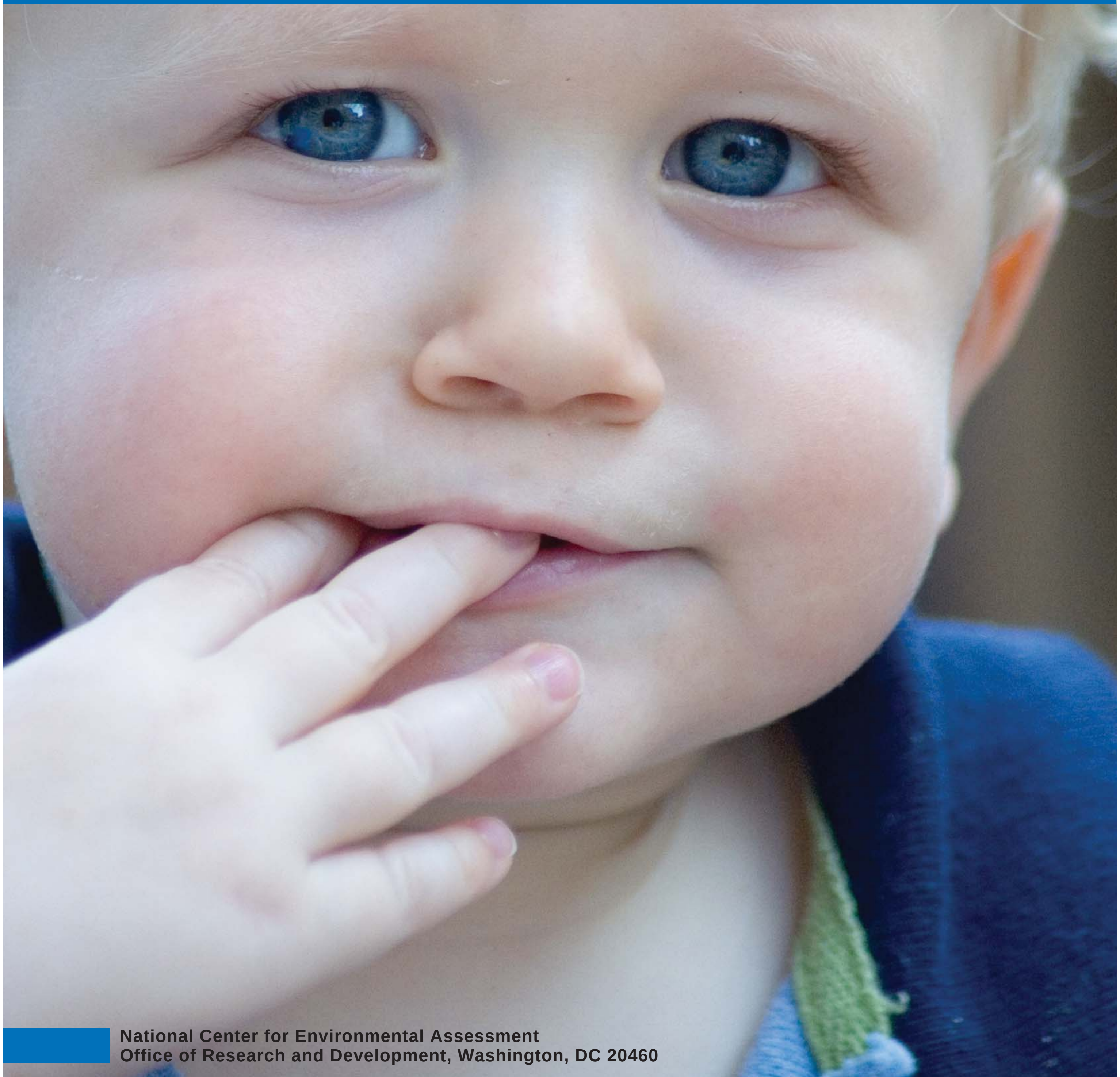
EPA
United States
Environmental Protection
Agency

EPA/600/R-06/096F | September 2008 | www.epa.gov/ncea

Child-Specific Exposure Factors Handbook



National Center for Environmental Assessment
Office of Research and Development, Washington, DC 20460

DISCLAIMER

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AAP	=	American Academy of Pediatrics
ADD	=	Average Daily Dose
AF	=	Adherence Factor
AIR	=	Acid Insoluble Residue
ANOVA	=	Analysis of Variance
ARS	=	Agricultural Research Service
ATSDR	=	Agency for Toxic Substances and Disease Registry
ATUS	=	American Time Use Study
BI	=	Bootstrap Interval
BMD	=	Benchmark Dose
BMI	=	Body Mass Index
BMR	=	Basal Metabolic Rate
BTM	=	Best Tracer Method
C	=	Contaminant Concentration
CARB	=	California Air Resources Board
CATI	=	Computer Assisted Telephone Interviewing
CDC	=	Centers for Disease Control and Prevention
CDS	=	Child Development Supplement
CHAD	=	Consolidated Human Activity Database
CI	=	Confidence Interval
cm^2	=	Square Centimeter
cm^3	=	Cubic Centimeter
CNRC	=	Children's Nutrition Research Center
CRITFC	=	Columbia River Inter-Tribal Fish Commission
CSFII	=	Continuing Survey of Food Intake by Individuals
CTFA	=	Cosmetic, Toiletry, and Fragrance Association
CV	=	Coefficient of Variation
DARLING	=	Davis Area Research on Lactation, Infant Nutrition and Growth
DIY	=	Do-it-yourself
DLW	=	Doubly Labeled Water
DONALD	=	Dortmund Nutritional and Anthropometric Longitudinally Designed
E or EE	=	Energy Expenditure
EBF	=	Exclusively Breastfed
ECG	=	Energy Cost of Growth
ED	=	Exposure Duration
EI	=	Energy Intake
EPA	=	Environmental Protection Agency
f_B	=	Breathing Frequency
FCID	=	Food Commodity Intake Database
FITS	=	Feeding Infant and Toddler Study
FQPA	=	Food Quality Protection Act
F/S	=	Food/Soil
g	=	Gram

GAF	=	General Assessment Factor
GLM	=	General Linear Model
H	=	Oxygen Uptake Factor
HEC	=	Human Equivalent Exposure Concentrations
HPV	=	High Production Volume
HR	=	Heart Rate
I	=	Tabulated Intake Rate
I_A	=	Adjusted Intake Rate
ICRP	=	International Commission on Radiological Protection
IEUBK	=	Integrated Exposure and Uptake Biokinetic Model
IFS	=	Iowa Fluoride Study
IOM	=	Institute of Medicine
IPCS	=	International Programme on Chemical Safety
IR	=	Intake Rate
IR_p	=	Intake Rate Percentile
IRIS	=	Integrated Risk Information System
KJ	=	Kilo Joules
KS	=	Kolmogorov-Smirnov
kg	=	Kilogram
L_1	=	Cooking or Preparation Loss
L_2	=	Post-cooking Loss
LADD	=	Lifetime Average Daily Dose
LTM	=	Limiting Tracer Method
m^2	=	Square Meter
m^3	=	Cubic Meter
mg	=	Milligram
MJ	=	Mega Joules
mL	=	Milliliter
METS	=	Metabolic Equivalents of Work
MSA	=	Metropolitan Statistical Area
N	=	Number of Subjects or Respondents
N_c	=	Weighted Number of Individuals Consuming Homegrown Food Item
N_T	=	Weighted Total Number of Individuals Surveyed
NAS	=	National Academy of Sciences
NCEA	=	National Center for Environmental Assessment
NCHS	=	National Center for Health Statistics
NERL	=	National Exposure Research Laboratory
NFCS	=	Nationwide Food Consumption Survey
NHANES	=	National Health and Nutrition Examination Survey
NHAPS	=	National Human Activity Pattern Survey
NHES	=	National Health Examination Survey
NHEXAS	=	National Human Exposure Assessment Survey
NIS	=	National Immunization Survey
NOAEL	=	No-observed-adverse-effect-level
NRC	=	National Research Council

OPP	=	Office of Pesticide Programs
ORD	=	Office of Research and Development
PBPK	=	Physiologically-Based Pharmacokinetic
PDIR	=	Physiological Daily Inhalation Rate
PSID	=	Panel Study of Income Dynamics
RAGS	=	Risk Assessment Guidance for Superfund
RDD	=	Random Digit Dial
RfD	=	Reference Dose
RfC	=	Reference Concentration
RME	=	Reasonable Maximum Exposure
RQ	=	Respiratory Quotient
RTF	=	Ready to Feed
SA	=	Surface Area
SA/BW	=	Surface Area to Body Weight Ratio
SCS	=	Soil Contact Survey
SD	=	Standard Deviation
SDA	=	Soaps and Detergent Association
SE	=	Standard Error
SEM	=	Standard Error of the Mean
SES	=	Socioeconomic Status
SPC	=	Science Policy Council
SPS	=	Statistical Processing System
SRD	=	Source Ranking Database
TDEE	=	Total Daily Energy Expenditure
TFEI	=	Total Food Energy Intake
USDA	=	United States Department of Agriculture
USDL	=	United States Department of Labor
USDHHS	=	United States Department of Health and Human Services
UV	=	Ultraviolet
VO_2	=	Oxygen Consumption Rate
VQ	=	Ventilatory Equivalent
VR	=	Ventilation Rate
W	=	Weight
w_i	=	Sample Weight Assigned to Observation x_i.
WHO	=	World Health Organization
WIC	=	USDA's Women, Infants, and Children Program
x_i	=	i^{th} observation

PREFACE

The Exposure Factors Program of the U.S. Environmental Protection Agency's (U.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 the U.S. EPA's ORD has prepared this handbook to provide information on various physiological and behavioral factors commonly used in assessing children's exposure to environmental chemicals. Children have different exposure circumstances than do adults. Understanding these differences is key for evaluating potential for environmental hazards from pollutants. They consume more of certain foods and water and have higher inhalation rates per unit 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. Ingestion of breast milk is another potential pathway of exposure for infants and young children.

NCEA published the *Exposure Factors Handbook* in 1997. That document includes exposure factors and related data on children, as well as adults. However, the U.S. EPA Program Offices identified the need to prepare a document specifically for children's exposure factors. The *Child-Specific Exposure Factors Handbook* is intended to fulfill this need.

This handbook was first offered to the public in 2002. Since that time, the U.S. EPA has incorporated updated data and revised the recommendations for several exposure factors and developed a standardized set of age categories to be used for children's exposure assessment. Where possible, the U.S. EPA has used this standard set of age categories 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 to <21 years old. This handbook provides nonchemical-specific data on exposure factors for the U.S. EPA recommended set of childhood age groups in the following areas:

- ingestion of water and other select liquids (Chapter 3);
- non-dietary ingestion factors (Chapter 4);
- ingestion of soil and dust (Chapter 5);
- inhalation rates (Chapter 6);
- dermal exposure factors such as surface area and adherence (Chapter 7);
- body weight (Chapter 8);
- intake of fruits and vegetables (Chapter 9);
- intake of fish and shellfish (Chapter 10);
- intake of meat, dairy products, and fats (Chapter 11);
- intake of grain products (Chapter 12);
- intake of home-produced foods (Chapter 13);
- total food intake (Chapter 14);
- human milk intake (Chapter 15);
- activity factors (Chapter 16); and
- consumer products (Chapter 17).

The *Child-specific Exposure Factors Handbook* was first published in 2002. Subsequently, recognizing that exposures among infants, toddlers, adolescents, and teenagers can vary significantly, the U.S. EPA published its *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005). 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 the U.S. 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 the U.S. EPA's *Exposure Factor Handbook* (U.S. EPA, 1997), 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 the U.S. 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: (1) soundness (adequacy of approach and minimal or defined bias); (2) applicability and utility (focus on the exposure factor of interest, representativeness of the population, currency of the information, and adequacy of the data collection period); (3) clarity and completeness (accessibility, reproducibility, and quality assurance); (4) variability and uncertainty (variability in the population and uncertainty in the results); and (5) evaluation and review (level of peer review and number and agreement of studies). Overall confidence ratings of high, medium, or low were derived for the various exposure factors based on the evaluation of the elements described above.

Many scientific studies were reviewed for possible inclusion in this handbook. The handbook contains summaries of selected studies published through July 2008. Generally, studies were designated as "key" or "relevant" studies. Key studies were considered the most useful for deriving recommendations; while relevant studies provided applicable or pertinent data, but not necessarily the most important for a variety of reasons (e.g., data were outdated, limitations in study design). The recommended values for exposure factors are based on the results of key studies. The U.S. EPA's procedure for developing recommendations was as follows:

1. Key studies were evaluated in terms of both quality and relevance to specific populations (general U. S. population, age groups, gender, etc.). The criteria for assessing the quality of studies are described in Section 1.4.

2. If only one study was classified as key for a particular factor, the mean value from that study was selected as the recommended central tendency value for that population. If multiple key studies with reasonably equal quality, relevance, and study design information were available, a weighted mean (if appropriate, considering sample size and other statistical factors) of the studies was chosen as the recommended mean value. If the key studies were judged to be unequal in quality, relevance, or study design, the range of means is presented and the user of this handbook should employ judgment in selecting the most appropriate value for the lifestage or local population of interest. Recommendations for upper percentiles, when multiple studies were available, were calculated as the midpoint of the range of upper percentile values of the studies for each age group where data were available.

3. Aspects of exposure factors variability have been discussed. This document attempts to characterize the variability of each of the factors. Variability refers to true heterogeneity or diversity in a population. Differences among individuals in a population are referred to as inter-individual variability, differences for one individual over time is referred to as intra-individual variability. Since most of the studies used to derive exposure factors data are short term in nature, they present the variability in short term exposures across a population sample and often do not allow analysis of either inter-temporal variability within individuals nor inter-individual variability of long term average exposures. Inter-individual variability in this handbook is characterized in one or more of the following ways: (1) as a table with various percentiles or ranges of values; (2) as analytical distributions with specified parameters; and/or (3) as a qualitative discussion.

4. Uncertainties were discussed in terms of data limitations, the range of circumstances over which the estimates were (or were not) applicable, possible biases in the values themselves, a statement about parameter uncertainties (measurement error, sampling error) and model or scenario uncertainties if models or scenarios were used to derive the recommended value.

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

6. Finally, the U.S. EPA developed a table for each exposure factor to summarize the recommended values for that factor. Table ES-1 summarizes key recommended values for the exposure factors included in this handbook. Additional recommendations and detailed supporting information can be found in the individuals chapters that address these factors.

In providing recommendations for the various exposure factors, an attempt was made to present percentile values that are consistent with the exposure estimators defined in *Guidelines for Exposure Assessment* (U.S. EPA, 1992) (i.e., mean, 50th, 90th, 95th, 98th, and 99.9th percentile). However, this was not always possible, because the data available were limited for some factors, or the authors of the study did not provide such information. It is important to note, however, that these percentiles were discussed in the guidelines within the context of risk descriptors and not individual exposure factors. For example, the guidelines state that the assessor may derive a high-end estimate of exposure by using maximum or near maximum values for one or more sensitive exposure factors, leaving others at their mean value. The term "upper percentile" is used throughout this handbook, and it is intended to represent values in the upper tail (i.e., between 90th and 99.9th percentile) of the distribution of values for a particular exposure factor.

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

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

U.S. EPA. (1992) Guidelines for exposure assessment. Washington, DC: Office of Research and Development, Office of Health and Environmental Assessment. EPA/600/Z-92/001.

U.S. EPA. (1997) Exposure factors handbook. Washington, DC: National Center for Environmental Assessment, Office of Research and Development. EPA/600/P-95/002Fa,b,c.

U.S. EPA. (2005) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants (2005). U.S. Environmental Protection Agency, Washington, D.C., EPA/630/P-03/003F.

<table>
<tr><th colspan="12">Table ES-1. Summary of Recommended Exposure Factors for Children</th></tr>
<tr><th>Age Group</th><th>0 to <1 mo.</th><th>1 to <3 mos.</th><th>3 to <6 mos.</th><th>6 to <12 mos.</th><th>1 to <2 yrs.</th><th>2 to <3 yrs.</th><th>3 to <6 yrs.</th><th>6 to <11 yrs.</th><th>11 to <16 yrs.</th><th>16 to<18 yrs.</th><th>18 to <21 yrs.</th></tr>
<tr><td colspan="12">Ingestion of Drinking Water (mL/day) - See Chapter 3</td></tr>
<tr><td>Mean per capita
95th percentlile per capita
Mean consumer only
95th percentile consumer only</td><td>184
839
470
858</td><td>227
896
552
1,053</td><td>362
1,056
556
1,171</td><td>360
1,055
467
1,147</td><td>271
837
308
893</td><td>317
877
356
912</td><td>380
1,078
417
1,099</td><td>447
1,235
480
1,251</td><td>606
1,727
652
1,744</td><td>731
1,983
792
2,002</td><td>826
2,540
895
2,565</td></tr>
<tr><td colspan="12">Ingestion of Drinking Water (mL/kg-day) - See Chapter 3</td></tr>
<tr><td>Mean per capita
95th percentile per capita
Mean consumer only
95th percentile consumer only</td><td>52
232
137
238</td><td>48
205
119
285</td><td>52
159
80
173</td><td>41
126
53
129</td><td>23
71
27
75</td><td>23
60
26
62</td><td>22
61
24
65</td><td>16
43
17
45</td><td>12
34
13
34</td><td>11
31
12
32</td><td>12
35
13
35</td></tr>
<tr><td colspan="12">Ingestion of Water while Swimming (mL/hour) - See Chapter 3</td></tr>
<tr><td>Mean
Upper percentile</td><td colspan="7">-
-</td><td colspan="2">50
100</td><td>-
-</td><td>20
70</td></tr>
<tr><td colspan="12">Hand-to-mouth Frequency (contacts/hour) - See Chapter 4</td></tr>
<tr><td>Indoor Mean
95th percentile
Outdoor Mean
95th percentile</td><td colspan="2">-
-
-
-</td><td>28
65
-
-</td><td>19
52
15
47</td><td>20
63
14
42</td><td>13
37
5
20</td><td>15
54
9
36</td><td>7
21
3
12</td><td colspan="3">-
-
-
-</td></tr>
<tr><td colspan="12">Object-to-mouth Frequency (contacts/hour) - See Chapter 4</td></tr>
<tr><td>Mean
95th percentile</td><td colspan="3">-
-</td><td colspan="2">20
-</td><td colspan="2">10
-</td><td>1
-</td><td colspan="3">-
-</td></tr>
<tr><td colspan="12">Object-to-mouth Duration (minutes/hour) - See Chapter 4</td></tr>
<tr><td>Mean
95th percentile</td><td colspan="2">-
-</td><td colspan="2">11
26</td><td>8
22</td><td>13
16</td><td colspan="5">-
-</td></tr>
</table>

Table ES-1. Summary of Recommended Exposure Factors for Children (Continued)

Age Group		0 to <1 mo.	1 to <3 mos.	3 to <6 mos.	6 to <12 mos.	1 to <2 yrs.	2 to <3 yrs.	3 to <6 yrs.	6 to <11 yrs.	11 to <16 yrs.	16 to<18 yrs.	18 to <21 yrs.
Soil/dust Ingestion (mg/day) - See Chapter 5												
Soil	Central	-			30	50						
Dust	Central	-			30	60						
Soil + Dust	Central	-			60	100						
Soil pica	Upper percentile	-			-	1,000						
Geophagy	Upper percentile	-			-	50,000						
Inhalation Rate - Long-term (m^3/day)- See Chapter 6												
Mean		3.6	-	4.1	5.4	8.0	9.5	10.9	12.4	15.1	16.5	
95th percentile		7.1	-	6.1	8.1	12.8	15.9	16.2	18.7	23.5	27.6	
Inhalation Rate - Short-term (m^3/minute) - See Chapter 6												
Sleep/nap	Mean	3.0E-03				4.5E-03	4.6E-03	4.3E-03	4.5E-03	5.0E-03	4.9E-03	
	95th percentile	4.6E-03				6.4E-03	6.4E-03	5.8E-03	6.3E-03	7.4E-03	7.1E-03	
Sedentary	Mean	3.1E-03				4.7E-03	4.8E-03	4.5E-03	4.8E-03	5.4E-03	5.3E-03	
	95th percentile	4.7E-03				6.5E-03	6.5E-03	5.8E-03	6.4E-03	7.5E-03	7.2E-03	
Light	Mean	7.6E-03				1.2E-02	1.2E-02	1.1E-02	1.1E-02	1.3E-02	1.2E-02	
	95th percentile	1.1E-02				1.6E-02	1.6E-02	1.4E-02	1.5E-02	1.7E-02	1.6E-02	
Moderate	Mean	1.4E-02				2.1E-02	2.1E-02	2.1E-02	2.2E-02	2.5E-02	2.6E-02	
	95th percentile	2.3E-02				2.9E-02	2.9E-02	2.7E-02	2.9E-02	3.4E-02	3.7E-02	
Heavy	Mean	2.6E-02				3.8E-02	3.9E-02	3.7E-02	4.2E-02	4.9E-02	4.9E-02	
	95th percentile	4.1E-02				5.2E-02	5.3E-02	4.8E-02	5.9E-02	7.0E-02	7.3E-02	
Skin Surface Area - Total (m^2) - See Chapter 7												
Total Body	Mean	0.29	0.33	0.38	0.45	0.53	0.61	0.76	1.08	1.59	1.84	
	95th	0.34	0.38	0.44	0.51	0.61	0.70	0.95	1.48	2.06	2.33	

Table ES-1. Summary of Recommended Exposure Factors for Children (Continued)

Age Group		0 to <1 mo.	1 to <3 mos.	3 to <6 mos.	6 to <12 mos.	1 to <2 yrs.	2 to <3 yrs.	3 to <6 yrs.	6 to <11 yrs.	11 to <16 yrs.	16 to<18 yrs.	18 to <21 yrs.
Skin Surface Area - Body Parts (m^2) - See Chapter 7												
Head	Mean	0.053	0.060	0.069	0.082	0.087	0.087	0.104	0.136	0.149	0.144	
	95th percentile	0.062	0.069	0.080	0.093	0.101	0.099	0.130	0.186	0.194	0.182	
Trunk	Mean	0.104	0.118	0.136	0.161	0.188	0.235	0.241	0.375	0.536	0.592	
	95th percentile	0.121	0.136	0.157	0.182	0.217	0.270	0.301	0.514	0.694	0.750	
Arms	Mean	0.040	0.045	0.052	0.062	0.069	0.072	0.108	0.137	0.205	0.282	
	95th percentile	0.047	0.052	0.060	0.070	0.079	0.083	0.135	0.188	0.266	0.356	
Hands	Mean	0.015	0.017	0.020	0.024	0.030	0.032	0.045	0.054	0.084	0.099	
	95th percentile	0.018	0.020	0.023	0.027	0.035	0.037	0.056	0.074	0.109	0.126	
Legs	Mean	0.060	0.068	0.078	0.093	0.122	0.142	0.207	0.301	0.498	0.592	
	95th percentile	0.070	0.078	0.091	0.105	0.141	0.162	0.259	0.413	0.645	0.750	
Feet	Mean	0.019	0.021	0.025	0.029	0.033	0.043	0.055	0.078	0.119	0.131	
	95th percentile	0.022	0.025	0.029	0.033	0.038	0.050	0.069	0.107	0.155	0.165	
Adherence of Solids to Skin (means; mg/cm^2) - See Chapter 7 for specific activities and age groups represented by these values												
Residential indoor		0.0041 (arms); 0.011 (hands); 0.0035 (legs); 0.010 (feet)										
Daycare (in & outdoors)		0.024 (arms); 0.099 (hands); 0.020 (legs); 0.071 (feet)										
Outdoor sports		0.012 (face); 0.011 (arms); 0.11 (hands); 0.031 (legs)										
Indoor sports		0.0019 (arms); 0.0063 (hands); 0.0020 (legs); 0.0022 (feet)										
Activities with soil		0.054 (face); 0.046 (arms); 0.17 (hands); 0.051 (legs); 0.20 (feet)										
Playing in mud		11 (arms); 47 (hands); 23 (legs); 15 (feet)										
Playing in sediment		0.040 (face); 0.17 (arms); 0.49 (hands); 0.70 (legs); 21 (feet)										
Body Weight (kg) - See Chapter 8												
Mean		4.8	5.6	7.4	9.2	11.4	13.8	18.6	31.8	56.8	71.6	
Total Fruit Intake (g/kg-day)[a] - See Chapter 9												
Mean per capita		5.7				6.2		4.6	2.4	0.8		
95th percentile per capita		21				19		14	8.8	3.5		
Mean consumer only		10				6.9		5.1	2.7	1.1		
95th percentile consumer		26				19		15	9.3	3.8		

Table ES-1. Summary of Recommended Exposure Factors for Children (Continued)

Age Group	0 to <1 mo.	1 to <3 mos.	3 to <6 mos.	6 to <12 mos.	1 to <2 yrs.	2 to <3 yrs.	3 to <6 yrs.	6 to <11 yrs.	11 to <16 yrs.	16 to<18 yrs.	18 to <21 yrs.
Total Vegetable Intake (g/kg-day) [a] - See Chapter 9											
Mean per capita	4.5				6.9		5.9	4.1	2.9		
95th percentile per capita	15				17		15	9.9	6.9		
Mean consumer only	6.2				6.9		5.9	4.1	2.9		
95th percentile consumer	16				17		15	9.9	6.9		
Fish and Shellfish Intake (g/kg-day) [a] - See Chapter 10											
General Population											
Total Fish											
Mean per capita	-						0.43	0.28	0.23	0.16	-
95th percentile per capita	-						3.0	1.9	1.5	1.3	-
Mean consumer only	-						4.2	3.2	2.2	2.1	-
95th consumer	-						10	8.7	6.2	6.6	-
Marine											
Mean per capita	-						0.31	0.20	0.15	0.10	-
95th percentile per capita	-						2.3	1.5	1.3	0.46	-
Mean consumer only	-						3.7	2.8	2.0	2.0	-
95th percentile consumer	-						9.3	8.0	5.2	6.5	-
Freshwater											
Mean per capita	-						0.12	0.08	0.08	0.07	-
95th percentile per capita	-						0.71	0.35	0.48	0.29	-
Mean consumer only	-						2.3	1.8	1.3	1.4	-
95th percentile consumer	-						7.2	6.2	4.4	3.3	-
Recreational Marine - No age-specific recommendations; see Chapter 10.											
Recreational Freshwater - No age-specific recommendations; see Chapter 10.											
Native American - No age-specific recommendations; see Chapter 10.											

Table ES-1. Summary of Recommended Exposure Factors for Children (Continued)

Age Group	0 to <1 mo.	1 to <3 mos.	3 to <6 mos.	6 to <12 mos.	1 to <2 yrs.	2 to <3 yrs.	3 to <6 yrs.	6 to <11 yrs.	11 to <16 yrs.	16 to<18 yrs.	18 to <21 yrs.
Total Meat Intake (g/kg-day)[a] - See Chapter 11											
Mean per capita	1.2				4.1		4.1	2.9	2.1		
95th percentile per capita	6.7				9.8		9.4	6.5	4.8		
Mean consumer only	3.0				4.2		4.2	2.9	2.1		
95th percentile consumer	9.2				9.8		9.4	6.5	4.8		
Total Dairy Intake (g/kg-day)[a] - See Chapter 11											
Mean per capita	13				37		23	14	5.6		
95th percentile per capita	49				88		49	32	16		
Mean consumer only	16				37		23	14	5.6		
95th percentile consumer	58				88		49	32	16		
Total Fat Intake (g/kg-day)[a] - See Chapter 11											
Mean per capita	5.2	4.5	4.1	3.7	4.0	3.6	3.4	2.6	1.6	1.3	
95th percentile per capita	16	11	8.2	7.0	7.1	6.4	5.8	4.2	3.0	2.7	
Mean consumer only	7.8	6.0	4.4	3.7	4.0	3.6	3.4	2.6	1.6	1.3	
95th percentile consumer	16	12	8.3	7.0	7.1	6.4	5.8	4.2	3.0	2.7	
Total Grain Intake (g/kg-day)[a] - See Chapter 12											
Mean per capita	2.5				6.4		6.3	4.3	2.5		
95th percentile per capita	8.6				12		12	8.2	5.1		
Mean consumer only	3.6				6.4		6.3	4.3	2.5		
95th percentile consumer	9.2				12		12	8.2	5.1		

Table ES-1. Summary of Recommended Exposure Factors for Children (Continued)

Age Group		0 to <1 mo.	1 to <3 mos.	3 to <6 mos.	6 to <12 mos.	1 to <2 yrs.	2 to <3 yrs.	3 to <6 yrs.	6 to <11 yrs.	11 to <16 yrs.	16 to<18 yrs.	18 to <21 yrs.
Home-produced Food Intake (g/kg-day) [b] - See Chapter 13												
Fruits	Mean	-				8.7		4.1	3.6	1.9		
	95th percentile	-				60.6		8.9	15.8	8.3		
Vegetables	Mean	-				5.2		2.5	2.0	1.5		
	95th percentile	-				19.6		7.7	6.2	6.0		
Meats	Mean	-				3.7		3.6	3.7	1.7		
	95th percentile	-				10.0		9.1	14.0	4.3		
Fish	Mean	-							2.8	1.5		
	95th percentile	-							7.1	4.7		
Total Food Intake (g/kg-day) - See Chapter 14												
Mean per capita		20	16	28	56	90	74	61	40	24	18	
95th percentile per capita		61	40	65	134	161	126	102	70	45	35	
Human Milk Intake (mL/day) - See Chapter 15												
Mean		510	690	770	620	NA						
Upper percentile		950	980	1,000	1,000	NA						
Human Milk Intake (mL/kg-day) - See Chapter 15												
Mean		150	140	110	83	NA						
Upper percentile		220	190	150	130	NA						
Lipid Intake from Human Milk (mL/day) - See Chapter 15												
Mean		20	27	30	25	NA						
Upper percentile		38	40	42	42	NA						

Table ES-1. Summary of Recommended Exposure Factors for Children (Continued)												
Age Group		0 to <1 mo.	1 to <3 mos.	3 to <6 mos.	6 to <12 mos.	1 to <2 yrs.	2 to <3 yrs.	3 to <6 yrs.	6 to <11 yrs.	11 to <16 yrs.	16 to<18 yrs.	18 to <21 yrs.
Lipid Intake from Human Milk (mL/kg-day) - See Chapter 15												
Mean		6.0	5.5	4.2	3.3	NA						
Upper percentile		8.7	8.0	6.0	5.2	NA						
Activity Factors - See Chapter 16												
Mean (minutes/day)												
Indoors, total	Mean	1,440	1,432	1,414	1,301	1,353	1,316	1,278	1,244	1,260	1,248	
Outdoors, total	Mean	0	8	26	139	36	76	107	132	100	102	
Indoors, at residence	Mean	1,108				1,065	979	957	893	889	833	
	95th	1,440				1,440	1,296	1,355	1,275	1,315	1,288	
Showering	Mean	15				20	22	17	18	18	20	
	95th	-				-	44	34	41	40	45	
Bathing	Mean	19				23	23	24	24	25	33	
	95th	30				32	45	60	46	43	60	
Playing on sand/gravel	Mean	18				43	53	60	67	67	83	
	95th	-				121	121	121	121	121	-	
Playing on grass	Mean	52				68	62	79	73	75	60	
	95th	-				121	121	121	121	121	-	
Playing on dirt	Mean	33				56	47	63	63	49	30	
	95th	-				121	121	121	121	120	-	
Mean (minutes/month)												
Swimming	Mean	96				105	116	137	151	139	145	
	95th	-				-	181	181	181	181	181	

Table ES-1. Summary of Recommended Exposure Factors for Children (Continued)

Age Group	0 to <1 mo.	1 to <3 mos.	3 to <6 mos.	6 to <12 mos.	1 to <2 yrs.	2 to <3 yrs.	3 to <6 yrs.	6 to <11 yrs.	11 to <16 yrs.	16 to<18 yrs.	18 to <21 yrs.
Consumer Products - See Chapter 17											
No age-specific recommendations; see Chapter 17.											

[a] Analysis was conducted using slightly different age groups than those recommended in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005). Data were placed in the recommended age categories closest to those used in the analysis.
[b] Analysis was conducted prior to Agency's issuance of *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005). Thus, age groups in the original study are slightly different than those presented here. See chapter for details.
\- = No data available and/or no recommendation made.
NA = Not applicable.

AUTHORS, CONTRIBUTORS, AND REVIEWERS

The National Center for Environmental Assessment (NCEA), Office of Research and Development (ORD) was responsible for the preparation of this handbook. Adraft of this document was prepared by the Exposure Assessment Division of Versar Inc. in Springfield, Virginia, under U.S. EPA Contract No. EP-W-04-035. Earlier versions (i.e., 2002 and 2005) were prepared under Contract Nos. 68-W-99-0041 and EP-W-04-035. The U.S. EPA/NCEA's Jacqueline Moya served as Work Assignment Manager for both the original and the revision, providing overall direction, technical assistance, and serving as contributing author. The draft was reviewed by U.S. EPA staff who have an interest in exposure factors as well as by an independent panel of outside experts.

AUTHORS

Versar, Inc.
Adria Diaz
Marit Espevik
Christopher Greene
Ron Lee
Clarkson Meredith
Nica Mostaghim
Chuck Peck
Todd Perryman
Linda Phillips
Kathleen Saunders-Coon
Diane Sinkowski
Patricia Wood

WORD PROCESSING

Versar, Inc.
Susan Perry
Malikah Moore
Valerie Schwartz

U.S. EPA
Becky Cuthbertson
Jacqueline Moya
Linda Phillips
John Schaum
Laurie Schuda

The following U.S. EPA individuals reviewed an earlier draft of this document and provided valuable comments:

Marcia Bailey, U.S. EPA, Region X

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

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

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

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

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

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

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

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

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

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

Henry Kahn, U.S. EPA, National Center for Environmental Assessment

Youngmoo Kim, U.S. EPA, Region VI

Steve Kroner, U.S. EPA, Office of Solid Waste

Tom McCurdy, U.S. EPA, National Exposure Research Laboratory

David Miller, U.S. EPA Office of Pesticide Programs

Deirdre Murphy, U.S. EPA, Office of Air Quality Planning and Standards

Steve Nako, U.S. EPA, Office of Pesticide Programs
Marian Olsen, U.S. EPA, Region II

Glenn Rice, U.S. EPA, National Center for Environmental Assessment

Harvey Richmond, U.S. EPA, Office of Air Quality Planning and Standards

David Riley, U.S. EPA Region VI

Marybeth Smuts, U.S. EPA, Region I

Marc Stifelman, U.S. EPA, Region X

Valerie Zartarian, U.S. EPA, National Exposure Research Laboratory

Acknowledgment

The authors wish to acknowledge the important contributions of the following U.S. EPA individuals who conducted additional analyses for the revisions of this handbook:

David Hrdy, Office of Pesticide Programs

Henry Kahn, National Center for Environmental Assessment

David Miller,Office of Pesticide Programs

James Nguyen, Office of Pesticide Programs

Bernard Scheneider, Office of Pesticide Programs

Nicole Tulve, National Exposure Research Laboratory

Philip Villanueva, Office of Pesticide Programs

Jianping Xue, National Exposure Research Laboratory

Valerie Zartarian, National Exposure Research Laboratory

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

Ed Avol, Keck School of Medicine, University of Southern California

James Bruckner, College of Pharmacy, University of Georgia

Anna Fan, California Environmental Protection Agency

Panos Georgopoulos, UMDNJ Robert Wood Johnson Medical School

Lynn Goldman, Johns Hopkins Bloomberg School of Public Health

Annette Guiseppi-Elie, Dupont Engineering

Dale Hattis, Clark University

Diane Rohiman, Oregon Health and Science University

P. Barry Ryan, Emory University

Edward Stanek, University of Massachusetts at Amherst

Alan Stern, University of Medicine and Dentistry of New Jersey

Nga Tran, Exponent

Bernard Weiss, University of Rochester School of Medicine and Dentistry

Robin Wyatt, Columbia University

Rosemary Zaleski, ExxonMobil Biomedical Sciences, Inc.

Finally, the following U.S. EPA/NCEA individuals reviewed this document for final clearance:

David Bussard
Jeffrey Frithsen
Nicole Hagan
Charles Ris
John Vandenberg

1 INTRODUCTION

1.1 PURPOSE

The purpose of the *Child-Specific Exposure Factors Handbook* is to provide exposure factors for children. The handbook highlights the changes in risk assessment practices that were first presented in the U.S. Environmental Protection Agency's (EPA) Cancer Guidelines, regarding the need to consider children as lifestages rather than as subpopulations (U.S. EPA, 2005b). It also emphasizes a major recommendation in U.S. EPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (U.S. EPA, 2005c) to sum exposures and risks across lifestages rather than relying on the use of a lifetime average adult exposure to calculate risk. This handbook also uses updated information to incorporate any new exposure factors data/research that have become available since the early 2000's, and is consistent with the U.S. EPA's new set of recommended childhood age groups (U.S. EPA 2005a), including a standardized way to define specific age groups.

As with the earlier version of the handbook, this new version summarizes key data on human behaviors and characteristics that affect children's exposure to environmental contaminants, and provides recommended values to use for these factors. These recommendations are not legally binding on any U.S. EPA program and should be interpreted as suggestions that Program Offices or individual exposure/risk assessors can consider and modify as needed. The decision as to whether to use site-specific or national values for an assessment may depend on the quality of the competing data sets as well as on the purpose of the specific assessment. The handbook has strived to include discussions of the issues that assessors may consider in assessing exposure among children of different ages, and may be used in conjunction with the U.S. EPA document entitled *Socio-demographic Data Used for Identifying Potentially Highly Exposed Populations* (U.S. EPA, 1999).

1.2 INTENDED AUDIENCE

The *Child-Specific Exposure Factors Handbook* may be used by exposure and risk assessors, economists, and other interested parties as a source for data and/or U.S. EPA recommendations on numeric estimates for behavioral and physiological characteristics needed to estimate childhood exposure to toxic contaminants.

1.3 BACKGROUND

Because of physiological and behavioral differences, exposures among children are expected to be different from exposures among adults. Children may be more exposed to some environmental contaminants, because they consume more of certain foods and water per unit of body weight and have a higher ratio of body surface area to volume than adults. Equally important, rapid changes in behavior and physiology may lead to differences in exposure as a child grows up. Recognizing that exposures among infants, toddlers, adolescents, and teenagers can vary significantly, the U.S. EPA published its "*Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005a)." This update and revision of the 2002 interim final *Child-Specific Exposure Factors Handbook* (U.S. EPA, 2002a) is designed specifically to complement U.S. 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.

Many studies have shown that young children can be exposed to various contaminants, including pesticides, during normal oral exploration of their environment (i.e., hand-to-mouth behavior) and by touching floors, surfaces, and objects such as toys (Eskenazi et al., 1999; Gurunathan et al., 1998; Lewis et al., 1999; Nishioka et al., 1999; Garry, 2004). Dust and tracked-in soil accumulate in carpets, where young children spend a significant amount of time (Lewis et al., 1999). Children living in agricultural areas may experience higher exposures to pesticides than do other children (Curwin et al., 2007). Pesticides may be tracked into their homes by family members. In addition, children living in agricultural areas may also play in nearby fields or be exposed via consumption of contaminated human milk from their farmworker mother (Eskenazi et al., 1999).

In terms of risk, children may also differ from adults in their vulnerability to environmental pollutants because of toxicodynamic differences (e.g., when exposures occur during periods of enhanced susceptibility) and/or toxicokinetic differences (i.e., differences in absorption, metabolism, and excretion) (U.S. EPA, 2000a). The immaturity of metabolic enzyme systems and clearance mechanisms in young children can result in longer half-lives of environmental contaminants (Ginsberg et al., 2002, Clewell et al., 2004). The cellular immaturity of children and the ongoing growth processes account for elevated risk (AAP, 1997). Toxic chemicals in the environment can cause neurodevelopmental disabilities, and the developing brain can be particularly sensitive to environmental contaminants. For example, elevated blood lead levels and prenatal exposures to even relatively low levels of lead can result in behavior disorders and reductions of intellectual function in children (Landrigan et al., 2005). Exposure to high levels of methylmercury can result in developmental disabilities among children (Myers et al., 2000). Other authors have described the importance of exposure timing (i.e., preconceptional, prenatal, and postnatal) and how it affects the outcomes observed (Selevan et al., 2000). Breysee et al. (2005) suggests that higher levels of exposure to indoor air pollution and allergens among inner-city children compared to non-inner-city children may explain the difference in asthma levels between these two groups. With respect to contaminants that are carcinogenic via a mutagenic mode of action, the U.S. EPA has found that childhood is a particularly sensitive period of development, in which cancer potencies per year of exposure can be an order of magnitude higher than during adulthood (U.S. EPA, 2005c).

Executive Order 13045: *Protection of Children from Environmental Health Risks and Safety Risks*, signed in 1997, requires all federal agencies to address health and safety risks to children, to coordinate research priorities on children's health, and to ensure that their standards take into account special risks to children (EO, 1997). To implement the Order, the U.S. EPA established the Office of Children's Health Protection (OCHP) (renamed the Office of Children's Health Protection and Environmental Education (OCHPEE) in 2005), whose job it is to work with Program and regional offices within the U.S. EPA to promote a safe and healthy environment for children by ensuring that all regulations, standards, policies, and risk assessments take into account risks to children. Legislation, such as the Food Quality Protection Act and the Safe Drinking Water Act amendments, has made coverage of children's health issues more explicit, and research on children's health issues is continually expanding. As a result of the emphasis on children's risk, the U.S. EPA Office of Research and Development (ORD) developed a *Strategy for Research on Environmental Risks to Children* (U.S. EPA, 2000a). The goal of the Strategy is to improve the quality of risk assessments for children. This *Child-Specific Exposure Factors Handbook* is also intended to support the U.S. EPA/ORD/NCEA's efforts to improve exposure and risk assessments for children.

In 1997, the U.S. EPA/ORD/NCEA published the *Exposure Factors Handbook* (U.S. EPA, 1997a). The handbook includes exposure factors and related data on both adults and children. Subsequently, the U.S. EPA Program Offices identified the need to consolidate all children's exposure data into a single document and the *Child-Specific Exposure Factors Handbook* was published in 2002 to fulfill this need. This handbook updates the 2002 edition of the *Child-Specific Exposure Factors Handbook* (U.S. EPA 2002a). It provides non-chemical-specific data on exposure factors that can be used to assess contributions from dietary and non-dietary ingestion exposure, dermal exposure, and inhalation exposure among children. Although the preconceptional and prenatal (fetal) life stages are important to consider they are not covered in this handbook. Preconceptional exposures are included in the *Exposure Factors Handbook* since they relate to maternal and paternal exposures, and exposure factors for pregnant and lactating women are being developed as part of a separate effort. This document does not include chemical-specific data or information on physiological parameters that may be needed for exposure assessments involving physiologically-based pharmacokinetic (PBPK) modeling. The U.S. EPA has developed guidance on how to use PBPK information in risk assessment. More information on the application of PBPK models and supporting data is found in U.S. EPA (2006a, 2006b).

This handbook provides updated exposure factor information for children in the following areas:

- ingestion of water and other select liquids;
- non-dietary ingestion;
- soil and dust ingestion;
- inhalation rates;
- dermal exposure factors such as surface area and adherence;
- body weight;
- intake of fruits and vegetables;
- intake of fish and shellfish;
- intake of meat, dairy products, and fats;
- intake of grain products;
- intake of home-produced foods;
- total food intake;
- human milk intake;
- activity factors; and
- consumer products.

This handbook is a compilation of available data from a variety of sources. Most of these data have been described in detail in the U.S. EPA's *Exposure Factors Handbook* (1997a), but data published after the release of the *Exposure Factors Handbook* are also included here. This latest handbook updates the 2002 interim final *Child-Specific Exposure Factors Handbook* (U.S. EPA 2002). With very few exceptions, the data presented here derive from the analyses of the individual study authors. Because the studies included in this handbook vary in terms of their objectives, design, scope, presentation of results, etc., the level of detail, statistics, and terminology may vary from study to study and from factor to factor. For example, some authors used geometric means to present their results, while others used arithmetic means or distributions. Authors have sometimes used different age ranges to describe data for children. In most cases, the original data are unavailable, and the study results cannot be reallocated into the standard age groups used in this handbook. Every effort has been made to reallocate source data into the standard age groups recommended by the U.S. EPA in the report entitled *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005a; see Section 1.7), when sufficiently detailed data are available. Within the constraint of presenting the original material as accurately as possible, the U.S. EPA has made an effort to present discussions and results in a consistent manner. The strengths and limitations of each study are discussed to provide the reader with a better understanding of the uncertainties associated with the values derived from the study.

Most of the data presented in this handbook are derived from studies that target (1) the general population (e.g., USDA food consumption surveys) or (2) a sample population from a specific area or group (e.g., fish consumption among Native American children). If it is necessary to characterize a population that is not directly covered by the data in this handbook, the risk or exposure assessor may need to evaluate whether these data may be used as suitable substitutes for the population of interest or whether there is a need to seek additional population-specific data. If information is needed for identifying and enumerating populations who may be at risk for greater contaminant exposures or who exhibit a heightened sensitivity to particular chemicals, the reader is referred to *Socio-demographic Data Used for Identifying Potentially Highly Exposed Populations* (U.S. EPA, 1999).

Because of the large number of tables in this handbook, tables are presented at the end of each chapter, before the appendices, if any. In conjunction with the *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005a), this handbook is adopting the age group notation "X to < Y" (e.g., the age group 3 to < 6 years is meant to span a 3-year time interval from a child's 3rd birthday up until the day before his or her 6th birthday).

1.4 SELECTION OF STUDIES FOR THE HANDBOOK

Information in this handbook has been summarized from studies documented in the scientific literature and other available sources. Studies were chosen that were seen as useful and appropriate for estimating exposure factors for children. The handbook contains summaries of selected studies published through July 2008.

Certain studies described in this handbook are designated as "key," that is, the most useful for deriving exposure factors. The recommended values for most exposure factors are based on the results of the key studies (See Section 1.5). Other studies are designated "relevant," meaning applicable or pertinent, but not necessarily the most important. This distinction was made on the strength of the attributes listed in the "General Assessment Factors" listed below.

1.4.1 General Assessment Factors

Many scientific studies were reviewed for possible inclusion in this handbook. Generally, studies identified in the *Exposure Factors Handbook* (U.S. EPA, 1997a) as key studies are also included in this handbook as key studies. Also included are new studies that became available after publication of the *Exposure Factors Handbook* and the 2002 *Child-Specific Exposure Factors Handbook* (U.S. EPA, 2002a). Key studies from the *Exposure Factors Handbook* were generally defined as the most useful for deriving recommendations for exposure factors. The recommended values for most exposure factors are based on the results of these studies. The Agency recognizes the need to evaluate the quality and relevance of scientific and technical information used in support of Agency actions (U.S. EPA 2002b, 2003a, 2006c). When evaluating scientific and technical information, the U.S. EPA's Science Policy Council (SPC) recommends using five General Assessment Factors (GAFs): (1) soundness, (2) applicability and utility, (3) clarity and completeness, (4) uncertainty and variability, and (5) evaluation and review (U.S. EPA 2003a). These GAFs were adapted and expanded to include specific considerations deemed to be important during evaluation of exposure factors data, and were used to judge the quality of the underlying data used to derive recommendations.

1.4.2 Selection Criteria

The confidence ratings for the various exposure factor recommendations, and selection of the key studies that form the basis for these recommendations, were based on specific criteria within each of the five GAFs, as follows:

(1) Soundness: *Scientific and technical procedures, measures, methods or models employed to generate the information are reasonable for, and consistent with, the intended application.* The soundness of the experimental procedures or approaches in the study designs of the available studies were evaluated according to the following:

Adequacy of the Study Approach Used: In general, more confidence was placed on experimental procedures or approaches that more likely or closely captured the desired measurement. Direct exposure data collection techniques, such as direct observation, personal monitoring devices, or other known methods were preferred where available. If studies utilizing direct measurement were not available, studies were selected that relied on validated indirect measurement methods such as surrogate measures (such as heart rate for inhalation rate), and use of questionnaires. If questionnaires or surveys were used, proper design and procedures include an adequate sample size for the population under consideration, a response rate large enough to avoid biases, and avoidance of bias in the design of the instrument and interpretation of the results. More confidence was placed in exposures factors that relied on studies that gave appropriate consideration to these study design issues. Studies were also deemed preferable if based on primary data, but studies based on secondary sources were also included where they offered an original analysis. In general, higher confidence was placed on exposure factors based on primary data.

Minimal (or Defined) Bias in Study Design: Studies were sought that were designed with minimal bias, or at least if biases were suspected to be present, the direction of the bias (i.e., an over or underestimate of the parameter) was either stated or apparent from the study design. More confidence was placed on exposure factors based on studies that minimized bias.

(2) Applicability and utility: *The information is relevant for the Agency's intended* The applicability and utility of the available studies were evaluated based on the following criteria:

Focus on Exposure Factor of Interest: Studies were preferred that directly addressed the exposure factor of interest, or addressed related factors that have significance for the factor under consideration. As an example of the latter case, a selected study contained useful ancillary information concerning fat content in fish, although it did not directly address fish consumption.

Representativeness of the Population: More confidence was placed in studies that addressed the U.S. population. Data from populations outside the U.S. were sometimes included if behavioral patterns or other characteristics of exposure were similar. Studies seeking to characterize a particular region or sub-population were selected, if appropriately representative of that population. In cases where data were limited, studies with limitations in this area were included and limitations were noted in the handbook. Higher confidence ratings were given to exposure factors where the available data were representative of the population of interest.

Currency of Information: More confidence was placed in studies that were sufficiently recent to represent current exposure conditions. This is an important consideration for those factors that change with time. Older data were evaluated and considered in instances where the variability of the exposure factor over time was determined to be insignificant or unimportant. In some cases, recent data were very limited. Therefore, the data provided in these instances were the only available data. Limitations on the age of the data were noted. Recent studies are more likely to use state-of-the-art methodologies that reflect advances in the exposure assessment field. Consequently, exposure factor recommendations based on current data were given higher confidence ratings than those based on older data, except in cases where the age of the data would not affect the recommended values.

Adequacy of data collection period: Because most users of the handbook are primarily addressing chronic exposures, studies were sought that utilized the most appropriate techniques for collecting data to characterize long-term behavior. Higher confidence ratings were given to exposure factor recommendations that were based on an adequate data collection period.

(3) Clarity and completeness**:** *The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented*. Clarity and completeness was evaluated based on the following criteria.

Accessibility: Studies that the user could access in their entirety, if needed, were preferred.

Reproducibility: Studies that contained sufficient information so that methods could be reproduced, or could be evaluated, based on the details of the author's work, were preferred.

Quality Assurance: Studies with documented quality assurance/quality control measures were preferred. Higher confidence ratings were given to exposure factors that were based on studies where appropriate quality assurance/quality control measures were used.

(4) Variability and uncertainty: *The variability and uncertainty (quantitative and qualitative) in the information or the procedures, measures, methods or models are evaluated and characterized.* Variability arises from true heterogeneity across people, places or time and can affect the precision of exposure estimates and the degree to which they can be generalized. The types of variability include: spatial, temporal, and inter-individual. Uncertainty represents a lack of knowledge about factors affecting exposure or risk and can lead to inaccurate or biased estimates of exposure. The types of uncertainty include: scenario, parameter, and model. The uncertainty and variability associated with the studies was evaluated based on the following criteria.

Variability in the population: Studies were sought that characterized any variability within populations. The variability associated with the studies presented in this handbook is characterized as described in Section 1.5. Higher confidence ratings were given to exposure factors that were based on studies where variability was well characterized.

Uncertainty: Studies were sought with minimal uncertainty in the data, which was judged by evaluating all the considerations listed above. Studies were preferred that identified uncertainties, such as those due to inherent variability in environmental and exposure-related parameters or possible measurement error. Higher confidence ratings were given to exposure factors based on studies where uncertainty had been minimized.

(5) Evaluation and review: *The information or the procedures, measures, methods or models are independently verified, validated, and peer reviewed.* Relevant factors that were considered included:

Peer review: Studies selected were those from the peer-reviewed literature and final government reports. Unpublished and internal or interim reports were avoided.

Number and agreement of studies: Higher confidence was placed on recommendations where data were available from more than one key study and there was good agreement between studies.

1.5 APPROACH USED TO DEVELOP RECOMMENDATIONS FOR EXPOSURE FACTORS

As discussed above, the U.S. EPA first reviewed the literature pertaining to a factor and determined key studies. These key studies were used to derive recommendations for the values of each factor. The recommended values were derived solely from the U.S. EPA's interpretation of the available data. Different values may be appropriate for the user in consideration of policy, precedent, strategy, or other factors such as site-specific information. The U.S. EPA's procedure for developing recommendations was as follows:

(1) Study Review and Evaluation: Key studies were evaluated in terms of both quality and relevance to specific populations (general U. S. population, age groups, gender, etc.). The criteria for assessing the quality of studies are described in Section 1.4.

(2) Single versus Multiple Key Studies: If only one study was classified as key for a particular factor, the mean value from that study was selected as the recommended central value for that population. If multiple key studies with reasonably equal quality, relevance, and study design information were available, a weighted mean (if appropriate, considering sample size and other statistical factors) of the studies was chosen as the recommended mean value. If the key studies were judged to be unequal in quality, relevance, or study design, the range of means is presented and the user of this handbook must employ judgment in selecting the most appropriate value for the population of interest. Recommendations for upper percentiles, when multiple studies were available, were calculated as the midpoint of the range of upper percentile values of the studies for each age group where data were available.

(3) Variability: The variability of the factor across the population is discussed. For recommended values, as well as for each of the studies on which the recommendations are base, variability is characterized in one or more of three ways: (1) as a table with various percentiles or ranges of values; (2) as analytical distributions with specified parameters; and/or (3) as a qualitative discussion. Analyses to fit standard or parametric distributions (e.g., normal, lognormal) to the exposure data have not been performed by the authors of this handbook, but have been reproduced as they were found in the literature. Recommendations on the use of these distributions are made where appropriate based on the adequacy of the supporting data. The list of exposure factors and the way in which variability has been characterized throughout this handbook (i.e., average, median, upper percentiles, multiple percentiles, fitted distribution) are presented in Table 1-1.

In the providing recommendations for the various exposure factors, an attempt was made to present percentile values that are consistent with the exposure estimators defined in *Guidelines for Exposure Assessment* (U.S. EPA, 1992a) (i.e., mean, 50th, 90th, 95th, 98th, and 99.9th percentile). However, this was not always possible, because the data available were limited for some factors, or the authors of the study did not provide such information. It is important to note, however, that these percentiles were discussed in the guidelines within the context of risk descriptors and not individual exposure factors. For example, the guidelines state that the assessor may derive a high-end estimate of exposure by using maximum or near maximum values for one or more sensitive exposure factors, leaving others at their mean value. The term "upper percentile" is used throughout this handbook, and it is intended to represent values in the upper tail (i.e., between 90th and 99.9th percentile) of the distribution of values for a particular exposure factor.

(4) Uncertainty: Uncertainties are discussed in terms of data limitations, the range of circumstances over which the estimates were (or were not) applicable, possible biases in the values themselves, a statement about parameter uncertainties (measurement error, sampling error) and model or scenario uncertainties if models or scenarios were used to derive the recommended value. A discussion of variability and uncertainty for exposure factors is presented in Chapter 2 of this handbook.

(5) Confidence Ratings: Finally, the U.S. EPA assigned a confidence rating of low, medium or high to each recommended value. This rating is not intended to represent an uncertainty analysis; rather, it represents the U.S. EPA's judgment on the quality of the underlying data used to derive the recommendation. This judgment was made using the General Assessment Factors (GAFs) described in Section 1.4. Table 1-2 provides an adaptation of the GAFs, as they pertain to the confidence ratings for the exposure factor recommendations. Clearly, there is a continuum from low to high, and judgment that was used to determine these ratings. Recommendations given in this handbook are accompanied by a discussion of the rationale for their rating.

It is important to note that the study elements listed in Table 1-2 do not have the same weight when arriving at the overall confidence rating for the various exposure factors. The relative weight of each of these elements for the various factors were subjective and based on the professional judgement of the authors of this handbook. Also, the relative weights depend on the exposure factor of interest. For example, the adequacy of the data collection period may be more important when determining usual intake of foods in a population, but it is not as important for factors where long-term variability may be small, such as tapwater intake. In the case of tapwater intake, the currency of the data was a critical element in determining the final rating. In general, most studies ranked high with regard to "level of peer review," "accessibility," "focus on the factor of interest," and "data pertinent to the U.S." because the U.S. EPA specifically sought studies for the handbook that met these criteria.

The elements in Table 1-2 were important considerations for inclusion of a study in this handbook. However, a high score for these elements did not necessarily translate into a high overall score. Other considerations went into determining the overall score. One such consideration was the ease at which the exposure factor of interest could be measured. For example, soil ingestion by children can be estimated by measuring, in the feces of children, the levels of certain elements found in soil. Body weight, however, can be measured directly, and it is therefore a more reliable measurement. The fact that soil ingestion is more difficult to measure than body weight is reflected in the overall confidence rating given to both of these factors. In general, the better the methodology used to measure the exposure factor, the higher the confidence in the value.

(6) Recommendation Tables: The U.S. EPA developed a table at the beginning of each chapter that summarizes the recommended values for the relevant factor. Table ES-1 of the Executive Summary of this handbook summarizes the principal exposure factors addressed in this handbook and provides the confidence ratings for each exposure factor.

1.6 SUGGESTED REFERENCES FOR USE IN CONJUNCTION WITH THIS HANDBOOK

Some of the steps for performing an exposure assessment are: (1) identifying source of the environmental contamination and the media that transports the contaminant; (2) determining the contaminant concentration; (3) determining the exposure scenarios, and pathways and routes of exposure; (4) determining the exposure time, frequency, and duration; and (5) identifying the exposed population. Many of the issues related to characterizing exposure from selected exposure pathways have been addressed in a number of existing U.S. EPA documents. Some of these provide guidance while others demonstrate various aspects of the exposure process. These include, but are not limited, to the following references listed in chronological order:

- *Methods for Assessing Exposure to Chemical Substances, Volumes 1-13* (U.S. EPA, 1983-1989);
- *Standard Scenarios for Estimating Exposure to Chemical Substances During Use of Consumer Products* (U.S. EPA, 1986a);
- *Selection Criteria for Mathematical Models Used in Exposure Assessments: Surface Water Models* (U.S. EPA, 1987);
- *Selection Criteria for Mathematical Models Used in Exposure Assessments: Groundwater Models* (U.S. EPA, 1988);
- *Risk Assessment Guidance for Superfund, Volume I, Part A, Human Health Evaluation Manual* (U.S. EPA, 1989);
- *Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions* (U.S. EPA, 1990);
- *Risk Assessment Guidance for Superfund, Volume I, Part B, Development of Preliminary Remediation Goals* (U.S. EPA, 1991a);
- *Risk Assessment Guidance for Superfund, Volume I, Part C, Risk Evaluation of Remedial Alternatives* (U.S. EPA, 1991b);
- *Guidelines for Exposure Assessment* (U.S. EPA, 1992a);
- *Dermal Exposure Assessment: Principles and Applications* (U.S. EPA, 1992b);
- *Estimating Exposures to Dioxin-Like Compounds* (U.S. EPA, 1994a);
- *Soil Screening Guidance* (U.S. EPA 1996a);
- *Series 875 Occupational and Residential Exposure Test Guidelines - Final Guidelines - Group A - Application Exposure Monitoring Test Guidelines* (U.S. EPA 1996b);
- *Series 875 Occupational and Residential Exposure Test Guidelines - Group B - Post Application Exposure Monitoring Test Guidelines* (U.S. EPA 1996c);

- *Policy for Use of Probabilistic Analysis in Risk Assessment at the U.S. Environmental Protection Agency*, (U.S. EPA, 1997b);

- *Guiding Principles for Monte Carlo Analysis* (U.S. EPA, 1997c);

- *Sociodemographic Data for Identifying Potentially Highly Exposed Populations* (U.S. EPA, 1999);

- *Options for Developing Parametric Probability Distributions for Exposure Factors* (U.S. EPA 2000b);

- *Risk Assessment Guidance for Superfund, Volume I, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments* (U.S. EPA, 2001a);

- *Risk Assessment Guidance for Superfund Volume III, Part A, Process for Conducting Probabilistic Risk Assessments* (U.S. EPA, 2001b);

- *Framework for Cumulative Risk Assessment* (U.S. EPA, 2003b);

- *Example Exposure Scenarios* (U.S. EPA, 2003c);

- *Risk Assessment Guidance for Superfund, Volume I, Part E, Supplemental Guidance for Dermal Risk Assessment* (U.S. EPA, 2004);

- *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005a);

- *Cancer Guidelines for Carcinogen Risk Assessment Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (U.S. EPA, 2005b);

- *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (U.S. EPA, 2005c);

- *Protocol for Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (U.S. EPA, 2005d);

- *A Framework for Assessing Health Risk of Environmental Exposures to Children* (Final). (U.S. EPA 2006d); and

- *Concepts, methods, and data sources for cumulative health risk assessment of multiple chemicals, exposures and effects: a resource document* (Final) (U.S. EPA, 2008).

These documents may serve as valuable information resources to assist in the assessment of exposure. The reader is encouraged to refer to them for more detailed discussion.

1.7 THE USE OF AGE GROUPINGS WHEN ASSESSING EXPOSURE

When this handbook was first published in 2002, no specific guidance existed with regard to which age groupings should be used when assessing children's exposure. Age groupings varied from case to case and among Program Offices within the U.S. EPA. They depended on availability of data and were often based on professional judgement. More recently, the U.S. EPA has endeavored to establish a consistent set of age groupings and publish guidance on this topic (U.S. EPA 2005a). This revision of the handbook attempts to present data in a manner consistent with the U.S. EPA's recommended set of age groupings.

The development of standardized age bins was the subject of discussion in a 2000 workshop sponsored by the U.S. EPA Risk Assessment Forum. The workshop was titled "Issues Associated with Considering Developmental Changes in Behavior and Anatomy When Assessing Exposure to Children" (U.S. EPA, 2001c). The purpose of this workshop was to gain insight and input into factors that need to be considered when developing standardized age bins and identify future research necessary to accomplish these goals. Panelists were divided into two groups. One group focused their discussions on defining and characterizing the important facets of behavioral development during childhood, while the other group focused on defining and characterizing physiological development during childhood. During the workshop, it was recognized that the ultimate goal of exposure assessment is to develop a day-to-day model of human life that can predict the chemical exposures an individual is likely to face at any point in life. However, this is not likely to be accomplished in the near future, and assessors often need to classify individuals into age bins in order to simplify the exposure model. The recommendations listed below are those of the panel members and were considered by the U.S. EPA in the development of age groupings:

- Panelists agreed that child development is a series of discrete events, but these events occur along a continuum.
- Age grouping/bins are a useful guide to fulfill the Agency's immediate need, but are only a crude approximation of an underlying distribution. Ultimately, sufficient data should be gathered to develop a continuous multivariate model that can replace bins.
- Adequacy of existing exposure data is highly variable.
- A considerable amount of additional information already exists, but it is dispersed in the literature. It was recommended that the U.S. EPA consults with experts in developmental biology, physiology, pharmacology, and toxicology and conducts an in-depth review of the literature.
- Long term research should include the development of integrated data sets that combines information about the exposure factors with biomarkers of exposure and effects.
- The definition of age groups/bins for childhood exposure assessment are inextricably linked to toxicokinetic and toxicodynamic issues.
- The two break out groups (i.e., behavioral and physiological) offered the following preliminary ideas for age groupings:

Age grouping based on behavioral characteristics

0-2 months
2 - 6 months
6-12 months
1-2 years
2-6 years
6-11 years
11-16 years
16-21 years

Age grouping based on physiological characteristics

0-1 month
1-6 months
6-12 months
1- 3 years
3-9 years
9-21 years

One can observe that there was fairly good agreement among the two groups with regard to the age groupings that are important for infants and toddlers. However, there was some disagreement with regard to the older children. Appropriate age groupings depend not only on behavioral and physiological characteristics, but also on the specific scenario being studied and chemical of concern.

Based upon consideration of the findings of the technical workshop, as well as analysis of available data, U.S. EPA developed guidance that established a set of recommended age groups for development of exposure factors for children entitled "*Guidance for Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants*" (U.S. EPA, 2005a). This revision of the handbook was developed specifically to present exposure factors data in a manner consistent with U.S. EPA's recommended set of childhood age groupings. The recommended age groups (U.S. EPA, 2005a) are as follows:

Birth to <1 month

1 to <3 months
3 to <6 months
6 to <12 months
1 to <2 years
2 to <3 years
3 to <6 years
6 to <11 years
11 to <16 years
16 to <21 years

1.8 CONSIDERING LIFESTAGE WHEN CALCULATING EXPOSURE AND RISK

A key component of U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA 2005a) involves the need to sum age-specific differences in exposure across time when assessing long-term exposure, as well as integrating these age-specific exposures with age-specific differences in toxic potency in those cases where information exists to describe such differences: an example is carcinogens that act via a mutagenic mode of action (*Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* - U.S. EPA, 2005c). When assessing chronic risks (i.e., exposures greater than 10 percent of human lifespan), rather than assuming a constant level of exposure for 70 years (usually consistent with an adult level of exposure), the Agency is now recommending that assessors calculate chronic exposures by summing time-weighted exposures that occur at each lifestage; this handbook provides data arrayed by childhood age in order to follow this new guidance (U.S. EPA 2005a). This approach is expected to increase the accuracy of risk assessments, because it will take into account lifestage differences in exposure. Depending on whether body-weight-adjusted childhood exposures are either smaller or larger compared to those for adults, calculated risks could either decrease or increase when compared with the historical approach of assuming a lifetime of a constant adult level of exposure.

The *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* also recommended that in those cases where age-related differences in toxicity were also found to occur, differences in both toxicity and exposure would need to be integrated across all relevant age intervals. This guidance describes such a case for carcinogens that act via a mutagenic mode of action, where age dependent potency adjustments factors (ADAFs) of 10x and 3x are recommended for children ages birth < 2 years, and 2 < 16 years, respectively when there is exposure during those years and available data are insufficient to derive chemical-specific adjustment factors.

Table 1-3, along with Chapter 6 of the "*Supplemental Guidance*" have been developed to help the reader understand how to use the new sets of exposure and potency age groupings when calculating risk through the integration of lifestage specific changes in exposure and potency.

Thus, Lifetime Cancer Risk (for a population with average life expectancy of 70 years) = ? (Exposure x Duration/70 yrs x Potency x ADAF) summed across all the age groups presented in Table 1-3. This is a departure from the way cancer risks have historically been calculated based upon the premise that risk is proportional to the daily average of the long term adult dose.

1.9 FUNDAMENTAL PRINCIPLES OF EXPOSURE ASSESSMENT

The definition of exposure as used by the International Programme on Chemical Safety (IPCS, 2001) is the "contact of an organism with a chemical or physical agent, quantified as the amount of chemical available at the exchange boundaries of the organism and available for absorption." This means contact with the visible exterior of a person such as the skin, and openings such as the mouth, nostrils, and lesions. The process of a chemical entering the body can be described in two steps: contact (exposure) followed by entry (crossing the boundary). In the context of environmental risk assessment, risk to an individual or population can be represented as a continuum from the source through exposure to dose to effect as shown in Figure 1-1 (U.S. EPA, 2003d; IPCS, 2006). The process begins with a chemical or agent released from a source into the environment. Once in the environment, the chemical or agent can be transformed and transported through the environment via air, water, soil, dust, and diet. Individuals become in contact with the chemical through inhalation, ingestion, or skin/eye contact. The individual's activity patterns as well as the concentration of the chemical will determine the magnitude, frequency, and duration of the exposure. The exposure becomes an absorbed dose when the chemical crosses an absorption barrier. When the chemical or its metabolites interact with a target tissue, it becomes a target tissue dose, which may lead to an adverse health outcome. The text under the boxes in Figure 1-1 indicates the specific information that may be needed to characterize each box.

1.9.1 Dose Equations

Starting with a general integral equation for exposure (U.S. EPA, 1992a), several dose equations can be derived depending upon boundary assumptions.

One of the more useful of these derived equations is the Average Daily Dose (ADD). The ADD, which is used for many noncancer effects, averages exposures or doses over the period of time exposure occurred. The ADD can be calculated by averaging the potential dose over body weight and an averaging time.

$$ADD_{pot} = \frac{\text{External Dose}}{\text{Body Weight} \times \text{Averaging Time}} \quad \text{(Eqn 1-1)}$$

The exposure can be expressed as follows:

$$\text{External Dose} = C \times IR \times E \quad \text{(Eqn 1-2)}$$

Where:

C = Contaminant Concentration
IR = Intake Rate
ED = Exposure Duration

Contaminant concentration is the concentration of the contaminant in the medium (air, food, soil, etc.) contacting the body and has units of mass/volume or mass/mass.

The intake rate refers to the rates of inhalation, ingestion, and dermal contact, depending on the route of exposure. For ingestion, the intake rate is simply the amount of food containing the contaminant of interest that an individual ingests during some specific time period (units of mass/time). Much of this handbook is devoted to rates of ingestion for some broad classes of food. For inhalation, the intake rate is the rate at which contaminated air is inhaled. Factors presented in this handbook that affect dermal exposure are skin surface area and estimates of the amount of soil that adheres to the skin.

The exposure duration is the length of time of contaminant contact. The length time a person lives in an area, frequency of bathing, time spent indoors versus outdoors, etc., all affect the exposure duration. Chapter 16, Activity Factors, gives some examples of population behavior/activity patterns that may be useful for estimating exposure durations.

When the above parameter values IR and ED remain constant over time, they are substituted directly into the exposure equation. When they change with time, a summation approach is needed to calculate exposure. In either case, the exposure duration is the length of time exposure occurs at the concentration and the intake rate specified by the other parameters in the equation.

Note that the advent of childhood age groupings means that separate ADD's should be calculated for each age group considered. Chronic exposures can then be calculated by summing across each lifestage-specific ADD.

Cancer risks have traditionally been calculated in those cases where a linear non-threshold model is assumed, in terms of lifetime probabilities by utilizing dose values presented in terms of lifetime ADDs (LADDs). The LADD takes the form of the Equation 1-1, with lifetime replacing averaging time. While the use of LADD may be appropriate when developing screening level estimates of cancer risk, as discussed in Section 1.8 above, the U.S. EPA is now recommending that risks should be calculated by integrating exposures or risks throughout all lifestages (U.S. EPA, 1992a).

For some types of analyses, dose can be expressed as a total amount (with units of mass, e.g., mg) or as a dose rate in terms of mass/time (e.g., mg/day), or as a rate normalized to body mass (e.g., with units of mg of chemical per kg of body weight per day (mg/kg-day)). The LADD is usually expressed in terms of mg/kg-day or other mass/mass-time units.

In most cases (inhalation and ingestion exposures), the dose-response parameters for carcinogenic risks have been adjusted for the difference in absorption across body barriers between humans and the experimental animals used to derive such parameters. Therefore, the exposure assessment in these cases is based on the potential dose, with no explicit correction for the fraction absorbed. However, the exposure assessor needs to make such an adjustment when calculating dermal exposure and in other specific cases when current information indicates that the human absorption factor used in the derivation of the dose-response factor is inappropriate.

For carcinogens, the duration of a lifetime has traditionally been assigned the nominal value of 70 years as a reasonable approximation. For exposure estimates to be used for assessments other than carcinogenic risk, various averaging periods have been used. For acute exposures, the doses are usually averaged over a day or a single event. For nonchronic noncancer effects, the time period used is the actual period of exposure (exposure duration). The objective in selecting the exposure averaging time is to express the exposure in a way which can be combined with the dose-response relationship to calculate risk.

The body weight to be used in the exposure Equation 1-1 depends on the units of the exposure data presented in this handbook. For example, for food ingestion, the body weights of the surveyed populations were known in the USDA surveys, and they were explicitly factored into the food intake data in order to calculate the intake as g/kg body weight-day. In this case, the body weight has already been included in the “intake rate” term in Equation 1-2, and the exposure assessor does not need to explicitly include body weight.

The units of intake in this handbook for the incidental ingestion of soil and dust are not normalized to body weight. In this case, the exposure assessor will need to use (in Equation 1-1) the average weight of the exposed population during the time when the exposure actually occurs. When making body weight assumptions, care must be taken that the values used for the population parameters in the dose-response analysis are consistent with the population parameters used in the exposure analysis. Intraspecies adjustments based on lifestage can be made using a scaling factor of $BW^{3/4}$ (U.S. EPA 2006d, 2006e). Some of the parameters (primarily concentrations) used in estimating exposure are exclusively site specific, and therefore default recommendations should not be used. It should be noted that body weight is correlated with food consumption rates and inhalation rates.

The link between the intake rate value and the exposure duration value is a common source of confusion in defining exposure scenarios. It is important to define the duration estimate so that it is consistent with the intake rate:

- The intake rate can be based on an individual event (e.g., serving size per event). The duration should be based on the number of events or, in this case, meals.

- The intake rate also can be based on a long-term average, such as 10 g/day. In this case the duration should be based on the total time interval over which the exposure occurs.

The objective is to define the terms so that, when multiplied, they give the appropriate estimate of mass of contaminant contacted. This can be accomplished by basing the intake rate on either a long-term average (chronic exposure) or an event (acute exposure) basis, as long as the duration value is selected appropriately.

Inhalation dosimetry is employed to derive the human equivalent exposure concentrations on which inhalation unit risks, and reference concentrations, are based (U.S. EPA, 1994b). U.S. EPA has traditionally approximated children’s respiratory exposure by using adult values, although a recent review (Ginsberg et al., 2005) concluded that there may be some cases where young children’s greater inhalation rate per body weight or pulmonary surface area as compared to adults can result in greater exposures than adults. The implications of this difference for inhalation dosimetry and children’s risk assessment were discussed at a peer involvement workshop hosted by the U.S.EPA in 2006 (Foos et al., 2008).

Consideration of lifestage-particular physiological characteristics in the dosimetry analysis may result in a refinement to the human equivalent concentration to insure relevance in risk assessment across lifestages, or might conceivably conclude with multiple human equivalent concentrations, and corresponding inhalation unit risk values (e.g., separate for childhood and adulthood) (U.S. EPA, 2005b). The RfC methodology, which is described in *Methods for Derivation of Inhalation Reference Concentrations and Applications of Inhalation Dosimetry* (U.S. EPA, 1994b), allows the user to incorporate population-specific assumptions into the models. The reader is referred to U.S. EPA guidance (U.S. EPA, 1994b) on how to make these adjustments.

There are no specific exposure factor assumptions in the derivation of Reference Doses (RfDs). The assessment of the potential for adverse health effects in infants and children is part of the overall hazard and dose-response assessment for a chemical. Available data pertinent to children's health risks are evaluated along with data on adults and the no-observed-adverse-effect-level (NOAEL) or benchmark dose (BMD) for the most sensitive critical effect(s), based on consideration of all health effects. By doing this, protection of the health of children will be considered along with that of other sensitive populations. In some cases, it is appropriate to evaluate the potential hazard to children separately from the assessment for the general population or other population subgroups.

1.9.2 Use of Exposure Factors Data in Probabilistic Analyses

Although this handbook is not intended to provide complete guidance on the use of Monte Carlo and other probabilistic analyses, some of the data in this handbook may be appropriate for use in probabilistic assessments. The use of Monte Carlo or other probabilistic analysis requires characterization of the variability of exposure factors and requires the selection of distributions or histograms for the input parameters of the dose equations presented in Section 1.9.1. The following suggestions are provided for consideration when using such techniques:

- The exposure assessor should only consider using probabilistic analysis when there are credible distribution data (or ranges) for the factor under consideration. Even if these distributions are known, it may not be necessary to apply this technique. For example, if only average exposure values are needed, these can often be computed accurately by using average values for each of the input parameters unless a non-linear model is used. Probabilistic analysis is also not necessary when conducting assessments for screening purposes, i.e., to determine if unimportant pathways can be eliminated. In this case, bounding estimates can be calculated using maximum or near maximum values for each of the input parameters. Alternatively, the assessor may use the maximum values for those parameters that have the greatest variance.

- It is important to note that the selection of distributions can be highly site-specific and dependent on the purpose of the assessment. In some cases the selection of distributions are driven by specific legislation. It will always involve some degree of judgment. Distributions derived from national data may not represent local conditions. The assessor needs to evaluate the site-specific data, when available, to assess their quality and applicability. The assessor may decide to use distributional data drawn from the national or other surrogate population. In this case, it is important that the assessor address the extent to which local conditions may differ from the surrogate data.

- It is also important to consider the independence/dependence of variables and data used in a simulation. For example, it may be reasonable to assume that ingestion rate and contaminant concentration in foods are independent variables, but ingestion rate and body weight may or may not be independent.

In addition to a qualitative statement of uncertainty, the representativeness assumption should be appropriately addressed as part of a sensitivity analysis.

- Distribution functions to be used in probabilistic analysis may be derived by fitting an appropriate function to empirical data. In doing this, it should be recognized that in the lower and upper tails of the distribution the data are scarce, so that several functions, with radically different shapes in the extreme tails, may be consistent with the data. To avoid introducing errors into the analysis by the arbitrary choice of an inappropriate function, several techniques can be used. One technique is to avoid the problem by using the empirical data itself rather than an analytic function. Another is to do separate analyses with several functions that have adequate fit but form upper and lower bounds to the empirical data. A third way is to use truncated analytical distributions. Judgment must be used in choosing the appropriate goodness-of-fit test. Information on the theoretical basis for fitting distributions can be found in a standard statistics text, (e.g., Gilbert, 1987, among others). Off-the-shelf computer software can be used to statistically determine the distributions that fit the data. Other software tools are available to identify outliers and for conducting Monte Carlo simulations.

- If only a range of values is known for an exposure factor, the assessor has several options.
  - keep that variable constant at its central value.
  - assume several values within the range of values for the exposure factor.
  - calculate a point estimate(s) instead of using probabilistic analysis.
  - assume a distribution. (The rationale for the selection of a distribution should be discussed at length.) There are, however, cases where assuming a distribution is not recommended. These include:
    - -- data are missing or very limited for a key parameter;
    - -- data were collected over a short time period and may not represent long term trends (the respondent usual behavior) - examples include: food consumption surveys; activity pattern data;
    - -- data are not representative of the population of interest because sample size was small or the population studied was selected from a local area and was therefore not representative of the area of interest; for example, soil ingestion by children; and
    - -- ranges for a key variable are uncertain due to experimental error or other limitations in the study design or methodology; for example, soil ingestion by children.

1.10 CUMULATIVE EXPOSURES

The U.S. EPA recognizes that children may be exposed to mixtures of chemicals both indoors and outdoors through more than one pathway. New directions in risk assessments in the U.S. EPA put more emphasis on total exposures via multiple pathways (U.S. EPA, 2003d, U.S. EPA, 2008). Over the last several years, the U.S. EPA has developed a methodology for assessing risk from multiple chemicals (U.S. EPA, 1986b, 2000c). For more information, the reader is referred to the U.S. EPA's *Framework for Cumulative Risk Assessment* (U.S. EPA, 2003b).

1.11 ORGANIZATION

The handbook is organized as follows:

Chapter 1	Introduction
Chapter 2	Variability and uncertainty
Chapter 3	Ingestion of water and other select liquids
Chapter 4	Non-dietary ingestion
Chapter 5	Soil and dust ingestion
Chapter 6	Inhalation rates
Chapter 7	Dermal exposure factors
Chapter 8	Body weight
Chapter 9	Intake of fruits and vegetables
Chapter 10	Intake of fish and shellfish

	Chapter 11	Intake of meats, dairy products, and fats
.	Chapter 12	Intake of grain products
	Chapter 13	Intake of home-produced foods
	Chapter 14	Total food intake
	Chapter 15	Human milk intake
	Chapter 16	Activity factors
	Chapter 17	Consumer products

Recommended values for exposure factors are presented at the beginning of each chapter, followed by detailed discussions of the data on which these recommendations are based. Because of the large number of tables in this handbook, tables are presented at the end of each chapter, before the appendices, if any.

1.12 REFERENCES FOR CHAPTER 1

AAP (1997) Child Health Issues for the Second Session of the 106th Congress. Environmental Health. American Academy of Pediatrics Department of Federal Affairs 601 13th Street, NW Suite 400 North Washington, DC 20005. AAP Washington Office Child Health Issues for the Second Session of the 106th Congress: Environmental Health. Available online at http://www.aap.org/advocacy/washing/chieh/htm.

Breysee, P.N.; Buckley, T.J.; Williams, D.; Beck, C.M.; Jo, S.; Merriman, B.; Kanchanaraksa, S.; Swartz, L.J.; Callahan, K.A.; Butz, A.M.; Rand, C.S.; Diette, G.B.; Krishman, J.A.; Moseley, A.M.; Curlin-Brosnan, J.; Durkin, N.B.; Eggleston, P.A. (2005) Indoor exposures to air pollutants and allergens in the homes of asthmatic children in inner-city Baltimore. Environ Res. 98:167-176.

Clewell, H.J.; Gentry, P.R.; Covington, T.R.; Sarangapani, R.; Teeguarden, J.G. (2004) Evaluation of the potential impact of age- and gender-specific pharmacokinetic differences on tissue dosimetry. Toxicol Sci. 79:381-393.

Curwin, B.D.; Hein, M.J.; Sanderson, W.T.; Striley, C.; Heederik, D.; Kromhout, H.; Reynolds, J.j.; Alavanja, M.C. (2007) Pesticide dose estimates for children of Iowa farmers and non-farmers. Environ Res. 105: 307-315.

EO (1997) Executive Order 13045. Protection of Children for Environmental Health Risks and Safety Risks. Available on line at http://yosemite.epa.gov/ochp/ochpweb.nsf/content/whatwe_executiv.htm.

Eskenazi, B.; Bradman, A.; Castriona, R. (1999) Exposure of children to organophosphate pesticides and their potential adverse health effects. Environ Health Perspect. 107(3):409-419.

Foos, B.; Marty, M.; Schwartz, J.; Bennet, W.; Moya, J.; Jarabek, A.M.; Salmon, A.G. (2008) Focusing on children's inhalation dosimetry and health effects for risk assessment: an introduction. J Toxicol Environ Health, Part A, 71(3):149-165.

Garry, V.F. (2004) Pesticides and children. Toxicol Appl Pharmaol. 198(2004):152-163.

Gilbert, R.O. (1987) Statistical methods for environmental pollution monitoring. New York: Van Nostrand Reinhold.

Ginsberg, G.; Hattis, D.; Sonawame, B.; Russ, A.; Banati, P.; Kozlak, M.; Smolenski, S.; Goble, R. (2002) Evaluation of child/adult pharmacokinetic differences from a database derived from the therapeutic drug literature. Toxicol Sci. 66:185-200.

Gurunathan, S.; Robson, M.; Freeman N.; Buckley, B.; Roy, A.; Meyer, R.; Bukowski, J.; Lioy, P.J. (1998) Accumulation of chloropyrifos on residential surfaces and toys accessible to children. Environ Health Perspect. 106(1):9-16.

IPCS (2001) Glossary of exposure assessment-related terms: a compilation. IPCS Exposure Terminology Subcommittee, International Programme on Chemical Safety, World Health Organization. Available on line at http://www.who.int/ipcs/publications/methods/harmonization/en/compilation_nov2001.pdf

IPCS (2006) Principles for Evaluating Health Risks in Children Associated with Exposure to Chemicals. Environmental Health Criteria 237. International Programme on Chemical Safety, World Health Organization.

Landrigan, P.J.; Sonawane, B.; Butler, R.N.; Transande, L.; Callan, R. (2005) Early environmental origins of neurodegenerative disease in later life. Environ Health Perspect. 113(9):1230-1233.

Lewis, R. G.; Fortune C.; Willis, R. D.; Camann, D. E.; Antley, J. T. (1999) Distribution of pesticides and polycyclic aromatic hydrocarbons in house dust as a function of particle size. Environ Health Perspect. 107(9):721-726.

Myers, G.J.; Davidson, P.W. (2000) Does methylmercury have a role in causing developmental disabilities in children? Environ Health Perspect. 108(3):413-419.

Nishioka, M.G.; Burkholder, H.M.; and Brinkman, M.C.; Lewis, R.G. (1999) Distribution of 2,4-dihlorophenoxyacetic acid in floor dust throughout homes following homeowner and commercial lawn application: quantitative effects of children, pets, and shoes. Environ Sci Technol. 33:1359-1365.

Selevan, S.G.; Kimmel, C.A.; Mendola, P. (2000) Identifying critical windows of exposure for children's health- monograph based on papers developed from the Workshop: Identifying Critical Windows of Exposure for Children's Health held September 14-15, 1999 in Richmond, VA. Environ Health Perspect. 108(3):451-455.

U.S. EPA. (1983-1989) Methods for assessing exposure to chemical substances. Volumes 1 - 13. Office of Toxic Substances, Exposure Evaluation Division, Washington, DC.

U.S. EPA. (1986a) Standard scenarios for estimating exposure to chemical substances during use of consumer products. Volumes I and II. Office of Toxic Substance, Exposure Evaluation Division, Washington, DC.

U.S. EPA. (1986b) Guidance for the health risk assessment of chemical mixtures. Risk Assessment Forum, Washington, DC. EPA/630/R-98/002. Available on line at http://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryID=20533

U.S. EPA. (1987) Selection criteria for mathematical models used in exposure assessments: surface water models. Exposure Assessment Group, Office of Health and Environmental Assessment, Washington, DC. WPA/600/8 87/042. Available from NTIS, Springfield, VA; PB-88-139928/AS.

U.S. EPA. (1988) Selection criteria for mathematical models used in exposure assessments: groundwater models. Exposure Assessment Group, Office of Health and Environmental Assessment, Washington, DC. EPA/600/8 88/075. Available from NTIS, Springfield, VA; PB-88-248752/AS.

U.S. EPA. (1989) Risk assessment guidance for Superfund. Volume I Human health evaluation manual: Part A. Interim Final. Office of Solid Waste and Emergency Response, Washington, DC. EPA/540-1-89/002. Available online at http://www.epa.gov/oswer/riskassessment/ragsa/index.htm.

U.S. EPA. (1990) Methodology for assessing health risks associated with indirect exposure to combustor emissions. EPA 600/6-90/003. Available from NTIS, Springfield, VA; PB-90-187055/AS.

U.S. EPA. (1991a) Risk assessment guidance for Superfund. Volume I Human health evaluation manual: Part B, Development of preliminary remediation goals. Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/R-92-003. Available online at http://www.epa.gov/oswer/riskassessment/ragsb/index.htm.

U.S. EPA. (1991b) Risk assessment guidance for Superfund. Volume I Human health evaluation manual: Part C, Risk evaluation of remedial alternatives. Office of Solid Waste and Emergency Response, Washington, DC. Publication 9285.7-01C. Available online at http://www.epa.gov/oswer/riskassessment/ragsc/index.htm.

U.S. EPA. (1992a) Guidelines for exposure assessment. Washington, DC: Office of Research and Development, Office of Health and Environmental Assessment. EPA/600/Z-92/001. Available at http://www.epa.gov/NCEA/raf/pdfs/exposure.pdf.

U.S. EPA. (1992b) Dermal exposure assessment: principles and applications. Washington, DC: Office of Health and Environmental Assessments. EPA/600/8-9/011F. Available online at http://www.epa.gov/ncea/pdfs/efh/references/DEREXP.PDF.

U.S. EPA. (1994a) Estimating exposures to dioxin-like compounds. Draft Report. Office of Research and Development, Washington, DC. EPA/600/6-88/005Cb.

U.S. EPA. (1994b) Methods for derivation of inhalation reference concentrations and applications of inhalation dosimetry Washington, DC. EPA/600/8-90/066F.

U.S.EPA (1996a) Soil screening guidance. Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/F-95/041. Available online at http://www.epa.gov/superfund/health/conmedia/soil/index.htm

U.S.EPA. (1996b) Series 875 Occupational and Residential Exposure Test Guidelines - Final Guidelines - Group A - Application Exposure Monitoring Test Guidelines. EPA712-C96-261. Available online at http://www.epa.gov/opptsfrs/publications/OPPTS_Harmonized/875_Occupational_and_Residential_Exposure_Test_Guidelines/Series/875_000.pdf

U.S. EPA. (1996c) Series 875 Occupational and Residential Exposure Test Guidelines - Group B - Post Application Exposure Monitoring Test Guidelines. EPA712-C96-266. Available online at http://www.epa.gov/opptsfrs/publications/OPPTS_Harmonized/875_Occupational_and_Residential_Exposure_Test_Guidelines/Series/875-2000.pdf

U.S. EPA. (1997a) Exposure factors handbook. National Center for Environmental Assessment, Office of Research and Development, Washington, DC. EPA/600/P-95/002Fa,b,c. Available online at http://www.epa.gov/ncea/efh/.

U.S. EPA. (1997b) Policy for use of probabilistic analysis in risk assessment at the U.S. Environmental Protection Agency. Science Policy Council. Available online at http://www.epa.gov/OSA/spc/pdfs/probpol.pdf

U.S. EPA. (1997c) Guiding principles for Monte Carlo analysis. Office of Research and Development, Risk Assessment Forum, Washington, DC. EPA/600/R-97/001. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29596.

U.S. EPA. (1999) Sociodemographic data used for identifying potentially highly exposed populations. U.S. Environmental Protection Agency, Washington, DC. EPA/600/R-99/060. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=22562.

U.S. EPA. (2000a) Strategy for research on risks to children. Office of Research and Development, Washington, DC. EPA/600/R-00/068.

U.S. EPA. (2000b) Options for developing parametric probability distributions for exposure factors. National Center for Environmental Assessment, Office of Research and Development, Washington, DC. EPA/600/R-00/058. Available on line at http://www.epa.gov/ncea/paramprob4ef.htm.

U.S. EPA. (2000c) Supplementary guidance for conducting health risk assessment of chemical mixutres. Risk Assessment Forum, Washington, DC. EPA/630/00/002F. Available on line at http://www.epa.gov/NCEA/raf/pdfs/chem_mix/chem_mix_08_2001.pdf

U.S. EPA. (2001a) Risk assessment guidance for Superfund. Volume I Human health evaluation manual: Part D, Standardized planning, reporting and review of Superfund risk assessments. Office of Solid Waste and

Emergency Response, Washington, DC. Publication 9285.7-47. Available online at http://www.epa.gov/oswer/riskassessment/ragsd/tara.htm.

U.S. EPA. (2001b) Risk assessment guidance for Superfund. Volume III, Part A, Process for conducting probabilistic risk assessment. Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/R-02/002. Available online at http://www.epa.gov/oswer/riskassessment/rags3adt/

U.S. EPA (2001c) Summary report of the technical workshop on issues associated with considering developmental changes in behavior and anatomy when assessing exposure to children. Office of Research and Development, Risk Assessment Forum, Washington, DC. EPA/630/R-00/005. Available online at http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=20680

U.S. EPA. (2002a) Child-Specific exposure factors handbook. Interim Final. National Center for Environmental Assessment, Office of Research and Development, Washington, DC. EPA/600/P-00/002B.

U.S. EPA (2002b). Overview of the EPA quality system for environmental data and technology. Office of Environmental Information, Washington DC. EPA/240-R/02/003. Accessed online at http://www.epa.gov/quality/qs-docs/overview-final.pdf

U.S. EPA (2003a). A summary of general assessment factors for evaluating the quality of scientific and technical information. Science Policy Council, Washington DC. EPA/100/B-03/001. Accessed online at http://www.epa.gov/osa/spc/pdfs/assess2.pdf

U. S. EPA. (2003b) Framework for cumulative risk assessment. Risk Assessment Forum, Washington, DC. EPA/630/P-02/001F. Available online at http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=54944.

U.S. EPA. (2003c) Example exposure scenarios. Office of Research and Development, Washington, DC; EPA/600/R03/036. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=85843.

U.S. EPA. (2003d) Human health research strategy. Office of Research and Development, Washington DC 20460. EPA/600/R-02/050. Available online at http://www.epa.gov/ORD/htm/researchstrategies.htm#rs01

U.S. EPA. (2004) Risk assessment guidance for Superfund. Volume I Human health evaluation manual: Part E, Supplemental guidance for dermal risk assessment. Interim. Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/R/99/005. Available online at http://www.epa.gov/oswer/riskassessment/ragse/index.htm.

U.S. EPA. (2005a) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants. Office of Research and Development, Washington, DC. EPA/630/P-03/003F. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=146583

U.S. EPA. (2005b) Guidelines for carcinogen risk assessment. EPA/630/P-03/001F. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=116283.

U.S. EPA. (2005c) Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. Risk Assessment Forum, Washington, DC. EPA/630/R-03/003F. Available online at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=116283.

U.S. EPA. (2005d) Protocol for human health risk assessment protocol for hazardous waste combustion facilities. EPA530-R-05-006. Available online at http://www.epa.gov/combustion/risk.htm

U.S. EPA. (2006a) Approaches for the application of physiologically based pharmacokinetic

(PBPK) models and supporting data in risk assessment. Office of Research and Development, Washington DC. EPA/600/R-05/043F. Available online at http://cfpub.epa.gov/ncea/CFM/recordisplay.cfm?deid=157668

U.S. EPA. (2006b) Use of physiologically based pharmacokinetic (PBPK) models to quantify the impact of human age and interindividual differences in physiology and biochemistry pertinent to risk (Final Report). Office of Research and Development, Washington, DC. EPA/600/R-06/014A. Available online at http://cfpub.epa.gov/ncea/CFM/recordisplay.cfm?deid=151384

U.S. EPA (2006c) Guidance on systematic planning using the data quality objectives process. Office of Environmental Information, Washington DC. EPA/240B/06/001. Availabel online at

http://www.epa.gov/QUALITY/qs-docs/g4-final.pdf

U.S. EPA. (2006d) A framework for assessing health risk of environmental exposures to children (Final). Office of Research and Development, Washington, DC. EPA/600/R-05/093F. Available online at

http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=158363

U.S. EPA (2006e) Harmonization in interspecies extrapolation: use of $BW^{3/4}$ as default method in derivation of the oral RfD (External Review Draft). Risk Assessment Forum, Washington, DC. EPA/630/R-06/001. Available online at http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=148525

U.S. EPA (2008) Concepts, methods, and data sources for cumulative health risk assessment of multiple chemicals, exposures and effects: a resource document (final). Office of Research and Development, Washington, DC. EPA/600/R-06/013F. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190187

Table 1-1. Characterization of Variability in Exposure Factors				
Exposure Factors	Average	Median	Upper percentile	Multiple Percentiles
Ingestion of water and other select liquids	✓	✓	✓	✓
Non-dietary ingestion	✓	✓	✓	
Soil and dust ingestion	✓	✓	✓[a]	
Inhalation rate	✓	✓	✓	✓
Surface area	✓		✓	✓
Soil adherence	✓			
Body weight	✓	✓	✓	✓
Intake of fruits and vegetables	✓	✓	✓	✓
Intake of fish and shellfish	✓	✓	✓	✓
Intake of meats, dairy products, and fats	✓	✓	✓	✓
Intake of grain products	✓	✓	✓	✓
Intake of home produced foods	✓	✓	✓	✓
Total food intake	✓	✓	✓	✓
Human milk intake	✓		✓	
Time indoors	✓			
Time outdoors	✓			
Time showering	✓	✓	✓	✓
Time bathing	✓	✓	✓	✓
Time swimming	✓	✓	✓	✓
Time playing on sand/gravel	✓	✓	✓	✓
Time playing on grass	✓	✓	✓	✓
Time playing on dirt	✓	✓	✓	✓

[a] Soil pica and geophagy.

✓ = Data available

Table 1-2. Considerations Used to Rate Confidence in Recommended Values

General Assessment Factors	Increasing Confidence	Decreasing Confidence
Soundness		
Adequacy of Approach	The studies used the best available methodology and capture the measurement of interest.	There are serious limitations with the approach used; study design does not accurately capture the measurement of interest.
	As the sample size relative to that of the target population increases, there is greater assurance that the results are reflective of the target population.	Sample size too small to represent the population of interest.
	The response rate is greater than 80 percent for in-person interviews and telephone surveys, or greater than 70 percent for mail surveys.	The response rate is less than 40 percent.
	The studies analyzed primary data.	The studies are based on secondary sources.
Minimal (or defined) Bias	The study design minimizes measurement errors.	Uncertainties with the data exist due to measurement error.
Applicability and Utility		
Exposure Factor of Interest	The studies focused on the exposure factor of interest.	The purpose of the studies was to characterize a related factor.
Representativeness	The studies focused on the U.S. population.	Studies are not representative of the U.S. population.
Currency	The studies represent current exposure conditions.	Studies may not be representative of current exposure conditions.
Data Collection Period	The data collection period is sufficient to estimate long-term behaviors.	Shorter data collection periods may not represent long-term exposures.
Clarity and Completeness		
Accessibility	The study data could be accessed.	Access to the primary data set was limited.
Reproducibility	The results can be reproduced or methodology can be followed and evaluated.	The results cannot be reproduced, the methodology is hard to follow, and the author(s) cannot be located.
Quality Assurance	The studies applied and documented quality assurance/quality control measures	Information on quality assurance/control was limited or absent.

Table 1-2. Considerations Used to Rate Confidence in Recommended Values (continued)

General Assessment Factors	Increasing Confidence	Decreasing Confidence
Variability and Uncertainty		
Variability in Population	The studies characterize variability in the population studied.	The characterization of variability is limited.
Uncertainty	The uncertainties are minimal and can be identified. Potential bias in the studies are stated or can be determined from the study design.	Estimates are highly uncertain and cannot be characterized. The study design introduces biases in the results.
Evaluation and Review		
Peer Review	The studies received high level of peer review (e.g., they are published in peer review journals).	The studies received limited peer review.
Number and Agreement of Studies	The number of studies is greater than 3. The results of studies from different researchers are in agreement.	The number of studies is 1. The results of studies from different researchers are in disagreement.

Table 1-3. Integrating U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005a) with U.S. EPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (U.S. EPA, 2005c) For Those Contaminants Which Act Via a Mutagenic Mode of Action

Exposure Age Group[a]	Exposure Duration (yr)	ADAF (Age-Dependent Potency Adjustment Factor)
Birth to < 1 month	0.083	10x
1 < 3 months	0.167	10x
3 < 6 months	0.25	10x
6 < 12 months	0.5	10x
1 to < 2 years	1	10x
2 to < 3 years	1	3x
3 to < 6 years	3	3x
6 to < 11 years	5	3x
11 to < 16 years	5	3x
16 to < 21 years	5	1x
> 21 years (21 to < 70 yr)	49	1x

[a] EPA's recommended childhood age groups (excluding ages >21 years).

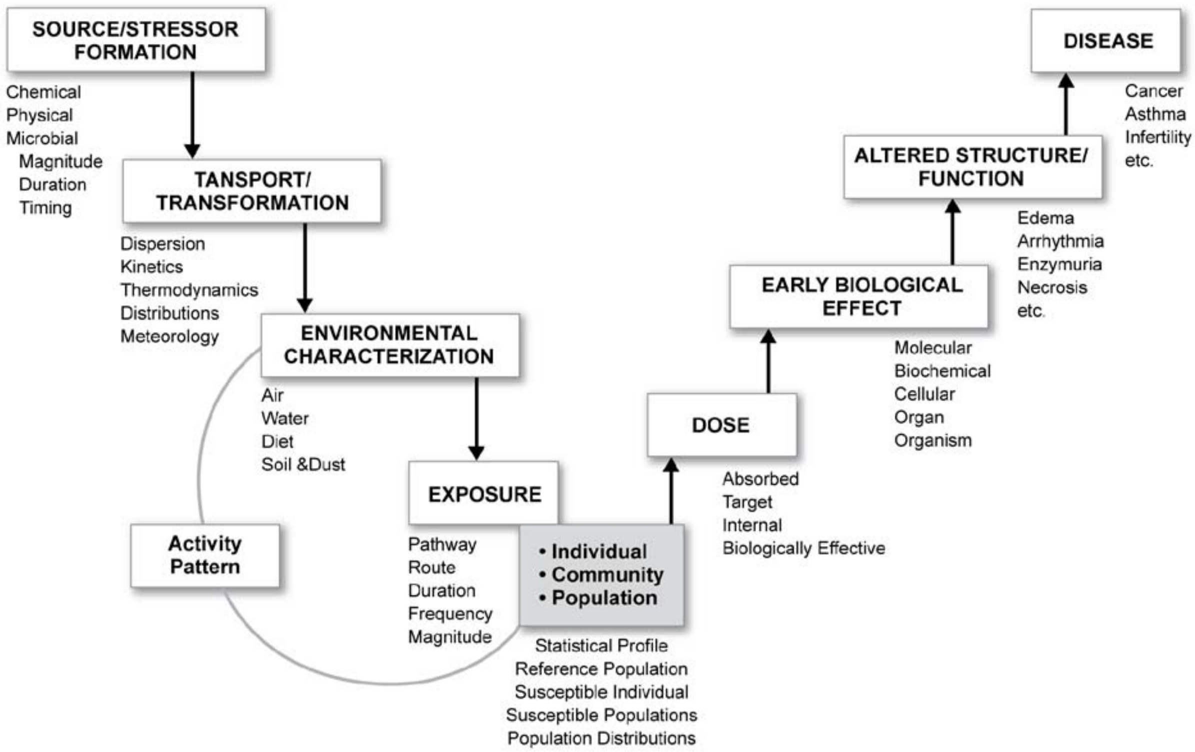


Figure 1-1 The Exposure-Dose-Effect Continuum

Source: U.S. EPA, 2003d; IPCS, 2006.

2 VARIABILITY AND UNCERTAINTY

Variability and uncertainty are inherent in the exposure assessment process. Addressing variability and uncertainty will increase the likelihood that results of an assessment or analysis will be used in an appropriate manner. Thus, careful consideration of the variabilities and uncertainties associated with the exposure factors information used in an exposure assessment is of utmost importance. The characterization of variability and uncertainty will also assist in communicating risks to the risk manager and the public.

Exposure assessment can involve a broad array of information sources and analysis techniques (U.S. EPA, 1992). Even in situations where actual exposure-related measurements exist, assumptions or inferences will still be required because data are not likely to be available for all aspects of the exposure assessment. Moreover, the data that are available may be of questionable or unknown quality. Thus, exposure assessors have a responsibility to present not just numbers, but also a clear and explicit explanation of the implications and limitations of their analyses.

Morgan and Henrion (1990) provide an argument for the need for variability and uncertainty analysis in exposure assessment. They state that when scientists report quantities that they have measured, they are expected to routinely report an estimate of the probable error associated with such measurements. They conclude that because variabilities and uncertainties inherent in policy analysis (of which exposure assessment is a part) tend to be even greater than those in the natural sciences, exposure assessors also should be expected to report or comment on the variabilities and uncertainties associated with their estimates.

Some additional reasons for addressing variability and uncertainty in exposure or risk assessments (U.S. EPA, 1992, Morgan and Henrion, 1990) include the following:

- Decisions may need to be made about whether or how to expend resources to acquire additional information;
- Biases may occur in providing a so-called "best estimate" that in actuality is not very accurate; and
- Important factors and potential sources of disagreement in a problem may be able to be identified.

This chapter is intended to acquaint the exposure assessor with some of the fundamental concepts and precepts of variability and uncertainty as they relate to exposure assessment and the exposure factors presented in this handbook. It also provides methods and considerations for evaluating and presenting the uncertainty associated with exposure estimates. Subsequent sections in this chapter are devoted to the following topics:

- Variability versus uncertainty;
- Types of variability;
- Addressing variability;
- Types of uncertainty;
- Reducing uncertainty;
- Analysis of variability and uncertainty; and
- Presenting results of variability/uncertainty analysis.

Fairly extensive treatises on the topic of uncertainty have been provided, for example, by Morgan and Henrion (1990), the National Research Council (NRC, 1994) and, to a lesser extent, the U.S. EPA (1992; 1995). The topic commonly has been treated as it relates to the overall process of conducting risk assessments; because exposure assessment is a component of risk-assessment process, the general concepts apply equally to the exposure-assessment component. Since the publication of the National Research Council's report entitled *Science and Judgement in Risk Assessment* (NRC, 1994), the field of variability and uncertainty analysis has continued to evolve. The use of probabilistic techniques to address variability and uncertainty have continued to increase. There are numerous on going efforts in the Agency and elsewhere to further improve the characterization of variability and uncertainty. For example, an Agency task force is developing white papers on the use of expert elicitation for characterizing uncertainty in risk assessments. The U.S. EPA's Risk Assessment Forum has established a workgroup to promote the use of probabilistic techniques to better assess and communicate risk. The International Programme on Chemical Safety (IPCS) is developing guidance on characterizing and communicating uncertainty in exposure assessment (WHO, 2006).

2.1 VARIABILITY VERSUS UNCERTAINTY

While some authors have treated variability as a specific type or component of uncertainty, the U.S. EPA (1995) has advised the risk assessor (and, by analogy, the exposure assessor) to distinguish between variability and uncertainty. Uncertainty represents a lack of knowledge about factors affecting exposure or risk, whereas variability arises from true heterogeneity across people, places or time. In other words, uncertainty can lead to inaccurate or biased estimates, whereas variability can affect the precision of the estimates and the degree to which they can be generalized. Most of the data presented in this handbook concerns variability.

Variability and uncertainty can complement or confound one another, and it may not always be appropriate to give special significance to distinguishing between the two in every case. Consider a situation that relates to exposure, such as estimating the average daily dose by one exposure route -- ingestion of contaminated drinking water. Suppose that it is possible to measure an individual's daily water consumption (and concentration of the contaminant) exactly, thereby eliminating uncertainty in the measured daily dose. The daily dose still has an inherent day-to-day variability, however, due to changes in the individual's daily water intake or the contaminant concentration in water.

> Uncertainty - a lack of knowledge about factors affecting exposure or risk.
> Variability - arises from true heterogeneity across people, places or time.

It is impractical to measure the individual's dose every day. For this reason, the exposure assessor may estimate the average daily dose (ADD) based on a finite number of measurements, in an attempt to "average out" the day-to-day variability. The individual has a true (but unknown) ADD, which has now been estimated based on a sample of measurements. Because the individual's true average is unknown, it is uncertain how close the estimate is to the true value. Thus, the variability across daily doses has been translated into uncertainty in the ADD. Although the individual's true ADD has no variability, the estimate of the ADD has some uncertainty. It should be noted, however, that a rigid delineation of variability and uncertainty may not be as useful as assessing the available information and attendant variation and properly accounting for it (e.g., sensitivity analysis).

The above discussion pertains to the ADD for one person. Now consider a distribution of ADDs across individuals in a defined population (e.g., the general U.S. population). In this case, variability refers to the range and distribution of ADDs across individuals in the population. By comparison, uncertainty refers to the exposure assessor's state of knowledge about that distribution, or about parameters describing the distribution (e.g., mean, standard deviation, general shape, various percentiles).

As noted by the National Research Council (NRC, 1994), the realms of variability and uncertainty have fundamentally different ramifications for science and judgment. For example, uncertainty may force decision-makers to judge how probable it is that exposures have been overestimated or underestimated for every member of the exposed population, whereas variability forces them to cope with the certainty that different individuals are subject to exposures both above and below any of the exposure levels chosen as a reference point.

2.2 TYPES OF VARIABILITY

Variability in exposure is a function of the variability in human exposure factors (i.e., those related to an individual's location, activity, behavior or preferences at a particular point in time, or physiological characteristics such as body weight), as well as variations in contaminants concentrations (i.e., those related to pollutant emission rates and physical/chemical processes that affect concentrations in various media; e.g., air, soil, food and water). The variations in human exposure factors and chemical concentrations are not necessarily independent of one another. For example, both personal activities and pollutant concentrations at a specific location might vary in response to weather conditions, or between weekdays and weekends.

At a more fundamental level, four types of variability can be distinguished:

- Variability across locations (Spatial Variability);
- Variability over time (Temporal Variability);
- Variability within an individual (Intra-individual Variability; and
- Variability among individuals (Inter-individual Variability).

Spatial variability can occur both at regional (macroscale) and local (microscale) levels. For example, fish intake rates can vary depending on the region of the country. Higher consumption may occur among populations located near large bodies of water such as the Great Lakes or coastal areas. As another example, outdoor pollutant levels can be affected at the regional level by industrial activities and at the local level by activities of individuals. In general, higher exposures tend to be associated with closer proximity to the pollutant source, whether it be an industrial plant or related to a personal activity such as showering or gardening. In the context of exposure to airborne pollutants, the concept of a "microenvironment" has been introduced (Duan, 1982) to denote a specific locality (e.g., a residential lot or a room in a specific building) where the airborne concentration can be treated as homogeneous (i.e., invariant) at a particular point in time.

Temporal variability refers to variations over time, whether long- or short-term. Seasonal fluctuations in weather, pesticide applications, use of woodburning appliances and fraction of time spent outdoors are examples of longer-term variability. Examples of shorter-term variability are differences in industrial or personal activities on weekdays versus weekends or at different times of the day.

Intra-individual variability is a function of fluctuations in an individual's physiologic (e.g., body weight), or behavioral characteristics (e.g., ingestion rates or activity patterns). For example, patterns of food intake change from day to day, and may change significantly over a lifetime. Intra-individual variability may be associated with spatial or temporal variability. For example, because an individual's dietary intake may reflect local food sources, intake patterns may change if place of residence changes. Also, physical activity may vary depending upon the season, lifestage, or other factors associated with temporal variability.

Inter-individual variability can be either of two types: (1) human characteristics such as age or body weight, and (2) human behaviors such as location, activity patterns, and ingestion rates. Each of these variabilities, in turn, may be related to several underlying phenomena that vary. For example, the natural variability in human weight is due to a combination of genetic, nutritional, and other lifestyle or environmental factors. Variability arising from independent factors that combine multiplicatively generally will lead to an approximately lognormal distribution across the population, or across spatial/temporal dimensions. Inter-individual variability may also be related to spatial and temporal factors.

2.3 ADDRESSING VARIABILITY

As noted in Section 1.6 of this handbook, this document attempts to characterize variability of each of the exposure factors presented. Variability is addressed by presenting data on the exposure factors in one of the following three ways: (1) as tables with percentiles or ranges of values, (2) as analytical distributions with specified parameters, or (3) as a qualitative discussion.

According to the National Research Council (NRC 1994), variability in exposure estimates can be addressed, especially with regard to point estimates such as central tendency (CT) or high end exposures (e.g., reasonable maximum exposure (RME) used in the Superfund program) in four basic ways (Table 2-1) when dealing with science-policy questions surrounding issues such as exposure or risk assessment. The first is to **ignore the variability**. This strategy is likely to be used in combination with one of the other strategies described below (e.g., use the average value), and tends to work best when the variability is relatively small, as in the case with adult body weights. For example, the U.S.EPA practice of assuming that all adults weigh 70 kg is likely to be correct within ±25% for most adults and within a factor of 3 for virtually all adults (NRC,1994). However, it is cautioned that this approach may not be appropriate for children, where variability may be large.

The second strategy involves **disaggregating the variability** in some explicit way, in order to better understand it or reduce it. Mathematical models are appropriate in some cases, as in fitting a sine wave to the annual outdoor concentration cycle for a particular pollutant and location. In other cases, particularly those involving human characteristics or behaviors, it is easier to disaggregate the data by considering all the relevant subgroups or subpopulations. For example, distributions of body weight could be developed separately for adults, adolescents and children, and even for males and females within each of these subgroups. Temporal and spatial analogies for this concept involve measurements on appropriate time scales and choosing appropriate subregions or microenvironments.

The third strategy is to **use the average value** of a quantity that varies. Although this strategy might appear as tantamount to ignoring variability, it needs to be based on a decision that the average value can be estimated reliably in light of the variability (e.g., when the variability is known to be relatively small, as in the case of adult body weight).

The fourth strategy involves **using the maximum or minimum value** for an exposure factor. In this case, the variability is characterized by the range between the extreme values and a measure of central tendency. This is perhaps the most common method of dealing with variability in exposure or risk assessment -- to focus on one time period (e.g., the period of peak exposure), one spatial region (e.g., in close proximity to the pollutant source of concern), or one subpopulation (e.g., exercising asthmatics). As noted by the U.S. EPA (1992), when an exposure assessor develops estimates of high-end individual exposure and dose, care must be taken not to set all factors to values that maximize exposure or dose -- such an approach will almost always lead to an overestimate.

Probabilistic techniques (e.g., Monte Carlo or Latin Hypercube Simulation) are frequently used for characterizing the variability in risk estimates by repeatedly sampling the probability distributions of the risk equation inputs and using these inputs to calculate a distribution of risk. This approach is used less frequently in uncertainty analysis. Techniques for characterizing both uncertainty and variability are available, and generally require two-dimensional Monte Carlo analysis (U.S. EPA, 2001). In situations in which an analyst wishes to apply probabilistic techniques, and data lend themselves to such analysis, more robust techniques to describe data goodness-of-fit, identification and deposition of data outliers, and sensitivity analysis of the respective model should be used to address parameter variability. These techniques are described in Section 1.9.2 of this document.

2.4 TYPES OF UNCERTAINTY

Uncertainty in exposure analysis is related to the lack of knowledge concerning one or more components of the assessment process.

The U.S. EPA (1992) has classified uncertainty in exposure assessment into three broad categories:

1. Uncertainty regarding missing or incomplete information needed to fully define exposure and dose (Scenario Uncertainty).
2. Uncertainty regarding some parameter (Parameter Uncertainty).
3. Uncertainty regarding gaps in scientific theory required to make predictions on the basis of causal inferences (Model Uncertainty).

Sources and examples for each type of uncertainty are summarized in Table 2-2. As described in Section 1.6 of this handbook, U.S. EPA has attempted to address the uncertainty associated with the various exposure factors presented in the handbook by applying confidence ratings to the recommended data. In general, these confidence rating are based on detailed discussions of any limitations of the data presented. This information may be useful in analyzing the uncertainty associated with an overall exposure/risk assessment.

2.5 REDUCING UNCERTAINTY

Identification of the sources of uncertainty in an exposure assessment is the first step in determining how to reduce that uncertainty. The types of uncertainty listed in Table 2-2 can be further defined by examining their principal causes.

Because uncertainty in exposure assessments is fundamentally tied to a lack of knowledge concerning important exposure factors, strategies for reducing uncertainty necessarily involve reduction or elimination of knowledge gaps. Example strategies to reduce uncertainty include (1) collection of new data using a larger sample size, an unbiased sample design, a more direct measurement method or a more appropriate target population, and (2) use of more sophisticated modeling and analysis tools if data quality allows.

2.6 ANALYZING VARIABILITY AND UNCERTAINTY

Exposure assessments often are developed in a tiered approach. The initial tier usually screens out the exposure scenarios or pathways that are not expected to pose much risk, to eliminate them from more detailed, resource-intensive review. Screening-level assessments typically examine exposures that would fall on or beyond the high end of the expected exposure distribution. Because screening-level analyses usually are included in the final exposure assessment, the final document may contain scenarios that differ quite markedly in sophistication, data quality, and amenability to quantitative expressions of variability or uncertainty.

According to the U.S. EPA (1992), uncertainty characterization and uncertainty assessment are two ways of describing uncertainty at different degrees of sophistication. Uncertainty characterization usually involves a qualitative discussion of the thought processes used to select or reject specific data, estimates, scenarios, etc. Uncertainty assessment is a more quantitative process that may range from simpler measures (e.g., ranges) and simpler analytical techniques (e.g., sensitivity analysis) to more complex measures and techniques. Its goal is to provide decision makers with information concerning the quality of an assessment, including the potential variability in the estimated exposures, major data gaps, and the effect that these data gaps have on the exposure estimates developed.

A distinction between variability and uncertainty was made in Section 2.1. Although the quantitative process mentioned above applies more directly to variability and the qualitative approach more so to uncertainty, there is some degree of overlap. In general, either method provides the assessor or decision-maker with insights to better evaluate the assessment in the context of available data and assumptions. The following paragraphs describe some of the more common procedures for analyzing variability and uncertainty in exposure assessments. Principles that pertain to presenting the results of variability/uncertainty analysis are discussed in the next section.

Several approaches can be used to characterize uncertainty in parameter values. When uncertainty is high, the assessor may use order-of-magnitude bounding estimates of parameter ranges (e.g., from 0.1 to 10 liters for daily water intake). Another method describes the range for each parameter including the lower and upper bounds as well as a "best estimate" (e.g., 1.4 liters per day) determined by available data or professional judgement.

When sensitivity analysis indicates that a parameter profoundly influences exposure estimates, the assessor should develop a probabilistic description of its range. If there are enough data to support their use, standard statistical methods are preferred. If the data are inadequate, expert judgment can be used to generate a subjective probabilistic representation. Such judgments should be developed in a consistent, well-documented manner. Morgan and Henrion (1990) and Rish (1988) describe techniques to solicit expert judgment.

Most approaches to quantitative analysis examine how variability and uncertainty in values of specific parameters translate into the overall uncertainty of the assessment. Details may be found in various papers and reviews such as Bogen and Spear (1987), Cox and Baybutt (1981), Whitmore (1985), Inman and Helton (1988), Seller (1987), and Rish and Marnicio (1988). These approaches can generally be described (in order of increasing complexity and data needs) as: (1) sensitivity analysis; (2) analytical uncertainty propagation; (3) probabilistic uncertainty analysis; or (4) classical statistical methods (U.S. EPA 1992). The four approaches are summarized in Table 2-3.

Additional discussions describing approaches to address variability and uncertainty in human exposure assessments can be found in the following references: Burin and Saunders (1999), Burmaster (1998a, b, and c), Burmaster and Crouch (1997), Calaberse and Baldwin (1998), Cox (1999), Cullen and Frey (1999), Fayerweather et al. (1999), Finkel (1997), Frey (2002), Frey and Patil (2002), Greenland, (2001), Hattis (1997), Hattis and Anderson (1999), Hattis and Silver (1994), Illing (1999), Jayjock (1997), Kalberlah et al. (2003), Kelley and Campbell (2000), Meek (2001), Nayak and Kundu (2001), Nicas and Jayjock (2002), Peretz et al. (1997), Price et al. (1997, 1999), Rai and Krewski (1998), Renwick (1999), Renwick et al. (2001), Robinson and Hurst (1997), Saltelli (2002), Semple et al. (2003), Simon (1997), Shlyakhter (1994), Slob and Pieters (1998), Wallace et al. (1994), Wallace and Williams (2005), Weiss (2001), and Zheng and Frey (2005).

2.7 PRESENTING RESULTS OF VARIABILITY AND UNCERTAINTY ANALYSIS

Comprehensive qualitative analysis and rigorous quantitative analysis are of little value for use in the decision-making process, if their results are not clearly presented. In this chapter, variability (the receipt of different levels of exposure by different individuals) has been distinguished from uncertainty (the lack of knowledge about the correct value for a specific exposure measure or estimate). Most of the data that are presented in this handbook deal with variability directly, through inclusion of statistics that pertain to the distributions for various exposure factors.

Not all approaches historically used to construct measures or estimates of exposure have attempted to distinguish between variability and uncertainty. The assessor is advised to use a variety of exposure descriptors, and where possible, the full population distribution, when presenting the results. This information will provide risk managers with a better understanding of how exposures are distributed over the population and how variability in population activities influences this distribution.

Although incomplete analysis is essentially unquantifiable as a source of uncertainty, it should not be ignored. At a minimum, the assessor should describe the rationale for excluding particular exposure scenarios; characterize the uncertainty in these decisions as high, medium, or low; and state whether they were based on data, analogy, or professional judgment. Where uncertainty is high, a sensitivity analysis can be used to estimate upper limits on exposure by way of a series of "what if" questions.

Although assessors have always used descriptors to communicate the kind of scenario being addressed, the 1992 Exposure Guidelines establish clear quantitative definitions for these risk descriptors. These definitions were established to ensure that consistent terminology is used throughout the Agency. The risk descriptors defined in the Guidelines include descriptors of individual risk and population risk. Individual risk descriptors are intended to address questions dealing with risks borne by individuals within a population, including not only measures of central tendency (e.g., average or median), but also those risks at the high end of the distribution. Population risk descriptors refer to an assessment of the extent of harm to the population being addressed. It can be either an estimate of the number of cases of a particular effect that might occur in a population (or population segment), or a description of what fraction of the population receives exposures, doses, or risks greater than a specified value. The data presented in this handbook is one of the tools available to exposure assessors to construct the various risk descriptors.

However, it is not sufficient to merely present the results using different exposure descriptors. Risk managers should also be presented with an analysis of the uncertainties surrounding these descriptors. Uncertainty may be presented using simple or very sophisticated techniques, depending on the requirements of the assessment and the amount of data available. It is beyond the scope of this handbook to discuss the mechanics of uncertainty analysis in detail. The assessor can address uncertainty qualitatively by answering questions such as:

- What is the basis or rationale for selecting these assumptions/parameters, such as data, modeling, scientific judgment, Agency policy, "what if" considerations, etc.?

- What is the range or variability of the key parameters? How were the parameter values selected for use in the assessment? Were average, median, or upper-percentile values chosen? If other choices had been made, how would the results have differed?

- What is the assessor's confidence (including qualitative confidence aspects) in the key parameters and the overall assessment? What are the quality and the extent of the data base(s) supporting the selection of the chosen values?

Any exposure estimate developed by an assessor will have associated assumptions about the setting, chemical, population characteristics, and how contact with the chemical occurs through various exposure routes and pathways. The exposure assessor will need to examine many sources of information that bear either directly or indirectly on these components of the exposure assessment. In addition, the assessor may need to make many decisions regarding the use of existing information in constructing scenarios and setting up the exposure equations. In presenting the scenario results, the assessor should strive for a balanced and impartial treatment of the evidence bearing on the conclusions with the key assumptions highlighted. For these key assumptions, one should cite data sources and explain any adjustments of the data.

The exposure assessor also should qualitatively describe the rationale for selection of any conceptual or mathematical models that may have been used. This discussion should address their verification and validation status, how well they represent the situation being assessed (e.g., average versus high-end estimates), and any plausible alternatives in terms of their acceptance by the scientific community.

Table 2-2 summarizes the three types of uncertainty, associated sources, and examples. Table 2-3 summarizes four approaches to analyze uncertainty quantitatively. These are described further in the 1992 Exposure Guidelines (U.S. EPA, 1992).

To the extent possible, this handbook provides information that can be used to characterize the variability and uncertainty of data for the various exposure factors. In general, variability is addressed by providing distribution of data, where available, or qualitative discussions of the data sets used. Uncertainty is addressed by applying confidence rating to the recommendations provided for the various factors, along with detailed discussions of any limitations of the data presented.

2.8 REFERENCES FOR CHAPTER 2

Bogen, K.T. (1990) Uncertainty in environmental health risk assessment. Garland Publishing, New York, NY.

Bogen, K.T.; Spear, R.C. (1987). Integrating uncertainty and interindividual variability in environmental risk assessment. Risk Analysis. 7(4):427-436.

Burin, G.J.; Saunders, D.R. (1999). Addressing human variability in risk assessment–the robustness of the intraspecies uncertainty factor. Reg. Tox. Pharm. 30: 209-216.

Burmaster, D.E.; Crouch, E.A.C. (1997). Lognormal distributions for body weight as a function of age for males and females in the United States, 1976-1980. Risk Analysis. 17: 499-505.

Burmaster, D.E. (1998a). A lognormal distribution for time spent showering. Risk Analysis. 18: 33-35.

Burmaster, D.E. (1998b). Lognormal distributions for total water intake and tap water intake by pregnant and lactating women in the United States. Risk Analysis 18: 215-219.

Burmaster, D.E. (1998c). Lognormal distributions for skin area as a function of body weight. Risk Analysis 18: 27-32.

Calabrese, E.J.; Baldwin, L.A. (1998). Hormesis as a biological hypothesis. Environ. Health Persp. 106(Supp. 1): 357-362.

Cox, D.C.; Baybutt, P.C. (1981) Methods for uncertainty analysis. A comparative survey. Risk Analysis 1(4):251-258.

Cox Jr., L.A. (1999). Internal dose, uncertainty analysis, and complexity of risk models. Environ. Inter. 25: 841-852.

Cullen, A.C.; Frey, H.C. (1999). Probabilistic Techniques in Exposure Assessment. New York: Plenum Press.

Duan, N. (1982) Microenvironment types: A model for human exposure to air pollution. Environ. Intl. 8:305-309.

Fayerweather, W.E.; Collins, J.J.; Schnatter, A.R.; Hearne, F.T.; Menning, R.A.; Reyner, D.P. (1999). Quantifying uncertainty in a risk assessment using human data. Risk Analysis 19: 1077-1090.

Finkel, A.M. (1997). Not to decide is to decide: ignoring susceptibility in not 'good science'. Environ. Tox. Pharm. 4: 219-228.

Frey, H.C. (2002). Guest Editorial: Introduction to special section on sensitivity analysis and summary of NCSU/USDA workshop on sensitivity analysis. Risk Analysis 22: 539-545.

Frey, H.C.; Patil, S.R. (2002). Identification and review of sensitivity analysis methods. Risk Analysis 22: 553-578.

Greenland, S. (2001). Sensitivity analysis, Monte Carlo risk analysis, and Bayesian uncertainty assessment. Risk Analysis 21: 579-583.

Hattis, D. (1997). Human variability in susceptibility: how big, how often, for what responses to what agents? Environ. Tox. Pharm. 4: 195-208.

Hattis, D. and Anderson, E.L. (1999). What should be the implications of uncertainty, variability, and inherent 'biases'/'conservatism' for risk management decision-making. Risk Analysis 19: 95-107.

Hattis, D. and Silver, K. (1994). Human interindividual variability - A major source of uncertainty in assessing risks for noncancer health effects. Risk Analysis. 14(4):421-431.

Illing, H.P.A. (1999). Are societal judgements being incorporated into the uncertainty factor used in toxicological risk assessment? Reg. Toxicol. Pharm. 29: 300-308.

Inman, R.L.; Helton, J.C. (1988) An investigation of uncertainty and sensitivity analysis techniques for computer models. Risk Analysis. 8(1):71-91.

Jayjock, M.A. (1997). Uncertainty analysis in the estimation of exposure. Amer. Ind. Hyg. Assoc. J. 58: 380-382.

Kalberlah, F.; Schneider, K.; et al. (2003). Uncertainty in toxicological risk assessment for non-carcinogenic health effects. Reg. Tox. Pharm. 37: 92-104.

Kelly, E.J.; Campbell, K. (2000). Separating variability and uncertainty in environmental risk assessment–making choices. Human Ecol. Risk Assess. 6: 1-13.

Meek, M.E. (2001) Categorical default uncertainty factors–interspecies variation and adequacy of database. Human Ecol. Risk Assess. 7: 157-163.

Morgan, M.G.; Henrion, M. (1990) Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis. Cambridge University Press, New York, NY.

National Research Council (NRC). (1994) Science and Judgment in Risk Assessment. National Academy Press, Washington, DC.

Nayak, T.K.; Kundu, S. (2001). Calculating and describing uncertainty in risk assessment: The Bayesian approach. Human Ecol. Risk Assess. 7: 307-328.

Nicas, M.; Jayjock, M. (2002). Uncertainty in exposure estimates made by modeling versus monitoring. AIHA J. 63: 275-283.

Peretz, C.; Goldberg, P.; Kahan, E.; Grady, S.; Goren, A. (1997). The variability of exposure over time: a prospective longitudinal study. Ann. Occup. Hyg. 41: 485-500.

Price, P.S.; Keenan, R.E.; Schwab, B. (1999). Defining the interindividual (intraspecies) uncertainty factor. Human Ecol. Risk Assess. 5: 1023-1033.

Price, P.S.; Keenan, R.E.; Swartout, J.C., Gillis, C.A., Carlson-Lynch, H., and Dourson, M.L. (1997). An approach for modeling noncancer dose responses with an emphasis on uncertainty. Risk Analysis 17: 427-437.

Rai, S.N.; Krewski, D. (1998). Uncertainty and variability analysis in multiplicative risk models. Risk Analysis. 18: 37-45.

Renwick, A.G. (1999). Subdivision of uncertainty factors to allow for toxicokinetics and toxicodynamics. Human Ecol. Risk Assess. 5: 1035-1050.

Renwick, A.G.; Dorne, J.-L.C.M.; Walton, K. (2001). Pathway-related factors: The potential for human data to improve the scientific basis of risk assessment. Human Ecol. Risk Assess. 7: 165-180.

Rish, W.R. (1988) Approach to uncertainty in risk analysis. Oak Ridge National Laboratory. ORNL/TM-10746.

Rish, W.R.; Marnicio, R.J. (1988) Review of studies related to uncertainty in risk analysis. Oak Ridge National Laboratory. ORNL/TM-10776.

Robinson, R.B.; Hurst, B.T. (1997). Statistical quantification of the sources of variance in uncertainty analyses. Risk Analysis. 17: 447-453.

Saltelli, A. (2002). Sensitivity Analysis for Importance Assessment. Risk Analysis. 22: 579-590.

Seller, F.A. (1987) Error propagation for large errors. Risk Analysis 7(4):509-518.

Semple, S.E.; Proud, L.A.; Cherrie, J.W. (2003). Use of Monte Carlo simulation to investigate uncertainty in exposure modeling. Scand. J. Work Environ. Health. 29: 347-353.

Shlyakhter, A.I. (1994). An improved framework for uncertainty analysis: Accounting for unsupected errors. Risk Analysis. 14(4): 441-447.

Simon, T.W. (1997). Combining physiologically based pharmacokinetic modeling with Monte Carlo simulation to derive an acute inhalation guidance value for trichlorethylene. Reg. Tox. Pharm. 26: 257-270.

Slob, W.; Pieters, M.N. (1998). A probabilistic approach for deriving acceptable human intake limits and human health risks from toxicological studies: General framework. Risk Analysis. 18: 787-798.

U.S. EPA (1992) Guidelines for exposure assessment. Washington, DC: Office of Research and Development, Office of Health and Environmental Assessment. EPA/600/2-92/001.

U.S. EPA (1995) Guidance for risk characterization. Science Policy Council, Washington, DC.

U.S. EPA (2001) Risk Assessment Guidance for Superfund: Volume III - Part A, Process for Conducting Probabilistic Risk Assessment. Washington, DC: Office of Solid Waste and Emergency Response. EPA/540-R-02-002.

Wallace, L.A. et al. (1994). Can long-term exposure distributions be predicted from short-term measurements? Risk Analysis . 14(1):75-85.

Wallace, L;. Williams, R. (2005). Validation of a method for estimating long-term exposures based on short-term measurements. Risk Analysis. 25(3): 687-694.

Weiss, B. (2001). A Web-based survey method for evaluating different components of uncertainty in relative health risk judgments. Neurotoxicology 22: 707-721.

WHO (2006) Draft guidance on characterizing and communicating uncertainty in exposure assessment. Accessed on line at: http://www.who.int/ipcs/methods/harmonization/areas/exposure_assessment/en/index.html

Whitmore, R.W. (1985) Methodology for characterization of uncertainty in exposure assessments. EPA/600/8-86/009.

Zheng, J.; Frey, H.C. (2005). Quantitative analysis of variability and uncertainty with known measurement error: Methodology and case study. Risk Analysis. 25: 663-675.

Table 2-1. Four Strategies for Confronting Variability

Strategy	Example	Comment
Ignore variability	Assume that all adults weigh 70 kg	Works best when variability is small
Disaggregate the variability	Develop distributions of body weight for age/gender groups	Variability will be smaller in each group; it depends on availability of data
Use the average value	Use average body weight for adults	Can the average be estimated reliably given what is known about the variability of a specific population or group with potential exposures?
Use a maximum or minimum value	Use a lower-end value from the weight distribution	Conservative approach -- can lead to unrealistically high exposure estimate if taken for all factors. It may be useful as a screening method for eliminating pathways of exposure that are not significant.

Source: NRC, 1994.

Table 2-2. Three Types of Uncertainty and Associated Sources and Examples

Type of Uncertainty	Sources	Examples
Scenario Uncertainty	Descriptive errors	Incorrect or insufficient information
	Aggregation errors	Spatial or temporal approximations
	Judgment errors	Selection of an incorrect model
	Incomplete analysis	Overlooking an important pathway
Parameter Uncertainty	Measurement errors	Imprecise or biased measurements
	Sampling errors	Small or unrepresentative samples
	Variability	In time, space or activities
	Surrogate data	Structurally-related chemicals
Model Uncertainty	Relationship errors	Incorrect inference on the basis for correlations
	Modeling errors	Excluding relevant variables

Source: U.S. EPA, 1992.

Table 2-3. Approaches to Quantitative Analysis of Uncertainty

Approach	Description	Example
Sensitivity Analysis	Changing one input variable at a time while leaving others constant, to examine effect on output	Fix each input at lower (then upper) bound while holding others at nominal values (e.g., medians)
Analytical Uncertainty Propagation	Examining how uncertainty in individual parameters affects the overall uncertainty of the exposure assessment	Analytically or numerically obtain a partial derivative of the exposure equation with respect to each input parameter
Probabilistic Uncertainty Analysis	Varying each of the input variables over various values of their respective probability distributions	Assign probability density function to each parameter; randomly sample values from each distribution and insert them in the exposure equation (Monte Carlo)
Classical Statistical Methods	Estimating the population exposure distribution directly, based on measured values from a representative sample	Compute confidence interval estimates for various percentiles of the exposure distribution

Source: U.S. EPA, 1992.

3 INGESTION OF WATER AND OTHER SELECT LIQUIDS

3.1 INTRODUCTION

Water ingestion can be a pathway of exposure to environmental chemicals among children. Contamination of water may occur at the water supply source (ground water or surface water); during treatment (for example toxic by-products may be formed during chlorination); or post-treatment (such as leaching of lead or other materials from plumbing systems). Children may be exposed to contaminants in water when consuming water directly as a beverage, indirectly from foods and drinks made with water, or incidentally while swimming. Estimating the magnitude of the potential dose of toxics from water ingestion requires information on the quantity of water consumed. The purpose of this section is to describe key and relevant published studies that provide information on water ingestion among children and to provide recommended ingestion rate values for use in exposure assessments. The studies described in this section provide information on ingestion of water consumed as a beverage, ingestion of other select liquids, and ingestion of water while swimming.

Currently, the U.S. EPA uses the quantity 1 L per day for infants (individuals of 10 kg body mass or less) and children as a default drinking water ingestion rate (U.S. EPA, 2000). This rate includes water consumed in the form of juices and other beverages containing tapwater. The National Academy of Sciences (NAS, 1977) estimated that daily consumption of water may vary with levels of physical activity and fluctuations in temperature and humidity. It is reasonable to assume that children engaging in physically-demanding activities or living in warmer regions may have higher levels of water ingestion. However, there is limited information on the effects of activity level and climatic conditions on water ingestion.

Various studies cited in this section have generated data on water ingestion rates; in general, these sources support U.S. EPA's use of 1 L/day as an upper-percentile tapwater ingestion rate for children under 10 years of age. Based on the applicability of the survey design to exposure assessments of the entire US population, the study by Khan and Stralka (2008) was selected as a key study of drinking water ingestion. In this study, ingestion rates for direct and indirect ingestion of water are reported. *Direct ingestion* is defined as direct consumption of water as a beverage, while *indirect ingestion* includes water added during food preparation, but not water intrinsic to purchased foods (i.e. water that is naturally contained in foods) (Kahn and Stralka, 2008). Data for consumption of water from various sources (i.e., the community water supply, bottled water, and other sources) are also presented. For the purposes of exposure assessments involving site-specific contaminated drinking water, ingestion rates based on the community supply are most appropriate. Given the assumption that bottled water, and purchased foods and beverages that contain water are widely distributed and less likely to contain source-specific water, the use of total water ingestion rates may overestimate the potential exposure to toxic substances present only in local water supplies; therefore, tapwater ingestion of community water, rather than total water ingestion, is emphasized in this section.

The studies on water ingestion that are currently available are based on short-term survey data (two days). Although short-term data may be suitable for obtaining mean or median ingestion values that are representative of both short- and long-term ingestion distributions, upper and lower -percentile values may be different for short-term and long-term data. It should also be noted that most currently available water ingestion surveys are based on recall. This may be a source of uncertainty in the estimated ingestion rates because of the subjective nature of this type of survey technique. Percentile distributions for water ingestion are presented in this handbook, where sufficient data are available. Data were not available to estimate drinking water ingestion rates for children during high activity levels or in extreme climates (i.e., hot weather). Also, data are not provided for the location of water consumption (i.e., home, school, day care center, etc.).

Limited information was available regarding children's incidental ingestion of water while swimming. This exposure pathway may be important since children are likely to ingest larger volumes of water while swimming compared to adults; and therefore, may have a greater exposure to pathogenic microorganisms and chemicals present in the water than adults. A recent pilot study (Dufour et al., 2006) has provided some quantitative experimental data on water ingestion for child and adult swimmers. These data are provided in this chapter.

The recommendations for water ingestion rates are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on the key study identified by U.S. EPA for this factor. Following the recommendations, the key study on water ingestion is summarized. Relevant data on ingestion of water and other select liquids are also provided. These studies are presented to provide the reader with added perspective on the current state-of-knowledge pertaining to ingestion of water and select liquids.

3.2 RECOMMENDATIONS

3.2.1 Water Ingestion from Consumption of Water as a Beverage and from Food and Drink

The recommended water ingestion rates for children are based on Kahn and Stralka (2008 and supplementary data). This study presents estimates of water ingestion by age range categories for the population of the United States using data collected in the U.S. Department of Agriculture's (USDA's) 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) (USDA, 1998). A summary of the recommended values for water ingestion rates is presented in Table 3-1. A characterization of the overall confidence in the accuracy and appropriateness of the recommendations for drinking water intake is presented in Table 3-2.

3.2.2 Water Ingestion while Swimming

Based on the results of the Dufour et al. (2006) study, a mean water ingestion rate of 50 mL/hour for children ages 6 to 15 years is recommended for exposure scenarios involving swimming activities. The recommended upper percentile value is 100 mL/hour. The recommended values for children between 18 and 21 years of age are based on the results for adults from Dufour et al. (2006). The mean value is 20 mL/hour and the upper percentile value is 70 mL/hour. Although this estimate was derived from swimming pool experiments, Dufour et al. (2006) noted that swimming behavior of pool swimmers may be similar to freshwater swimmers. Estimates may be different for salt water swimmers. The confidence ratings for these recommendations are presented in Table 3-3. Data on the amount of time spent swimming can be found in chapter 16, Table 16-21.

Table 3-1. Recommended Values for Drinking Water Ingestion Rates[a]

Age Group	Mean		95th Percentile		Multiple Percentiles	Source
	mL/day	mL/kg-day	mL/day	mL/kg-day		
Per Capita						
Birth to <1 month	184	52	839[b]	232[b]	See Tables 3-4 and 3-9	Kahn and Stralka (2008)
1 to <3 months	227	48	896[b]	205[b]		
3 to <6 months	362	52	1,056	159		
6 to <12 months	360	41	1,055	126		
1 to <2 years	271	23	837	71		
2 to <3 years	317	23	877	60		
3 to <6 years	380	22	1,078	61		
6 to <11 years	447	16	1,235	43		
11 to <16 years	606	12	1,727	34		
16 to <18 years	731	11	1,983[b]	31[b]		
18 to <21 years	826	12	2,540[b]	35[b]		
Consumers Only						
Birth to <1 month	470[b]	137[b]	858[b]	238[b]	See Tables 3-14 and 3-19	Kahn and Stralka (2008)
1 to <3 months	552	119	1,053[b]	285[b]		
3 to <6 months	556	80	1,171[b]	173[b]		
6 to <12 months	467	53	1,147	129		
1 to <2 years	308	27	893	75		
2 to <3 years	356	26	912	62		
3 to <6 years	417	24	1,099	65		
6 to <11 years	480	17	1,251	45		
11 to <16 years	652	13	1,744	34		
16 to <18 years	792	12	2,002[b]	32[b]		
18 to <21 years	895	13	2,565[b]	35[b]		

[a] Ingestion rates for combined direct and indirect water from community water supply.

[b] The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Table 3-2. Confidence in Recommendations for Drinking Water Ingestion Rates

General Assessment Factors	Rationale	Rating
Soundness		Medium to High
Adequacy of Approach	The survey methodology and data analysis was adequate. The survey sampled approximately 10,000 individuals under the age of 21 years; sample size varied with age.	
Minimal (or defined) Bias	No physical measurements were taken. The method relied on recent recall of standardized volumes of drinking water containers.	
Applicability and Utility		Medium to High
Exposure Factor of Interest	The key study was directly relevant to water ingestion.	
Representativeness	The data were demographically representative (based on stratified random sample).	
Currency	Data were collected between 1994 and 1998.	
Data Collection Period	Data were collected for two non-consecutive days. However, long term variability may be small. Use of a short-term average as a chronic ingestion measure can be assumed.	
Clarity and Completeness		High
Accessibility	The CSFII data are publicly available. The Kahn and Stralka (2008) analysis of the CSFII 1994-96, 1998 data was published in a peer-reviewed journal.	
Reproducibility	The methodology was clearly presented; enough information was included to reproduce the results.	
Quality Assurance	Quality assurance of the CSFII data was good; quality control of the secondary data analysis was not well described.	
Variability and Uncertainty		High
Variability in Population	Full distributions were given in a separate document (Khan and Stralka, 2008b).	
Uncertainty	Except for data collection based on recall, sources of uncertainty were minimal.	
Evaluation and Review		Medium
Peer Review	The USDA CSFII survey received high level of peer review. The Kahn and Stralka (2008) study was published in a peer-reviewed journal.	
Number and Agreement of Studies	There was 1 key study for drinking water ingestion.	
Overall Rating		**Medium to High**

Table 3-3. Confidence in Recommendations for Water Ingestion while Swimming

General Assessment Factors	Rationale	Rating
Soundness		Medium
Adequacy of Approach	The approach appears to be appropriate given that cyanuric acid (a tracer used in treated pool water) is not metabolized, but the sample size was small (41 children). The Dufour et al. (2006) study analyzed primary data on water ingestion during swimming.	
Minimal (or defined) Bias	Data were collected over a period of 45 minutes; this may not accurately reflect the time spent by a recreational swimmer.	
Applicability and Utility		Low to Medium
Exposure Factor of Interest	The key study was directly relevant to water ingestion while swimming.	
Representativeness	The sample was not representative of the U.S. population. Data cannot be broken out by age categories	
Currency	It appears that the study was conducted in 2005.	
Data Collection Period	Data were collected over a period of 45 minutes.	
Clarity and Completeness		Medium
Accessibility	The Dufour et al. (2006) study was published in a peer-reviewed journal.	
Reproducibility	The methodology was clearly presented; enough information was included to reproduce the results..	
Quality Assurance	Quality assurance methods were not described in the study.	
Variability and Uncertainty		Low
Variability in Population	Only mean values for water ingestion were provided. Data were not broken out by age groups	
Uncertainty	There were multiple sources of uncertainty (e.g., sample population may not reflect swimming practices for all swimmers, rates based on swimming duration of 45 minutes, differences by age group not defined).	
Evaluation and Review		Medium
Peer Review	Dufour et al. (2006) was published in a peer-reviewed journal.	
Number and Agreement of Studies	There was 1 study for ingestion of water when swimming.	
Overall Rating		**Low**

3.3 DRINKING WATER INGESTION STUDIES

3.3.1 Key Drinking Water Ingestion Study

3.3.1.1 *Kahn and Stralka, 2008 - Estimated Daily Average Per Capita Water Ingestion by Child and Adult Age Categories Based on USDA's 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals*

Kahn and Stralka (2008) analyzed the combined 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) data sets to examine water ingestion rates of adults and children. USDA surveyed households in the United States and District of Columbia and collected food and beverage recall data as part of the CSFII (USDA,1998). In the initial 1994-96 survey, over 15,000 respondents provided data on what they ate and drank over two non-consecutive days. A 1998 supplement, using the same methodology, added responses for approximately 5,000 children aged 9 years and younger to the database. Of the more than 20,000 individuals surveyed, approximately 10,000 were under 21 years of age, and approximately 9,000 were under the age of 11. For both survey days, data were collected by an in-home interviewer. The day two interview was conducted 3 to 10 days later and on a different day of the week. The 1994-96 survey and 1998 supplement are referred to collectively as CSFII 1994-96, 1998. Each individual in the survey was assigned a sample weight based on his or her demographic data. These weights were taken into account when calculating mean and percentile water ingestion rates from various sources.

Khan and Stralka (2008) derived mean and percentile estimates of daily average water ingestion for children in eleven different age categories: <1 month, 1 to <3 months, 3 to <6 months, 6 to <12 months, 1 to <2 years of age, 2 to <3 years, 3 to <6 years, 6 to <11 years, 11 to <16 years, 16 to <18 years, and 18 to <21 years of age. The increased sample size for children younger than 11 years of age (from 4,339 in the initial 1994-96 survey to 9,643 children in the combined 1994-96, 1998 survey) enabled water ingestion estimates to be categorized into the finer age categories recommended by U.S. EPA (2005). Per capita and consumers only water ingestion estimates were reported in the Kahn and Stralka (2008) study for two water source categories: all sources and community water. "All sources" included water from all supply sources such as community water supply (i.e., tap water), bottled water, other sources, and missing sources. "Community water" included tap water from a community or municipal water supply. Other sources included wells, springs, and cisterns; missing sources represented water sources that the survey respondent was unable to identify. The water ingestion estimates included both water ingested directly as a beverage (direct water) and water added to foods and beverages during final preparation at home or by local food service establishments such as school cafeterias and restaurants (indirect water). Commercial water added by a manufacturer (i.e., water contained in soda or beer) and intrinsic water in foods and liquids (i.e., milk and natural undiluted juice) were not included in the estimates. Kahn and Stralka (2008) only reported the mean, 90th and 95th percentile estimates of per capita and consumers only ingestion. The full distribution of ingestion estimates for various water source categories (all sources, community water, bottled water, and other sources) were provided by the author. Tables 3-4 to 3-7 provide mean and percentile per capita ingestion estimates of total water (combined direct and indirect water) in mL/day for the various water source categories (i.e., community, bottled, other, and all sources). The 90 percent confidence intervals around the estimated means and the 90 percent bootstrap intervals around the 90th and 95th percentiles of total water ingestion from all water sources are presented in Table 3-8. Tables 3-9 to 3-13 present the same information as Tables 3-4 to 3-8 but in units of mL/kg-day. Consumers only combined direct and indirect water ingestion estimates in mL/day for the various source categories are provided in Tables 3-14 to 3-17. Table 3-18 presents confidence and bootstrap intervals for total water ingestion estimates by consumers only from all sources. Tables 3-19 to 3-23 present the same information as Tables 3-14 to 3-18 but in units of mL/kg-day.

The data show that the total quantity of water ingested per unit mass of body weight is at a maximum in the first month of life and decreases with increasing age. The per capita ingestion rate of water from all sources combined for children under 1 month of age is approximately four times higher than that adults, and consumers younger than 1 month of age ingest approximately 8 times the amount of water (all sources combined) as adults (Kahn and Stralka, 2008). The pattern of decreasing water ingestion per unit of body weight is also observed in per capita and consumers only estimates of community water (Tables 3-9 and 3-

19), bottled water (Table 3-10 and 3-20) and other sources (Tables 3-11 and 3-21).

The CSFII 1994-96, 1998 data have both strengths and limitations with regard to estimating water ingestion. These are discussed in detail in U.S. EPA (2004) and Kahn and Stralka (2008). The principal advantages of this survey are (1) that the survey was designed to obtain a statistically valid sample of the entire United States population that included children and low income groups; (2) sample weights were provided that facilitated proper analysis of the data and accounted for non-response; and (3) that the sample size (approximately 10,000 children) is sufficient to allow categorization within narrowly defined age categories. Over sampling of children enhanced the precision and accuracy of the estimates for the child population subsets. One limitation of this survey is that data were collected for only 2 days and does not necessarily represent "usual intake." "Usual dietary intake" refers to the long-term average of daily intakes by an individual. Thus, upper percentile water ingestion estimates based on short-term data may differ from long-term rates because short-term consumption data tend to be inherently more variable. However, Kahn and Stralka (2008) noted that variability due to short term duration of the survey does not result in bias of estimates of overall mean. In addition, the survey was conducted on non-consecutive days, which improves the variance over consecutive days of consumption. However, the two non-consecutive days of data collection, although an advantage over two consecutive days, provide limited information on individual respondents. The two-day mean for an individual can easily be skewed for numerous reasons. Estimation at the individual respondent level was not, however, an objective of the survey. The large sample provides useful information on the overall distribution of ingestion by the population, and should adequately reflect the range among respondent variability. Another limitation of these data is that the survey design, while being well-tailored for the overall population of the United States and conducted throughout the year to account for seasonal variation, is of limited utility for assessing small and potentially at-risk subpopulations based on ethnicity, medical status, geography/climate, or other factors such as activity level.

3.3.2 Relevant Drinking Water Ingestion Studies

3.3.2.1 *Levy et al., 1995 - Infant Fluoride Intake From Drinking Water Added to Formula, Beverages, and Food*

Levy et al. (1995) conducted a study to determine fluoride intake by infants through drinking water and other beverages prepared with water and baby foods. The study was longitudinal and covered the ages from birth to 9 months old. A total of 192 mothers, recruited from the *post partum* wards of two hospitals in Iowa City, completed mail questionnaires and three-day beverage and food diaries for their infants at ages 6 weeks, and 3, 6, and 9 months of age (Levy et al., 1995). The questionnaire addressed feeding habits, water sources and ingestion, and the use of dietary fluoride supplements during the preceding week (Levy et al., 1995). Data on the quantity of water consumed by itself or as an additive to infant formula, other beverages, or foods were obtained. In addition, the questionnaire addressed the infants' ingestion of cow's milk, breast-milk, ready-to-feed infant products (formula, juices, beverages, baby food), and table foods.

Mothers were contacted for any clarifications of missing data and discrepancies (Levy et al., 1995). Levy et al. (1995) assessed non-response bias and found no significant differences in the reported number of adults or children in the family, water sources, or family income at 3, 6, or 9 months. Table 3-24 provides the range of water ingestion from water by itself and from addition to selected foods and beverages. The percentage of infants ingesting water by itself increased from 28 percent at 6 weeks to 66 percent at 9 months, respectively, and the mean intake increased slightly over this time frame. During this time frame, the largest proportion of the infants' water ingestion (i.e., 36 percent at 9 months to 48 percent at 6 months) came from the addition of water to formula. Levy et al. (1995) noted that 32 percent of the infants at age 6 weeks and 23 percent of the infants at age 3 months did not receive any water from any of the sources studied. Levy et al. (1995) also noted that the proportion of children ingesting some water from all sources gradually increased with age.

The advantages of this study are that it provides information on water ingestion of infants starting at 6 weeks old and the data are for water only and for water added to beverages and foods. The limitations of the study are that the sample size was small for each age group, it captured information from a select geographical location, and data were collected through self reporting. The authors noted, however, that the three-day diary has been shown to be a valid assessment tool. Levy et al. (1995) also stated that (1) for each time period, the ages of the infants varied by a few days to a few weeks, and are, therefore, not exact and could, at early ages, have an effect on age-specific intake patterns, and (2) the same number of infants were not available at each of the four time periods.

3.3.2.2 *Heller et al., 2000 - Water Consumption and Nursing Characteristics of Infants by Race and Ethnicity*

Heller et al. (2000) analyzed data from the 1994-96 CSFII to evaluate racial/ethnic differences in the ingestion rates of water in children younger than 2 years old. Using data from 946 children in this age group, the mean amounts of water consumed from eight sources were determined for various racial/ethnic groups, including black non-Hispanic, white non-Hispanic, Hispanic and "other" (Asian, Pacific Islander, American Indian, Alaskan Native, and other non-specified racial/ethnic groups). The sources analyzed included: (1) plain tap water, (2) milk and milk drinks, (3) reconstituted powdered or liquid infant formula made from drinking water, (4) ready-to-feed and other infant formula, (5) baby food, (6) carbonated beverages, (7) fruit and vegetable juices and other noncarbonated drinks, and (8) other foods and beverages. In addition, Heller et al. (2000) calculated mean plain water and total water ingestion rates for children by age, sex, region, urbanicity, and poverty category. Ages were defined as less than 12 months and 12 to 24 months. Region was categorized as Northeast, Midwest, South, and West. The states represented by each of these regions was not reported in Heller et al. (2000). However, it is likely that these regions were defined in the same way as in Sohn et al. (2001). See Section 3.3.2.4 for a discussion on the Sohn et al. (2001) study. Urbanicity of the residence was defined as urban (i.e., being in a Metropolitan Statistical Area [MSA], suburban [outside of an MSA], or rural [being in a non-MSA]). Poverty category was derived from the poverty income ratio. In this study, a poverty income ratio was calculated by dividing the family's annual income by the federal poverty threshold for that size household. The poverty categories used were 0-1.30, 1.31-3.50, and greater than 3.50 times the federal poverty level (Heller et al., 2000).

Table 3-25 provides water ingestion estimates for the eight water sources evaluated, for each of the race/ethnic groups. Heller et al. (2000) reported that black non-Hispanic children had the highest mean plain tap water intake (21.3 mL/kg-day), and white non-Hispanic children had the lowest mean plain tap water intake (12.7 mL/kg-day). The only statistically significant difference between the racial/ethnic groups was found to be in plain tap water consumption and total water consumption. Reconstituted baby formula made up the highest proportion of total water intake for all race/ethnic groups. Table 3-26 presents tap water and total water ingestion by age, sex, region, urbanicity, and poverty category. On average, children younger than 12 months of age consumed less plain tap water (11.0 mL/kg-day) than children aged 12-24 months (17.7 mL/kg-day). There were no significant differences in plain tap water consumption by sex, region, or urbanicity. Heller et al. (2000) reported a significant association between higher income and lower plain tap water consumption. For total water consumption, ingestion per kg body weight was lower for the 12-24-month-old children than for those younger than 12 months of age. Urban children consumed more plain tap water and total water than suburban and rural children. In addition, plain tap water and total water ingestion was found to decrease with increasing poverty category (i.e., higher wealth).

A major strength of the Heller et al. (2000) study is that it provides information on tap water and total water consumption by race, age, sex, region, urbanicity, and family income. The weaknesses in the CSFII data set have been discussed under Kahn and Stralka (2008) and U.S. EPA (2004) and include surveying participants for only two days.

3.3.2.3 *Sichert-Hellert et al., 2001 - Fifteen Year Trends in Water Intake in German Children and Adolescents: Results of the DONALD Study*

Water and beverage consumption was evaluated by Sichert-Hellert et al. (2001) using 3-day dietary records of 733 children, ages 2 to 13 years, enrolled in the Dortmund Nutritional and Anthropometric Longitudinally Designed Study (DONALD study). The DONALD study is a cohort study, conducted in Germany, that collects data on diet, metabolism, growth and development from healthy subjects between infancy and adulthood (Sichert-Hellert et al., 2001). Beginning in 1985, approximately 40 to 50 infants were enrolled in the study annually. Mothers of the participants were recruited in hospital maternity wards. Older children and parents of younger children were asked to keep dietary records for three days by recording and weighing (to the nearest 1 gram) all foods and fluids, including water, consumed.

Sichert-Hellert et al. (2001) evaluated 3,736 dietary records from 733 subjects (354 males and 379 females) collected between 1985 and 1999. Total water ingestion was defined as the sum of water content from food (intrinsic water), beverages and oxidation. Beverages included milk, mineral water, tap water, juice, soft drinks, and coffee and tea. Table 3-27 presents the mean water ingestion rates for these different sources, as well as mean total water ingestion rates for three age ranges of children (age 2 to 3 years, age 4 to 8 years, and age 9 to 13 years). According to Sichert-Hellert et al. (2001), mean total water ingestion increased with age from 1,114 mL/day in the 2 to 3 year old subjects to 1,891 and 1,676 mL/day in 9 to 13-year-old boys and girls, respectively. However, mean total water intake per body weight decreased with age. Sichert-Hellert et al. (2001) observed that the most important source of total water ingestion was mineral water for all children, except the 2 to 3 year olds. For these children, the most important source of total water ingestion was milk .

One of the limitations of this study is that it evaluated water and beverage consumption in German children and, as such, it may not be representative of consumption patterns of U.S. children.

3.3.2.4 *Sohn et al., 2001 - Fluid Consumption Related to Climate Among Children in the United States*

Sohn et al. (2001) investigated the relationship between fluid consumption among children aged l to 10 years and local climate using data from the third National Health and Nutrition Examination Survey (NHANES III, 1988-94). Children aged 1 to 10 years who completed the 24-hour dietary interview (or proxy interview for the younger children) during the NHANES III survey were selected for the analysis. Breast-fed children were excluded from the analysis. Among 8,613 children who were surveyed, 688 (18 percent) were excluded due to incomplete data. A total of 7,925 eligible children remained. Since data for climatic conditions were not collected in the NHANES III survey, the mean daily maximum temperature from 1961 to 1990, averaged for the month during which the NHANES III survey was conducted, was obtained for each survey location from the U.S. Local Climate Historical Database. Of the 7,925 eligible children with complete dietary data, temperature information was derived for only 3,869 children (48.8 percent) since detailed information on survey location, in terms of county and state, was released only for counties with a population of more than a half million

Sohn et al. (2001) calculated the total amount of fluid intake for each child by adding the fluid intake from plain drinking water and the fluid intake from foods and beverages other than plain drinking water provided by NHANES III. Sohn et al. (2001) identified major fluid sources as milk (and milk drinks), juice (fruit and vegetable juices and other noncarbonated drinks), carbonated drinks, and plain water. Fluid intake from sources other than these major sources were all grouped into other foods and beverages. Other foods and beverages included bottled water, coffee, tea, baby food, soup, water-based beverages, and water used for dilution of food. Mean fluid ingestion rates of selected fluids for the total sample population and for the subsets of the sample population with and without temperature information are presented in Table 3-28. The estimated mean total fluid and plain water ingestion rates for the 3,869 children for whom temperature information was obtained are presented in Table 3-29 according to age (years), sex, race/ethnicity, poverty/income ratio, region, and urban or rural. Poverty/income ratio was defined as the ratio of the reported family income to the federal poverty level. The following categories were assigned: low socioeconomic status (SES) = 0.000-1.300 times the poverty/income ratio; medium SES = 1.3.01-3.500 times the poverty/income level; and high SES = 3.501 or greater times the poverty/income level. Regions were as Northeast, Midwest, South, and West, as defined by the U.S. Census (see Table 3-29). Sohn et al. (2001) did not find significant association between mean daily maximum temperature and total fluid or plain water ingestion, either before or after controlling for sex, age, SES and race or ethnicity. However, significant associations between fluid ingestion and age, sex, socioeconomic status and race and ethnicity were reported.

The main strength of the Sohn et al. (2001) study is the evaluation of water intake as it relates to weather data. The main limitations of this study were that northeast and western regions were over represented since temperature data was only available for counties with populations in excess of a half million. In addition, whites were under-represented compared to other racial or ethnic groups. Other limitations include lack of data for children from extremely cold or hot weather conditions.

3.3.2.5 *Hilbig et al., 2002 - Measured Consumption of Tap Water in German Infants and Young Children as Background for Potential Health Risk Assessment: Data of the DONALD Study*

Hilbig et al. (2002) estimated tap water ingestion rates based on 3-day dietary records of 504 German children aged 3, 6, 9, 12, 18, 24 and 36 months. The data were collected between 1990 and 1998 as part of the DONALD study. Details of data collection for the DONALD study have been provided previously under the Sichert-Hellert et al. (2001) study in Section 3.3.2.3 of this handbook. Tap water ingestion rates were calculated for three subgroups of children: (1) breast-fed infants ≤12 months of age (exclusive and partial breast-fed infants) (2) formula-fed infants ≤12 months of age (no human milk, but including weaning food) and (3) mixed-fed young children aged 18 to 36 months. Hilbig et al. (2002) defined "total tap water from household" as water from the tap consumed as a beverage or used in food preparation. "Tap water from food manufacturing" was defined as water used in industrial production of foods, and "Total Tap Water" was defined as tap water consumed from both the household and that used in manufacturing.

Table 3-30 summarizes total tap water ingestion (in mL/day and mL/kg-day) and tap water ingestion from household and manufacturing sources (in mL/kg-day) for breastfed, formula fed and mixed-fed children. Mean total tap water intake was higher in formula-fed infants (53 mL/kg-day) than in breast-fed infants (17 g/kg-day) and mixed-fed young children (19 g/kg-day). Tap water from household sources constituted 66 to 97 percent of total tap water ingestion in the different age groups.

The major limitation of this study is that the study sample consists of families from an upper social background in Germany (Hilbig et al., 2002). Because the study was conducted in Germany, the data may not be directly applicable to the U.S. population.

3.3.2.6 *Marshall et al., 2003a - Patterns of Beverage Consumption During the Transition Stage of Infant Nutrition*

Marshall et al. (2003a) investigated beverage ingestion during the transition stage of infant nutrition. Mean ingestion of infant formula, cow's milk, combined juice and juice drinks, water, and other beverages were estimated using a frequency questionnaire. A total of 701 children, ages six months through 24 months, participated in the Iowa Fluoride Study (IFS). Mothers of newborns were recruited from 1992 through 1995. The parents were sent questionnaires when the children were 6, 9, 12, 16, 20, and 24 months old. Of the 701 children, 470 returned all six questionnaires, 162 returned five, 58 returned four and 11 returned three, with the minimum criteria being three questionnaires to be included in the data set (Marshall et al., 2003a). The questionnaire was designed to assess the type and quantity of the beverages consumed during the previous week. The validity of the questionnaire was assessed using a three-day food diary for reference (Marshall et al., 2003a). The percentage of subjects consuming beverages and mean daily beverage ingestion for children with returned questionnaires are presented in Table 3-31. Human milk ingestion was not quantified, but the percent of children consuming human milk was provided at each age category (Table 3-31). Juice (100 percent) and juice drinks were not distinguished separately, but categorized as juice and juice drinks. Water used to dilute beverages beyond normal dilution and water consumed alone were combined. Based on Table 3-31, 97 percent of the children consumed human milk, formula, or cow's milk throughout the study period, and the percentage of infants consuming human milk decreased with age, while the percent consuming water increased (Marshall et al., 2003a). Marshall et al. (2003a) observed that in general, lower family incomes were associated with less breastfeeding and increased ingestion of other beverages.

The advantage of this study is that it provides mean ingestion data for various beverages. Limitations of the study are that the it is based on samples gathered in one geographical area and may not be reflective of the general population. The authors also noted the following limitations: the parents were not asked to differentiate between 100 percent juice and juice drinks; the data are parent-reported and could reflect perceptions of appropriate ingestion instead of actual ingestion, and a substantial number of the infants from well educated, economically secure households dropped out during the initial phase.

3.3.2.7 *Marshall et al., 2003b - Relative Validation of a Beverage Frequency Questionnaire in Children Ages 6 Months through 5 Years Using 3-day Food and Beverage Diaries*

This study was based on data taken from 700 children in the IFS. This study compared estimated beverage ingestion rates reported in questionnaires for the preceding week and dairies for the following week. Packets were sent periodically (every 4 to 6 months) to parents of children aged 6 weeks through 5 years of age. This study analyzed data from children, ages 6 and 12 months, and 2 and 5 years of age. Beverages were categorized as human milk, infant formula, cow's milk, juice and juice drinks, carbonated and rehydration beverages, prepared drinks (from powder) and water. The beverage questionnaire was completed by parents and summarized the average amount of each beverage consumed per day by their children. The data collection for the diaries maintained by parents included 1 weekend day and 2 week days and included detailed information about beverages consumed. Table 3-32 presents the mean ingestion rates of all beverages for children aged 6 and 12 months and 3 and 5 years. Marshall et al. (2003b) concluded that estimates of beverage ingestion derived from quantitative questionnaires are similar to those derived from diaries. They found that it is particularly useful to estimate ingestion of beverages consumed frequently using quantitative questionnaires.

The advantage of this study is that the survey was conducted in two different forms (questionnaire and diary) and that diaries for recording beverage ingestion were maintained by parents for three days. The main limitation is the lack of information regarding whether the diaries were populated on consecutive or non-consecutive days. The IFS survey participants may not be representative of the general population of the U.S. since participants were primarily white, and from affluent and well-educated families in one geographic region of the country.

3.3.2.8 *Skinner et al., 2004 - Transition in Infants' and Toddlers' Beverage Patterns*

Skinner et al. (2004) investigated the pattern of beverage consumption by infants and children participating in the Feeding Infant and Toddlers Study (FITS) sponsored by Gerber Products Company. The FITS is a cross-sectional study designed to collect and analyze data on feeding practices, food consumption, and usual nutrient intake of U.S. infants and toddlers (Devaney et al., 2004). It included a stratified random sample of 3,022 infants and toddlers between 4 and 24 months of age. Parents or primary caregivers of sampled infants and toddlers completed a single 24-hour dietary recall of all foods and beverages consumed by the child on the previous day by telephone interview. All recalls were completed between March and July 2002. Detailed information on data collection, coding and analyses related to FITS are provided in Devaney et al. (2004).

Beverages consumed by FITS participants were identified as total milks (i.e., human milk, infant formulas, cows milk, soy milk, goat milk), 100 percent juices, fruit drinks, carbonated beverages, water and "other" drinks (i.e., tea, cocoa, dry milk mixtures, and electrolyte replacement beverages). There were six age groupings in the FITS study: 4 to 6, 7 to 8, 9 to 11, 12 to 14, 15 to 18, and 19 to 24 months. Skinner et al. (2004) calculated the percentage of children in each age group consuming any amount in a beverage category and the mean amounts consumed. Table 3-33 provides the mean beverage consumption rates in mL/day for the six age categories. Skinner et al. (2004) found that some form of milk beverage was consumed by almost all children at each age; however, total milk ingestion decreased with increasing age. Water consumption also doubled with age, from 163 mL/day in children aged 4 to 6 months old to 337 mL/day at 19 to 24 months old. The percentages of children consuming water increased from 34 percent at 4 to 6 months of age to 77 percent at 19 to 24 months of age.

A major strength of the Skinner et al. (2004) study is the large sample size (3,022 children). However, beverage ingestion estimates are based on one day of dietary recall data and human milk quantity derived from studies that weighed infants before and after each feeding to determine the quantity of human milk consumed (Devaney et al., 2004); therefore, estimates of total milk ingestion may not be accurate.

3.4 WATER INGESTION WHILE SWIMMING

3.4.1 Dufour et al., 2006 - Water Ingestion During Swimming Activities in a Pool: A Pilot Study

Dufour et al. (2006) estimated the amount of water ingested while swimming, using cyanuric acid as an indicator of pool water ingestion exposure. Cyanuric acid is a breakdown product of chloroisocyanates which are commonly used as disinfectant stabilizers in recreational water treatment. Because ingested cyanuric acid passes through the body unmetabolized, the volume of water ingested can be estimated based on the amount of cyanuric acid measured in the pool water and in the urine of swimmers, as follows:

$$V_{pool\ water\ ingested} = V_{urine} \times CA_{urine}/CA_{pool} \qquad \text{(Eqn. 3-1)}$$

where:

$V_{pool\ water\ ingested}$	=	volume of pool water ingested (mL)
V_{urine}	=	volume of urine collected over a 24-hour period (mL)
CA_{urine}	=	concentration of cyanuric acid in urine (mg/L)
CA_{pool}	=	concentration of cyanuric acid in pool water (mg/L)

Dufour et al. (2006) estimated pool water intake among 53 swimmers that participated in a pilot study at an outdoor swimming pool treated with chloroisocyanate. This pilot study population included 12 adults (4 males and 8 females) and 41 children between 6 and 15 years of age (20 males and 21 females). The study participants were asked not to swim for 24 hours before or after a 45 minute period of active swimming in the pool. Pool water samples were collected prior to the start of swimming activities and swimmers' urine was collected for 24 hours after the swimming event ended. The pool water and urine sample were analyzed for cyanuric acid.

The results of this pilot study are presented in Table 3-34. The mean volume of water ingested by children over a 45-minute period was 37 mL. The maximum volume of water ingested by children was 154 mL/45 minutes and the 97th percentile was 90 mL. Individuals older than 18 years of age ingested an average of 16 mL over a 45-minute period; the maximum amount ingested by these individuals was 53mL over a 45-minute period. The mean ingestion rates for males tended to be higher than that of females, but these differences were not statistically significant. The advantages of this study is that it is one of the first attempts to measure water ingested while swimming. However, the number of study participants was low and data cannot be broken out by the recommended age categories. As noted by the Dufour et al. (2006), swimming behavior of pool swimmers may be similar to freshwater swimmers, but may differ from salt water swimmers.

Based on the results of the Dufour et al. (2006) study, the recommended mean water ingestion rate for exposure scenarios involving swimming activities is 50 mL/hour for children under 16 years of age (37 mL/0.75 hour, rounded to one significant figure) and the upper percentile value is 100 mL/hour (90 mL/0.75 hour, rounded to one significant figure). For children, ages 18 to <21 years, the recommended mean water ingestion rate for scenarios involving swimming activities is 20 mL/hour (16 mL/0.75 hour, rounded to one significant figure). Because the data set is limited, the upper percentile water ingestion rate for 18 to <21 year olds is based on the maximum value observed in adults in the Dufour et al. (2006) study: 70 mL/hour (53 mL/0.75 hour, rounded to one significant figure).

3.5 REFERENCES FOR CHAPTER 3

Devaney, B.; Kalb, L.; Briefel, R.; Zavitsky-Novak, T.; Clusen, N.; Ziegler, P. (2004) Feeding Infants and Toddlers Study: Overview of the study design. J Am Diet Assoc 104 (supplement 1): S8-S13.

Dufour, A.P.; Evans, O.; Behymer, T.D., Cantu, R. (2006) Water ingestion during swimming activities in a pool: a pilot study. J Water Health 4(4):425-430.

Heller, K.; Sohn, W.; Burt, B.; Feigal, R. (2000) Water consumption and nursing characteristics of infants by race and ethnicity. J Public Health Dent 60 (3) 140-146.

Hilbig, A.; Kersting, M.; Sichert-Hellert, W. (2002) - Measured consumption of tap water in German infants and young children as background for potential health risk assessment: Data of the DONALD study. Food Addit Contam 19 (9): 829-836.

Kahn, H.; Stralka, K. (2008) Estimated daily average per capita water ingestion by child and adult age categories based on USDA's 1994-96 and 1998 continuing survey of food intakes by individuals. J Expo Anal Environ Epidemiol (accepted for publication May 2008).

Levy, S.; Kohout, F.; Guha-Chowdhury, N.; Kiristy, J., Heilman, et al. (1995) Infants' fluoride intake from drinking water alone, and from water added to formula, beverages, and food. J Dent Res (74):1399-1407.

LSRO (1995) Life Sciences Research Office, Federation of American Societies for Experimental Biology Prepared for the Interagency Board for Nutrition Monitoring and Related Research. Third Report on Nutrition Monitoring in the United States: Volume 1. U.S. Government Printing Office, Washington, D.C.

Marshall, T.; Levy, S.; Broffitt, B.; Eichenberger-Gilmore, J.; Stumbo, P. (2003a) Patterns of beverage consumption during the transition stage of infant nutrition. J Amer Diet Assoc 103 (10):1350-1353.

Marshall, T.; Eichenberger Gilmore, J; Broffitt, B.; Levy, S.; Stumbo, P. (2003b) Relative Validation of a beverage frequency questionnaire in children Ages 6 months through 5 years using 3-day food and beverage diaries. J Amer Diet Assoc 103 (6):714-720.

National Academy of Sciences (NAS). (1977) Drinking water and health. Vol. 1. Washington, DC: National Academy of Sciences-National Research Council.

Sichert-Hellert, W.; Kersting, M.; Manz, F. (2001) Fifteen year trends in water intake in German children and adolescents: results of the DONALD study. Acta Paediatr 90: 732-7.

Skinner, J.; Ziegler, P.; Ponza, M. (2004) - Transition in Infants' and Toddles' Beverage Patterns. J Amer Diet Assoc Supplement 1 104 (1): S45-S50.

Sohn, W.; Heller, K. E.; Burt, B. A. (2001) Fluid consumption related to climate among children in the United States. J Public Health Dent. 61(2): 99-106.

USDA. (1998) Continuing survey of food intakes by individuals: 1994-96, 1998. U.S. Department of Agriculture, Agricultural Research Service.

U.S. EPA. (2000) Methodology for deriving ambient water quality criteria for the protection of human health (2000). U.S. Environmental Protection Agency, Office of Water, Washington, D.C., EPA-822-00-004. October 2000.

U.S. EPA. (2004) Estimated Per Capita Water Ingestion and Body Weight in the United States— an Update: Based on Data Collected by the United States Department of Agriculture's 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals. U.S. Environmental Protection Agency, Office of Water, Washington, D.C., EPA-822-R-00-001. October 2004.

U.S. EPA. (2005) Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants. U.S. Environmental Protection Agency, Washington, D.C., EPA/630/P-03/003F. November 2005.

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	91	184	-	-	-	322	687*	839*	860*
1 to <3 months	253	227	-	-	-	456	804	896*	1,165*
3 to <6 months	428	362	-	-	148	695	928	1,056	1,424*
6 to <12 months	714	360	-	17	218	628	885	1,055	1,511*
1 to <2 years	1,040	271	-	60	188	402	624	837	1,215*
2 to <3 years	1,056	317	-	78	246	479	683	877	1,364*
3 to <6 years	4,391	380	4	98	291	547	834	1,078	1,654
6 to <11 years	1,670	447	22	133	350	648	980	1,235	1,870*
11 to <16 years	1,005	606	30	182	459	831	1,387	1,727	2,568*
16 to <18 years	363	731	16	194	490	961	1,562	1,983*	3,720*
18 to <21 years	389	826	24	236	628	1,119	1,770	2,540*	3,889*

Table 3-4. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Community Water (mL/day)

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-5. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Bottled Water (mL/day)

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	91	104	-	-	-	18	437*	556*	1,007*
1 to <3 months	253	106	-	-	-	-	541	771*	1,056*
3 to <6 months	428	120	-	-	-	-	572	774	1,443*
6 to <12 months	714	120	-	-	-	53	506	761	1,284*
1 to <2 years	1,040	59	-	-	-	-	212	350	801*
2 to <3 years	1,056	76	-	-	-	-	280	494	1,001*
3 to <6 years	4,391	84	-	-	-	-	325	531	1,031*
6 to <11 years	1,670	84	-	-	-	-	330	532	1,079*
11 to <16 years	1,005	111	-	-	-	-	382	709	1,431*
16 to <18 years	363	109	-	-	-	-	426	680*	1,605*
18 to <21 years	389	185	-	-	-	-	514	1,141*	2,364*

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	91	13	-	-	-	-	-	-	393*
1 to <3 months	253	35	-	-	-	-	-	367*	687*
3 to <6 months	428	45	-	-	-	-	-	365	938*
6 to <12 months	714	45	-	-	-	-	31	406	963*
1 to <2 years	1,040	22	-	-	-	-	-	118	482*
2 to <3 years	1,056	39	-	-	-	-	52	344	718*
3 to <6 years	4,391	43	-	-	-	-	58	343	830
6 to <11 years	1,670	61	-	-	-	-	181	468	1,047*
11 to <16 years	1,005	102	-	-	-	-	344	786	1,698*
16 to <18 years	363	97	-	-	-	-	295	740*	1,760*
18 to <21 years	389	47	-	-	-	-	-	246*	1,047*

Table 3-6. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Other Sources (mL/day)

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-7. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: All Sources (mL/day)

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	91	301	-	-	135	542	846*	877*	1,088*
1 to <3 months	253	368	-	-	267	694	889	1,020*	1,265*
3 to <6 months	428	528	-	89	549	812	1,025	1,303	1,509*
6 to <12 months	714	530	37	181	505	771	1,029	1,278	1,690*
1 to <2 years	1,040	358	68	147	287	477	735	961	1,281*
2 to <3 years	1,056	437	104	211	372	588	825	999	1,662*
3 to <6 years	4,391	514	126	251	438	681	980	1,200	1,794
6 to <11 years	1,670	600	169	304	503	803	1,130	1,409	2,167*
11 to <16 years	1,005	834	224	401	663	1,099	1,649	1,960	3,179*
16 to <18 years	363	964	236	387	742	1,273	1,842	2,344*	3,854*
18 to <21 years	389	1,075	189	406	803	1,394	2,117	2,985*	4,955*

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-8. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: All Sources (mL/day)

Age	Sample size	Mean			90th percentile			95th percentile		
			90% C.I.			90% B.I.			90% B.I.	
		Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound
Birth to <1 month	91	301	215	387	846*	638*	859*	877*	798*	993*
1 to <3 months	253	368	304	432	889	862	896	1,020*	918*	1,070*
3 to <6 months	428	528	485	571	1,025	955	1,083	1,303	1,170	1,351
6 to <12 months	714	530	495	564	1,029	973	1,100	1,278	1,142	1,385
1 to <2 years	1,040	358	338	377	735	686	778	961	879	1,001
2 to <3 years	1,056	437	418	455	825	784	857	999	952	1,051
3 to <6 years	4,391	514	494	533	980	953	1,004	1,200	1,167	1,240
6 to <11 years	1,670	600	571	629	1,130	1,065	1,162	1,409	1,314	1,468
11 to <16 years	1,005	834	770	898	1,649	1,567	1,775	1,960	1,873	2,218
16 to <18 years	363	964	870	1,057	1,842	1,743	1,988	2,344*	2,071*	2,599*
18 to <21 years	389	1,075	980	1,171	2,117	1,952	2,299	2,985*	2,504*	3,785*

[a] Includes all participants whether or not they ingested any water from the source during survey period.

[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.

* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

CI = Confidence Interval.

BI = Bootstrap Interval.

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-9. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Community Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	88	52	-	-	-	101	196*	232*	253*
1 to <3 months	245	48	-	-	-	91	151	205*	310*
3 to <6 months	411	52	-	-	20	98	135	159	216*
6 to <12 months	678	41	-	2	24	71	102	126	185*
1 to <2 years	1,002	23	-	5	17	34	53	71	106*
2 to <3 years	994	23	-	6	17	33	50	60	113*
3 to <6 years	4,112	22	-	6	17	31	48	61	93
6 to <11 years	1,553	16	1	5	12	22	34	43	71*
11 to <16 years	975	12	1	4	9	16	25	34	54*
16 to <18 years	360	11	-	3	8	15	23	31*	55*
18 to <21 years	383	12	1	4	10	16	17	35*	63*

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-10. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Bottled Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	88	33	-	-	-	6	131*	243*	324*
1 to <3 months	245	22	-	-	-	-	97	161*	242*
3 to <6 months	411	16	-	-	-	-	74	117	193*
6 to <12 months	678	13	-	-	-	4	52	87	139*
1 to <2 years	1,002	5	-	-	-	-	18	28	67*
2 to <3 years	994	5	-	-	-	-	19	35	84*
3 to <6 years	4,112	5	-	-	-	-	18	30	59
6 to <11 years	1,553	3	-	-	-	-	10	18	41*
11 to <16 years	975	2	-	-	-	-	8	14	26*
16 to <18 years	360	2	-	-	-	-	6	10*	27*
18 to <21 years	383	3	-	-	-	-	8	19*	34*

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-11. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Other Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	88	4	-	-	-	-	-	-	122*
1 to <3 months	245	7	-	-	-	-	-	52*	148*
3 to <6 months	411	7	-	-	-	-	-	55	155*
6 to <12 months	678	5	-	-	-	-	3	35	95*
1 to <2 years	1,002	2	-	-	-	-	-	11	45*
2 to <3 years	994	3	-	-	-	-	4	23	61*
3 to <6 years	4,112	2	-	-	-	-	3	19	48
6 to <11 years	1,553	2	-	-	-	-	7	16	36*
11 to <16 years	975	2	-	-	-	-	7	14	34*
16 to <18 years	360	2	-	-	-	-	5	11*	27*
18 to <21 years	383	1	-	-	-	-	-	4*	14*

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-12. Per Capita[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: All Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	88	89	-	-	21	168	235*	269*	338*
1 to <3 months	245	77	-	-	46	134	173	246*	336*
3 to <6 months	411	75	-	9	73	118	156	186	225*
6 to <12 months	678	59	4	20	53	86	118	148	194*
1 to <2 years	1,002	31	6	13	24	39	63	85	122*
2 to <3 years	994	31	7	15	26	41	59	73	130*
3 to <6 years	4,112	29	7	14	25	38	56	69	102
6 to <11 years	1,553	21	6	10	18	27	39	50	76*
11 to <16 years	975	16	4	8	13	20	31	39	60*
16 to <18 years	360	15	4	6	12	18	28	37*	59*
18 to <21 years	383	16	3	6	12	21	32	41*	73*

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- = Zero.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-13. Per Capita[a] Estimates of Total Direct and Indirect[b] Water Ingestion: All Sources (mL/kg-day)

Age	Sample size	Mean			90th percentile			95th percentile		
		Estimate	90% C.I. Lower Bound	90% C.I. Upper Bound	Estimate	90% B.I. Lower Bound	90% B.I. Upper Bound	Estimate	90% B.I. Lower Bound	90% B.I. Upper Bound
Birth to <1 month	88	89	64	114	235*	198*	269*	269*	236*	332*
1 to <3 months	245	77	62	91	173	164	217	246*	187*	295*
3 to <6 months	411	75	68	82	156	145	162	186	176	199
6 to <12 months	678	59	54	63	118	112	128	148	134	166
1 to <2 years	1,002	31	29	32	63	59	68	85	73	95
2 to <3 years	994	31	30	33	59	57	62	73	69	81
3 to <6 years	4,112	29	28	30	56	54	56	69	66	72
6 to <11 years	1,553	21	20	22	39	36	41	50	47	52
11 to <16 years	975	16	15	17	31	29	34	39	36	41
16 to <18 years	360	15	13	16	28	27	32	37*	33*	44*
18 to <21 years	383	16	14	17	32	29	35	41*	36*	44*

[a] Includes all participants whether or not they ingested any water from the source during survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence Interval.
BI = Bootstrap Interval.

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-14. Consumers Only[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Community Water (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	40	470*	32*	215*	482*	692*	849*	858*	919*
1 to <3 months	114	552	67*	339	533	801	943*	1,053*	1,264*
3 to <6 months	281	556	44	180	561	837	1,021	1,171*	1,440*
6 to <12 months	562	467	44	105	426	710	971	1,147	1,586*
1 to <2 years	916	308	43	107	229	428	674	893	1,248*
2 to <3 years	934	356	49	126	281	510	700	912	1,388*
3 to <6 years	3,960	417	57	146	336	581	867	1,099	1,684
6 to <11 years	1,555	480	74	177	373	682	994	1,251	2,024*
11 to <16 years	937	652	106	236	487	873	1,432	1,744	2,589*
16 to <18 years	341	792	106	266	591	987	1,647	2,002*	3,804*
18 to <21 years	364	895	114	295	674	1,174	1,860	2,565*	3,917*

[a] Excludes individuals who did not ingest water from the source during the survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-15. Consumers Only[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Bottled Water (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	25	-	-	-	-	-	-	-	-
1 to <3 months	64	450*	31*	62*	329*	743*	886*	1,045*	1,562*
3 to <6 months	103	507	48*	88	493	747	1,041*	1,436*	1,506*
6 to <12 months	200	425	47	114	353	630	945*	1,103*	1,413*
1 to <2 years	229	262	45	88	188	324	600	709*	1,083*
2 to <3 years	232	352	57	116	241	471	736	977*	1,665*
3 to <6 years	1,021	380	72	149	291	502	796	958	1,635*
6 to <11 years	332	430	88	168	350	557	850	1,081*	1,823*
11 to <16 years	192	570	116*	229	414	719	1,162*	1,447*	2,705*
16 to <18 years	63	615*	85*	198*	446*	779*	1,365*	1,613*	2,639*
18 to <21 years	97	769	118*	236	439	943	1,788*	2,343*	3,957*

[a] Excludes individuals who did not ingest water from the source during the survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
\- Insufficient sample size to estimate mean and percentiles.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-16. Consumers Only[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: Other Sources (mL/day)

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	3	-	-	-	-	-	-	-	-
1 to <3 months	19	-	-	-	-	-	-	-	-
3 to <6 months	38	562*	59*	179*	412*	739*	983*	1,205*	2,264*
6 to <12 months	73	407*	31*	121*	300*	563*	961*	1,032*	1,144*
1 to <2 years	98	262	18*	65	143	371	602*	899*	1,204*
2 to <3 years	129	354	56*	134	318	472	704*	851*	1,334*
3 to <6 years	533	396	59	148	314	546	796	1,019	1,543*
6 to <11 years	219	448	89	177	347	682	931	1,090*	1,596*
11 to <16 years	151	687	171*	296	482	947	1,356*	1,839*	2,891*
16 to <18 years	53	657*	152*	231*	398*	823*	1,628*	1,887*	2,635*
18 to <21 years	33	569*	103*	142*	371*	806*	1,160*	1,959*	1,962*

a Excludes individuals who did not ingest water from the source during the survey period.
b Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
\- Insufficient sample size to estimate means and percentiles.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-17. Consumers Only[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: All Sources (mL/day)

Age	Sample size	Mean	Percentiles 10	25	50	75	90	95	99
Birth to <1 month	58	511*	51*	266*	520*	713*	858*	986*	1,274*
1 to <3 months	178	555	68*	275	545	801	946*	1,072*	1,470*
3 to <6 months	363	629	69	384	612	851	1,064	1,330*	1,522*
6 to <12 months	667	567	90	250	551	784	1,050	1,303	1,692*
1 to <2 years	1,017	366	84	159	294	481	735	978	1,281*
2 to <3 years	1,051	439	105	213	375	589	825	1,001	1,663*
3 to <6 years	4,350	518	134	255	442	682	980	1,206	1,796
6 to <11 years	1,659	603	177	310	506	805	1,131	1,409	2,168*
11 to <16 years	1,000	837	229	404	665	1,105	1,649	1,961	3,184*
16 to <18 years	357	983	252	395	754	1,276	1,865	2,346*	3,866*
18 to <21 years	383	1,094	219	424	823	1,397	2,144	3,002*	4,967*

a Excludes individuals who did not ingest water from the source during the survey period.
b Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-18. Consumers Only[a] Estimates of Combined Direct and Indirect[b] Water Ingestion: All Sources (mL/day)

Age	Sample size	Mean			90th percentile			95th percentile		
			90% C.I.			90% B.I.			90% B.I.	
		Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Birth to <1 month	58	511*	417*	606*	858*	856*	993*	986*	974*	1,076*
1 to <3 months	178	555	487	622	946*	891*	1,042*	1,072*	1,022*	1,183*
3 to <6 months	363	629	587	672	1,064	1,011	1,177	1,330*	1,183*	1,431*
6 to <12 months	667	567	534	600	1,050	1,001	1,141	1,303	1,181	1,372
1 to <2 years	1,017	366	346	385	735	715	765	978	915	1,001
2 to <3 years	1,051	439	420	457	825	784	857	1,001	944	1,075
3 to <6 years	4,350	518	499	537	980	961	1,000	1,206	1,171	1,253
6 to <11 years	1,659	603	574	632	1,131	1,075	1,162	1,409	1,336	1,468
11 to <16 years	1,000	837	773	901	1,649	1,568	1,749	1,961	1,873	2,104
16 to <18 years	357	983	896	1,071	1,865	1,774	1,982	2,346*	2,129*	2,599*
18 to <21 years	383	1,094	999	1,189	2,144	1,951	2,299	3,002*	2,576*	3,785*

[a] Excludes individuals who did not ingest water from the source during the survey period.

[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.

* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

CI = Confidence Interval.

BI = Bootstrap Interval.

Source: Kahn and Stralka, 2008 .

Table 3-19. Consumers Only[a] Estimates of Direct and Indirect[b] Water Ingestion: Community Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	37	137*	11*	65*	138*	197*	235*	238*	263*
1 to <3 months	108	119	12*	71	107	151	228*	285*	345*
3 to <6 months	269	80	7	27	77	118	148	173*	222*
6 to <12 months	534	53	5	12	47	81	112	129	186*
1 to <2 years	880	27	4	9	20	36	56	75	109*
2 to <3 years	879	26	4	9	21	36	52	62	121*
3 to <6 years	3,703	24	3	8	19	33	49	65	97
6 to <11 years	1,439	17	3	6	13	23	35	45	72*
11 to <16 years	911	13	2	5	10	17	26	34	54*
16 to <18 years	339	12	1	4	9	16	24	32*	58*
18 to <21 years	361	13	2	5	10	17	29	35*	63*

[a] Excludes individuals who did not ingest water from the source during the survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source Kahn and Stralka, 2008 and supplementary data.

Table 3-20. Consumers Only[a] Estimates of Direct and Indirect[b] Water Ingestion: Bottled Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	25	-	-	-	-	-	-	-	-
1 to <3 months	64	92*	7*	12*	76*	151*	164*	220*	411*
3 to <6 months	95	72	6*	15	69	100	149*	184*	213*
6 to <12 months	185	47	5*	11	34	73	104*	120*	166*
1 to <2 years	216	22	5	8	16	27	49	66*	103*
2 to <3 years	211	25	4	8	17	35	54	81*	91*
3 to <6 years	946	21	4	8	16	29	45	57	90*
6 to <11 years	295	15	3	5	11	19	30	42*	69*
11 to <16 years	180	11	2*	4	8	14	24*	27*	44*
16 to <18 years	63	10*	1*	3*	7*	11*	23*	27*	37*
18 to <21 years	93	11	2*	3	6	14	27*	30*	54*

[a] Excludes individuals who did not ingest water from the source during the survey period.
[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
\- Insufficient sample size to estimate means and percentiles.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-21. Consumers Only[a] Estimates of Direct and Indirect[b] Water Ingestion: Other Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	3	-	-	-	-	-	-	-	-
1 to <3 months	19	-	-	-	-	-	-	-	-
3 to <6 months	38	80*	10*	23*	59*	106*	170*	200*	246*
6 to <12 months	68	44*	4*	10*	33*	65*	95*	106*	147*
1 to <2 years	95	23	1*	5	13	28	46*	84*	125*
2 to <3 years	124	26	4*	10	21	34	55*	66*	114*
3 to <6 years	505	22	3	8	17	30	46	56	79*
6 to <11 years	208	16	3	6	12	23	32	39*	62*
11 to <16 years	148	13	3*	6	9	18	27*	36*	56*
16 to <18 years	52	10*	2*	4*	7*	12*	24*	29*	43*
18 to <21 years	33	8*	1*	2*	6*	10*	16*	27*	31*

a Excludes individuals who did not ingest water from the source during the survey period.
b Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
- Means insufficient sample size to estimate distribution percentiles.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source Kahn and Stralka, 2008 and supplementary data.

Table 3-22. Consumers Only[a] Estimates of Direct and Indirect[b] Water Ingestion: All Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	55	153*	13*	83*	142*	208*	269*	273*	400*
1 to <3 months	172	116	12*	50	107	161	216*	291*	361*
3 to <6 months	346	90	9	52	86	125	161	195*	233*
6 to <12 months	631	63	10	27	58	88	120	152	198*
1 to <2 years	980	31	7	14	25	40	64	86	122*
2 to <3 years	989	31	7	15	27	41	59	73	130*
3 to <6 years	4,072	29	7	15	25	38	56	70	102*
6 to <11 years	1,542	21	6	10	18	27	39	50	76*
11 to <16 years	970	16	4	8	13	20	31	39	60*
16 to <18 years	354	15	4	7	12	18	29	37*	60*
18 to <21 years	378	16	3	6	12	21	32	41*	73*

a Excludes individuals who did not ingest water from the source during the survey period.
b Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.
* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source Kahn and Stralka, 2008 and supplementary data.

Table 3-23. Consumer Only[a] Estimates of Total Direct and Indirect[b] Water Ingestion (mL/kg-day)

Age	Sample size	Mean			90th percentile			95th percentile		
			90% C.I.			90% B.I.			90% B.I.	
		Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound
Birth to <1 month	55	153*	125*	181*	269*	234*	273*	273*	263*	332*
1 to <3 months	172	116	100	132	216*	176*	259*	291*	214*	316*
3 to <6 months	346	90	83	97	161	145	178	195*	174*	212*
6 to <12 months	631	63	59	67	120	117	127	152	137	166
1 to <2 years	980	31	30	33	64	57	67	86	70	89
2 to <3 years	989	31	30	33	59	56	61	73	67	81
3 to <6 years	4,072	29	28	30	56	54	57	70	67	73
6 to <11 years	1,542	21	20	22	39	37	41	50	46	52
11 to <16 years	970	16	15	17	31	29	33	39	38	42
16 to <18 years	354	15	14	16	29	27	32	37*	33v	44*
18 to <21 years	378	16	15	18	32	29	35	41*	36*	56*

[a] Excludes individuals who did not ingest water from the source during the survey period.

[b] Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.

* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

CI = Confidence Interval.

BI = Bootstrap Interval.

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-24. Water Ingested (mL/day)[a] from Water By Itself and Water Added to Other Beverages and Foods

Category		6 Weeks (N = 124)	3 Months (N = 120)	6 Months (N = 99)	9 Months (N = 77)
Water by Itself	Range	0-355	0-355	0-266	0-473
	Per capita mean[b] ± SD	30 ± 89	30 ± 59	30 ± 59	89 ± 89
	Consumer only mean[c]	89	89	118	118
	Percent consuming[d]	28	24	42	66
Water Added to Formula Powdered Concentrate	Range	0-1,242	0-1,242	0-1,124	0-1,064
	Per capita mean ± SD	177 ± 296	266 ± 384	266 ± 355	207 ± 325
	Consumer only mean	473	621	562	562
	Percent consuming	39	42	48	36
Liquid Concentrate	Range	0-621	0-680	0-710	0-532
	Per capita mean ± SD	89 ±148	237 ± 207	148 ± 207	59 ± 148
	Consumer only mean	355	384	414	325
	Percent consuming	23	30	35	21
All Concentrated Formula	Range	0-1,242	0-1,242	0-1,123	0-1,064
	Per capita mean ± SD	266 ± 296	384 ± 355	414 ± 325	266 ± 296
	Consumer only mean	444	562	532	503
	Percent consuming	60	68	81	56
Water Added to Juices and Other Beverages	Range	0-118	0-710	0-473	0-887
	Per capita mean ± SD	<30 ± 30	30 ± 89	30 ± 89	59 ± 148
	Consumer only mean	89	207	148	207
	Percent consuming	3	9	18	32
Water Added to Powdered Baby Foods and Cereals	Range	0-30	0-177	0-266	0-177
	Per capita mean ± SD	<30 ± 30	<30 ± 30	59 ± 59	30 ± 59
	Consumer only mean	30	59	89	89
	Percent consuming	2	17	64	43
Water Added to Other Foods (Soups, Jell-o, Puddings)	Range	-	0-118	0-118	0-355
	Per capita mean ± SD	-	30 ± 30	<30 ± 30	30 ± 59
	Consumer only mean	-	89	59	118
	Percent consuming	0	2	8	29
ALL SOURCES OF WATER	Range	0-1,242	0-1,419	0-1,123	0-1,745
	Per capita mean ± SD	296 ± 325	414 ± 414	473 ± 325	444 ± 355
	Consumer only mean	414	562	503	473
	Percent consuming	68	77	94	97

a Converted from ounces/day; 1 fluid ounce = 29.57 mL.
b Mean intake among entire sample.
c Mean intake for only those ingesting water from the particular category.
d Percentage of infants receiving water from that individual source.
N = Number of observations.
SD = Standard Deviation.

Source: Levy et al., 1995.

Table 3-25. Mean Water Consumption (mL/kg-day) by Race/Ethnicity

Race/Ethnic Group	N	Plain Tap Water	Milk and Milk Drinks	Reconstituted Formula	RTF Formula	Baby Food	Juices and Carbonated Drinks	Non-carbonated Drinks	Other	Total[a]
Black non-Hispanic	121	21 (1.7)	24 (4.6)	35 (6.0)	4 (2.0)	8 (1.6)	2 (0.7)	14 (1.3)	21 (1.7)	129 (5.7)
White non-Hispanic	620	13 (0.8)	23 (1.2)	29 (2.7)	8 (1.5)	10 (1.2)	1 (0.2)	11 (0.7)	18 (0.8)	113 (2.6)
Hispanic	146	15 (1.2)	23 (2.4)	38 (7.3)	12 (4.0)	10 (1.4)	1 (0.3)	10 (1.6)	16 (1.4)	123 (5.2)
Other	59	21 (2.4)	19 (3.7)	31 (9.1)	19 (11.2)	7 (4.0)	1 (0.5)	8 (2.0)	19 (3.2)	124 (10.6)

[a] Totals may be slightly different from the sums of all categories due to rounding.
N = Number of observations.
RTF = Ready-to-Feed.
Note: Standard Error shown in parentheses.

Source: Heller et al., 2000.

Table 3-26. Plain Tap Water and Total Water Consumption by Age, Sex, Region, Urbanicity, and Poverty Category

		Plain Tap Water (mL/kg-day)		Total Water (mL/kg-day)	
Variable	N	Mean	SE	Mean	SE
Age					
<12 months	296	11	1.0	130	4.6
12-24 months	650	18	0.8	108	1.7
Sex					
Male	475	15	1.0	116	4.1
Female	471	15	0.8	119	3.2
Region					
Northeast	175	13	1.4	121	6.3
Midwest	197	14	1.0	120	3.1
South	352	15	1.3	113	3.7
West	222	17	1.1	119	4.6
Urbanicity					
Urban	305	16	1.5	123	3.5
Suburban	446	13	0.9	117	3.1
Rural	195	15	1.2	109	3.9
Poverty category[a]					
0-1.30	289	19	1.5	128	2.6
1.31-3.50	424	14	1.0	117	4.2
>3.50	233	12	1.3	109	3.5
Total	946	15	0.6	118	2.3

[a] Poverty category represents family's annual incomes of 0-1.30, 1.31-3.50, and greater than 3.50 times the federal poverty level.

N = Number of observations.

SE = Standard Error.

Source: Heller et al., 2000.

Table 3-27. Intake of Water from Various Sources in 2-13-y-old Participants of the DONALD Study 1985-1999

Water Intake from:	Boys and girls 2-3 years N = 858[b]	Boys and girls 4-8 years N = 1,795[b]	Boys 9-13 years N = 541[b]	Girls 9-13 years N = 542[b]
	Mean			
Water in Food (mL/day)[a]	365 (33)[c]	487 (36)	673 (36)	634 (38)
Beverages (mL/day)[a]	614 (55)	693 (51)	969 (51)	823 (49)
Milk (mL/day)[a]	191 (17)	177 (13)	203 (11)	144 (9)
Mineral water (mL/day)[a]	130 (12)	179 (13)	282 (15)	242 (15)
Tap water (mL/day)[a]	45 (4)	36 (3)	62 (3)	56 (3)
Juice (mL/day)[a]	114 (10)	122 (0)	133 (7)	138 (8)
Soft drinks (mL/day)[a]	57 (5)	111 (8)	203 (11)	155 (9)
Coffee/tea (mL/day)[a]	77 (7)	69 (5)	87 (4)	87 (5)
	Mean ± SD			
Total water intake[a,d] (mL/day)	1,114 ± 289	1,363 ± 333	1,891 ± 428	1,676 ± 386
Total water intake[a,d] (mL/kg-day)	78 ± 22	61 ± 13	49 ± 11	43 ± 10
Total water intake[a,d] (mL/kcal-day)	1.1 ± 0.3	0.9 ± 0.2	1.0 ± 0.2	1.0 ± 0.2

[a] Converted from g/day, g/kg-day, or g/kcal-day; 1 g = 1 mL.
[b] N = Number of records.
[c] Percent of total water shown in parentheses.
[d] Total water = water in food + beverages + oxidation.
SD = Standard deviation.

Source: Sichert-Hellert et al., 2001.

Table 3-28. Mean (± Standard Error) Fluid Intake (mL/kg/day) by Children Aged 1-10 years, NHANES III, 1988-94

	Total Sample (N = 7,925)	Sample with Temperature Information (N = 3,869)	Sample without Temperature Information (N = 4,056)
Total fluid	84 ± 1.0	84 ± 1.0	85 ± 1.4
Plain water	27 ± 0.8	27 ± 1.0	26 ± 1.1
Milk	18 ± 0.3	18 ± 0.6	18 ± 0.4
Carbonated drinks	6 ± 0.2	5 ± 0.3	6 ± 0.3
Juice	12 ± 0.3	11 ± 0.6	12 ± 0.4

N = Number of observations.

Source: Sohn et al., 2001.

Table 3-29. Estimated Mean (± Standard Error) Amount of Total Fluid and Plain Water Intake among Children[a] Aged 1-10 Years: (NHANES III, 1988-94)

	N	Total Fluid		Plain Water	
		mL/day	mL/kg-day	mL/day	mL/kg-day
Age (years)					
1	578	1,393 ± 31	124 ± 2.9	298 ± 19	26 ± 1.8
2	579	1,446 ± 31	107 ± 2.3	430 ± 26	32 ± 1.9
3	502	1,548 ± 75	100 ± 4.6	482.± 27	31 ± 1.8
4	511	1,601 ± 41	91 ± 2.8	517 ± 23	29 ± 1.3
5	465	1,670 ± 54	84 ± 2.3	525 ± 36	26 ± 1.7
6	255	1,855 ± 125	81 ± 4.9	718 ± 118	31 ± 4.7
7	235	1,808 ± 66	71 ± 2.3	674 ± 46	26 ± 1.9
8	247	1,792 ± 37	61 ± 1.8	626 ± 37	21 ± 1.2
9	254	2,113 ± 78	65 ± 2.1	878 ± 59	26 ± 1.4
10	243	2,051 ± 97	58 ± 2.4	867 ± 74	24 ± 2.0
Sex					
Male	1,974	1,802 ± 30	86 ± 1.8	636 ± 32	29 ± 1.3
Female	1,895	1,664 ± 24	81 ± 1.5	579 ± 26	26 ± 1.0
Race/ethnicity					
White	736	1,653 ± 26	79 ± 1.8	552 ± 34	24 ± 1.3
African American	1,122	1,859 ± 42	88 ± 1.8	795 ± 36	36 ± 1.5
Mexican American	1,728	1,817 ± 25	89 ± 1.7	633 ± 23	29 ± 1.1
Other	283	1,813 ± 47	90 ± 4.2	565 ± 39	26 ± 1.7
Poverty income ratio[b]					
Low	1,868	1,828 ± 32	93 ± 2.6	662 ± 27	32 ± 1.3
Medium	1,204	1,690 ± 31	80 ± 1.6	604 ± 35	26 ± 1.4
High	379	1,668 ± 54	76 ± 2.5	533 ± 41	22 ± 1.7
Region[c,d]					
Northeast	679	1,735 ± 31	87 ± 2.3	568 ± 52	26 ± 2.1
Midwest	699	1,734 ± 45	84 ± 1.5	640 ± 54	29 ± 1.8
South	869	1,739 ± 31	83 ± 2.2	613 ± 24	28 ± 1.3
West	1,622	737 ± 25	81 ± 1.7	624 ± 44	27 ± 1.9
Urban/rural[d]					
Urban	3,358	1,736 ± 18	84 ± 1.0	609 ± 29	27 ± 1.1
Rural	511	1,737 ± 19	84 ± 4.3	608 ± 20	28 ± 1.2
Total	3,869	1,737 ± 15	84 ± 1.1	609 ± 24	27 ± 1.0

[a] Children for whom temperature data were obtained.

[b] Based on ratio of household income to federal poverty threshold. Low: ≤1.300; medium: 1.301-3.500; high ≥3.501.

[c] All variables except for Region and Urban/rural showed statistically significant differences for both total fluid and plain water intake by Bonferroni multiple comparison method.

[d] Northeast = Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont;
Midwest = Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin;
South = Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia;
West = Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming.

N = Number of observations.

Source: Sohn et al., 2001.

Table 3-30. Tap Water Intake in Breastfed and Formula-fed Infants and Mixed-fed Young Children at Different Age Points

Age	N[a]	Tap water intake[b] (mL/day)					Tap water intake[b] (mL/kg-day)											
		Total					Total						From Household[c]			From Manufacturing[d]		
		Mean	SD	Median	P95	Max	Mean	SD	Median	P95	Max	%[e]	Mean	SD	%[f]	Mean	SD	%[f]
Breastfed																		
≤1 year, total	30	130	180	50	525	1,172	17	24**	6	65	150	17	15	23**	85	2.4	4.7**	15
3 months	11	67	167	0	493	746	10	25**	0	74	125	10	10	25**	97	0.3	1.9**	3
6 months	12	136	150	68	479	634	18	20**	8	5`8	85	18	14	19**	79	3.8	6.3*	21
9 months	47	254	218	207	656	1,172	30	27**	23	77	150	28	26	27**	87	3.7	3.4	13
12 months	18	144	170	85	649	649	15	18**	9	66	66	19	13	18**	86	2.2	2.1	14
Formula fed																		
≤1 year, total	75	441	244	440	828	1,603	53	33	49	115	200	51	49	33	92	4.0	8.0	8
3 months	78	662	154	673	874	994	107	23	107	147	159	93	103	28	97	3.4	17.9	3
6 months	14	500	178	519	757	888	63	23	65	99	109	64	59	25	92	4.8	8.0	8
9 months	24	434	236	406	839	1,579	49	27	45	94	200	50	44	27	91	4.5	6.3	9
12 months	29	360	256	335	789	1,603	37	26	32	83	175	39	33	25	91	3.3	3.7	9
Mixed - Breast and Formula																		
1-3 years, total	90	241	243	175	676	2,441	19	20	14	56	203	24	15	20	78	3.9	5.5	22
18 months	27	280	264	205	828	1,881	25	23	18	70	183	28	22	23	88	3.0	4.1	12
24 months	29	232	263	158	630	2,441	18	21	12	49	203	23	15	21	80	3.7	5.0	20
36 months	33	217	199	164	578	1,544	14	13	11	36	103	22	9	12	66	4.9	6.6	34

[a] Numbers of 3-day diet records.
[b] Total tap water = tap water from the household and tap water from food manufacturing. Converted from g/day and g/kg-day; 1 g = 1 mL.
[c] Tap water from household = tap water from the household tap consumed directly as a beverage or used to prepare foods and beverages.
[d] Tap water from food = manufacturing tap water from the industrial food production used for the preparation of foods (bread, butter/margarine, tinned fruit, vegetables and legumes, ready to serve meals, commercial weaning food) and mixed beverages (lemonade, soft drinks).
[e] Mean as a percentage of total water.
[f] Mean as a percentage of total tap water.
* Significantly different from formula-fed infants, $p<0.05$.
** Significantly different from formula-fed infants, $p<0.0001$.
SD = Standard Deviation.
P95 = 95th percentile.

Source: Hilbig et al., 2002.

Table 3-31. Percentage of Subjects Consuming Beverages and Mean Daily Beverage Intakes (mL/day) for Children With Returned Questionnaires

Age at Questionnaire	6 Months	9 Months	12 Months	16 Months	20 Months	24 Months	6-24 Months[a]
Actual Age (Months)	6.29 ± 0.35	9.28 ± 0.35	12.36 ± 0.46	16.31 ± 0.49	20.46 ± 0.57	24.41 ± 0.53	-
N[b]	677	681	659	641	632	605	585[c]
Human Milk[d]	30	19	11	5	3	0	-
Infant Formula[e]							
%[d]	68	69	29	4	2	0	67[g]
mL/day[f]	798 ± 234	615 ± 328	160 ± 275	12 ± 77	9 ± 83	-	207 ± 112
Cows' Milk[e]							
%[d]	5	25	79	91	93	97	67[g]
mL/day[f]	30 ± 145	136 ± 278	470 ± 310	467 ± 251	402 ± 237	358 ± 225	355 ± 163
Formula and Cows' Milk[e]							
%[d]	70	81	88	92	94	98	67[g]
mL/day[f]	828 ± 186	751 ± 213	630 ± 245	479 ± 248	411 ± 237	358 ± 228	562 ± 154
Juice and Juice Drinks							
%[d]	55	73	89	94	95	93	99[h]
mL/day[f]	65 ± 95	103 ± 112	169 ± 151	228 ± 166	269 ± 189	228 ± 172	183 ± 103
Water							
%[d]	36	59	75	87	90	94	99[h]
mL/day[f]	27 ± 47	53 ± 71	92 ± 109	124 ± 118	142 ± 127	145 ± 148	109 ± 74
Other Beverages[i]							
%[d]	1	9	23	42	62	86	80[h]
mL/day[f]	3 ± 18	6 ± 27	27 ± 71	53 ± 109	83 ±121	89 ± 133	44 ± 59
Total Beverages mL/day[e,f,j]	934 ± 219	917 ± 245	926 ± 293	887 ± 310	908 ± 310	819 ± 299	920 ± 207

[a] Cumulative number of children and percentage of children consuming beverage and beverage intakes for the 6 through 24 month period.
[b] Number of children with returned questionnaires at each time period.
[c] Number of children with cumulative intakes for six-through 24 month period.
[d] Percentage of children consuming beverage.
[e] Children are not included when consuming human milk.
[f] Mean ± standard deviation of beverage intake. Converted from ounces/day; 1 fluid ounce = 29.57 mL.
[g] Percentage of children consuming beverage during six-through 24 month period. Children who consumed human milk are not included.
[h] Percentage of children consuming beverage during six-through 24 month period.
[i] Other beverages include non juice beverages (e.g., carbonated beverages, Kool-Aid).
[j] Total beverages includes all beverages except human milk.

Source: Marshall et al., 2003a.

Table 3-32. Mean (± Standard Deviation) Daily Beverage Intakes Reported on Beverage Frequency Questionnaire and 3-day Food and Beverage Dairies

Beverage	Age											
	6 months (N = 240)			12 months (N = 192)			3 years (N = 129)			5 years (N = 112)		
	Questionnaire	Diary		Questionnaire	Diary		Questionnaire	Diary		Questionnaire	Diary	
	mL/day[a]		%[b]	mL/day[a]		%[b]	mL/day[a]		%[b]	mL/day[a]		%[b]
Human Milk	204 ± 373	195 ± 358	28.0	9 ± 21	56 ± 225	12.6	NA[c]	NA	-	NA	NA	-
Infant formula	609 ± 387	603 ± 364	85.8	180 ± 290	139 ± 251	37.0	NA	NA	-	NA	NA	-
Cow's milk	24 ± 124	24 ±124	6.7	429 ± 349	408 ± 331	90.4	316 ± 216	358 ± 216	100	319 ± 198	325 ± 177	98.2
Juice/juice drinks	56 ± 124	33 ± 59	57.5	151 ± 136	106 ± 101	92.2	192 ± 169	198 ± 169	96.9	189 ± 169	180 ± 163	95.5
Liquid soft drinks	6 ± 68	0 ± 0	1.3	9 ± 30	3 ± 15	20.9	62 ± 71	74 ± 101	74.2	74 ± 95	101 ± 121	82.1
Powdered soft drinks	0 ± 18	0 ± 0	0.4	12 ± 47	3 ± 18	10.5	62 ± 115	47 ± 101	51.2	74 ± 124	47 ± 95	52.7
Water	44 ± 80	30 ± 53	61.7	127 ± 136	80 ± 109	84.9	177 ± 204	136 ± 177	95.3	240 ± 242	169 ± 183	99.1
Total	940 ± 319	896 ± 195	100	905 ± 387	804 ± 284	100	795 ± 355	816 ± 299	100	896 ± 399	819 ± 302	100

[a] Mean ± standard deviation of all subjects. Converted from ounces/day; 1 fluid ounce = 29.57 mL.
[b] Percent of subjects consuming beverage on either questionnaire or diary.
[c] NA = not applicable.
N = Number of observations.

Source: Marshall et al., 2003b.

Table 3-33. Consumption of Beverages by Infants and Toddlers (Feeding Infants and Toddlers Study)

Beverage category	Age (months)											
	4-6 (N = 862)		7-8 (N = 483)		9-11 (N = 679)		12-14 (N = 374)		15-18 (N = 308)		19-24 (N = 316)	
	Consumers %[a]	Mean ± SD mL/day[b]	Consumers %[a]	Mean ± SD mL/day[b]	Consumers %[a]	Mean ± SD mL/day[b]	Consumers %[a]	Mean ± SD mL/day[b]	Consumers %[a]	Mean ± SD mL/day[b]	Consumers %[a]	Mean ± SD mL/day[b]
Total milks[c]	100	778 ± 257	100	692 ± 257	99.7	659 ± 284	98.2	618 ± 293	94.2	580 ± 305	93.4	532 ± 281
100% juice[d]	21.3	121 ± 89	45.6	145 ± 109	55.3	160 ± 127	56.2	186 ± 145	57.8	275 ± 189	61.6	281 ± 189
Fruit drinks[e]	1.6	101 ± 77	7.1	98 ± 77	12.4	157 ± 139	29.1	231 ± 186	38.6	260 ± 231	42.6	305 ± 308
Carbonated	0.1	86 ± 0	1.1	6 ± 9	1.7	89 ± 92	4.5	115 ± 83	11.2	157 ± 106	11.9	163 ± 172
Water	33.7	163 ± 231	56.1	174 ± 219	66.9	210 ± 234	72.2	302 ± 316	74.0	313 ± 260	77.0	337 ± 245
Other[f]	1.4	201 ± 192	2.2	201± 219	3.5	169 ± 166	6.6	251 ± 378	12.2	198 ± 231	11.2	166 ± 248
Total beverages	100	863 ± 254	100	866 ± 310	100	911 ± 361	100	1,017 ± 399	100	1,079 ± 399	100	1,097 ± 482

a Weighted percentages, adjusted for over sampling, nonresponse, and under representation of some racial and ethnic groups.
b Amounts consumed only by those children who had a beverage from this beverage category. Converted from ounces/day; 1 fluid ounce = 29.57 mL.
c Includes human milk, infant formula, cow's milk, soy milk, and goat's milk.
d Fruit or vegetable juices with no added sweeteners.
e Includes beverages with less than 100% juice and often with added sweeteners; some were fortified with one or more nutrients.
f "Other" beverages category included tea, cocoa and similar dry milk beverages, and electrolyte replacement beverages for infants.
N = Number of observations.
SD = Standard deviation.

Source: Skinner et al., 2004.

Table 3-34. Pool Water Ingestion by Swimmers

Study Group	Number of Participants	Average Water Ingestion Rate (mL/45-minute interval)	Average Water Ingestion Rate (mL/hour)[a]
Children <16 years old	41	37	49
Males <16 years old	20	45	60
Females <16 years old	21	30	43
Adults (>18 Years)	12	16	21
Men	4	22	29
Women	8	12	16

[a] Converted from mL/45 minute interval.

Source: Dufour et al., 2006.

4 NON-DIETARY INGESTION FACTORS

4.1 INTRODUCTION

Young children have the potential for exposure to toxic substances through non-dietary ingestion pathways other than soil and dust ingestion (e.g., ingesting pesticide residues that have been transferred from treated surfaces to the hands or objects that are mouthed). Young children mouth objects or their fingers as they explore their environment. Mouthing behavior includes all activities in which objects, including fingers, are touched by the mouth or put into the mouth except for eating and drinking, and includes licking, sucking, chewing, and biting (Groot et al., 1998). Videotaped observations of children's mouthing behavior demonstrate the intermittent nature of hand to mouth and object to mouth behaviors in terms of the number of contacts recorded per unit of time (e.g., Ko et al., 2007).

In a large non-random sample of children born in Iowa, non-nutritive sucking behaviors were reported by parents to be very common in infancy, and to continue for a substantial proportion of children up to the third and fourth birthdays (Warren et al., 2000). Hand to mouth behavior has been observed in both pre-term and full term infants (Rochat et al., 1988, Blass et al., 1989, Takaya et al., 2003). Infants are born with a sucking reflex for breast feeding, and within a few months, they begin to use sucking or mouthing as a means to explore their surroundings. Sucking also becomes a means of comfort when a child is tired or upset. In addition, teething normally causes substantial mouthing behavior (i.e., sucking or chewing) to alleviate discomfort in the gums (Groot et al., 1998). Children's mouthing behavior can potentially result in ingestion of toxic substances (Lepow et al., 1975).

There are three general approaches to gather data on children's mouthing behavior: real-time hand recording, in which trained observers manually record information (e.g., Davis et al., 1995); video-transcription, in which trained videographers tape a child's activities and subsequently extract the pertinent data manually or with computer software (e.g., Black et al., 2005); and questionnaire, or survey response, techniques (e.g., Stanek et al., 1998). With real-time hand recording, observations made by trained professionals (rather than parents) may offer the advantage of consistency in interpreting visible behaviors and may be less subjective than observations made by someone who maintains a care giving relationship to the child. On the other hand, young children's behavior may be influenced by the presence of unfamiliar people (e.g., Davis et al., 1995). Groot et al. (1998) indicated that parent observers perceived that deviating from their usual care giving behavior by observing and recording mouthing behavior appeared to have influenced the children's behavior. With video-transcription methodology, an assumption is made that the presence of the videographer or camera does not influence the child's behavior. This assumption may result in minimal biases introduced when filming newborns, or when the camera and videographer are not visible to the child. However, if the children being studied are older than newborns and can see the camera or videographer, biases may be introduced. Ferguson et al. (2006) described apprehension caused by videotaping and described situations where a child's awareness of the videotaping crew caused "play-acting" to occur, or parents indicated that the child was behaving differently during the taping session. Another possible source of measurement error may be introduced when children's movements or positions cause their mouthing not to be captured by the camera. Data transcription errors can bias results in either the negative or positive direction. Finally, measurement error can occur if situations arise in which care givers are absent during videotaping and researchers must stop videotaping and intervene to prevent risky behaviors (Zartarian et al., 1995). Survey response studies rely on responses to questions about a child's mouthing behavior posed to parents or care givers. Measurement errors from these studies could occur for a number of different reasons, including language/dialect differences between interviewers and respondents, question wording problems and lack of definitions for terms used in questions, differences in respondents' interpretation of questions, and recall/memory effects.

Some researchers express mouthing behavior as the frequency of occurrence (e.g., contacts per hour or contacts per minute). Others describe the duration of specific mouthing events, expressed in units of seconds or minutes. This handbook does not address issues related to contaminant transfer from thumbs, fingers, or objects or surfaces, into the mouth, and subsequent ingestion. The recommendations for mouthing frequency and duration are provided in Section 4.2, along with a summary of the confidence ratings for these recommendations. The recommended values are based on key studies identified by U.S. EPA for this factor. Although some studies in sections 4.3.1 and 4.4.1 are classified as key, they were not directly used to provide the recommendations. They are included as key because they were used by Xue et al., 2007 in a meta analysis, which is the primary source of the recommendations provided in this chapter for hand-to-mouth frequency. Following the recommendations, key and relevant studies on mouthing frequency (section 4.3) and duration (section 4.4) are summarized and the methodologies used in the key and relevant studies are described. Information on the prevalence of mouthing behavior is presented in Section 4.5.

4.2 RECOMMENDATIONS

The key studies described in Section 4.3 and Section 4.4 were used to develop recommended values for mouthing frequency and duration, respectively, among children. In several cases, key studies pre-dated the recommendations on age groups in U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005), and were performed on groups of children of varying ages. For cases in which age groups of children in the key studies did not correspond exactly to U.S. EPA's recommended age groups, the closest age group was used.

Table 4-1 shows recommended mouthing frequencies, expressed in units of contacts per hour, between either any part of the hand (including fingers and thumbs) and the mouth, or between an object or surface and the mouth. The recommended hand-to-mouth frequencies are based on data from Xue et al. (2007). Xue et al. (2007) conducted a secondary analysis of data from several of the studies summarized in this chapter, as well as data from unpublished studies. Xue et al. 2007, provided data for the age groups of interest to U.S. EPA and categorized the data according to indoor and outdoor contacts. The recommendations for frequency of object-to-mouth contact are based on data from Reed et al., (1999), Freeman et al., (2001), Tulve et al., (2002), AuYeung et al., (2004), and Black et al., 2005. Recommendations for duration of object-to-mouth are based on data from Juberg et al., (2001) and Greene, (2002). Recommendations for hand-to-mouth duration are not provided since those estimates may not be relevant to environmental exposures. Table 4-2 presents the confidence ratings for the recommended values. The overall confidence rating is low for both frequency and duration of hand-to-mouth and object-to-mouth.

Table 4-1. Summary of Recommended Values for Mouthing Frequency and Duration

Age Group	Hand-to-Mouth				Source
	Indoor Frequency (contacts/hour)		Outdoor Frequency (contacts/hour)		
	Mean	95^{th} Percentiile	Mean	95^{th} Percentile	
Birth to <1 month	-	-	-	-	Xue et al., 2007
1 to <3 months	-	-	-	-	
3 to <6 months	28	65	-	-	
6 to <12 months	19	52	15	47	
1 to <2 years	20	63	14	42	
2 to <3 years	13	37	5	20	
3 to <6 years	15	54	9	36	
6 to <11 years	7	21	3	12	
11 to <16 years	-	-	-	-	
16 to <21 years	-	-	-	-	
	Object-to-mouth				
	Mean Frequency (contacts/hour)		95^{th} Percentile Frequency (contacts/hour)		
Birth to <1 month	-		-		Reed et al., 1999; Freeman et al., 2001; Tulve et al., 2002; AuYeung et al., 2004; and Black et al., 2005.
1 to <3 months	-		-		
3 to <6 months	-		-		
6 to <12 months	24[a]		-		
1 to <2 years	20[b]		-		
2 to <3 years	10[c]		-		
3 to <6 years	10[c]		-		
6 to <11 years	1[d]		-		
11 to <16 years	-		-		
16 to <21 years	-		-		
	Mean Duration (minutes/hour)		95^{th} Percentile Duration (minutes/hour)		
Birth to <1 month	-		-		Juberg et al., 2001 and Greene, 2002.
1 to <3 months	-		-		
3 to <6 months	11[e]		26[f]		
6 to <12 months	11[e]		26[f]		
1 to <2 years	8		22		
2 to <3 years	13[g]		16[h]		
3 to <6 years	-		-		
6 to <11 years	-		-		
11 to <16 years	-		-		
16 to <21 years	-		-		

[a] Mean calculated from Black et al., 2005 (7 to 12 months).

[b] Mean calculated from Tulve et al., 2002 ($\leq$24 months), AuYeung et al., 2004 ($\leq$24 months), and Black et al., 2005 (1 and 2 years).

[c] Mean calculated from Reed et al., 1999 (2 to 6 years), Freeman et al., 2001 (3 to 4 years and 5 to 6 years), Tulve et al., 2002 ($>$24 months), AuYeung et al., 2004 (2 to 6 years), and Black et al., 2005 (37 to 53 months).

[d] Mean calculated from Freeman et al., 2001 (7 to 8 years and 10 to 12 years).

[e] Mean calculated from Juberg et al., 2001 (0 to 18 months) and Greene, 2002 (3 to 12 months).

[f] Calculated 95^{th} percentile from Greene, 2002 (3 to 12 months).

[g] Mean calculated from Juberg, et al., 2001 (19 to 36 months) and Greene, 2002 (24 to 36 months).

[h] Calculated 95^{th} percentile from Greene, 2002 (24 to 36 months).

– = No data.

Table 4-2. Confidence in Recommendations for Mouthing Frequency and Duration

General Assessment Factors	Rationale	Rating
Soundness		Low
Adequacy of Approach	The approaches for data collection and analysis used were adequate to provide estimates of children's mouthing frequencies and durations. Sample sizes were very small relative to the population of interest. Almost all key studies published primary data; in cases where secondary data were used, U.S. EPA judged the secondary data to be of suitable utility for the purposes for developing recommendations.	
Minimal (or defined) Bias	Bias in either direction likely exists in both frequency and duration estimates; the magnitude of bias is unknown.	
Applicability and Utility		Low
Exposure Factor of Interest	Key studies for older children focused on mouthing behavior while the infant studies were designed to research developmental issues.	
Representativeness	Most key studies were of samples of U.S. children, but due to the small sample sizes and small number of locations under study, the study subjects may not be representative of the overall U.S. child population.	
Currency	The studies were conducted over a wide range of dates. However, the currency of the data are not expected to affect mouthing behavior recommendations.	
Data Collection Period	Extremely short data collection periods may not represent behaviors over longer time periods.	
Clarity and Completeness		Low
Accessibility	The journal articles are in the public domain, but in many cases, primary data were unavailable.	
Reproducibility	Data collection methodologies were capable of providing results that were reproducible within a certain range, when compared with results obtained using alternate data collection techniques (e.g., Smith and Norris, 2003).	
Quality Assurance	Several of the key studies applied and documented quality assurance/quality control measures.	
Variability and Uncertinty		Low
Variability in Population	The key studies characterized inter-individual variability to a limited extent, and did not characterize intra-individual variability over diurnal or longer term time frames.	
Description of Uncertainty	The study authors typically did not attempt to quantify uncertainties inherent in data collection methodology (such as the influence of observers on behavior), although some described these uncertainties qualitatively. The study authors typically did attempt to quantify uncertainties in data analysis methodoloogies (if video-transcription methods were used). Uncertainties arising from short data collection periods typically were unaddressed either qualitatively or quantitatively.	
Evaluation and Review		Medium
Peer Review	All key studies appear in peer review journals.	
Number and Agreement of Studies	Several key studies were available for both frequency and duration, but data were not available for all age groups. The results of studies from different researchers are generally in agreement.	
Overall rating		**Low**

4.3 NON-DIETARY INGESTION - MOUTHING FREQUENCY STUDIES

4.3.1 Key Studies of Mouthing Frequency

4.3.1.1 *Zartarian et al.,1997a - Quantifying Videotaped Activity Patterns: Video Translation Software and Training Technologies/Zartarian et al., 1997b - Quantified Dermal Activity Data From a Four-Child Pilot Field Study/Zartarian et al., 1998 - Quantified Mouthing Activity Data From a Four-Child Pilot Field Study*

Zartarian et al. (1997a, 1997b, 1998) conducted a pilot study of the video-transcription methodology to investigate the applicability of using videotaping for gathering information related to children's activities, dermal exposures and mouthing behaviors. The researchers had conducted studies using the real-time hand recording methodology, resulting in poor inter-observer reliability and observer fatigue when attempted for long periods of time, prompting the investigation into using videotaping with transcription of the children's activities at a point in time after the observations (videotaping) occurred.

Four Mexican-American farm worker children in the Salinas Valley of California each were videotaped with a hand-held videocamera during their waking hours, excluding time spent in the bathroom, over one day in September 1993. The boys were 2 years 10 months old and 3 years, 9 months old; the girls were 2 years 5 months old and 4 years 2 months old. Time of videotaping was 6.0 hours for the younger girl, 6.6 hours for the older girl, 8.4 hours for the younger boy and 10.1 hours for the older boy. The videotaping gathered information on detailed micro-activity patterns of children to be used to evaluate software for videotaped activities and translation training methods. The researchers reported measures taken to assess inter-observer reliability and several problems with the video-transcription process.

The hourly data showed that non-dietary object mouthing occurred in 30 of the 31 hours of tape time, with one child eating during the hour in which no non-dietary object mouthing occurred. Average object to mouth contacts for the four children were reported to be 9 contacts per hour, with the average per child ranging from 1 to 19 contacts per hour (Zartarian et al., 1997a). Objects mouthed included bedding/towels, clothes, dirt, grass/vegetation, hard surfaces, hard toys, paper/card, plush toy, and skin (Zartarian et al., 1997a). Average hand to mouth contacts for the four children were reported to be 13 contacts per hour (averaging the sum of left hand and right hand to mouth contacts and averaging across children, from Zartarian et al., 1997b), with the average per child ranging from 9 to 19 contacts per hour.

This study's primary purpose was to develop and evaluate the video-transcription methodology; a secondary purpose was collection of mouthing behavior data. The sample of children studied was very small and not likely to be representative of the national population. As with other video-transcription studies, the presence of non-family-member videographers and a video camera may have influenced the children's behavior.

4.3.1.2 *Reed et al., 1999 - Quantification of Children's Hand and Mouthing Activities Through a Videotaping Methodology*

In this study, Reed et al. (1999) used a video-transcription methodology to quantify the frequency and type of children's hand and mouth contacts, as well as a survey response methodology, and compared the videotaped behaviors with parents' perceptions of those behaviors. Twenty children ages 3 to 6 years old selected randomly at a day care center in New Brunswick, New Jersey, and ten children ages 2 to 5 years old at residences in Newark and Jersey City, New Jersey who were not selected randomly, were studied (gender not specified). For the video-transcription methodology, inter-observer reliability tests were performed during observer training and at four points during the two years of the study. The researchers compared the results of videotaping the ten children in the residences with their parents' reports of the children's daily activities. Mouthing behaviors studied included hand to mouth and hand bringing object to mouth.

The video-transcription mouthing contact frequency results are presented in Table 4-3. The authors analyzed parents' responses on frequencies of their children's mouthing behaviors and compared those responses with the children's videotaped behaviors, which revealed certain discrepancies. Parents' reported hand to mouth contact of "almost never" corresponded to overall somewhat lower videotaped hand to mouth frequencies than those of children whose parents reported "sometimes," but there was little correspondence between parents' reports of object to mouth frequency and videotaped behavior.

The advantages of this study were that it compared the results of video-transcription with the survey response methodology results, and described quality assurance steps taken to assure reliability of transcribed videotape data. However, only a small number of children were studied, some were not selected for observation randomly, and the sample of children studied may not be representative of either the locations studied or the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may influence the video-transcription results. The parents' survey responses may also be influenced by recall/memory effects and other limitations of survey methodologies.

4.3.1.3 *Freeman et al., 2001 - Quantitative Analysis of Children's Microactivity Patterns: The Minnesota Children's Pesticide Exposure Study*

Freeman et al. (2001) conducted a survey response and video-transcription study of some of the respondents in a phased study of children's pesticide exposures in the summer and early fall of 1997. A probability-based sample of 168 families with children ages 3 to <14 years old in urban (Minneapolis/St. Paul) and non-urban (Rice and Goodhue Counties) areas of Minnesota answered questions about children's mouthing of paint chips, food-eating without utensils, eating of food dropped on the floor, mouthing of non-food items, and mouthing of thumbs/fingers. For the survey response portion of the study, parents provided the responses for children ages 3 and 4 years, and collaborated with or assisted older children with their responses. Of the 168 families responding to the survey, 102 were available, selected, and agreed to measurements of pesticide exposure. Of these 102 families, 19 agreed to videotaping of the study children's activities for a period of four consecutive hours.

Based on the survey responses for 168 children, the 3 year olds had significantly more positive responses for all reported behavior compared to the other age groups. The authors stated that they did not know whether parent reporting of 3 year olds' behavior influenced the responses given. Table 4-4 shows the percent of children, grouped by age, who were reported to exhibit non-food related mouthing behaviors. Table 4-5 presents the mean and median number of mouthing contacts by age for the 19 videotaped children. Among the four age categories of these children, object to mouth activities were significantly greater for the 3 and 4 year olds than any other age group, with a median of 3 and a mean of 6 contacts per hour ($P = 0.002$, Kruskal Wallis test comparison across four age groups). Hand to mouth contacts had a median of 3.5 and mean of 4 contacts per hour for the three 3 and 4 year olds observed, median of 2.5 and mean of 8 contacts per hour for the seven 5 and 6 year olds observed, median of 3 and mean of 5 contacts per hour for the four 7 and 8 year olds observed, and median of 2 and mean of 4 for the five 10, 11 and 12 year olds observed. Gender differences were observed for some of the activities, with boys spending significantly more time outdoors than girls. Hand to mouth and object to mouth activities were less frequent outdoors than indoors for both boys and girls.

For the 19 children in the video-transcription portion of the study, inter-observer reliability checks and quality control checks were performed on randomly sampled tapes. For four children's tapes, comparison of the manual video-transcription with a computerized transcription method (Zartarian et al., 1995) was also performed; no significant differences were found in the frequency of events recorded using the two techniques. The frequency of six behaviors (hand to mouth, hand to object, object to mouth, hand to smooth surface, hand to textured surface, and hand to clothing) was recorded. The amount of time each child spent indoors, outdoors, in contact with soil or grass, and whether the child was barefoot was also recorded. For the four children whose tapes were analyzed with the computerized transcription method, which calculates event durations, the authors stated that most hand to mouth and object to mouth activities were observed during periods of lower physical activity, such as television viewing.

An advantage to this study is that it included results from two separate methodologies, and included quality assurance steps taken to assure reliability of transcribed videotape data. However, the children in this study may not be representative of all children in the U.S. Variation in who provided the survey responses (sometimes parents only, sometimes children with parents) may have influenced the responses given. Children studied using the video-transcription methodology were not chosen randomly from the survey response group. The presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.3.1.4 *Tulve et al., 2002 - Frequency of Mouthing Behavior in Young Children*

Tulve et al. (2002) coded the unpublished Davis et al. (1995) data for location (indoor and outdoor) and activity type (quiet or active) and analyzed the subset of the data that consisted of indoor mouthing behavior during quiet activity (72 children, ranging in age from 11 to 60 months). A total of 186 15-minute observation periods were included in the study, with the number of observation periods per child ranging from 1 to 6.

Results of the data analyses indicated that there was no association between mouthing frequency and gender, but a clear association between mouthing frequency and age was observed. The analysis indicated that children ≤24 months had the highest frequency of mouthing behavior (81 events/hour) and children >24 months had the lowest (42 events/hour) (Table 4-6). Both groups of children were observed to mouth toys and hands more frequently than household surfaces or body parts other than hands.

An advantage of this study is that the randomized design may mean that the children studied were relatively representative of young children living in the study area, although they may not be representative of the U.S. population. Due to the ages of the children studied, the observers' use of headphones and manual recording of mouthing behavior on observation sheets may have influenced the children's behavior.

4.3.1.5 *AuYeung et al., 2004 - Young Children's Mouthing Behavior: An Observational Study via Videotaping in a Primarily Outdoor Residential Setting*

AuYeung et al. (2004) used a video-transcription methodology to study a group of 38 children (20 females and 18 males; ages 1 to 6 years), 37 of whom were selected randomly via a telephone screening survey of a 300 to 400 square mile portion of the San Francisco, California peninsula, along with one child selected by convenience due to time constraints. Families who lived in a residence with a lawn and whose annual income was >$35,000 were asked to participate. Videotaping took place between August 1998 and May 1999 for approximately two hours per child. Videotaping by one researcher was supplemented with field notes taken by a second researcher who was also present during taping. Most of the videotaping took place during outdoor play, however, data were included for several children (one child <2 years old and 8 children >2 years old) who had more than 15 minutes of indoor play during their videotaping sessions.

The videotapes were translated into ASCII computer files using VirtualTimingDevice™ software described in Zartarian et al. (1997a). Both frequency and duration (see Section 4.4.2.5 of this Chapter) were analyzed. Between 5 and 10 percent of the data files translated were randomly chosen for quality control checks for inter-observer agreement. Ferguson et al. (2006) described quality control aspects of the study in detail.

For analysis, the mouthing contacts were divided into indoor and outdoor locations, and 16 object/surface categories. Mouthing frequency was analyzed by age and gender separately, and in combination. Mouthing contacts were defined as contact with the lips, inside of the mouth, and/or the tongue; dietary contacts were ignored. Mouthing frequencies for indoor locations are shown in Table 4-7. For the one child observed that was ≤24 months of age, the total mouthing frequency was 84.8 contacts/hour; for children >24 months, the median indoor mouthing frequency was 19.5 contacts/hour. Outdoor median mouthing frequencies (Table 4-8) were very similar for children ≤24 months of age (13.9 contacts/hour) and >24 months (14.6 contacts/hour).

Nonparametric tests, such as the Wilcoxon rank sum test were used for the data analyses. Both age and gender were found to be associated with differences in mouthing behavior. Girls had significantly higher frequencies of mouthing contacts with the hands and non-dietary objects than boys ($p = 0.01$ and $p = 0.008$, respectively).

This study provides distributions of outdoor mouthing frequencies with a variety of objects and surfaces. Although indoor mouthing data were also included in this study, the results were based on a small number of children (N=9) and a limited amount of indoor play. The sample of children may be representative of certain socioeconomic strata in the study area, but is not likely to be representative of the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.3.1.6 *Black et al., 2005 - Children's Mouthing and Food-Handling Behavior in an Agricultural Community on the U.S./Mexico Border*

Black et al. (2005) studied mouthing behavior of children in a Mexican-American community along the Rio Grande River in Texas, in the spring and summer of 2000, using a survey response and a video-transcription methodology. A companion study of this community (Shalat et al., 2003) identified 870 occupied households during the April 2000 U.S. census and contacted 643 of these via in-person interview to determine presence of children under the age of 3 years. Of the 643 contacted, 91 had at least one child under the age of 3 years (Shalat et al., 2003). Of these 91 households, the mouthing and food-handling behavior of 52 children (26 boys and 26 girls) from 29 homes was videotaped, and the children's parents answered questions about children's hygiene, mouthing and food-handling activities (Black et al., 2005). The study was of children ages 7 to 53 months, grouped into four age categories: infants (7 to 12 months), 1 year olds (13 to 24 months), 2 year olds (25 to 36 months), and preschoolers (37 to 53 months).

The survey asked questions about children's ages, genders, reported hand-washing, mouthing and food-handling behavior (N=52), and activities (N=49). Parental reports of thumb/finger placement in the mouth showed decreases with age. The researchers attempted to videotape each child for four hours. The children were followed by the videographers through the house and yard, except for times when they were napping or using the bathroom. Virtual Timing Device™ software was used to analyze the videotapes.

Based on the results of videotaping, most of the children (49 of 52) spent the majority of their time indoors. Of the 39 children who spent time both indoors and outdoors, all three behaviors (hand to mouth, object to mouth and food handling) were more frequent and longer while the child was indoors. Hand to mouth activity was recorded during videotaping for all but one child, a 30 month old girl.

For the four age groups, the mean hourly hand to mouth frequency ranged from 11.9 (2 year olds) to 22.1 (preschoolers), and the mean hourly object to mouth frequency ranged from 7.8 (2 year olds) to 24.4 (infants). No significant linear trends were seen with age or gender for hand to mouth hourly frequency. A significant linear trend was observed for hourly object to mouth frequency, which decreased as age increased (adjusted $R^2 = 0.179$; $P = 0.003$). Results of this study are shown in Table 4-9.

One advantage of this study is that it compared survey responses with videotaped information on mouthing behavior. A limitation is that the sample was fairly small and was from a limited area (mid-Rio Grande Valley) and is not likely to be representative of the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.3.1.7 *Xue et al., 2007 - A Meta-analysis of Children's Hand-to-Mouth Frequency Data for Estimating Nondietary Ingestion Exposure*

Xue et al. (2007) gathered hand-to-mouth frequency data from 9 available studies representing 429 subjects and more than 2,000 hours of behavior observation. The studies used in this analysis included several of the studies summarized in this chapter (Zartarian et al. ,1998; Reed et al., 1999; Freeman et al., 2001; Greene, 2002; Tulve et al., 2002; and Black et al., 2005), as well as several other sets of unpublished data. These data were used to conduct a meta-analysis to study differences in hand-to-mouth behavior. The purpose of the analysis was to:

1) examine differences across studies by age (using the new U.S. EPA recommended age groupings (U.S. EPA, 2005)), gender, and indoor/outdoor location;
2) fit variability distributions to the available hand-to-mouth frequency data for use in one dimensional Monte Carlo exposure assessments;
3) fit uncertainty distributions to the available hand-to-mouth frequency data for use in two dimensional Monte Carlo exposure assessments; and
4) assess hand-to-mouth frequency data needs using the new U.S. EPA recommended age groupings (U.S. EPA, 2005).

The data were sorted into age groupings. Visual inspection of the data and statistical methods (method of moments and maximum likelihood estimation) were used, and goodness-of-fit tests were applied to verify the selection among lognormal, Weibull, and normal distributions (Xue et al., 2007). Analyses to study inter- and intra- individual variability of indoor and outdoor hand to mouth frequency were conducted. There were 894 hours of behavior observation data for the 429 children, ages 0.3 to 12 years, across all available studies. It was found that age and location (indoor vs. outdoor) were important factors contributing to hand to mouth frequency, but study and gender were not (Xue et al., 2007). Distributions of hand to mouth frequencies were developed for both indoor and outdoor activities. Distributions are presented in Table 4-10 for indoor settings and Table 4-11 for outdoor settings. Hand to mouth frequencies decreased for both indoor and outdoor activity as age increased, and were higher indoors than outdoors for all age groups (Xue et al., 2007).

A strength of this study is that it is the first effort to fit hand to mouth distributions using U.S. EPA's recommended age groups using available data on mouthing behavior from studies using different methodologies, of children in different locations. Limitations of the studies used in this meta-analysis apply to the results from the meta-analysis as well; the uncertainty analysis in this study does not account for uncertainties arising out of differences in approaches used in the various studies used in the meta-analysis.

4.3.2 Relevant Studies of Mouthing Frequency

4.3.2.1 *Davis et al., 1995 - Soil Ingestion in Children with Pica: Final Report*

In 1992, under a Cooperative Agreement with U.S. EPA, the Fred Hutchinson Cancer Research Center conducted a survey response and real-time hand recording study of mouthing behavior data. The study included 92 children (46 males, 46 females) ranging in age from <12 months to 60 months, from Richland, Kennewick, and Pasco, Washington. The children were selected randomly based on date of birth through a combination of birth certificate records and random digit dialing of residential telephone numbers. For each child, data were collected during a seven day period in January to April, 1992. Eligibility included residence within the city limits, residence duration >1 month, and at least one parent or guardian who spoke English. Most of the adults who responded to the survey reported their marital status as being married (90 percent), their race as Caucasian (89 percent), their household income in the >$30,000 range (56 percent) or their housing status as single-family home occupants (69 percent).

The survey asked questions about thumb-sucking and frequency questions about pacifier use, placing fingers, hands and feet in the mouth, and mouthing of furniture, railings, window sills, floor, dirt, sand, grass, rocks, mud, clothes, toys, crayons, pens, and other items. Table 4-12 shows the survey responses for the 92 study children. For most of the children in the study, the mouthing behavior real-time hand recording data were collected simultaneously by parents and by trained observers who described and quantified the mouthing behavior of the children in their home environment. The observers recorded mouth and tongue contacts with hands, other body parts, natural objects, surfaces, and toys every 15 seconds during 15-minute observation periods spread over 4 days. Parents and trained observers wore headphones that indicated elapsed time (Davis et al., 1995). If all attempted observation periods were successful, each child would have a total of 16 15-minute observation periods with 60 15-second intervals per 15-minute observation period, or 960 15-second intervals in all. The number of successful intervals of observation ranged from 0 to 840 per child. Comparisons of the inter-observer reliability between the trained observers and parents showed "a high degree of correlation between the overall degree of both mouth and tongue activity recorded by parents and observers. For total mouth activity, there was a significant correlation between the rankings obtained according to parents and observers, and parents were able to identify the same individuals as observers as being most and least oral in 60 percent of the cases."

One advantage of this study is the simultaneous observations by both parents and trained observers that allows comparisons to be made regarding the consistency of the recorded observations. The random nature in which the population was selected may provide a representative population of the study area, within certain limitations, but not of the national population. Simultaneous collection of food, medication, fecal, and urine samples that occurred as part of the overall study (not described in this summary) may have contributed a degree of deviation from normal routines within the households during the 7 days of data collection and may have influenced children's usual behaviors. Wearing of headphones by parents and trained observers during mouthing observations, presence of non-family-member observers, and parents' roles as observers as well as care givers may also have influenced the results; the authors state "Having the child play naturally while being observed was challenging. Usually the first day of observation was the most difficult in this respect, and by the third or fourth day of observation the child generally paid little attention to the observers."

4.3.2.2 *Lew and Butterworth, 1997 - The Development of Hand-Mouth Coordination in 2- to 5-Month-Old Infants: Similarities With Reaching and Grasping*

Lew and Butterworth (1997) studied 14 mostly first-born infants (10 males, 4 females) in Stirling, United Kingdom, in 1990 using a video-transcription methodology. Attempts were made to study each infant within a week of the infant's 2-month, 3-month, 4-month and 5-month birthdays. After becoming accustomed to the testing laboratory, and with their mothers present, infants were placed in semi-reclining seats and filmed during an experimental protocol in which researchers placed various objects into the infants' hands. Infants were observed for two baseline periods of 2 minutes each. The researchers coded all contacts to the face and mouth that occurred during baseline periods (prior to and after the object handling period) as well as contacts occurring during the object handling period. Hand to mouth contacts included contacts that landed directly in or on the mouth as well as those in which the hand landed on the face first and then moved to the mouth. The researchers assessed inter-observer agreement using a rater not involved with the study, for a random proportion (approximately 10 percent) of the movements documented during the object handling period, and reported inter-observer agreement of 0.90 using Cohen's kappa (a measure of the agreement between two raters) for the location of contacts. The frequency of contacts ranged between 0 and 1 contacts per minute.

The advantages of this study were that use of video cameras could be expected to have minimal impact on infant behavior for infants of these ages, and the researchers performed tests of inter-observer reliability. A disadvantage is that the study included baseline observation periods of only 2 minutes' duration, during which spontaneous hand to mouth movements could be observed. The extent to which these infants' behavior is representative of other infants of these ages is unknown.

4.3.2.3 *Tudella et al., 2000 - The Effect of Oral-Gustatory, Tactile-Bucal, and Tactile-Manual Stimulation on the Behavior of the Hands in Newborns*

Tudella et al. (2000) studied the frequency of hand to mouth contact, as well as other behaviors, in 24 full-term Brazilian newborns (10 to 14 days old) using a video-transcription methodology. Infants were in an alert state, in their homes in silent and previously heated rooms in a supine position and had been fed between 1 and 1 1/2 hours before testing. Infants were studied for a four minute baseline period without stimuli before experimental stimuli were administered. Results from the four minute baseline period, without stimuli, indicated that the mean frequency of hand to mouth contact (defined as right hand or left hand touching the lips or entering the buccal cavity, either with or without rhythmic jaw movements) was almost 3 right hand contacts and slightly more than 1.5 left hand contacts, for a total hand to mouth contact frequency of about 4 contacts in the four minute period. The researchers performed inter-observer reliability tests on the videotape data and reported an inter-coder Index of Concordance of 93 percent.

The advantages of this study were that use of video cameras could be expected to have virtually no impact on newborns' behavior, and inter-observer reliability tests were performed. However, the study data may not represent newborn hand to mouth contact during non-alert periods such as sleep. The extent to which these infants' behavior is representative of other full-term 10 to 14 day old infants' behavior is unknown.

4.3.2.4 *Ko et al., 2007 - Relationships of Video Assessments of Touching and Mouthing Behaviors During Outdoor Play in Urban Residential Yards to Parental Perceptions of Child Behaviors and Blood Lead Levels*

Ko et al. (2007) compared parent survey responses with results from a video-transcription study of children's mouthing behavior in outdoor settings, as part of a study of relationships between children's mouthing behavior and other variables with blood lead levels. A convenience sample of 37 children (51 percent males, 49 percent females) 14 to 69 months old was recruited via an urban health center and direct contacts in the surrounding area, apparently in Chicago, Illinois. Participating children were primarily Hispanic (89 percent). The mouth area was defined as within 1 inch of the mouth, including the lips. Items passing beyond the lips were defined as in the mouth. Placement of an object or food item in the mouth along with part of the hand was counted as both hand and food or object in mouth. Mouthing behaviors included hand-to-mouth area both with and not with food, hand-in-mouth with or without food, and object-in-mouth including food, drinks, toys or other objects.

Survey responses for the 37 children who were also videotaped included parents reporting children's inserting hand, toys or objects in mouth when playing outside, and inserting dirt, stones or sticks in mouth. Video-transcription results of outdoor play for these 37 children indicated 0 to 27 hand-in-mouth, and 3 to 69 object-in-mouth touches per hour for the 13 children reported to frequently insert hand, toys or objects in mouth when playing outside; 0 to 67 hand in mouth, and 7 to 40 object-in-mouth touches per hour for the 10 children reported to "sometimes" perform this behavior; 0 to 30 hand-in-mouth, and 0 to 125 object in mouth touches per hour for the 12 children reported to "hardly ever" perform this behavior, and 1 to 8 hand-in-mouth, and 3 to 6 object-in-mouth touches per hour for the 2 children reported to "never" perform this behavior.

Videotaping was attempted for two hours per child over two or more play sessions, with videographers trying to avoid interacting with the children. Children played with their usual toys and partners, and no instructions were given to parents regarding their supervision of the children's play. The authors stated that during some portion of the videotape time, children's hands and mouths were out of camera view. Videotape transcription was performed manually, according to a modified version of the protocol used in the Reed et al. (1999) study. Inter-observer reliability between three video-transcribers was checked with seven 30 minute video segments.

One strength of this study is its comparison of survey responses with results from the video-transcription methodology. A limitation is that the non-randomly selected sample of children studied is unlikely to be representative of the national population. Comparing results from this study with results from other video-transcription studies may be problematic due to inclusion of food handling with hand to mouth and object to mouth frequency counts. Due to the children's ages, their behavior may have differed from normal patterns due to the presence of strangers who videotaped them.

4.4 NON-DIETARY INGESTION - MOUTHING DURATION STUDIES

4.4.1 Key Mouthing Duration Studies

4.4.1.1 *Juberg et al., 2001 - An Observational Study of Object Mouthing Behavior by Young Children*

Juberg et al. (2001) studied 385 children ages 0 to 36 months in western New York state, with parents collecting real-time hand-recording mouthing behavior data, primarily in children's own home environments. The study consisted of an initial pilot study conducted in February 1998, a second phase conducted in April

1998, and a third phase conducted at an unspecified later time. The study's sample was drawn from families identified in a child play research center database or whose children attended a child care facility in the same general area; some geographic variation within the local area was obtained by selecting families with different zip codes in the different study phases. The pilot phase had 30 children who participated out of 150 surveys distributed; the second phase had 187 children out of approximately 300 surveys distributed, and the third phase had 168 participants out of 300 surveys distributed.

Parents were asked to observe their child's mouthing of objects only; hand to mouth behavior was not included. Data were collected on a single day (pilot and second phases) or five days (third phase); parents recorded the insertion of objects into the mouth by noting the "time in" and "time out" and the researchers summed the recorded data to tabulate total times spent mouthing the various objects during the day(s) of observation. Thus, the study data were presented as minutes per day of object mouthing time. Mouthed items were classified as pacifiers, teethers, plastic toys, or other objects.

The results of the combined pilot and second phase II data are shown in Table 4-13. For both age groups, mouthing time for pacifiers greatly exceeded mouthing time for non-pacifiers, with the difference more acute for the older age group than for the younger age group. Histograms of the observed data show a peak in the low end of the distribution (0 to 100 minutes per day) and a rapid decline at longer durations.

A third phase of the study focused on children between the ages of 3 and 18 months and included only non-pacifier objects. Subjects were observed for 5 non-consecutive days over a 2 month period. A total of 168 participants returned surveys for at least one day, providing a total of 793 person-days of data. The data yielded a mean non-pacifier object mouthing duration of 36 minutes per day; the mean was the same when calculated on the basis of 793 person-days of data as on the basis of 168 daily average mouthing times.

One advantage of this study is the large sample size (385 children); however, the children apparently were not selected randomly, although some effort was made to obtain local geographic variation among study participants. There is no description of the socioeconomic status or racial and ethnic identities of the study participants. The authors do not describe the methodology (such as stopwatches, analog or digital clocks, or guesses) parents used to record mouthing event durations. The authors stated that using mouthing event duration units of minutes, rather than seconds, may have yielded observations rounded to the nearest minute.

4.4.1.2 *Greene, 2002 - A Mouthing Observation Study of Children Under Six Years of Age*

The U.S. Consumer Product Safety Commission (CPSC) conducted a survey response and real-time hand recording study between December 1999 and February 2001 to quantify the cumulative time per day that young children spend awake, not eating, and mouthing objects. "Mouthing" was defined as sucking, chewing, or otherwise putting an object on his/her lips or into his/her mouth. Participants were recruited via a random digit dialing telephone survey in urban and nearby rural areas of Houston, Texas and Chicago, Illinois. Of the 115,289 households surveyed, 1,745 households had a child under the age of 6 years and were willing to participate. In the initial phase of the study, 491children ages 3 to 81 months participated. Parents were instructed to use watches with second hands, or count seconds to estimate mouthing event durations. Parents also were to record mouthing frequency and types of objects mouthed. Parents collected data in four separate, non-consecutive 15-minute observation periods. Initially, parents were called back by the researchers and asked to provide their data over the telephone. Of the 491 children, 43 children (8.8 percent) had at least one 15-minute observation period with mouthing event durations recorded as exceeding 15 minutes. Due to this data quality problem, the researchers excluded the parent observation data from further analysis.

In a second phase, trained observers used stopwatches to record the mouthing behaviors and mouthing event durations of the subset of 109 of these children ages 3 to 36 months, and an additional 60 children (total in second phase, 169), on two hours of each of two days. The observations were done at different times of the day at the child's home and/or child care facility. Table 4-14 shows the prevalence of observed mouthing among the 169 children in the second phase. All children were observed to mouth during the four hours of observation time; 99 percent mouthed the category defined as "anatomy." Pacifiers were mouthed by 27 percent in an age-declining pattern ranging from 47 percent of children less than 12 months old to 10 percent of the 2 to <3 year olds.

Table 4-15 provides the average mouthing time by object category and age in minutes per hour. The average mouthing time for all objects ranged from 5.3 to 10.5 minutes per hour, with the highest mouthing time corresponding to children <1 year of age and the lowest to the 2 to <3 years of age category. Among the objects mouthed, pacifiers represented about one third of the total mouthing time, with 3.4 minutes per hour for the youngest children, 2.6 minutes per hour for the children between 1 and 2 years and 1.8 minutes per hour for children 2 to <3 years old. The next largest single item category was anatomy. In this category, children under 1 year of age spent 2.4 minutes per hour mouthing fingers and thumbs; this behavior declined with age to 1.2 minutes per hour for children 2 to <3 years old.

Of the 169 children in the second phase, there were usable data on the time awake and not eating (or "exposure time") for only 109; data for the remaining 60 children were missing. Thus, in order to develop extrapolated estimates of daily mouthing time, from the 2 hours of observation per day for two days, for the 109 children, the researchers developed a statistical model that accounted for the children's demographic characteristics, in order to estimate exposure times for the 60 children for whom exposure time data were missing, and then computed statistics for the extrapolated daily mouthing times for all 169 children, using a "bootstrap" procedure. Using this method, the estimated mean daily mouthing time of objects other than pacifiers ranged from 37 minutes/day to 70 minutes/day with the lowest number corresponding to the 2 to <3 year old children and the largest number corresponding to the 3 to <12 month old children.

The 551 child participants were 55 percent males, 45 percent females. The study's sample was drawn in an attempt to duplicate the overall U.S. demographic characteristics with respect to race, ethnicity, socioeconomic status and urban/suburban/rural settings. The sample families' reported annual incomes were generally higher than those of the overall U.S. population.

This study's strength was that it consisted of a randomly selected sample of children from both urban and non-urban areas in two different geographic areas within the U.S. However, the observers' presence and use of a stopwatch to time mouthing durations may have affected the children's behavior.

4.4.2 Relevant Mouthing Duration Studies

4.4.2.1 *Barr et al., 1994 - Effects of Intra-Oral Sucrose on Crying, Mouthing and Hand-Mouth Contact in Newborn and Six Week Old Infants*

Barr et al. (1994) studied hand to mouth contact, as well as other behaviors, in 15 newborn (8 males, 7 females) and 15 five to seven week old (8 males, 7 females) full-term Canadian infants using a video-transcription methodology. The newborns were 2 to 3 days old, in a quiet, temperature-controlled room at the hospital, in a supine position and had been fed between 2 1/2 and 3 1/2 hours before testing. Barr et al. (1994) analyzed a one minute baseline period, with no experimental stimuli, immediately before a sustained crying episode lasting 15 seconds. For the newborns, reported durations of hand to mouth contact during 10 second intervals of the one minute baseline period were in the range of 0 to 2 percent. The five to seven week old infants apparently were studied at primary care pediatric facilities when they were in bassinets inclined at an angle of 10 degrees. For these slightly older infants, the baseline periods analyzed were less than 20 seconds in length, but Barr et al. (1994) reported similarly low mean percentages of the 10 second intervals (approximately 1 percent of the time with hand to mouth contact). Hand to mouth contact was defined as "any part of the hand touching the lips and/or the inside of the mouth." The researchers performed inter-observer reliability tests on the videotape data and reported a mean inter-observer reliability of 0.78 by Cohen's kappa (a measure of the agreement between two raters).

The advantages of this study were that use of video cameras could be expected to have virtually no impact on newborns' or five to seven week old infants' behavior, and inter-observer reliability tests were performed. The study data did not represent newborn or five to seven week old infant hand to mouth contact during periods in which infants of these ages were in a sleeping or other non-alert state, and may only represent behavior immediately prior to a state of distress (sustained crying episode). The extent to which these infants' behavior is representative of other full-term infants of these ages is unknown.

4.4.2.2 *Zartarian et al., 1997a - Quantifying Videotaped Activity Patterns: Video Translation Software and Training Technologies/Zartarian et al., 1997b - Quantified Dermal Activity Data From a Four-Child Pilot Field Study/Zartarian et al., 1998 - Quantified Mouthing Activity Data From a Four-Child Pilot Field Study*

As described in Section 4.3.1.1, Zartarian et al. (1997a, 1997b, 1998) conducted a pilot study of the video-transcription methodology to investigate the applicability of using videotaping for gathering information related to children's activities, dermal exposures and mouthing behaviors. The researchers had conducted studies using the real-time hand recording methodology, resulting in poor inter-observer reliability and observer fatigue when attempted for long periods of time, prompting the investigation into using videotaping with transcription of the children's activities at a point in time after the observations (videotaping) occurred.

Four Mexican-American farm worker children in the Salinas Valley of California each were videotaped with a hand-held videocamera during their waking hours, excluding time spent in the bathroom, over one day in September 1993. The boys were 2 years 10 months old and 3 years, 9 months old; the girls were 2 years 5 months old and 4 years 2 months old. Time of videotaping was 6.0 hours for the younger girl, 6.6 hours for the older girl, 8.4 hours for the younger boy and 10.1 hours for the older boy. The videotaping gathered information on detailed micro-activity patterns of children to be used to evaluate software for videotaped activities and translation training methods.

The four children mouthed non-dietary objects an average of 4.35 percent (range 1.41 to 7.67 percent) of the total observation time, excluding the time during which the children were out of the camera's view (Zartarian et al., 1997a). Objects mouthed included bedding/towels, clothes, dirt, grass/vegetation, hard surfaces, hard toys, paper/card, plush toy, and skin (Zartarian et al., 1997a). Frequency distributions for the four children's non-dietary object contact durations were reported to be similar in shape. Reported hand to mouth contact presumably is a subset of the object to mouth contacts described in Zartarian et al., 1997a, and is described in Zartarian et al., 1997b. The four children mouthed their hands an average of 2.35 percent (range 1.0 to 4.4 percent) of observation time. The researchers reported measures taken to assess inter-observer reliability and several problems with the video-transcription process.

This study's primary purpose was to develop and evaluate the video-transcription methodology; a secondary purpose was collection of mouthing behavior data. The sample of children studied was very small and not likely to be representative of the national population. Thus, U.S. EPA did not judge it to be suitable for consideration as a key study of children's mouthing behavior. As with other video-transcription studies, the presence of non-family-member videographers and a video camera may have influenced the children's behavior.

4.4.2.3 *Groot et al., 1998 - Mouthing Behavior of Young Children: An Observational Study*

In this study, Groot et al. (1998) examined the mouthing behavior of 42 Dutch children (21 boys and 21 girls) between the ages of 3 and 36 months in late July and August 1998. Parent observations were made of children in 36 families. Parents were asked to observe their children ten times per day for 15 minute intervals (i.e., 150 minutes total per day) for two days and measure mouthing times with a stopwatch. In this study, mouthing was defined as "all activities in which objects are touched by mouth or put into the mouth except for eating and drinking. This term includes licking as well as sucking, chewing and biting."

For the study, a distinction was made between toys meant for mouthing (e.g., pacifiers, teething rings) and those not meant for mouthing. Inter-observer and intra-observer reliability was measured by trained observers who co-observed a portion of observation periods in three families, and who co-observed and repeatedly observed some video-transcriptions made of one child. Another quality assurance procedure performed for the extrapolated total mouthing time data was to select 12 times per hour randomly during the entire waking period of four children during one day, in which the researchers recorded activities and total mouthing times.

Although the sample size was relatively small, the results provided estimates of mouthing times, other than pacifier use, during a day. The results were extrapolated to the entire day based on the 150 minutes of observation per day, and the mean value for each child for the two days of observations was interpreted as the estimate for that child. Summary statistics are shown in Table 4-16. The standard deviation in all four age categories except the 3 to 6 month old children exceeded the estimated mean. The 3 to 6 month children (N=5) were estimated to have mean non-pacifier mouthing durations of 36.9 minutes per day, with toys as the most frequently mouthed product category, and the 6 to 12 month children (N=14) 44 minutes per day (fingers most frequently mouthed). The 12 to 18 month olds' (N=12) estimated mean non-pacifier mouthing time was 16.4 minutes per day, with fingers most frequently mouthed, and 18 to 36 month olds' (N=11) estimated mean non-pacifier mouthing time was 9.3 minutes per day (fingers most frequently mouthed).

One strength of this study is that the researchers recognized that observing children's behavior might affect the behavior, and emphasized to the parents the importance of making observations under conditions that were as normal as possible. In spite of these efforts, many parents perceived that their children's behavior was affected by being observed, and observation interfered with care giving responsibilities such as comforting children when they were upset. Other limitations included a small sample size that was not representative of the Dutch population and that also may not be representative of U.S. children. Technical problems with the stopwatches affected at least 14 of 36 parents' data.

4.4.2.4 *Smith and Norris, 2003 - Reducing the Risk of Choking Hazards: Mouthing Behavior of Children Aged 1 Month to 5 Years/Norris and Smith, 2002 - Research Into the Mouthing Behaviour of Children up to 5 Years Old*

Smith and Norris (2003) conducted a real-time hand recording study of mouthing behavior among 236 children (111 males, 125 females) in the United Kingdom (exact locations not specified) who were from 1 month to 5 years old. Children were observed at home by parents, who used stopwatches to record the time that mouthing began, the type of mouthing, the type of object being mouthed, and the time that mouthing ceased. Children were observed for a total of 5 hours over a two week period; the observation time consisted of twenty 15 minute periods spread over different times and days during the child's waking hours. Parents also recorded the times each child was awake and not eating meals so that the researchers could extrapolate estimates of total daily mouthing time from the shorter observation periods. Mouthing was defined as licking/lip touching, sucking/trying to bite, biting or chewing, with a description of each category, together with pictures, given to parents as guidance for what to record.

The results of the study are shown in Table 4-17. While no overall pattern could be found in the different age groups tested, a Kruskal-Wallis test on the data for all items mouthed indicated that there was a significant difference between the age groups. Across all age groups and types of items, licking and sucking accounted for 64 percent of all mouthing behavior. Pacifiers and fingers exhibited less variety on mouthing behavior (principally sucking), while other items had a higher frequency of licking, biting, or other mouthing.

The researchers selected 25of the 236 children randomly for a single 15 minute observation of each child (total observation time across all children: 375 minutes), in order to compare the mouthing frequency and duration data obtained according to the real-time hand recording and the video-transcription methodologies, as well as the reliability of parent observations versus those made by trained professionals. For this group of 25 children, the total number of mouthing behavior events recorded by video (160) exceeded those recorded by parents (114) and trained observers (110). Similarly, the total duration recorded by video (24 minutes and 15 seconds) exceeded that recorded by observers (parents and trained observers both recorded identical totals of 19 minutes and 44 seconds). The mean and standard deviation of observed mouthing time were both lower when recorded by video versus real-time hand recording. The maximum observed mouthing time was also lower (6 minutes and 7 seconds by video versus 9 minutes and 43 seconds for both parents and trained observers).

The strengths of this study were its comparison of three types of observation (parents, trained professional observers, and videotaping), and its detailed reporting of mouthing behaviors by type, object/item mouthed, and age group. However, the children studied may not be representative of the study population, and may not be representative of U.S. children.

4.4.2.5 *Au Yeung et al, 2004 - Young Children's Mouthing Behavior: An Observational Study via Videotaping in a Primarily Outdoor Residential Setting*

As described in Section 4.3.1.5, AuYeung et al. (2004) used a video-transcription methodology to study a group of 38 children (20 females and 18 males; ages 1 to 6 years), 37 of whom were selected randomly via a telephone screening survey of a 300 to 400 square mile portion of the San Francisco, California peninsula, along with one child selected by convenience due to time constraints. Families who lived in a residence with a lawn and whose annual income was >$35,000 were asked to participate. Videotaping took place between August 1998 and May 1999 for approximately two hours per child. Videotaping by one researcher was supplemented with field notes taken by a second researcher who was also present during taping. Most of the videotaping took place during outdoor play, however, data were included for several children (one child <2 years old and 8 children >2 years old) who had more than 15 minutes of indoor play during their videotaping sessions.

The videotapes were translated into ASCII computer files using VirtualTimingDevice™ software described in Zartarian et al. (1997a). Both frequency (see Section 4.3.1.5 of this Chapter) and duration were analyzed. Between 5 and 10 percent of the data files translated were randomly chosen for quality control checks for inter-observer agreement. Ferguson et al. (2006) described quality control aspects of the study in detail.

For analysis, the mouthing contacts were divided into indoor and outdoor locations, and 16 object/surface categories. Mouthing durations were analyzed by age and gender separately, and in combination. Mouthing contacts were defined as contact with the lips, inside of the mouth, and/or the tongue; dietary contacts were ignored. Mouthing durations are shown in Table 4-18 (outdoor locations). For the children in all age groups, the median duration of each mouthing contact was 1 to 2 seconds, confirming the observations of other researchers that children's mouthing contacts are of very short duration. For the one child observed that was ≤24 months, the total indoor mouthing duration was 11.1 minutes/hour; for children >24 months, the median indoor mouthing duration was 0.9 minutes/hour (Table 4-19). For outdoor environments, median contact durations for these age groups decreased to 0.8 and 0.6 minutes/hour, respectively (Table 4-20).

Nonparametric tests, such as the Wilcoxon rank sum test were used for the data analyses. Both age and gender were found to be associated with differences in mouthing behavior. Girls' hand to mouth contact durations were significantly shorter than for boys (p = 0.04).

This study provides distributions of outdoor mouthing durations with a variety of objects and surfaces. Although indoor mouthing data were also included in this study, the results were based on a small number of children (N=9) and a limited amount of indoor play. The sample of children may be representative of certain socioeconomic strata in the study area, but is not likely to be representative of the national population. Due to the children's ages, the presence of unfamiliar persons following the children with a video camera may have influenced the video-transcription methodology results.

4.5 MOUTHING PREVALENCE

4.5.1 Stanek et al., 1998 - Prevalence of Soil Mouthing/Ingestion Among Healthy Children Aged 1 to 6

Stanek et al. (1998) characterized the prevalence of mouthing behavior among healthy children based on a survey response study of parents or guardians of 533 children (289 females, 244 males) ages 1 to 6 years old. Study participants were attendees at scheduled well-child visits at three clinics in Western Massachusetts in August through October, 1992. Participants were questioned about the frequency of 28 mouthing behaviors of the children over the preceding month in addition to exposure time (e.g., time outdoors, play in sand or dirt) and children's characteristics (e.g., teething).

Table 4-21 presents the prevalence of reported non-food ingestion/mouthing behaviors by child's age as the percent of children whose parents reported the behavior in the preceding month. The table includes a column of data for the 3 to <6 year age category; this column was calculated by U.S. EPA as a weighted mean value of the individual data for 3, 4, and 5 year olds in order to conform to the standardized age categories used in this handbook. Among all the age groups, 1 year olds had the highest reported daily sucking of fingers/thumb; the proportion dropped for two year olds, but rose slightly for three and four year olds and declined again after age 4. A similar pattern was reported for more than weekly finger/thumb sucking, while more than monthly finger/thumb sucking showed a very slight increase for 6 year olds. Reported pacifier use was highest for one year olds and declined with age for daily and more than weekly use; for more than monthly use of a pacifier several six year olds were reported to use pacifiers, which altered the age-declining pattern for the daily and more than weekly reported pacifier use. A pattern similar to pacifier use existed with reported mouthing of teething toys, with highest reported use for one year olds, a decline with age until age 6 when reported use for daily, more than weekly, and more than monthly use of teething toys increased.

The authors developed an outdoor mouthing rate for each child as the sum of rates for responses to four questions on mouthing specific outdoor objects. Survey responses were converted to mouthing rates per week, using values of 0, 0.25, 1, and 7 for responses of never, monthly, weekly, and daily ingestion. Reported outdoor soil mouthing behavior prevalence was found to be higher than reported indoor dust mouthing prevalence, but both behaviors had the highest reported prevalence among 1 year old children and decreased for children 2 years and older. The investigators conducted principal component analyses on responses to four questions relating to ingestion/mouthing of outdoor objects in an attempt to characterize variability. Outdoor ingestion/mouthing rates constructed from the survey responses were that children 1 year of age were reported to mouth or ingest outdoor objects 4.73 times per week while 2 to 6 year olds were reported to mouth or ingest outdoor objects 0.44 times per week. The authors developed regression models to identify factors related to high outdoor mouthing rates. The authors found that children who were reported to play in sand or dirt had higher outdoor object ingestion/mouthing rates.

A strength of this study is that it was a large sample obtained in an area with urban and semi-urban residents within various socioeconomic categories and with varying racial/ethnic identities. However, difficulties with parents' recall of past events may have caused either over-estimates or under-estimates of the behaviors studied.

4.5.2 Warren et al., 2000 - Non-nutritive Sucking Behaviors in Preschool Children: A Longitudinal Study

Warren et al. (2000) conducted a survey response study of a non-random cohort of children born in certain Iowa hospitals from early 1992 to early 1995, as part of a study of children's fluoride exposure. For this longitudinal study of children's non-nutritive sucking behaviors, 1,374 mothers were recruited at the time of their newborns' birth, and over 600 were active in the study until the children were at least 3 years old. Survey questions on non-nutritive sucking behaviors were administered to the mothers when the children were 6 weeks, 3, 6, 9, 12, 16 and 24 months old, and yearly after age 24 months. Questions were posed regarding the child's sucking behavior over the previous 3 to 12 months.

The authors reported that nearly all children sucked non-nutritive items, including pacifiers, thumbs or other fingers, and/or other objects, at some point in their early years. The parent-reported sucking behavior prevalence peaked at 91 percent for 3 month old children. At 2 years of age, a majority (53 percent) retained a sucking habit, while 29 percent retained the habit at age 3 years and 21 percent at age 4 years. Parent-reported pacifier use was 28% for 1 year olds, 25% for 2 year olds, and 10% for 3 year olds. The authors cautioned against generalizing the results to other children due to study design limitations.

Strengths of this study were its longitudinal design and the large sample size. A limitation is that the non-random selection of original study participants and the self-selected nature of the cohort of survey respondents who participated over time means that the results may not be representative of other U.S. children of these ages.

4.6 REFERENCES FOR CHAPTER 4

AuYeung, W.; Canales, R.; Beamer, P.; Ferguson, A.C.; Leckie, J.O. (2004) Young children's mouthing behavior: An observational study via videotaping in a primarily outdoor residential setting. J Children's Health 2(3-4):271-295.

Barr, R.G.; Quek, V.S.H.; Cousineau, D.; Oberlander, T.F.; Brian, J.A.; Young, S.N. (1994) Effects of Intra-oral sucrose on crying, mouthing and hand-mouth contact in newborn and six-week-old infants. Dev Med Child Neurol 36:608-618.

Black, K.; Shalat, S.L.; Freeman, N.C.G.; Jimenez, M.; Donnelly, K.C.; Calvin, J.A. (2005) Children's mouthing and food-handling behavior in an agricultural community on the US/Mexico border. J Expo Anal Environ Epidemiol 15:244-251.

Blass, E.M.; Fillion, T.J.; Rochat, P.; Hoffmeyer, L.B.; Metzger, M.A. (1989) Sensorimotor and Motivational Determinants of Hand-Mouth Coordination in 1-3-Day-Old Human Infants. Dev Psych 25(6):963-975.

Davis, S.; Myers, P.A.; Kohler, E.; Wiggins, C. (1995). Soil Ingestion in Children with Pica: Final Report. U.S. EPA Cooperative Agreement CR 816334-01. Seattle, Washington: Fred Hutchinson Cancer Research Center.

Ferguson, A.C.; Canales, R.A.; Beamer, P.; AuYeung, W.; Key, M.; Munninghoff, A.; Lee, K. T.-W.; Robertson, A., Leckie, J.O. (2006) Video methods in the quantification of children's exposures. J Expo Sci Environ Epidemiol 16:287-298.

Freeman, C.G.; Jimenez, M.; Reed, K.J.; Gurunathan, S.; Edwards, R.D.; Roy, A.; Adgate, J.L.; Pellizzari, E.D.; Quackenboss, J.; Sexton, K.; Lioy, P.J. (2001) Quantitative analysis of children's microactivity patterns: The Minnesota children's pesticide exposure study. J Expo Anal Environ Epidemiol 11:501-509.

Greene, M.A. (2002) Mouthing times for children from the observational study. U.S. Consumer Product Safety Commission, Bethesda, MD.

Groot, M. E.; Lekkerkerk, M. C.; Steenbekkers, L. P. A. (1998) Mouthing Behavior of Young Children: An observational Study. Wageningen Agricultural University, Wageningen, the Netherlands.

Juberg, D.R.; Alfano, K.; Coughlin, R.J.; Thompson, K.M. (2001) An Observational Study of Object Mouthing Behavior by Young Children. Pediatrics 107(1)135-142.

Ko, S.; Schaefer, P.; Vicario, C.; Binns, H.J. (2007) Relationships of video assessments of touching and mouthing behaviors during outdoor play in urban residential yards to parental perceptions of child behaviors and blood lead levels. J Expo Sci Environ Epidemiol 17:47-47.

Lepow, M.L.; Bruckman, L.; Gillette, M.; Markowitz, S.; Robino, R.; Kapish, J. (1975) Investigations into Sources of Lead in the Environment of Urban Children. Environ Res 10:415-26.

Lew, A.R.; Butterworth, G. (1997) The Development of Hand-Mouth Coordination in 2- to 5-Month-Old Infants: Similarities with Reaching and Grasping. Infant Behav Dev 20(1):59-69.

Norris, B.; Smith, S. (2002) Research into the mouthing behaviour of children up to 5 years old. London: Consumer and Competition Policy Directorate, Department of Trade and Industry.

Reed, K.; Jimenez, M.; Freeman, N.; Lioy, P. (1999) Quantification of children's hand and mouthing activities through a videotaping methodology. J Expo Anal Environ Epidemiol 9:513-520.

Rochat, P.; Blass, E.M.; Hoffmeyer, L.B. (1988) Oropharyngeal Control of Hand-Mouth Coordination in Newborn Infants. Dev Psych 24(4):459-63.

Shalat, S.L.; Donnelly, K.C.; Freeman, N.C.G.; Calvin, J.A.; Ramesh, S.; Jimenez, M.; Black, K.; Coutinho, C.; Needham, L.L.; Barr, D.B.; Ramirez, J. (2003) Nondietary ingestion of pesticides by children in an agricultural community on the U.S./Mexico border: Preliminary Results. J Expos Anal Environ Epidemiol 13:42-50.

Smith, S.A.; Norris, B. (2003). Reducing the risk of choking hazards: mouthing behavior of children aged 1 month to 5 years. Injury Control and Safety Promotion 10(3):145-154.

Stanek, E.J.; Calabrese, E.J.; Mundt, K.; Pekow, P.; Yeatts, K.B. (1998) Prevalence of soil mouthing/ingestion among healthy children aged 1 to 6. J Soil Contam 7(2):227-242.

Takaya, R.; Yukuo, K.; Bos, A.F.; Einspieler, C. (2003) Preterm to early postterm changes in the development of hand-mouth contact and other motor patterns. Early Hum Dev 75 Suppl. S193-S202.

Tudella, E.; Oishi, J.; Puglia Bermasco, N.H. (2000) The Effect of Oral-Gustatory, Tactile-Bucal, and Tactile-Manual Stimulation on the Behavior of the Hands in Newborns. Dev Psychobiol 37:82-89.

Tulve, N.S.; Suggs, J.C.; McCurdy, T.; Cohen Hubal, E.A.; Moya, J. (2002) Frequency of mouthing behavior in young children. J Expo Anal Environ Epidemiol 12:259-264.

U.S. EPA. (2005) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants. Washington, DC.: U.S. Environmental Protection Agency, Office of Research and Development. EPA/630/P-03/003F.

Warren, J.J.; Levy, S.M.; Nowak, A.J.; Tang. S. Non-nutritive sucking behaviors in preschool children: a longitudinal study. (2000) Pediatr Dent 22(3):187-91.

Xue, J.; Zartarian, V.; Moya, J.; Freeman, N.; Beamer, P.; Black, K; Tulve, N.; Shalat, S. (2007) A Meta-Analysis of Children's Hand-to-Mouth Frequency Data for Estimating Nondietary Ingestion Exposure. Risk Analysis 27(2):411-420.

Zartarian, V.G.; Streicker, J.; Rivera, A.; Cornejo, C.S.; Molina, S.; Valadez, O.F.; Leckie, J.O. (1995) A Pilot Study to Collect Micro-Activity Data of Two- to Four-Year-Old Farm Labor Children in Salinas Valley, California. J Expo Anal Environ Epidemiol 5(1):21-34.

Zartarian V.G.; Ferguson A.C.; Ong, C.G.; Leckie J. (1997a) Quantifying Videotaped Activity Patterns: Video Translation Software and Training Methodologies. J Expo Anal Environ Epidemiol 7(4):535-542.

Zartarian V.G.; Ferguson A.; Leckie J. (1997b) Quantified dermal activity data from a four-child pilot field study. J Expo Anal Environ Epidemiol 7(4):543-553.

Zartarian, V.G.; Ferguson, A.C.; Leckie, J.O. (1998) Quantified mouthing activity data from a four-child pilot field study. J Expo Anal Environ Epidemiol 8(4):543-553.

Table 4-3. New Jersey Children's Mouthing Frequency (contacts/hour) from Video-transcription

Category	Minimum	Mean	Median	90th Percentile	Maximum
Hand to mouth	0.4	9.5	8.5	20.1	25.7
Object to mouth	0	16.3	3.6	77.1	86.2

Source: Reed et al., 1999.

Table 4-4. Survey-Reported Percent of 168 Minnesota Children Exhibiting Behavior, by Age

Age Group	Thumbs/fingers in Mouth	Toes in Mouth	Non-food Items in Mouth
3 years	71	29	71
4 years	63	0	31
5 years	33	-	20
6 years	30	-	29
7 years	28	-	28
8 years	33	-	40
9 years	43	-	38
10 years	38	-	38
11 years	33	-	48
12 years	33	-	17

\- = No data.

Source: Freeman et al., 2001.

Table 4-5. Video-transcription Median (Mean) Observed Mouthing in 19 Minnesota Children (contacts/hour)

Age Group	N	Object-to-mouth[a]	Hand-to-mouth
3 to 4 years	3	3 (6)	3.5 (4)
5 to 6 years	7	0 (1)	2.5 (8)
7 to 8 years	4	0 (1)	3 (5)
10 to 12 years	5	0 (1)	2 (4)

[a] Kruskal Wallis test comparison across four age groups, P=0.002.
N = Number of observations.

Source: Freeman et al., 2001.

Table 4-6. Variability in Objects Mouthed by Washington State Children (contacts/hour)

Variable	All Subjects				≤24 Months				>24 Months			
	N[a]	Mean[b]	Median	95% CI[c]	N[a]	Mean[b]	Median	95% CI[c]	N[a]	Mean[b]	Median	95% CI[c]
Mouth-body	186	8	2	2-3	69	10	4	3-6	117	7	1	0.8-1.3
Mouth-hand	186	16	11	9-14	69	18	12	9-16	117	16	9	7-12
Mouth-surface	186	4	1	0.8-1.2	69	7	5	3-8	117	2	1	0.9-1.1
Mouth-toy	186	27	18	14-23	69	45	39	31-48	117	17	9	7-12
Total events	186	56	44	36-52	69	81	73	60-88	117	42	31	25-39

[a] Number of observations.
[b] Arithmetic mean.
[c] The 95% confidence intervals (CI) apply to median. Values were calculated in logs and converted to original units.

Source: Tulve et al., 2002.

Table 4-7. Indoor Mouthing Frequency (Contacts per hour), Video-transcription of 9 Children with >15 minutes in View Indoors

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	9	Mean	20.5	29.6
		Median	14.8	22.1
		Range	2.5 - 70.4	3.2 - 82.2
≤24 months	1	-	73.5	84.8
>24 months	8	Mean	13.9	22.7
		Median	13.3	19.5
		Range	2.2 - 34.1	2.8 - 51.3

[a] Object/surface categories mouthed indoors included: Clothes/towels, hands, metal, paper/wrapper, plastic, skin, toys, and wood.
N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-8. Outdoor Mouthing Frequency (Contacts per hour), Video-transcription of 38 Children

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	38	Mean	11.7	18.3
		5th percentile	0.4	0.8
		25th percentile	4.4	9.2
		50th percentile	8.4	14.5
		75th percentile	14.8	22.4
		95th percentile	31.5	51.7
		99th percentile	47.6	56.6
≤24 months	8	Mean	13.0	20.4
		Median	7.0	13.9
		Range	1.3 - 47.7	6.2 - 56.4
>24 months	30	Mean	11.3	17.7
		5th percentile	0.2	0.6
		25th percentile	4.7	7.6
		50th percentile	8.6	14.6
		75th percentile	14.8	22.4
		95th percentile	27.7	43.8
		99th percentile	39.5	53.0

[a] Object/surface categories mouthed outdoors included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.
N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-9. Videotaped Mouthing Activity of Texas Children, Median Frequency (Mean ± SD)

Age	N	Hand to mouth	Object to Mouth
		Frequency (contacts/hour)	Frequency (contacts/hour)
Infant	13	14 (19.8 ± 14.5)	18.1 (24.4 ± 11.6)
1 year	12	13.3 (15.8 ± 8.7)	8.4 (9.8 ± 6.3)
2 years	18	9.9 (11.9 ± 9.3)	5.5 (7.8 ± 5.8)
Preschool	9	19.4 (22.1 ± 22.1)	8.4 (10.1 ± 12.4)

N = Number of subjects.
SD = Standard deviation.

Source: Black et al., 2005.

Table 4-10. Indoor Hand-to-Mouth Frequency (contacts/hour) Distributions from Various Studies

Age Group	N	Mean	SD	Percentiles				
				5	25	50	75	95
3 to <6 months	23	28.0	21.7	3.0	8.0	23.0	48.0	65.0
6 to <12 months	119	18.9	17.4	1.0	6.6	14.0	26.4	52.0
1 to <2 years	245	19.6	19.6	0.1	6.0	14.0	27.0	63.0
2 to <3 years	161	12.7	14.2	0.1	2.9	9.0	17.0	37.0
3 to <6 years	169	14.7	18.4	0.1	3.7	9.0	20.0	54.0
6 to <11 years	14	6.7	5.5	1.7	2.4	5.7	10.2	20.6

N = Number of subjects.
SD = Standard deviation.

Source: Xue et al., 2007.

Table 4-11. Outdoor Hand-to-Mouth Frequency (contacts/hour) Distributions from Various Studies

Age Group	N	Mean	SD	Percentiles				
				5	25	50	75	95
6 to <12 months	10	14.5	12.3	2.4	7.6	11.6	16.0	46.7
1 to <2 years	32	13.9	13.6	1.1	4.2	8.0	19.2	42.2
2 to <3 years	46	5.3	8.1	0.1	0.1	2.6	7.0	20.0
3 to <6 years	55	8.5	10.7	0.1	0.1	5.6	11.0	36.0
6 to <11 years	15	2.9	4.3	0.1	0.1	0.5	4.7	11.9

N = Number of subjects.
SD = Standard deviation.

Source: Xue et al., 2007.

Table 4-12. Survey Reported Mouthing Behaviors for 92 Washington State Children

Behavior	Never		Seldom		Occasionally		Frequently		Always		Unknown	
	N	%	N	%	N	%	N	%	N	%	N	%
Hand/Foot in Mouth	4	4	27	30	23	25	31	34	4	4	3	3
Pacifier	74	81	6	7	2	2	9	10	1	1	0	0
Mouth on Object	14	15	30	33	25	27	19	21	1	1	3	3
Non-Food in Mouth	5	5	25	27	33	36	24	26	5	5	0	0
Eat Dirt/Sand	37	40	39	43	11	12	4	4	1	1	0	0

N = Number of subjects.

Source: Davis et al. 1995.

Table 4-13. Estimated Daily Mean Mouthing Times of New York State Children, for Pacifiers and Other Objects

	Age 0 to 18 months		Age 19 to 36 months	
Object Type	All Children	Only Children Who Mouthed Object [a]	All Children	Only Children Who Mouthed Object [a]
	Minutes	Minutes	Minutes	Minutes
Pacifier	108 (N = 107)	221 (N=52)	126 (N=110)	462 (N=52)
Teether	6 (N=107)	20 (N=34)	0 (N=110)	30 (N=1)
Plastic Toy	17 (N=107)	28 (N=66)	2 (N=110)	11 (N=21)
Other Objects	9 (N=107)	22 (N=46)	2 (N=110)	15 (N=18)

[a] Refers to means calculated for the subset of the sample children who mouthed the object stated (zeroes are eliminated from the calculation of the mean).

N = Number of children.

Source: Juberg et al., 2001.

Table 4-14. Percent of Houston-area and Chicago-area Children Observed Mouthing, by Category and Child's Age

Object Category	All ages	<1 year	1 to 2 years	2 to 3 years
All Objects	100	100	100	100
Pacifiers	27	43	27	10
Non-pacifiers	100	100	100	100
Soft Plastic Food Content Items	28	13	30	41
Anatomy	99	100	97	100
Non-soft Plastic Toys, Teethers, and Rattles	91	94	91	86
Other Items	98	98	97	98

Source: Greene, 2002.

Table 4-15. Estimates of Mouthing Time for Various Objects (minutes/hour)

Age Group	Mean (SD)	Median	95th Percentile	99th Percentile
		All Items[a]		
3 to <12 months	10.5 (7.3)	9.6	26.2	39.8
12 to <24 months	7.3 (6.8)	5.5	22.0	28.8
24 to <36 months	5.3 (8.2)	2.4	15.6	47.8
		Non Pacifiers[b]		
3 to <12 months	7.1 (3.6)	6.9	13.1	14.4
12 to <24 months	4.7 (3.7)	3.6	12.8	18.9
24 to <36 months	3.5 (3.6)	2.3	12.8	15.6
		All Soft Plastic Items		
3 to <12 months	0.5 (0.6)	0.1	1.8	2.5
12 to <24 months	0.4 (0.4)	0.2	1.3	1.9
24 to <36 months	0.4 (0.6)	0.1	1.6	2.9
		Soft Plastic Items Not Food Contact		
3 to <12 months	0.4 (0.6)	0.1	1.8	2.0
12 to <24 months	0.3 (0.4)	0.1	1.1	1.5
24 to <36 months	0.2 (0.4)	0.0	1.3	1.8
		Soft Plastic Toys, Teethers, and Rattles		
3 to <12 months	0.3 (0.5)	0.1	1.8	2.0
12 to <24 months	0.2 (0.3)	0.0	0.9	1.3
24 to <36 months	0.1 (0.2)	0.0	0.2	1.6
		Soft Plastic Toys		
3 to <12 months	0.1 (0.3)	0.0	0.7	1.1
12 to <24 months	0.2 (0.3)	0.0	0.9	1.3
24 to <36 months	0.1 (0.2)	0.0	0.2	1.6
		Soft Plastic Teethers and Rattles		
3 to <12 months	0.2 (0.4)	0.0	1.0	2.0
12 to <24 months	0.0 (0.1)	0.0	0.1	0.6
24 to <36 months	0.0 (0.1)	0.0	0.0	1.0
		Other Soft Plastic Items		
3 to <12 months	0.1 (0.2)	0.0	0.8	1.0
12 to <24 months	0.1 (0.1)	0.0	0.4	0.6
24 to <36 months	0.1 (0.3)	0.0	0.5	1.4

Table 4-15. Estimates of Mouthing Time for Various Objects (minutes/hour) (continued)

Age Group	Mean (SD)	Median	95th Percentile	99th Percentile
Soft Plastic Food Contact Items				
3 to <12 months	0.0 (0.2)	0.0	0.3	0.9
12 to <24 months	0.1 (0.2)	0.0	0.7	1.2
24 to <36 months	0.2 (0.4)	0.0	1.2	1.9
Anatomy				
3 to <12 months	2.4 (2.8)	1.5	10.1	12.2
12 to <24 months	1.7 (2.7)	0.8	8.3	14.8
24 to <36 months	1.2 (2.3)	0.4	5.1	13.6
Non Soft Plastic Toys, Teethers, and Rattles				
3 to <12 months	1.8 (1.8)	1.3	6.5	7.7
12 to <24 months	0.6 (0.8)	0.3	1.8	4.6
24 to <36 months	0.2 (0.4)	0.1	0.9	2.3
Other Items				
3 to <12 months	2.5 (2.1)	2.1	7.8	8.1
12 to <24 months	2.1 (2.0)	1.4	6.6	9.0
24 to <36 months	1.7 (2.6)	0.7	7.1	14.3
Pacifiers				
3 to <12 months	3.4 (6.9)	0.0	19.5	37.3
12 to <24 months	2.6 (6.5)	0.0	19.9	28.6
24 to <36 months	1.8 (7.9)	0.0	4.8	46.3

[a] Object category “all items” is subdivided into pacifiers and non-pacifiers.
[b] Object category “non-pacifiers” is subdivided into all soft plastic items, anatomy (which includes hair, skin, fingers and hands), non-soft plastic toys/teethers/rattles, and other items.
[c] Object category “all soft plastic items” is subdivided into food contact items, nonfood contact items (toys, teethers and rattles) and other soft plastic.
SD = Standard deviation.

Source: Greeene, 2002.

Table 4-16. Mouthing Times of Dutch Children Extrapolated to Total Time While Awake, Without Pacifier, in Minutes per Day

Age Group	N	Mean	SD	Minimum	Maximum
3 to 6 months	5	36.9	19.1	14.5	67
6 to 12 months	14	44	44.7	2.4	171.5
12 to 18 months	12	16.4	18.2	0	53.2
18 to 36 months	11	9.3	9.8	0	30.9

Note: The object most mouthed in all age groups was the fingers, except for the 6 to 12 month group which mostly mouthed toys.
N = Number of children.
SD = Standard deviation.

Source: Groot et al., 1998.

Table 4-17. Estimated Mean Daily Mouthing Duration by Age Group for Pacifiers, Fingers, Toys, and Other Objects (hours:minutes:seconds)

Item Mouthed	Age Group											
	1 to 3 months	3 to 6 months	6 to 9 months	9 to 12 months	12 to 15 months	15 to 18 months	18 to 21 months	21 to 24 months	2 years	3 years	4 years	5 years
N =	9	14	15	17	16	14	16	12	39	31	29	24
Dummy (Pacifier)	0:47:13	0:27:45	0:14:36	0:41:39	1:00:15	0:25:22	1:09:02	0:25:12	0:32:55	0:48:42	0:16:40	0:00:20
Fingers	0:18:22	0:49:03	0:16:54	0:14:07	0:08:24	0:10:07	0:18:40	0:35:34	0:29:43	0:34:42	0:19:26	0:44:06
Toys	0:00:14	0:28:20	0:39:10	0:23:04	0:15:18	0:16:34	0:11:07	0:15:46	0:12:23	0:11:37	0:03:11	0:01:53
Other Objects	0:05:14	0:12:29	0:24:30	0:16:25	0:12:02	0:23:01	0:19:49	0:12:53	0:21:46	0:15:16	0:10:44	0:10:00
Not Recorded	0:00:45	0:00:24	0:00:00	0:00:01	0:00:02	0:00:08	0:00:11	0:14:13	0:02:40	0:00:01	0:00:05	0:02:58
Total (all objects)	1:11:48	1:57:41	1:35:11	1:35:16	1:36:01	0:15:13	1:58:49	1:43:39	1:39:27	1:50:19	0:50:05	0:59:17

N = Number of children in sample.

Source: Smith and Norris, 2003.

Table 4-18. Outdoor Median Mouthing Duration (seconds per contact), Video-transcription of 38 Children

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	38	Mean	3.5	3.4
		5th percentile	0	0
		25th percentile	1	1
		50th percentile	1	1
		75th percentile	2	3
		95th percentile	12	11
		99th percentile	41.6	40
≤24 months	8	Mean	9	2
		Median	3	1
		Range	0 to 136	0 to 40
>24 months	30	Mean	3.5	3.4
		5th percentile	0	0
		25th percentile	1	1
		50th percentile	1	1
		75th percentile	2	3
		95th percentile	12	11
		99th percentile	41.6	40

a Object/surface categories mouthed outdoors included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.

N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-19. Indoor Mouthing Duration (minutes per hour), Video-transcription of 9 Children with >15 minutes in View Indoors

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	9	Mean	1.8	2.3
		Median	0.7	0.9
		Range	0-10.7	0-11.1
≤24 months	1	Observation	10.7	11.1
>24 months	8	Mean	0.7	1.2
		Median	0.7	0.9
		Range	0-1.9	0-3.7

a Object/surface categories mouthed indoors included: Clothes/towels, hands, metal, paper/wrapper, plastic, skin, toys, and wood.

N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-20. Outdoor Mouthing Duration (minutes per hour), Video-transcription of 38 Children

Age Group	N	Statistic	Hands	Total non-dietary[a]
13 to 84 months	38	Mean	0.9	1.2
		5th percentile	0	0
		25th percentile	0.1	0.2
		50th percentile	0.2	0.6
		75th percentile	0.6	1.2
		95th percentile	2.6	2.9
		99th percentile	11.2	11.5
		Range	0-15.5	0-15.8
≤24 months	8	Mean	2.7	3.1
		5th percentile	0	0.2
		25th percentile	0.2	0.2
		50th percentile	0.4	0.8
		75th percentile	1.5	3.1
		95th percentile	11.5	11.7
		99th percentile	14.7	15
		Range	0-15.5	0.2-15.8
>24 months	30	Mean	0.4	0.7
		5th percentile	0	0
		25th percentile	0.1	0.2
		Median	0.2	0.6
		75th percentile	0.4	1
		95th percentile	1.2	2.1
		99th percentile	2.2	2.5
		Range	0-2.4	0-2.6

[a] Object/surface categories mouthed outdoors included: animal, clothes/towels, fabric, hands, metal, non-dietary water, paper/wrapper, plastic, skin, toys, vegetation/grass, and wood.

N = Number of subjects.

Source: AuYeung et al., 2004.

Table 4-21. Reported Daily Prevalence of Massachusetts Children's Non-Food Mouthing/Ingestion Behaviors

Object or substance mouthed or ingested	Percent of children reported to mouth/ingest daily				
	1 year N=171	2 years N=70	3 to <6 years[a] N=265	6 years N=22	All years N=528
Grass, leaves, flowers	16	0	1	0	6
Twigs, sticks, woodchips	12	0	0	0	4
Teething toys	44	6	2	9	17
Other toys	63	27	12	5	30
Blankets, cloth	29	11	10	5	16
Shoes, Footwear	20	1	0	0	7
Clothing	25	7	9	14	14
Crib, chairs, furniture	13	3	1	0	5
Paper, cardboard, tissues	28	9	5	5	13
Crayons, pencils, erasers	19	17	5	18	12
Toothpaste	52	87	89	82	77
Soap, detergent, shampoo	15	14	2	0	8
Plastic, plastic wrap	7	4	1	0	3
Cigarette butts, tobacco	4	0	1	0	2
Suck fingers/thumb	44	21	24	14	30
Suck feet or toes	8	1	0	0	3
Bite nails	2	7	10	14	7
Use pacifier	20	6	2	0	9

[a] Weighted mean of 3, 4, and 5 year-olds' data calculated by U.S. EPA to conform to standardized age categories used in this Handbook.

Source: Stanek et al. (1998).

5 SOIL AND DUST INGESTION

5.1 INTRODUCTION

The ingestion of soil and dust is a potential route of exposure to environmental chemicals. Children may ingest significant quantities of soil, due to their tendency to play on the floor indoors and on the ground outdoors and their tendency to mouth objects or their hands. Children may also ingest soil and dust through deliberate hand to mouth movements, or unintentionally by eating food that has dropped on the floor. Thus, understanding soil and dust ingestion patterns is an important part of estimating children's overall exposures to environmental chemicals.

At this point in time, knowledge of soil and dust ingestion patterns within the United States is somewhat limited. Only a few researchers have attempted to quantify soil and dust ingestion patterns in U.S. children. This chapter explains the concepts of soil ingestion, soil pica, and geophagy, defines these terms for the purpose of this handbook's exposure factors, and presents available data from the literature on the amount of soil and dust ingested.

The Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (ATSDR) held a workshop in June 2000 in which a panel of soil ingestion experts developed definitions for soil ingestion, soil-pica, and geophagy, to distinguish aspects of soil ingestion patterns that are important from a research perspective (ATSDR, 2001). This chapter uses the definitions that are based on those developed by participants in that workshop:

> **Soil ingestion** is the consumption of soil. This may result from various behaviors including, but not limited to, mouthing, contacting dirty hands, eating dropped food, or consuming soil directly.
>
> **Soil-pica** is the recurrent ingestion of unusually high amounts of soil (i.e., on the order of 1,000 - 5,000 mg/day or more).
>
> **Geophagy** is the intentional ingestion of earths and is usually associated with cultural practices.

Some studies are of a behavior known as "pica," and the subset of "pica" that consists of ingesting soil. A general definition of the concept of pica is that of ingesting non-food substances, or ingesting large quantities of certain particular foods. Definitions of pica often include references to recurring or repeated ingestion of these substances. Soil-pica is pica that is specific to ingesting materials that are defined as soil, such as clays, yard soil, and flower-pot soil. Researchers in many different disciplines have hypothesized motivations for human soil-pica or geophagy behavior, including alleviating nutritional deficiencies, a desire to remove toxins or self-medicate, and other physiological or cultural influences (e.g., Danford, 1982). Bruhn and Pangborn (1971) and Harris and Harper (1997) suggest a religious context for certain geophagy or soil ingestion practices. Some researchers have investigated subpopulations of children who may be more likely than other children to exhibit soil-pica behavior on a recurring basis. These subpopulations might include children who practice geophagy (Vermeer and Frate, 1979), institutionalized children (Wong, 1988), and children with developmental delays (Danford, 1983), autism (Kinnell, 1985), or celiac disease (Korman, 1990). However, identifying specific soil-pica and geophagy subpopulations remains difficult due to limited research on this topic.

In this handbook, soil, indoor settled and outdoor settled dust, and dust ingestion are defined generally as:

> **Soil**. Particles of unconsolidated mineral and/or organic matter from the earth's surface that are located outdoors, or are used indoors to support plant growth. It includes particles that have settled onto outdoor objects and surfaces (outdoor settled dust).
>
> **Indoor Settled Dust**. Particles in building interiors that have settled onto objects, surfaces, floors, and carpeting. These particles may include soil particles that have been tracked into the indoor environment from outdoors as well as organic matter.
>
> **Outdoor Settled Dust**. Particles that have settled onto outdoor objects and surfaces due to either wet or dry deposition. Note that it is not possible to distinguish between soil and outdoor settled dust, since outdoor settled dust generally would be present on the uppermost surface layer of soil.

For the purposes of this handbook, soil ingestion includes both soil and outdoor settled dust, and dust ingestion includes indoor settled dust only.

There are several methodologies represented in the literature related to soil and dust ingestion by children. Three methodologies combine biomarker measurements with measurements of the biomarker substance's presence in environmental media. A fourth methodology offers indirect evidence of soil/dust ingestion behaviors from the responses of caregivers and/or children to survey questions.

The first of the biomarker methodologies measures quantities of specific elements present in children's feces, urine, food and medications, yard soil, house dust, and sometimes also community soil and dust, and combines this information using certain assumptions about the elements' behavior in the gastrointestinal tract to produce estimates of soil and dust quantities ingested (e.g., Davis et al., 1990). In this chapter, this methodology is referred to as the "tracer element" methodology. The second biomarker methodology compares results from a biokinetic model of lead exposure and uptake that predict children's blood lead levels, with biomarker measurements of lead in children's blood (e.g., von Lindern et al., 2003). The model predictions are made using assumptions about ingested soil and dust quantities that are based, in part, on results from early versions of the first methodology. Therefore, the comparison with actual measured blood lead levels serves to confirm, to some extent, the assumptions about ingested soil and dust quantities used in the biokinetic model. In this chapter, this methodology is referred to as the "biokinetic model comparison" methodology. The third biomarker methodology, the "lead isotope ratio" methodology, involves measurements of different lead isotopes in children's blood and/or urine, food, water, and house dust and compares the ratio of different lead isotopes to infer sources of lead exposure that may include dust or other environmental exposures (e.g., Manton et al., 2000). In the fourth, "survey response" methodology, responses to survey questions regarding soil and dust ingestion are analyzed. This methodology includes questions asked of children directly, or their caregivers, about soil and dust ingestion behaviors, frequency, and sometimes quantity (e.g., Barltrop, 1966).

Although not directly evaluated in this chapter, a fifth methodology uses assumptions regarding ingested quantities of soil and dust that are based on general knowledge of children's behavior, and potentially supplemented or informed by data from other methodologies (e.g., Hawley, 1985; Kissel et al., 1998; Wong et al., 2000).

The recommendations for soil, dust, and soil + dust ingestion rates are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on key studies identified by U.S. EPA for this factor. Following the recommendations, key studies on soil and dust ingestion are summarized. Summaries of the relevant studies, methodology descriptions and methodological strengths and limitations are also provided.

5.2 RECOMMENDATIONS

The key studies described in Section 5.3 were used to recommend values for soil and dust ingestion among children. The key studies pre-dated the age groups recommended by U.S. EPA (2005) and were performed on groups of children of varying ages. As a result, central tendency recommendations can be used for the life stage categories of 6 to <12 months, 1 to <2 years, 2 to <3 years, 3 to <6 years, and part of the 6 to <11 years categories. Upper percentile recommendations can be used for the life stage categories of 1 to <2 years, 2 to <3 years, 3 to <6 years, 6 to <11 years, and part or all of the 11 to <16 years category. Due to the current state of research on soil and dust ingestion, the upper percentile recommendations are called "soil-pica" or "geophagy" recommendations that are likely to represent high soil ingestion episodes or behaviors at an unknown point on the high end of the distribution of soil ingestion.

The soil ingestion recommendations in Table 5-1 are intended to represent ingestion of a combination of soil and outdoor settled dust, without distinguishing between these two sources. The source of the soil in these recommendations could be outdoor soil, indoor containerized soil used to support growth of indoor plants, or a combination of both outdoor soil and containerized indoor soil. These recommendations are called "soil." The dust ingestion recommendations in Table 5-1 include soil tracked into the indoor setting, indoor settled dust and air-suspended particulate matter that is inhaled and swallowed. Central tendency "dust" recommendations are provided, in the event that assessors need recommendations for an indoor or inside a transportation vehicle scenario in which dust, but not outdoor soil, is the exposure medium of concern. The soil + dust recommendations would include soil, either from outdoor or containerized indoor sources, dust that is a combination of outdoor settled dust, indoor settled dust, and air-suspended particulate matter that is inhaled, subsequently trapped in mucous and moved from the respiratory system to the gastrointestinal tract, and a soil-origin material located on indoor floor surfaces that was tracked indoors by building occupants. Soil and dust recommendations exclude the soil or dust's moisture content. In other words, recommended values represent mass of ingested soil or dust that is represented on a dry weight basis.

Table 5-1 shows the central tendency recommendations for daily ingestion of soil, dust, or soil + dust, in mg/day. It also shows the soil-pica or geophagy recommendations for daily ingestion of soil, in mg/day. No data are available on which to base comparable upper percentile recommendations for "dust" or "soil + dust." Published estimates from the key studies have been rounded to one significant figure. The recommended central tendency soil + dust ingestion estimate for infants from 6 months up to their first birthday is 60 mg/day. If an estimate is needed for soil only, from outdoor or indoor sources, or both outdoor and indoor sources, the recommendation is 30 mg/day. If an estimate for indoor dust only is needed, that would include a certain quantity of tracked-in soil from outside, the recommendation is 30 mg/day. The confidence rating for this recommendation is low due to the small numbers of study subjects in the study on which the recommendation is based and the inferences needed to develop a quantitative estimate. Examples of these inferences include: an assumption that the relative proportions of soil and dust ingested by 6 to 12 month old children is the same as the central tendency assumption for older children (45 percent soil, 55 percent dust, based on U.S. EPA (1994a)), and the assumption that pre-natal or non-soil, non-dust sources of lead exposure do not dominate these children's blood lead levels.

When assessing risks for children who are not expected to exhibit soil-pica or geophagy behavior, the recommended central tendency soil + dust ingestion estimate is 100 mg/day for children ages 1 to <6 years. If an estimate for soil only is needed, for exposure to soil such as manufactured topsoil or potted-plant soil that could occur in either an indoor or outdoor setting, or when the risk assessment is not considering children's ingestion of indoor dust (in an indoor setting) as well, the recommendation is 50 mg/day. If an estimate for indoor dust only is needed, the recommendation is 60 mg/day. Although these quantities add up to 110 mg/day, the sum is rounded to one significant figure. Although there were no tracer element studies or biokinetic model comparison studies performed for children 6 to < 21 years, as a group, their mean or central tendency soil ingestion would not be zero. In the absence of data that can be used to develop specific central tendency soil and dust ingestion recommendations for children aged 6 to <11 years, 11 to <16 years and 16 to <21 years, U.S. EPA recommends using the same central tendency soil and dust ingestion rates that are recommended for children in the 1 to < 6 year old age range.

When assessing risks for children who may exhibit soil-pica behavior, or a group of children that includes individual children who may exhibit soil-pica behavior, the soil-pica ingestion estimate for children up to age 14 ranges from 400 to 41,000 mg/day. Due to the definition of soil-pica used in this chapter, that sets a lower bound on the quantity referred to as "soil-pica" at 1,000 mg/day, and due to the significant number of observations in the U.S. tracer element studies that are at or exceed that quantity, the recommended soil-pica ingestion rate is 1,000 mg/day. Currently, no data are available for upper percentile, soil-pica behavior for children ages 16 to <21 years. Because pica behavior may occur among some children ages ~1 to 21 years old (Hyman et al., 1990), it is prudent to assume that, for some children, soil-pica behavior may occur at any age up to <21 years.

The recommended geophagy soil estimate is 50,000 mg/day (50 grams). Risk assessors should use this value for soil ingestion in areas where residents are known to exhibit geophagy behaviors.

These recommendations are not robust enough for use in probabilistic risk assessments.

Table 5-2 shows the confidence ratings for these recommendations. Section 5.4 gives a more detailed explanation of the basis for the confidence ratings.

An important factor to consider when using these recommendations is that they are limited to estimates of soil and dust quantities ingested. The scope of this chapter is limited to quantities of soil and dust taken into the gastrointestinal tract, and does not extend to issues regarding bioavailability of environmental contaminants present in that soil and dust. Information from other sources is needed to address bioavailability. In addition, as more information becomes available regarding gastrointestinal absorption of environmental contaminants, adjustments to the soil and dust ingestion exposure equations may need to be made, to better represent the direction of movement of those contaminants within the gastrointestinal tract.

To place these recommendations into context, it is useful to compare these soil ingestion rates to common measurements. The bulk densities of surface soils are often in the range of 1.3 to 1.7 g/cm^3. U.S. EPA (1996) recommends using 1.5 g/cm^3 as a default value for dry soil bulk density. The central tendency recommendation of 50 mg/day, or 0.050 g/day, dry weight basis, with a 1.5 g/cm^3 bulk density would be equivalent to approximately 0.03 cm^3. A teaspoon is approximately 5 cm^3 in volume, so the 50 mg/day quantity would be roughly equivalent to seven thousandths of a teaspoon per day. The 50 g/day ingestion rate recommended to represent geophagy behavior would be roughly equivalent to 5 to 7 teaspoons per day in volume.

Indoor settled dust could be expected to have a lower dry bulk density than the surface soil bulk density cited above (for example, bulk densities of five grain dusts are reported by Parnell et al. (1986) to be 0.15-0.31 g/cm^3, "specific density" of Danish office building dust is reported by Mølhave et al. (2000) to be 1.0 gm/cm^3). Thus, volumes of indoor settled dust could be expected to weigh less than comparable volumes of surface soil. The central tendency "dust" recommendation for children of 60 mg/day, or 0.060 g/day, dry weight basis, with a 1.0 g/cm^3 bulk density would be equivalent to approximately 0.06 cm^3, or roughly equivalent to twelve thousandths of a teaspoon per day.

Table 5-1. Recommended Values for Daily Soil, Dust, and Soil + Dust Ingestion

Age Group	Soil[a]			Dust[b]	Soil + Dust
	Central Tendency (mg/day)	Upper Percentile		Central Tendency (mg/day)	Central Tendency (mg/day)
		Soil-Pica (mg/day)	Geophagy (mg/day)		
6 to <12 months	30	-	-	30	60
1 to < 6 years	50	1,000	50,000	60	100[c]
6 to <21 years	50	1,000	50,000	60	100[c]

- No recommendation.
[a] Includes soil and outdoor settled dust.
[b] Includes indoor settled dust only.
[c] Total soil and dust ingestion rate is 110 mg/day; rounded to one significant figure it is 100 mg/day.

Table 5-2. Confidence in Recommendations for Ingestion of Soil and Dust

General Assessment Factors	Rationale	Rating
Soundness		Low
Adequacy of Approach	The methodologies have significant limitations. The studies did not capture all of the information needed (quantities ingested, frequency of high soil ingestion episodes, prevalence of high soil ingestion). Four of the 9 studies were of census or randomized design. Sample selection may have introduced some bias in the results (i.e., children near smelter or Superfund sites, volunteers in nursery schools). The total number of children in key studies was 1,203 (859 U.S. children, 292 Dutch, and 52 Jamaican children), while the target population currently numbers more than 74 million (U.S. DOC, 2008). The response rates for in-person interviews and telephone surveys were often not stated in published articles. Primary data were collected for 381 U.S. children and 292 Dutch children; secondary data for 478 U.S. children and 52 Jamaican children.	
Minimal (or defined) Bias	Numerous sources of measurement error exist in the tracer element studies. Biokinetic model comparison study may contain less measurement error than tracer element studies. Survey response study may contain measurement error.	
Applicability and Utility		Low
Exposure Factor of Interest	8 of the 9 key studies focused on the soil exposure factor, with no or less focus on the dust exposure factor. Biokinetic model comparison study did not focus exclusively on soil and dust exposure factors.	
Representativeness	The study samples may not be representative of the U.S. in terms of race, ethnicity, socio-economics, and geographical location; studies focused on specific areas.	
Currency	Studies results are likely to represent current conditions.	
Data Collection Period	Tracer element studies' data collection periods may not represent long-term behaviors. Biokinetic model comparison and survey response studies do represent longer term behaviors.	
Clarity and Completeness		Low
Accessibility	Observations for individual children are available for only 3 of the 9 key studies.	
Reproducibility	For the methodologies used by more than one research group, reproducible results were obtained in some instances. Some methodologies have been used by only one research group and have not been reproduced by others.	
Quality Assurance	For some studies, information on quality assurance/quality control was limited or absent.	
Variability and Uncertainty		Low
Variability in Population	Tracer element studies characterized variability among study sample members; biokinetic model comparison and survey response studies did not. Day-to-day and seasonal variability was not very well characterized. Numerous factors that may influence variability have not been explored in detail.	
Minimal Uncertainty	Estimates are highly uncertain. Tracer element studies' design appears to introduces biases in the results.	
Evaluation and Review		Medium
Peer Review	All key studies appeared in peer review journals.	
Number and Agreement of Studies	9 key studies. Researchers using similar methodologies obtained generally similar results; somewhat general agreement between researchers using different methodologies.	
Overall Rating		**Low**

5.3 KEY AND RELEVANT STUDIES

The key tracer element, biokinetic model comparison, and survey response studies are summarized in the following sections. Certain studies were considered "key" and were used as a basis for developing the recommendations, using judgment about the study's design features, applicability, and utility of the data to U.S. children's soil and dust ingestion rates, clarity and completeness, and characterization of uncertainty and variability in ingestion estimates. Because the studies often were performed for reasons unrelated to developing soil and dust ingestion recommendations, their attributes that were characterized as "limitations" in this chapter might not be limitations when viewed in the context of the study's original purpose. However, when studies are used for developing a soil or dust ingestion recommendation, U.S. EPA has categorized some studies' design or implementation as preferable to other studies' design or implementation. In general, U.S. EPA chose studies designed either with a census, or randomized sample, approach, over studies that used a convenience sample or other, non-randomized, approach, as well as studies that more clearly explained various factors in the study's implementation that affect interpretation of the results. However, in some cases, studies that used a non-randomized design contain information that is useful for developing exposure factor recommendations (for example, if they are the only studies of children in a particular age category), and thus may have been designated as "key" studies. Other studies were considered "relevant" but not "key" because they provide useful information for evaluating the reasonableness of the data in the key studies, but in U.S. EPA's judgment they did not meet the same level of soundness, applicability and utility, clarity and completeness, and characterization of uncertainty and variability that the key studies did. In addition, studies that did not contain information that can be used to develop a specific recommendation for mg/day soil and dust ingestion were classified as relevant rather than key.

Some studies are re-analyses of data previously published. For this reason, the sections that follow are organized into key and relevant studies of primary analysis (that is, studies in which researchers have developed primary data pertaining to soil and dust ingestion) and key and relevant studies of secondary analysis (that is, studies in which researchers have interpreted previously published results, or data that were originally collected for a different purpose).

5.3.1 Methodologies Used in Key Studies

5.3.1.1 *Tracer Element Methodology*

The tracer element methodology attempts to quantify the amounts of soil ingested by analyzing samples of soil and dust from children's residences and/or play areas, and the children's feces, and sometimes also urine. The soil, dust, fecal, and urine samples are analyzed for the presence and quantity of tracer elements - typically, aluminum, silicon, titanium, and other elements. A key underlying assumption is that these elements are not metabolized into other substances in the body or absorbed from the gastrointestinal tract in significant quantities, and thus their presence in feces and urine can be used to estimate the quantity of soil ingested by mouth. Although they are sometimes called mass balance studies, none of the studies attempt to quantify amounts excreted in perspiration, tears, glandular secretions, or shed skin, hair or finger- and toe-nails, nor do they account for tracer element exposure via the dermal or inhalation into the lung routes, and thus they are not a complete "mass balance" methodology. Early studies using this methodology did not always account for the contribution of tracer elements from non-soil substances (food, medications, and non-food sources such as toothpaste) that children might swallow. U.S. studies using this methodology in or after the mid to late 1980s account for, or attempt to account for, tracer element contributions from these non-soil sources. Some study authors adjust their soil ingestion estimate results to account for the potential contribution of tracer elements found in household dust as well as soil.

The general algorithm that is used to calculate the quantity of soil or dust estimated to have been ingested by each child is as follows: the quantity of a given tracer element, in milligrams, present in the child's feces and urine, minus the quantity of that tracer element, in milligrams, present in the child's food and medicine, the result of which is divided by the tracer element's soil concentration, in milligrams of tracer per gram of soil, to yield an estimate of ingested soil, in grams.

The U.S. tracer element researchers have all assumed a certain offset, or lag time between ingestion of food, medication and soil, and the resulting fecal and urinary output. The lag times used are typically 24 or 28 hours; thus, these researchers subtract the previous day's food and medication tracer element quantity ingested from the current day's fecal and urinary tracer element quantity that was excreted. When compositing food, medication, fecal and urine samples across the entire study period, daily estimates can be obtained by dividing the total estimated soil ingestion by the number of days in which fecal and/or urine samples were collected. A variation of the algorithm that provides slightly higher estimates of soil ingestion is to divide the total estimated soil ingestion by the number of days on which feces were produced, which by definition would be equal to or less than the total number of days of the study period's fecal sample collection.

Substituting tracer element dust concentrations for tracer element soil concentrations yields a dust ingestion estimate. Because the actual non-food, non-medication quantity ingested is a combination of soil and dust, the unknown true soil and dust ingestion is likely to be somewhere between the estimates that are based on soil concentrations and estimates that are based on dust concentrations. Tracer element researchers have described ingestion estimates for soil that actually represent a combination of soil and dust, but were calculated based on tracer element concentrations in soil. Similarly, they have described ingestion estimates for dust that are actually for a combination of soil and dust but were calculated based on tracer element concentrations in dust. Other variations on these general soil and dust ingestion algorithms have been published, in attempts to account for time spent indoors, time spent away from the house, etc. that could be expected to influence the relative proportion of soil vs. dust.

Each child's soil and dust ingestion can be represented as an unknown constant in a set of simultaneous equations of soil or dust ingestion represented by different tracer elements. To date, only one of the U.S. research teams (Lásztity et al., 1989) has published estimates calculated for pairs of tracer elements using simultaneous equations.

The U.S. tracer element studies have been performed for only short-duration study periods, and only for 241 children (101 in Davis et al., 1990, 12 of whom were studied again in Davis and Mirick, 2006; 64 in Calabrese et al., 1989/Barnes 1990; 64 in Calabrese et al., 1997a; and 12 in Calabrese et al., 1997b). They provide information on quantities of soil and dust ingested for the studied groups of children for short time periods, but provide limited information on overall prevalence of soil ingestion by U.S. children, and limited information on the frequency of higher soil ingestion episodes.

The tracer element studies appear to contain numerous sources of error that influence the estimates upward and downward. Sometimes the error sources cause individual children's soil or dust ingestion estimates to be negative, which is not physically possible. In some studies, for some of the tracers, so many individual children's "mass balance" soil ingestion estimates were negative that median or mean estimates based on that tracer were negative. For soil and dust ingestion estimates based on each particular tracer, or averaged across tracers, the net impact of these competing upward and downward sources of error is unclear.

5.3.1.2 *Biokinetic Model Comparison Methodology*

The Biokinetic Model Comparison methodology compares direct measurements of a biomarker, such as blood or urine levels of a toxicant, with predictions from a biokinetic model of oral, dermal and inhalation exposure routes with air, food, water, soil, and dust toxicant sources. An example is to compare children's measured blood lead levels with predictions from the Integrated Exposure and Uptake Biokinetic (IEUBK) model. Where environmental contamination of lead in soil, dust, and drinking water has been measured and those measurements can be used as model inputs for the children in a specific community, the model's assumed soil and dust ingestion values can be confirmed or refuted by comparing the model's predictions of blood lead levels with those children's measured blood lead levels. It should be noted, however, that such confirmation of the predicted blood lead levels would be confirmation of the net impact of all model inputs, and not just soil and dust ingestions. Under the assumption that the actual measured blood lead levels of various groups of children studied have minimal error, and those measured blood lead levels roughly match the biokinetic model predictions for those groups of children, then the model's default assumptions may be roughly accurate for the central tendency, or typical, children in an assessed group of children. The model's default assumptions likely are not as useful for predicting outcomes for highly exposed children.

5.3.1.3 *Survey Response Methodology*

The survey response methodology includes studies that survey children's caretakers, or children themselves, via in-person or mailed surveys that ask about mouthing behavior and ingestion of various non-food items. Sometimes, questions about amounts ingested are included in the survey instrument. There could be either false positive or false negative responses to these questions, for various reasons.

5.3.2 Key Studies of Primary Analysis

5.3.2.1 *Vermeer and Frate, 1979 - Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications*

Vermeer and Frate (1979) performed a survey response study in Holmes County, Mississippi in the 1970s (date unspecified). Questions about geophagy (defined as regular consumption of clay over a period of weeks) were asked of household members (N=229 in 50 households; 140 were children or adolescents) of a subset of a random sample of nutrition survey respondents. Caregiver responses to questions about 115 children under 13 indicate that geophagy was likely to be practiced by a minimum of 18 (16 percent) of these children; however, 16 of these 18 children were 1 to 4 years old, and only 2 of the 18 were older than 4 years. There was no reported geophagy among 25 adolescent study subjects questioned. The average daily amount of clay consumed was reported to be about 50 grams, for the 32 adult and 18 under-age-13 years child respondents who acknowledged practicing geophagy. Quantities were usually described as either portions or multiples of the amount that could be held in a single, cupped hand. Clays for consumption were generally obtained from the B soil horizon, or subsoil rather than an uppermost layer, at a depth of 50 to 130 centimeters.

5.3.2.2 *Calabrese et al., 1989 - How Much Soil Do Young Children Ingest: An Epidemiologic Study/Barnes, 1990 - Childhood Soil Ingestion: How Much Dirt Do Kids Eat?/Calabrese et al., 1991 - Evidence of Soil-Pica Behaviour and Quantification of Soil Ingested*

Calabrese et al. (1989) and Barnes (1990) studied soil ingestion among children using eight tracer elements—aluminum, barium, manganese, silicon, titanium, vanadium, yttrium, and zirconium. A non-random sample of 30 male and 34 female 1, 2 and 3 year-olds from the greater Amherst, Massachusetts area were studied, presumably in 1987. The children were predominantly from two-parent households where the parents were highly educated. The study was conducted over a period of eight days spread over two weeks. During each week, duplicate samples of food, beverages, medicines, and vitamins were collected on Monday through Wednesday, while excreta were collected for four 24-hour cycles running from Monday/Tuesday through Thursday/Friday. Soil and dust samples were also collected from the child's home and play area. Study participants were supplied with toothpaste, baby cornstarch, diaper rash cream, and soap with low levels of most of the tracer elements. Fecal and urine samples, excluding wipes and toilet paper, were also collected and analyzed for tracer elements.

Table 5-3 shows the published mean soil ingestion estimates ranging from -294 mg/day based on manganese to 459 mg/day based on vanadium, median soil ingestion estimates ranging from -261 mg/day based on manganese to 96 mg/day based on vanadium, and 95^{th} percentile estimates ranged from 106 mg/day based on yttrium to 1,903 mg/day based on vanadium. Maximum daily soil ingestion estimates ranged from 1,391 mg/day based on zirconium to 7,281 mg/day based on manganese. Dust ingestions calculated using tracer concentrations in dust were often, but not always, higher than soil ingestions calculated using tracer concentrations in soil.

Data for the uppermost 23 subject-weeks (the highest soil ingestion estimates, averaged over the four days of excreta collection during each of the two weeks) were published in Calabrese et al. (1991). One child's soil-pica behavior was estimated in Barnes (1990) using both the subtraction/division algorithm and the simultaneous equations method. On two particular days during the second week of the study period, the child's aluminum-based soil ingestion estimates were 19 g/day (18,700 mg/day) and 36 g/day (35,600 mg/day), silicon-based soil ingestion estimates were 20 g/day (20,000 mg/day) and 24 g/day (24,000), and simultaneous-equation soil ingestion estimates were 20 g/day (20,100 mg/day) and 23 g/day (23,100 mg/day) (Barnes 1990). By tracer, averaged across the entire week, this child's estimates ranged from approximately 10 to 14 g/day during the second week of observation (Calabrese et al., 1991, shown in Table 5-4), and averaged 6 g/day across the entire study period. Additional information about this child's apparent ingestion of soil vs. dust during the study period, shown in Table 5-5, was published in Calabrese and Stanek (1992a).

5.3.2.3 *Van Wijnen et al., 1990 - Estimated Soil Ingestion by Children*

In a tracer element study by Van Wijnen et al. (1990), soil ingestion among Dutch children ranging in age from 1 to 5 years was evaluated using a tracer element methodology. Van Wijnen et al. (1990) measured three tracers (titanium, aluminum, and acid insoluble residue (AIR)) in soil and feces. The authors estimated soil ingestion based on an assumption called the Limiting Tracer Method (LTM), which assumed that soil ingestion could not be higher than the lowest value of the three tracers. LTM values represented soil ingestion estimates that were not corrected for dietary intake.

An average daily feces dry weight of 15 g was assumed. A total of 292 children attending daycare centers were studied during the first of two sampling periods and 187 children were studied in the second sampling period; 162 of these children were studied during both periods (i.e., at the beginning and near the end of the summer of 1986). A total of 78 children were studied at campgrounds. The authors reported geometric mean LTM values because soil ingestion rates were found to be skewed and the log transformed data were approximately normally distributed. Geometric mean LTM values were estimated to be 111 mg/day for children in daycare centers and 174 mg/day for children vacationing at campgrounds (Table 5-6). For the 162 daycare center children studied during both sampling periods the arithmetic mean LTM was 162 mg/day, and the median was 114 mg/day.

Fifteen hospitalized children were studied and used as a control group. These children's LTM soil ingestion estimates were 74 (geometric mean), 93 (mean), and 110 (median) mg/day. The authors assumed the hospitalized children's soil ingestion estimates represented dietary intake of tracer elements, and used rounded 95 percent confidence limits on the arithmetic mean, 70 to 120 mg/day, to correct the day-care and campground children's LTM estimates for dietary intake of tracers. Corrected soil ingestion rates were 69 mg/day (162 mg/day minus 93 mg/day) for daycare children and 120 mg/day (213 mg/day minus 93 mg/day) for campers. Corrected geometric mean soil ingestion was estimated to range from 0 to 90 mg/day, with a 90th percentile value of up to 190 mg/day for the various age categories within the daycare group and 30 to 200 mg/day, with a 90th percentile value of up to 300 mg/day for the various age categories within the camping group.

AIR was the limiting tracer in about 80 percent of the samples. Among children attending daycare centers, soil ingestion was also found to be higher when the weather was good (i.e., <2 days/week precipitation) than when the weather was bad (i.e., >4 days/week precipitation (Table 5-7).

5.3.2.4 *Davis et al., 1990 - Quantitative Estimates of Soil Ingestion in Normal Children between the Ages of 2 and 7 Years: Population-based Estimates Using Aluminum, Silicon, and Titanium as Soil Tracer Elements*

Davis et al. (1990) used a tracer element technique to estimate soil ingestion among children. In this study, 104 children between the ages of 2 and 7 years were randomly selected from a three-city area in southeastern Washington State. Soil and dust ingestion was evaluated by analyzing soil and house dust, feces, urine, and duplicate food, dietary supplement, medication and mouthwash samples for aluminum, silicon, and titanium. Data were collected for 101 of the 104 children during July, August or September, 1987. In each family, data were collected over a seven day period, with four days of excreta sample collection. Participants were supplied with toothpaste with known tracer element content. In addition, information on dietary habits and demographics was collected in an attempt to identify behavioral and demographic characteristics that influence soil ingestion rates among children. The amount of soil ingested on a daily basis was estimated using equation 5-1:

$$S_{i,e} = \frac{((DW_f + DW_p) \times E_f) + 2E_u) - (DW_{fd} \times E_{fd})}{E_{soil}} \quad \text{(Eq. 5-1)}$$

where:

$S_{i,e}$	=	soil ingested for child *i* based on tracer *e* (g);
DW_f	=	feces dry weight (g);
DW_p	=	feces dry weight on toilet paper (g);
E_f	=	tracer concentration in feces (µg/g);
E_u	=	tracer amount in urine (µg);
DW_{fd}	=	food dry weight (g);
E_{fd}	=	tracer concentration in food (µg/g); and
E_{soil}	=	tracer concentration in soil (µg/g).

The soil ingestion rates were corrected by adding the amount of tracer in vitamins and medications to the amount of tracer in food, and adjusting the food, fecal and urine sample weights to account for missing samples. Food, fecal and urine samples were composited over a 4-day period, and estimates for daily soil ingestion were obtained by dividing the 4 day composited tracer quantities by 4.

Soil ingestion rates were highly variable, especially those based on titanium. Mean daily soil ingestion estimates were 38.9 mg/day for aluminum, 82.4 mg/day for silicon and 245.5 mg/day for titanium (Table 5-8). Median values were 25 mg/day for aluminum, 59 mg/day for silicon, and 81 mg/day for titanium. The investigators also evaluated the extent to which differences in tracer concentrations in house dust and yard soil impacted estimated soil ingestion rates. The value used in the denominator of the soil ingestion estimate equation was recalculated to represent a weighted average of the tracer concentration in yard soil and house dust based on the proportion of time the child spent indoors and outdoors, using an assumption that the likelihood of ingesting soil outdoors was the same as that of ingesting dust indoors. The adjusted mean soil/dust ingestion rates were 64.5 mg/day for aluminum, 160.0 mg/day for silicon, and 268.4 mg/day for titanium. Adjusted median soil/dust ingestion rates were: 51.8 mg/day for aluminum, 112.4 mg/day for silicon, and 116.6 mg/day for titanium. The authors investigated whether nine behavioral and demographic factors could be used to predict soil ingestion, and found family income less than $15,000/year and swallowing toothpaste to be significant predictors with silicon-based estimates; residing in one of the three cities to be a significant predictor with aluminum-based estimates, and washing the face before eating significant for titanium-based estimates.

5.3.2.5 *Calabrese et al. 1997a - Soil Ingestion Estimates for Children Residing on a Superfund Site*

Calabrese et al. (1997a) estimated soil ingestion rates for children residing on a Superfund site using a methodology in which eight tracer elements were analyzed. The methodology used in this study is similar to that employed in Calabrese et al. (1989), except that rather than using barium, manganese, and vanadium as three of the eight tracers, the researchers replaced them with cerium, lanthanum and neodymium. A total of 64 children ages 1-3 years (36 male, 28 female) were selected for this study of the Anaconda, Montana area. The study was conducted for seven consecutive days during September or September and October, apparently in 1992, shortly after soil was removed and replaced in some residential yards in the area. Duplicate samples of meals, beverages, and over-the-counter medicines and vitamins were collected over the seven day period, along with fecal samples. In addition, soil and dust samples were collected from the children's home and play areas. Toothpaste containing nondetectable levels of the tracer elements, with the exception of silica, was provided to all of the children. Infants were provided with baby cornstarch, diaper rash cream, and soap which were found to contain low levels of tracer elements.

Calabrese et al. (1997a) estimated soil ingestion by each tracer element, as shown in Table 5-9.

5.3.2.6 *Stanek et al. 1998 - Prevalence of Soil Mouthing/Ingestion among Healthy Children Aged 1 to 6/Calabrese et al. 1997b - Soil Ingestion Rates in Children Identified by Parental Observation as Likely High Soil Ingesters*

Stanek et al. (1998) conducted a survey response study using in-person interviews of parents of children attending well visits at three western Massachusetts medical clinics in August, September and October of 1992. Of 528 children ages 1 to 7 with completed interviews, parents reported daily mouthing or ingestion of sand and stones in 6 percent, daily mouthing or ingestion of soil and dirt in 4 percent, and daily mouthing or ingestion of dust, lint and dustballs in 1 percent. Parents reported more than weekly mouthing or ingestion of sand and stones in 16 percent, more than weekly mouthing or ingestion of soil and dirt in 10 percent, and more than weekly mouthing or ingestion of dust, lint and dustballs in 3 percent. Parents reported more than monthly mouthing or ingestion of sand and stones in 27 percent, more than monthly mouthing or ingestion of soil and dirt in 18 percent, and more than monthly mouthing or ingestion of dust, lint and dustballs in 6 percent.

Calabrese and colleagues performed a follow-up tracer element study (Calabrese et al. 1997b) for a subset (n=12) of the Stanek et al. (1998) children whose caregivers had reported daily sand/soil ingestion (n=17). The time frame of the follow-up tracer study relative to the original survey response study was not stated; the study duration was 7 days. Of the 12 children in Calabrese et al. 1997b, one exhibited behavior that the authors believed was clearly soil pica; Table 5-10 shows estimated soil ingestion rates for this child during the study period. Estimated average daily soil ingestion estimates (calculated based on soil tracer element concentrations only) ranged from -0.015 to +1.783 g/day based on aluminum, -0.046 to +0.931 g/day based on silicon, and -0.047 to +3.581 g/day based on titanium. Estimated average daily dust ingestion estimates (calculated based on dust tracer element concentrations only) ranged from -0.039 to +2.652 g/day based on aluminum, -0.028 to +3.145 g/day based on silicon, and -0.098 to +3.632 g/day based on titanium. Calabrese et al. (1997b) question the validity of retrospective caregiver reports of soil pica on the basis of the tracer element results.

5.3.2.7 *Davis and Mirick, 2006 - Soil ingestion in children and adults in the same family*

Davis and Mirick (2006) calculated soil ingestion for children and adults in the same family using a tracer element approach. Data were collected in 1988, one year after the Davis et al. (1990) study was conducted. Samples were collected and prepared for laboratory analysis and then stored for a 12 year period prior to tracer element quantification with laboratory analysis. The 20 families in this study were a nonrandom subset of the 104 families who participated in the soil ingestion study by Davis et al. (1990), and were chosen based on high compliance with the previous study protocol and expressed willingness to participate in a future study. Data collection issues resulted in sufficiently complete data for only 19 of the 20 families consisting of a child participant from the Davis et al. (1990) study ages 3 to 7, inclusive, and a female and male parent or guardian living in the same house. Duplicate samples of all food and medication items consumed, and all feces excreted, were collected for 11 consecutive days. Urine samples were collected twice daily for 9 of the 11 days; for the remaining 2 days, attempts were made to collect full 24-hour urine specimens. Soil and house dust samples were also collected. Only 12 children had sufficiently complete data for use in the soil and dust ingestion estimates.

Tracer elements for this study included aluminum, silicon and titanium. Toothpaste was supplied for use by study participants. In addition, parents completed a daily diary of activities for themselves and the participant child for 4 consecutive days during the study period.

Children's estimated soil ingestion rates are shown in Table 5-11. The mean and median estimates for children for all three tracers ranged from 36.7 to 206.9 mg/day and 26.4 to 46.7 mg/day, respectively, calculated by setting negative estimates to zero. These estimates fall within the range of those reported by Davis et al., 1990. Similar to the previous Davis et al. study, the soil ingestion estimates were the highest for titanium.

Only two of a number of children's behaviors examined for their relationship to soil ingestion were found to be associated with increased soil ingestion in this study:

- reported eating of dirt; and
- hand washing before meals (based on 2 of 12 children who were reported not to wash hands before eating).

Several typical childhood behaviors, however, including thumb-sucking, furniture licking, and carrying around a blanket or toy were not associated with increased soil ingestion for the participating children. When investigating correlations within the same family, a child's soil ingestion rate was not found to be associated with either parent's soil ingestion rate.

5.3.3 Key Studies of Secondary Analysis

5.3.3.1 *Wong, 1988 - The Role of Environmental and Host Behavioural Factors in Determining Exposure to Infection with Ascaris lumbricoides and Trichuris Trichiura/Calabrese and Stanek, 1993 - Soil Pica: Not a Rare Event*

Calabrese and Stanek (1993) reviewed a tracer element study that was conducted by Wong (1988) to estimate the amount of soil ingested by two groups of children. Wong (1988) studied a total of 52 children in two government institutions in Jamaica. The younger group included 24 children with an average age of 3.1 years (range of 0.3 to 7.5 years). The older group included 28 children with an average age of 7.2 years (range of 1.8 to 14 years). One fecal sample was collected each month from each subject over the four-month study period. The amount of silicon in dry feces was measured to estimate soil ingestion.

An unspecified number of daily fecal samples were collected from a hospital control group of 30 children with an average age of 4.8 years (range of 0.3 to 12 years). Dry feces were observed to contain 1.45 percent silicon, or 14.5 mg Si per gram of dry feces. This quantity was used to correct measured fecal silicon from dietary sources. Fecal silicon quantities greater than 1.45 percent in the 52 studied children were interpreted as originating from soil ingestion.

For the 28 children in the older group, soil ingestion was estimated to be 58 mg/day, based on the mean minus one outlier, and 1,520 mg/day, based on the mean of all the children. The outlier was a child with an estimated average soil ingestion rate of 41 g/day over the 4 months.

Estimates of soil ingestion were higher in the younger group of 24 children. The mean soil ingestion of all the children was 470 ± 370 mg/day. Due to some sample losses, of the 24 children studied, only 15 had samples for each of the 4 months of the study. Over the entire 4-month study period, 9 of 84 samples (or 10.5 percent) yielded soil ingestion estimates in excess of 1 g/day.

Of the 52 children studied, 6 had one-day estimates of more than 1,000 mg/day. The estimated soil ingestion for these six children is shown in Table 5-12. The article describes 5 of 24 (or 20.8 percent) in the younger group of children as having a >1,000 mg/day estimate on at least one of the four study days; in the older group one child is described in this manner. A high degree of daily variability in soil ingestion was observed among these six children; three showed soil-pica behavior on 2, 3, and 4 days, respectively, with the most consistent (4 out of 4 days) soil-pica child having the highest estimated soil ingestion, 3.8 to 60.7 g/day.

5.3.3.2 *Hogan et al., 1998 - Integrated Exposure Uptake Biokinetic Model for Lead in Children: Empirical Comparisons with Epidemiologic Data*

Hogan et al. (1998) used the biokinetic model comparison methodology to review the measured blood lead levels of 478 children. These children were a subset of the entire population of children living in three historic lead smelting communities, whose environmental lead exposures (soil and dust lead levels) had been collected as part of public health evaluations in these communities.

The Integrated Exposure and Uptake Biokinetic (IEUBK) model is a biokinetic model for predicting children's blood lead levels that uses measurements of lead content in house dust, soil, drinking water, food and air, and child-specific estimates of intake for each exposure medium (dust, soil, drinking water, food and air). Model users can also use default assumptions for the lead contents and intake rates for each exposure medium when they do not have specific information for each child.

Hogan et al. (1998) compared children's measured blood lead levels with biokinetic model predictions (IEUBK version 0.99d) of blood lead levels, using the children's measured drinking water, soil, and dust lead contamination levels together with default IEUBK model inputs for soil and dust ingestion, relative proportions of soil and dust ingestion, lead bioavailability from soil and dust, and other model parameters. Thus, the default soil and dust ingestion rates in the model, and other default assumptions in the model, were tested by comparing measured blood lead levels with the model's predictions for those children's blood lead levels.

For Palmerton, Pennsylvania (n=34), the community-wide geometric mean measured blood lead levels (6.8 ug/dl) were slightly over-predicted by the model (7.5 ug/dl); for southeastern Kansas/southwestern Missouri (n=111), the blood lead levels (5.2 ug/dl) were slightly under-predicted (4.6 ug/dl), and for Madison County, Illinois (n=333), the geometric mean measured blood lead levels matched the model predictions (5.9 ug/dl measured and predicted), with very slight differences in the 95 percent confidence interval. These results suggest that the default soil and dust ingestion rates used in this version of the IEUBK model (approximately 50 mg/day soil and 60 mg/day dust for a total soil + dust ingestion of 110 mg/day, averaged over children ages 1 through 6) may be roughly accurate in representing the central tendency soil and dust ingestion rates of residence-dwelling children in the three locations studied.

5.3.4 Relevant Studies of Primary Analysis

The following studies are classified as relevant rather than key. The tracer element studies described in this section are not designated as key because the methodology to account for non-soil tracer exposures was not as well-developed as the methodology in the five U.S. tracer element studies. However, Clausing et al. (1987) was used in developing the biokinetic model default soil and dust ingestion rates (U.S. EPA 1994a) used in the Hogan et al. (1998) study, which was designated as key. In the survey response studies, in most cases the studies were of a non-randomized design, insufficient information was provided to determine important details regarding study design, or no data were provided to allow quantitative estimates of soil and/or dust ingestion rates.

5.3.4.1 *Dickins and Ford, 1942 - Geophagy (Dirt Eating) Among Mississippi Negro School Children*

Dickens and Ford conducted a survey response study of rural black school children (4th grade and above) in Oktibbeha County, Mississippi in September 1941. A total of 52 of 207 children (18 of 69 boys and 34 of 138 girls) studied gave positive responses to questions administered in a test-taking format regarding having eaten dirt in the previous 10 to 16 days. The authors stated that the study sample likely was more representative of the higher socioeconomic levels in the community, because older children from lower socioeconomic levels sometimes left school in order to work, and because children in the lower grades, who were more socioeconomically representative of the overall community, were excluded from the study. Clay was identified as the predominant type of soil eaten.

5.3.4.2 *Cooper, 1957 - Present Study*

Cooper (1957) conducted a non-randomized survey response study in the 1950s of children age 7 months or older referred to a Baltimore, Maryland mental hygiene clinic. For 86 out of 784 children studied, parents or caretakers gave positive responses to the question "Does your child have a habit, or did he ever have a habit, of eating dirt, plaster, ashes, etc.?" and identified dirt, or dirt combined with other substances, as the substance ingested. Cooper (1957) described a pattern of pica behavior, including ingesting substances other than soil, being most common between ages 2 and 4 or 5 years, with one of the 86 children ingesting clay at age 10 years and 9 months.

5.3.4.3 *Barltrop, 1966 - The Prevalence of Pica*

Barltrop (1966) conducted a randomized survey response study of children born in Boston, Massachusetts between 1958 and 1962, inclusive, whose parents resided in Boston and who were neither illegitimate nor adopted. A stratified random subsample of 500 of these children were contacted for in-person caregiver interviews, in which a total of 186 families (37 percent) participated. A separate stratified subsample of 1,000 children was selected for a mailed survey, in which 277 (28 percent) of the families participated. Interview-obtained data regarding care-giver reports of pica (in this study is defined as placing nonfood items in the mouth and swallowing them) behavior in all children ages 1 to 6 in the 186 families (n=439) indicated 19 had ingested dirt (defined as yard dirt, house dust, plant-pot soil, pebbles, ashes, cigarette ash, glass fragments, lint, and hair combings) in the preceding 14 days. It does not appear that these data were corrected for unequal selection probability in the stratified random sample, nor were they corrected for non-response bias. Interviews were conducted in the March/April time frame, presumably in 1964. Mail-survey obtained data regarding caregiver reports of pica in the preceding 14 days indicated that 39 of 277 children had ingested dirt, presumably using the same definition as above. Barltrop (1966) mentions several possible limitations of the study, including non-participation bias and respondents' memory, or recall, effects.

5.3.4.4 *Bruhn and Pangborn, 1971 - Reported Incidence of Pica among Migrant Families*

Bruhn and Pangborn (1971) conducted a survey among 91 low income families of migrant agricultural workers in California in May through August 1969. Families were of Mexican descent in two labor camps (Madison camp, 10 miles west of Woodland, and Davis camp, 10 miles east of Davis) and were "Anglo" families at the Harney Lane camp 17 miles north of Stockton. Participation was 34 of 50 families at the Madison camp, 31 of 50 families at the Davis camp, and 26 of 26 families at the Harney Lane camp. Respondents for the studied families (primarily wives) gave positive responses to open-ended questions such as "Do you know of anyone who eats dirt or laundry starch?" Bruhn and Pangborn (1971) apparently asked a modified version of this question pertaining to the respondents' own or relatives' families. They reported 18 percent (12 of 65) of Mexican families' respondents as giving positive responses for consumption of "dirt" among children within the Mexican respondents' own or relatives' families. They reported 42 percent (11 of 26) of "Anglo" families' respondents as giving positive responses for consumption of "dirt" among children within the Anglo respondents' own or relatives' families.

5.3.4.5 *Robischon, 1971 - Pica Practice and Other Hand-Mouth Behavior and Children's Developmental Level*

A survey response sample of 19- to 24-month old children examined at an urban well-child clinic in the late 1960s or 1970 in an unspecified location indicated that 48 of the 130 children whose caregivers were interviewed, exhibited pica behavior (defined as "ate nonedibles more than once a week"). The specific substances eaten were reported for 30 of the 48 children. All except 2 of the 30 children habitually ate more than one nonedible substance. The soil and dust-like substances reported as eaten by these 30 children were: ashes (17), "earth" (5), dust (3), fuzz from rugs (2), clay (1), and pebbles/stones (1). Caregivers for some of the study subjects (between 0 and 52 of the 130 subjects, exact number not specified) reported that the children "ate nonedibles less than once a week."

5.3.4.6 *Binder et al., 1986 - Estimating Soil Ingestion: The Use of Tracer Elements in Estimating the Amount of Soil Ingested by Young Children*

Binder et al. (1986) used a tracer technique modified from a method previously used to measure soil ingestion among grazing animals to study the ingestion of soil among children 1 to 3 years of age who wore diapers. The children were studied during the summer of 1984 as part of a larger study of residents living near a lead smelter in East Helena, Montana. Soiled diapers were collected over a 3-day period from 65 children (42 males and 23 females), and composited samples of soil were obtained from the children's yards. Both excreta and soil samples were analyzed for aluminum, silicon, and titanium. These elements were found in soil but were thought to be poorly absorbed in the gut and to have been present in the diet only in limited quantities. Excreta measurements were obtained for 59 of the children. Soil ingestion by each child was estimated on the basis of each of the three tracer elements using a standard assumed fecal dry weight of 15 g/day, and the following equation (5-2):

$$T_{i,e} = \frac{f_{i,e} \, x \, F_i}{S_{i,e}} \qquad \text{(Eq. 5-2)}$$

where:

$T_{i,e}$ - = estimated soil ingestion for child *i* based on element *e* (g/day);

$f_{i,e}$ - = concentration of element *e* in fecal sample of child *i* (mg/g);

F_i = fecal dry weight (g/day); and

$S_{i,e}$ - = concentration of element *e* in child *i*'s yard soil (mg/g).

The analysis assumed that (1) the tracer elements were neither lost nor introduced during sample processing; (2) the soil ingested by children originates primarily from their own yards; and (3) that absorption of the tracer elements by children occurred in only small amounts. The study did not distinguish between ingestion of soil and house dust, nor did it account for the presence of the tracer elements in ingested foods or medicines.

The arithmetic mean quantity of soil ingested by the children in the Binder et al. (1986) study was estimated to be 181 mg/day (range 25 to 1,324) based on the aluminum tracer; 184 mg/day (range 31 to 799) based on the silicon tracer; and 1,834 mg/day (range 4 to 17,076) based on the titanium tracer (Table 5-13). The overall mean soil ingestion estimate, based on the minimum of the three individual tracer estimates for each child, was 108 mg/day (range 4 to 708). The median values were 121 mg/day, 136 mg/day, and 618 mg/day for aluminum, silicon, and titanium, respectively. The 95th percentile values for aluminum, silicon, and titanium were 584 mg/day, 578 mg/day, and 9,590 mg/day, respectively. The 95th percentile value based on the minimum of the three individual tracer estimates for each child was 386 mg/day.

The authors were not able to explain the difference between the results for titanium and for the other two elements, but they speculated that unrecognized sources of titanium in the diet or in the laboratory processing of stool samples may have accounted for the increased levels. The frequency distribution graph of soil ingestion estimates based on titanium shows that a group of 21 children had particularly high titanium values (i.e., >1,000 mg/day). The remainder of the children showed titanium ingestion estimates at lower levels, with a distribution more comparable to that of the other elements.

5.3.4.7 *Clausing, et al., 1987 - A method for estimating soil ingestion by children*

Clausing et al. (1987) conducted a soil ingestion study with Dutch children using a tracer element methodology. Clausing et al. (1987) measured aluminum, titanium, and acid-insoluble residue contents of fecal samples from children aged 2 to 4 years attending a nursery school, and for samples of playground dirt at that school. Over a 5-day period, 27 daily fecal samples were obtained for 18 children. Using the average soil concentrations present at the school, and assuming a standard fecal dry weight of 10 g/day, soil ingestion was estimated for each tracer. Six hospitalized, bedridden children served as a control group, representing children who had very limited access to soil; 8 daily fecal samples were collected from the hospitalized children.

Without correcting for the tracer element contribution from background sources, represented by the hospitalized children's soil ingestion estimates, the aluminum-based soil ingestion estimates for the school children in this study ranged from 23 to 979 mg/day, the AIR-based estimates ranged from 48 to 362 mg/day, and the titanium-based estimates ranged from 64 to 11,620 mg/day. As in the Binder et al. (1986) study, a fraction of the children (6/18) showed titanium values above 1,000 mg/day, with most of the remaining children showing substantially lower values. Calculating an arithmetic mean quantity of soil ingested based on each fecal sample yielded 230 mg/day for aluminum; 129 mg/day for AIR, and 1,430 mg/day for titanium (Table 5-14). Based on the Limiting Tracer Method (LTM) and averaging across each fecal sample, the arithmetic mean soil ingestion was estimated to be 105 mg/day with a population standard deviation of 67 mg/day (range 23 to 362 mg/day); geometric mean soil ingestion was estimated to be 90 mg/day. Use of the LTM assumed that "the maximum amount of soil ingested corresponded with the lowest estimate from the three tracers" (Clausing et al., 1987).

The hospitalized children's arithmetic mean aluminum-based soil ingestion estimate was 56 mg/day; titanium-based estimates included estimates for three of the six children that exceeded 1,000 mg/day, with the remaining three children in the range of 28 to 58 mg/day (Table 5-15). AIR measurements were not reported for the hospitalized children. Using the LTM method, the mean soil ingestion rate was estimated to be 49 mg/day with a population standard deviation of 22 mg/day (range 26 to 84 mg/day). The geometric mean soil ingestion rate was 45 mg/day. The hospitalized children's data suggested a major nonsoil source of titanium for some children and a background nonsoil source of aluminum. However, conditions specific to hospitalization (e.g., medications) were not considered.

Clausing et al. (1987) estimated that the average soil ingestion of the nursery school children was 56 mg/day, after subtracting the mean LTM soil ingestion for the hospitalized children (49 mg/day) from the nursery school children's mean LTM soil ingestion (105 mg/day), to account for background tracer intake from dietary and other nonsoil sources.

5.3.4.8 *Smulian et al., 1995 - Pica in a Rural Obstetric Population*

In 1992, Smulian et al. (1995) conducted a survey response study of pica in a convenience sample of 125 pregnant women in Muscogee County, Georgia, who ranged in age from 12 to 37. Of the 18 women who acknowledged practicing pica, 4 acknowledged eating "white dirt" (common name for white clay) or "red dirt." Of the 18 women, 9 stated the amount of substances that they ingested (which included several substances besides white or red dirt). Thus, of the 4 respondents who acknowledged ingesting white or red dirt, an unknown number of them acknowledged ingesting 0.5 to 1.0 pounds of dirt or clay per week (roughly 200-500 g/week). Of the 9 women who stated amounts of substances ingested, 6 stated that their ingestion occurred daily and 3 stated that it occurred three times per week. The authors found a prevalence for the overall pica, by race/ethnicity, of 17.8 percent of the black women, 10.6 percent of the white women, and 0 percent of the Asian and Hispanic women in the sample, with no significant differences between pica and nonpica groups with respect to age distribution or race.

5.3.5 Relevant Studies of Secondary Analysis

The secondary analysis literature on soil and dust ingestion rates gives important insights into methodological strengths and limitations. The tracer element studies described in this section are grouped to some extent according to methodological issues associated with the tracer element methodology. These methodological issues include attempting to determine the origins of apparent positive and negative bias in the methodologies, including: food input/fecal output misalignment; missed fecal samples; assumptions about children's fecal weights; particle sizes of, and relative contributions of soils and dusts to total soil and dust ingestion; and attempts to identify a "best" tracer element or combination of tracer elements. Potential error from using short-term studies' estimates for long term soil and dust ingestion behavior estimates is also discussed.

5.3.5.1 *Stanek et al., 2001a - Biasing Factors for Simple Soil Ingestion Estimates in Mass Balance Studies of Soil Ingestion*

In order to identify and evaluate biasing factors for soil ingestion estimates, the authors developed a simulation model based on data from previous soil ingestion studies. The soil ingestion data used in this model were taken from Calabrese et al. (1989) (the Amherst study); Davis et al. (1990) (southeastern Washington State); Calabrese et al. (1997a) (the Anaconda study) and Calabrese et al. (1997b) (soil-pica in Massachusetts), and relied only on the aluminum and silicon trace element estimates provided in these studies.

Of the biasing factors explored, the impact of study duration was the most striking, with a positive bias of more than 100 percent for 95th percentile estimates in a 4-day tracer element study. A smaller bias was observed for the impact of absorption of trace elements from food. Although the trace elements selected for use in these studies are believed to have low absorption, whatever amount is not accounted for will result in an underestimation of the soil ingestion distribution. In these simulations, the absorption of trace elements from food of up to 30 percent was shown to negatively bias the estimated soil ingestion distribution by less than 20 mg/day. No biasing effect was found for misidentifying play areas for soil sampling (i.e., ingested soil from a yard other than the subject's yard).

5.3.5.2 *Calabrese and Stanek, 1995 - Resolving Intertracer Inconsistencies in Soil Ingestion Estimation*

Calabrese and Stanek (1995) explored sources and magnitude of positive and negative errors in soil ingestion estimates for children on a subject-week and trace element basis. Calabrese and Stanek (1995) identified possible sources of positive errors to be:

- Ingestion of high levels of tracers before the start of the study and low ingestion during the study period; and
- Ingestion of element tracers from a non-food or non-soil source during the study period.

Possible sources of negative bias were identified as:

- Ingestion of tracers in food that are not captured in the fecal sample either due to slow lag time or not having a fecal sample available on the final study day; and
- Sample measurement errors that result in diminished detection of fecal tracers, but not in soil tracer levels.

The authors developed an approach that attempted to reduce the magnitude of error in the individual trace element ingestion estimates. Results from a previous study conducted by Calabrese et al. (1989) were used to quantify these errors based on the following criteria: (1) a lag period of 28 hours was assumed for the passage of tracers ingested in food to the feces (this value was applied to all subject-day estimates); (2) a daily soil ingestion rate was estimated for each tracer for each 24-hour day a fecal sample was obtained; (3) the median tracer-based soil ingestion rate for each subject-day was determined; and (4) negative errors due to missing fecal samples at the end of the study period were also determined. Also, upper- and lower-bound estimates were determined based on criteria formed using an assumption of the magnitude of the relative standard deviation (RSD) presented in another study conducted by Stanek and Calabrese (1995a). Daily soil ingestion rates for tracers that fell beyond the upper and lower ranges were excluded from subsequent calculations, and the median soil ingestion rates of the remaining tracer elements were considered the best estimate for that particular day. The magnitude of positive or negative error for a specific tracer per day was derived by determining the difference between the value for the tracer and the median value.

Table 5-16 presents the estimated magnitude of positive and negative error for six tracer elements in the children's study (conducted by Calabrese et al., 1989). The original non-negative mean soil ingestion rates (Table 5-3) ranged from a low of 21 mg/day based on zirconium to a high of 459 mg/day based on vanadium. The adjusted mean soil ingestion rate after correcting for negative and positive errors ranged from 97 mg/day based on yttrium to 208 mg/day based on titanium. Calabrese and Stanek (1995) concluded that correcting for errors at the individual level for each tracer element provides more reliable estimates of soil ingestion.

5.3.5.3 *Stanek and Calabrese, 1995a - Daily Estimates of Soil Ingestion in Children*

Stanek and Calabrese (1995a) presented a methodology which links the physical passage of food and fecal samples to construct daily soil ingestion estimates from daily food and fecal trace-element concentrations. Soil ingestion data for children obtained from the Amherst study (Calabrese et al., 1989) were reanalyzed by Stanek and Calabrese (1995a). A lag period of 28 hours between food intake and fecal output was assumed for all respondents. Day 1 for the food sample corresponded to the 24 hour period from midnight on Sunday to midnight on Monday of a study week; day 1 of the fecal sample corresponded to the 24 hour period from noon on Monday to noon on Tuesday. Based on these definitions, the food soil equivalent was subtracted from the fecal soil equivalent to obtain an estimate of soil ingestion for a trace element. A daily overall ingestion estimate was constructed for each child as the median of trace element values remaining after tracers falling outside of a defined range around the overall median were excluded.

Table 5-17 presents adjusted estimates, modified according to the input/output misalignment correction, of mean daily soil ingestion per child (mg/day) for the 64 study participants. The approach adopted in this paper led to changes in ingestion estimates from those presented in Calabrese et al. (1989).

Estimates of children's soil ingestion projected over a period of 365 days were derived by fitting log-normal distributions to the overall daily soil ingestion estimates using estimates modified according to the input/output misalignment correction (Table 5-18). The estimated median value of the 64 respondents' daily soil ingestion averaged over a year was 75 mg/day, while the 95th percentile was 1,751 mg/day. In developing the 365-day soil ingestion estimates, data that were obtained over a short period of time (as is the case with all available soil ingestion studies) were extrapolated over a year. The 2-week study period may not reflect variability in tracer element ingestion over a year. While Stanek and Calabrese (1995a) attempted to address this through modeling of the long term ingestion, new uncertainties were introduced through the parametric modeling of the limited subject day data.

5.3.5.4 *Calabrese and Stanek, 1992b - What Proportion of Household Dust is Derived from Outdoor Soil?*

Calabrese and Stanek (1992b) estimated the amount of outdoor soil in indoor dust using statistical modeling. The model used soil and dust data from the 60 households that participated in the Calabrese et al. (1989) study, by preparing scatter plots of each tracer's concentration in soil versus dust. Correlation analysis of the scatter plots was performed. The scatter plots showed little evidence of a consistent relationship between outdoor soil and indoor dust concentrations. The model estimated the proportion of outdoor soil in indoor dust using the simplifying assumption that the following variables were constants in all houses: the amount of dust produced every day from both indoor and outdoor sources; the proportion of indoor dust due to outdoor soil; and the concentration of the tracer element in dust produced from indoor sources. Using these assumptions, the model predicted that 31.3 percent by weight of indoor dust came from outdoor soil. This model was then used to adjust the soil ingestion estimates from Calabrese et al. (1989). Using an assumption that 50 percent of excess fecal tracers were from indoor origin and 50 percent were from outdoor origin, and multiplying the 50 percent indoor-origin excess fecal tracer by the model prediction that 31.3 percent of indoor dust came from outdoor soil, results in an estimate that 15 percent of excess fecal tracers were from soil materials that were present in indoor dust. Adding this 15 percent to the 50 percent assumed outdoor (soil) origin excess fecal tracer quantity results in an estimate that approximately 65 percent of the total residual excess fecal tracer was of soil origin (Calabrese and Stanek, 1992b).

5.3.5.5 *Calabrese et al., 1996 - Methodology to Estimate the Amount and Particle Size of Soil Ingested by Children: Implications for Exposure Assessment at Waste Sites*

Calabrese et al., 1996 examined the hypothesis that one cause of the variation between tracers seen in soil ingestion studies could be related to differences in soil tracer concentrations by particle size. This study, published prior to the Calabrese et al. (1997a) primary analysis study results, used laboratory analytical results for the Anaconda, Montana soil's tracer concentration after it had been sieved to a particle size of <250 µm in diameter (it was sieved to <2 mm soil particle size in Calabrese et al. (1997a)). The smaller particle size was examined based on the assumption that children principally ingest soil of small particle size adhering to fingertips and under fingernails. For five of the tracers used in the original study (aluminum, silicon, titanium, yttrium, and zirconium), soil concentration was not changed by particle size. However, the soil concentrations of three tracers (lanthanum, cerium, and neodymium) were increased two- to fourfold at the smaller soil particle size. Soil ingestion estimates for these three tracers were decreased by approximately 60 percent at the 95th percentile compared to the Calabrese et al. (1997a) results.

5.3.5.6 *Stanek et al., 1999 - Soil Ingestion Estimates for Children in Anaconda Using Trace Element Concentrations in Different Particle Size Fractions*

Stanek et al. (1999) extends the findings from Calabrese et al. (1996) by quantifying trace element concentrations in soil based on sieving to particle sizes of 100 to 250 µm and to particle sizes of 53 to < 100 µm. This study used the data from soil concentrations from the Anaconda, Montana site reported by Calabrese et al. (1997a). Results of the study indicated that soil concentrations of aluminum, silicon and titanium do not increase at the two finer particle size ranges measured. However, soil concentrations of cerium, lanthanum and neodymium increased by a factor of 2.5 to 4.0 in the 100-250 µm particle size range when compared with the 0 to 2 µm particle size range. There was not a significant increase in concentration in the 53 to 100 µm particle size range.

5.3.5.7 *Stanek and Calabrese, 1995b - Soil Ingestion Estimates for Use in Site Evaluations Based on the Best Tracer Method*

Stanek and Calabrese (1995b) recalculated children's soil ingestion rates from two previous studies, using data for 8 tracers from Calabrese et al., 1989 and 3 tracers from Davis et al., 1990. Recalculations were performed using the Best Tracer Method (BTM). This method selected the "best"tracer(s), by dividing the total amount of tracer in a particular child's duplicate food sample by tracer concentration in that child's soil sample to yield a food/soil (F/S) ratio. The F/S ratio was small when the tracer concentration in food was low compared to the tracer concentration in soil. Small F/S ratios were desirable because they lessened the impact of transit time error (the error that occurs when fecal output does not reflect food ingestion, due to fluctuation in gastrointestinal transit time) in the soil ingestion calculation.

The BTM used a ranking scheme of F/S ratios to determine the best tracers for use in the ingestion rate calculation. To reduce the impact of biases that may occur as a result of sources of fecal tracers other than food or soil, the median of soil ingestion estimates based on the four lowest F/S ratios was used to represent soil ingestion.

Using the lowest four F/S ratios for each child, calculated on a per-week ("subject-week") basis, the median of the soil ingestion estimates from the Calabrese et al. (1989) study most often included aluminum, silicon, titanium, yttrium, and zirconium. Based on the median of soil ingestion estimates from the best four tracers, the mean soil ingestion rate was 132 mg/day and the median was 33 mg/day. The 95th percentile value was 154 mg/day. For the 101 children in the Davis et al. (1990) study, the mean soil ingestion rate was 69 mg/day and the median soil ingestion rate was 44 mg/day. The 95th percentile estimate was 246 mg/day. These data are based on the three tracers (i.e., aluminum, silicon and titanium) from the Davis et al. (1990) study. When the results for the 128 subject-weeks in Calabrese et al. (1989) and 101 children in Davis et al. (1990) were combined, soil ingestion for children was estimated to be 104 mg/day (mean); 37 mg/day (median); and 217 mg/day (95th percentile), using the BTM.

5.3.5.8 *Stanek and Calabrese, 2000 - Daily Soil Ingestion Estimates for Children at a Superfund Site*

Stanek and Calabrese (2000) reanalyzed the soil ingestion data from the Anaconda study. The authors assumed a lognormal distribution for the soil ingestion estimates in the Anaconda study to predict average soil ingestion for children over a longer time period. Using "best linear unbiased predictors," the authors predicted 95^{th} percentile soil ingestion values over time periods of 7 days, 30 days, 90 days, and 365 days. The 95^{th} percentile soil ingestion values were predicted to be 133 mg/day over 7 days, 112 mg/day over 30 days, 108 mg/day over 90 days, and 106 mg/day over 365 days. Based on this analysis, estimates of the distribution of longer term average soil ingestion are expected to be narrower, with the 95^{th} percentile estimates being as much as 25 percent lower (Stanek and Calabrese, 2000).

5.3.5.9 *Stanek et al., 2001b - Soil Ingestion Distributions for Monte Carlo Risk Assessment in Children*

Stanek et al. (2001b) developed "best linear unbiased predictors" to reduce the biasing effect of short-term soil ingestion estimates. This study estimated the long-term average soil ingestion distribution using daily soil ingestion estimates from children who participated in the Anaconda, Montana study. In this long-term (annual) distribution, the soil ingestion estimates were: mean 31, median 24, 75^{th}

percentile 42, 90th percentile 75, and 95th percentile 91 mg/day.

5.3.5.10 *von Lindern et al., 2003 - Assessing remedial effectiveness through the blood lead:soil/dust lead relationship at the Bunker Hill Superfund Site in the Silver Valley of Idaho*

Similar to Hogan et al. (1998), von Lindern et al. (2003) used the IEUBK model to predict blood lead levels in a non-random sample of several hundred children ages 0-9 years in an area of northern Idaho from 1989-1998 during community-wide soil remediation. Von Lindern et al. (2003) used the IEUBK default soil and dust ingestion rates together with observed house dust/soil lead levels (and imputed values based on community soil and dust lead levels, when observations were missing). The authors compared the predicted blood lead levels with observed blood lead levels and found that the default IEUBK soil and dust ingestion rates and lead bioavailability value overpredicted blood lead levels, with the overprediction decreasing as the community soil remediation progressed. The authors stated that the overprediction may have been caused either by a default soil and dust ingestion that was too high, a default bioavailability value for lead that was too high, or some combination of the two. They also noted underpredictions for some children, for whom follow up interviews revealed exposures to lead sources not accounted for by the model, and noted that the study sample included many children with a short residence time within the community.

Von Lindern et al. (2003) developed a statistical model that apportioned the contributions of community soils, yard soils of the residence, and house dust to lead intake; the models' results suggested that community soils contributed more (50 percent) than neighborhood soils (28 percent) or yard soils (22 percent) to soil found in house dust of the studied children.

5.4 LIMITATIONS OF KEY STUDY METHODOLOGIES

The three types of information needed to provide recommendations to exposure assessors on soil and dust ingestion rates among U.S. children include quantities of soil and dust ingested, frequency of high soil and dust ingestion episodes, and prevalence of high soil and dust ingesters. The methodologies provide different types of information: the tracer element and biokinetic model comparison methodologies provide information on quantities of soil and dust ingested; the tracer element methodology provides limited evidence of the frequency of high soil ingestion episodes; the survey response methodology can shed light on prevalence of high soil ingesters and frequency of high soil ingestion episodes. The methodologies used to estimate soil and dust ingestion rates and prevalence of soil and dust ingestion behaviors have certain limitations, when used for the purpose of developing recommended soil and dust ingestion rates. This section describes some of the known limitations, presents an evaluation of the current state of the science for U.S. children's soil and dust ingestion rates, and describes how the limitations affect the confidence ratings given to the recommendations.

5.4.1 Tracer Element Methodology

This section describes some previously identified limitations of the tracer element methodology as it has been implemented by U.S. researchers, as well as additional potential limitations that have not been explored. Some of these same limitations would also apply to the Dutch and Jamaican studies that used a control group of hospitalized children to account for dietary and pharmaceutical tracer intakes.

Binder et al. (1986) described some of the major and obvious limitations of the early U.S. tracer element methodology as follows:

> [T]he algorithm assumes that children ingest predominantly soil from their own yards and that concentrations of elements in composite soil samples from front and back yards are representative of overall concentrations in the yards....children probably eat a combination of soil and dust; the algorithm used does not distinguish between soil and dust ingestion....fecal sample weights...were much lower than expected...the assumption that aluminum, silicon and titanium are not absorbed is not entirely true....dietary intake of aluminum, silicon and titanium is not negligible when compared with the potential intake of these elements from soil....Before accepting these estimates as true values of soil ingestion in toddlers, we need a better understanding of the metabolisms of aluminum, silicon and titanium in children, and the validity of the assumptions we made in our calculations should be explored further.

The subsequent U.S. tracer element studies (Calabrese et al. (1989)/Barnes (1990), Davis et al. (1990), Calabrese et al. (1997a), and Davis and Mirick (2006)) made some progress in addressing some of the Binder et al. (1986) study's stated limitations.

Regarding the issue of non-yard (community-wide) soil as a source of ingested soil, one study (Calabrese et al. 1989/Barnes 1990) addressed this issue to some extent, by including samples of children's day care center soil in the analysis. Calabrese et al. (1997a) attempted to address the issue by excluding children in day care from the study sample frame. Homogeneity of community soils' tracer element content would play a role in whether this issue is an important biasing factor for the tracer element studies' estimates. Davis et al. (1990) evaluated community soils' aluminum, silicon and titanium content and found little variation among 101 yards throughout the three-city area. Stanek et al. (2001a) conclude that there is "minimal impact" on estimates of soil ingestion due to mis-specifying a child's play area.

Regarding the issue of soil and dust both contributing to measured tracer element quantities in excreta samples, the five key U.S. tracer element studies all attempt to address the issue by including samples of household dust in the analysis, and in some cases estimates are presented in the published articles that adjust soil ingestion estimates on the basis of the measured tracer elements found in the household dust. The relationship between soil ingestion rates and indoor settled dust ingestion rates has been evaluated in some of the secondary studies (e.g., Calabrese and Stanek (1992b)). An issue similar to the community-wide soil exposures in the previous paragraph could also exist with community-wide indoor dust exposures (such as dust found in schools and community buildings occupied by study subjects during or prior to the study period). A portion of the community-wide indoor dust exposures (that due to occupying day care facilities) was addressed in the Calabrese et al. (1989)/Barnes (1990) study, but not in the other three key tracer element studies. In addition, if the key studies' vacuum cleaner collection method for household and day care indoor settled dust samples influenced tracer element composition of indoor settled dust samples, the dust sample collection method would be another area of uncertainty with the key studies' indoor dust related estimates. The survey response studies suggest that some young children may prefer ingesting dust to ingesting soil. The existing literature on soil versus dust sources of children's lead exposure may provide useful information that has not yet been compiled for use in soil and dust ingestion recommendations.

Regarding the issue of fecal sample weights and the related issue of missing fecal and urine samples, the four key tracer element studies have varying strengths and limitations. The Calabrese et al. (1989) article stated that wipes and toilet paper were not collected by the researchers, and thus underestimates of fecal quantities may have occurred. Calabrese et al. (1989) stated that cotton cloth diapers were supplied for use during the study; commodes apparently were used to collect both feces and urine for those children who were not using diapers. Barnes (1990) described cellulose and polyester disposable diapers with significant variability in silicon and titanium content and suggested that children's urine was not included in the analysis. Thus, it is unclear to what extent complete fecal and urine output was obtained, for each study subject. The Calabrese et al. (1997a) study did not describe missing fecal samples and did not state whether urinary tracer element quantities were used in the soil and dust ingestion estimates, but stated that wipes and toilet paper were not collected. Missing fecal samples may have resulted in negative bias in the estimates from both of these studies. Davis et al. (1990) and Davis and Mirick (2006) were limited to children who no longer wore diapers. Missed fecal sample adjustments might affect those studies' estimates in either a positive or negative direction, due to the assumptions the authors made regarding the quantities of feces and urine in missed samples. Adjustments for missing fecal and urine samples could introduce errors sufficient to cause negative estimates if missed samples were heavier than the collected samples used in the soil and dust ingestion estimate calculations.

Regarding the issue of dietary intake, the five key U.S. tracer element studies have all addressed dietary (and non-dietary, non-soil) intake by subtracting quantitated estimates of these sources of tracer elements from excreta tracer element quantities, or by providing study subjects with personal hygiene products that were low in tracer element content. Applying the food and non-dietary, non-soil corrections required subtracting the tracer element contributions from these non-soil sources from the measured fecal/urine tracer element quantities. To perform this correction required assumptions to be made regarding the gastrointestinal transit time, or the time lag between inputs (food, non-dietary non-soil, and soil) and outputs (fecal and urine). The gastrointestinal transit time assumption introduced a new potential source of bias that some authors (e.g., Stanek and Calabrese, 1995a) called input/output misalignment or transit time error. This lag time may also be a function of age. Davis et al. (1990) and Davis and Mirick (2006) assumed a 24 hour lag time in contrast to the 28 hour lag times used in Calabrese et al. (1989)/Barnes (1990) and Calabrese et al. (1997a). ICRP (2002) suggested a lag time of 37 hours for one year old children and 5 to 15 year old children. Stanek and Calabrese (1995a) describe a method designed to reduce bias from this error source.

Regarding gastrointestinal absorption, the authors of three of the studies appeared to agree that the presence of silicon in urine represented evidence that silicon was being absorbed from the gastrointestinal tract (Davis et al., 1990; Calabrese et al., 1989/Barnes (1990); Davis and Mirick, 2006). There was some evidence of aluminum absorption in Calabrese et al., 1989/Barnes (1990); Davis and Mirick (2006) stated that aluminum and titanium did not appear to have been absorbed, based on low urinary levels. Davis et al. (1990) stated that silicon appears to have been absorbed to a greater degree than aluminum and titanium, based on urine concentrations.

Aside from the gastrointestinal absorption, lag time and missed fecal sample issues, Davis and Mirick (2006) offer another other possible explanation for the negative soil and dust ingestion rates estimated for some study participants. Because the weights of dried food and liquid (input) samples were sufficiently great, relative to the urine and fecal (output) samples, overestimates in laboratory analytical values for the input samples would not be compensated for by a similar overestimate in the output samples.

Another limitation on accuracy of tracer element-based estimates of soil and dust ingestion relates to inaccuracies inherent in environmental sampling and laboratory analytical techniques. The "percent recovery" of different tracer elements varies (according to validation of the study methodology performed with adults who swallowed gelatin capsules with known quantities of sterilized soil, as part of the Calabrese et al., 1989 and 1997a studies). Estimates based on a particular tracer element with a lower or higher recovery than the expected 100 percent in any of the study samples would be influenced in either a positive or negative direction, depending on the recoveries in the various samples and their degree of deviation from 100 percent (e.g., Calabrese et al., 1989).

Davis et al. (1990) offered an assessment of the impact of swallowed toothpaste on the tracer-based estimates by adjusting estimates for those children whose caregivers reported that they had swallowed toothpaste. Davis et al. (1990) had supplied study children with toothpaste that had been pre-analyzed for its tracer element content, but it is not known to what extent the children actually used the supplied toothpaste. Similarly, Calabrese et al., 1989 and 1997a supplied children in the Amherst, Massachusetts and Anaconda, Montana studies with toothpaste containing low levels of most tracers, but it is unclear to what extent those children used the supplied toothpaste.

Other research suggests additional possible limitations that have not yet been explored. First, lymph tissue structures in the gastrointestinal tract might serve as reservoirs for titanium dioxide food additives and soil particles, which could bias estimates either upward or downward depending on tracers' entrapment within, or release from, these reservoirs during the study period (ICRP (2002); Shepherd et al. (1987); Powell et al. (1996)). Second, gastrointestinal uptake of silicon may have occurred, which could bias those estimates downward. Evidence of silicon's role in bone formation (e.g., Carlisle (1980)) supported by newer research on dietary silicon uptake (Jugdaohsingh et al. (2002); Van Dyck et al. (2000)) suggests a possible negative bias in the silicon-based soil ingestion estimates, depending on the quantities of silicon absorbed by growing children. Third, regarding the potential for swallowed toothpaste to bias soil ingestion estimates upward, commercially available toothpaste may contain quantities of titanium and perhaps silicon and aluminum in the range that could be expected to affect the soil and dust ingestion estimates. Fourth, for those children who drank bottled or tap water during the study period, and did not include those drinking water samples in their duplicate food samples, slight upward bias may exist in some of the estimates for those children, since drinking water may contain small, but relevant, quantities of silicon and potentially other tracer elements. Fifth, the tracer element studies conducted to date have not explored the impact of soil properties' influence on toxicant uptake or excretion within the gastrointestinal tract. Nutrition researchers investigating influence of clay geophagy behavior on human nutrition have begun using in vitro models of the human digestion (e.g., Dominy et al., 2003; Hooda et al., 2004). A recent review (Wilson, 2003) covers a wide range of geophagy research in humans and various hypotheses proposed to explain soil ingestion behaviors, with emphasis on the soil properties of geophagy materials.

5.4.2 Biokinetic Model Comparison Methodology

It is possible that the IEUBK biokinetic model comparison methodology contained sources of both positive and negative bias, like the tracer element studies, and that the net impact of the competing biases was in either the positive or negative direction. U.S. EPA's judgment about the major sources of bias in the biokinetic model comparison studies is that there may be three significant sources of bias. The first source of potential bias was the possibility that the biokinetic model failed to account for sources of lead exposure that are important for certain children. For these children, the model might either under-predict, or accurately predict, blood lead levels compared to actual measured lead levels. However, this result may actually mean that the default assumed lead intake rates via either soil and dust ingestion, or another lead source that is accounted for by the model, are too high. The second source of potential bias was use of the biokinetic model for predicting blood lead levels in children who have not spent a significant amount of time in the areas characterized as the main sources of environmental lead exposure for those children, which could result in either upward or downward biases in those children's predicted blood lead levels. Comparing upward-biased predictions with actual measured blood lead levels and finding a relatively good match could lead to inferences that the model's default soil and dust ingestion rates are accurate, when in fact the children's soil and dust ingestion rates, or some other lead source, were actually higher than the default assumption. Comparing downward-biased predictions with actual measured blood lead levels and finding a relatively good match could lead to inferences that the model's default soil and dust ingestion rates were accurate, when in fact the children's soil and dust ingestion rates, or some other lead source, were actually lower than the default assumption. The third source of potential bias was the assumption within the model itself regarding the biokinetics of absorbed lead, which could result in either positively or negatively biased predictions and the same kinds of incorrect inferences as the second source of potential bias.

5.4.3 Survey Response Methodology

Each data collection methodology (in-person interview, mailed questionnaire, or questions administered in "test" format in a school setting) may have had specific limitations. In-person interviews could result in either positive or negative response bias due to distractions posed by young children, especially when interview respondents simultaneously care for young children and answer questions. Other limitations include positive or negative response bias due to respondents' perceptions of a "correct" answer, question wording difficulties, lack of understanding of definitions of terms used, language and dialect differences between investigators and respondents, respondents' desires to avoid negative emotions associated with giving a particular type of answer, and respondent memory problems ("recall" effects) concerning past events. Mailed questionnaires have many of the same limitations as in-person interviews, but may allow respondents to respond when they are not distracted by childcare duties. An in-school test format is more problematic than either interviews or mailed surveys, because respondent bias related to teacher expectations could influence responses.

Unweighted survey responses from the National Health and Nutrition Examination Survey (NHANES) I and II regarding children's clay and dirt ingestion are available (U.S. DHHS 1981a, U.S. DHHS 1981b, U.S. DHHS 1985a, U.S. DHHS 1985b) and appear generally to corroborate the results of the survey response studies summarized in this chapter, in that a small proportion of respondents acknowledge eating dirt or clay. U.S. EPA has undertaken an effort to weight the survey responses among adult caregiver respondents who acknowledged clay and dirt ingestion by children under age 12 years and among child respondents ages 12 up to 21 years who acknowledged clay and dirt ingestion, to develop an estimate of prevalence of the behavior among children.

One approach to evaluating the degree of bias in survey response studies may be to make use of a surrogate biomarker indicator providing suggestive evidence of ingestion of significant quantities of soil (although quantitative estimates would not be possible). The biomarker technique measures the presence of serum antibodies to *Toxocara* species, a parasitic roundworm from cat and dog feces. Two U.S. studies have found associations between reported soil ingestion and positive serum antibody tests for *Toxocara* infection (Marmor et al., 1987; Glickman et al., 1981);

a third (Nelson et al., 1996) has not, but the authors state that reliability of survey responses regarding soil ingestion may have been an issue. Further refinement of survey response methodologies, together with recent NHANES data on U.S. prevalence of positive serum antibody status regarding infection with *Toxocara* species, may be useful.

5.4.4 Key Studies: Representativeness of U.S. Population

The two key studies of Dutch and Jamaican children may represent different conditions and different study populations than those in the U.S.; thus, it is unclear to what extent those children's soil ingestion behaviors may differ from U.S. children's soil ingestion behaviors.

Limitations regarding the key studies performed in the U.S. for estimating soil and dust ingestion rates in the entire population of U.S. children ages 0 to < 21 years fall into the broad categories of geographic range and demographics (age, gender, race/ethnicity, socioeconomic status).

Regarding geographic range, the two most obvious issues relate to soil types and climate. Soil properties might influence the soil ingestion estimates that are based on excreted tracer elements. The Davis et al. (1990), Calabrese et al. (1989)/Barnes (1990), Davis and Mirick (2006) and Calabrese et al. (1997a) tracer element studies were in locations with soils that had sand content ranging from 21-80 percent, silt content ranging from 16-71 percent, and clay content ranging from 3-20 percent by weight, based on data from USDA (2008). The location of children in the Calabrese et al. (1997b) study was not specified, but due to the original survey response study's occurrence in western Massachusetts, the soil types in the vicinity of the Calabrese et al. (1997b) study are likely to be similar to those in the Calabrese et al. (1989)/Barnes (1990) study.

The Hogan et al. (1998) study included locations in the central part of the U.S. (an area along the Kansas/Missouri border, and an area in western Illinois) and one in the eastern U.S. (Palmerton, Pennsylvania). The only key study conducted in the southern part of the U.S. was Vermeer and Frate (1979).

Children might be outside and have access to soil in a very wide range of weather conditions (Wong et al., 2000). In the parts of the U.S. that experience moderate temperatures year-round, soil ingestion rates may be fairly evenly distributed throughout the year. During conditions of deep snow cover, extreme cold, or extreme heat, children could be expected to have minimal contact with outside soil. All children, regardless of location, could ingest soils located indoors in plant containers, or outdoor soil tracked inside buildings by human or animal building occupants. Davis et al. (1990) did not find a clear or consistent association between the number of hours spent indoors per day and soil ingestion, but reported a consistent association between spending a greater number of hours outdoors and high (defined as the uppermost tertile) soil ingestion levels across all three tracers used.

The five key tracer element studies all took place in northern latitudes. The temperature and precipitation patterns that occurred during these four studies' data collection periods was difficult to discern due to no mention of specific data collection dates in the published articles. The Calabrese et al. (1989)/Barnes (1990) study apparently took place in mid- to late September 1987 in and near Amherst, Massachusetts; Calabrese et al. (1997a) apparently took place in late September and early October 1992, in Anaconda, Montana; Davis et al. (1990) took place in July, August and September 1987, in Richland, Kennewick and Pasco, Washington; and Davis and Mirick (2006) took place in the same Washington state location in late July, August and very early September 1988 (raw data). Inferring exact data collection dates, a wide range of temperatures may have occurred during the four studies' data collection periods (daily lows from 22-60 ^{o}F and 25-48 ^{o}F, and daily highs from 53-81 ^{o}F and 55-88 ^{o}F in Calabrese et al. (1989) and Calabrese et al. (1997a), respectively, and daily lows from 51-72 ^{o}F and 51 - 67 ^{o}F, and daily highs from 69-103 ^{o}F and 80-102 ^{o}F in Davis et al. (1990) and Davis and Mirick (2006), respectively) (National Climatic Data Center, 2008). Significant amounts of precipitation occurred during Calabrese et al. (1989) (more than 0.1 inches per 24 hour period) on several days; somewhat less precipitation was observed during Calabrese et al. (1997a); precipitation in Kennewick and Richland during the data collection periods of Davis et al. (1990) was almost nonexistent; there was no recorded precipitation in Kennewick or Richland during the data collection period for Davis and Mirick (2006) (National Climatic Data Center, 2008).

The key biokinetic model comparison study (Hogan et al., 1998) targeted three locations in more southerly latitudes (Pennsylvania, southern Illinois, and southern Kansas/Missouri) than the five tracer element studies. The biokinetic model comparison methodology had an advantage over the tracer element studies in that the study represented long-term environmental exposures over periods up to several years, that would include a range of seasons and climate conditions.

A brief review of the representativeness of the key studies' samples with respect to gender and age suggested that males and females were represented roughly equally in those studies for which study subjects' gender was stated. Children up to age 8 years were studied in seven of the nine studies, with an emphasis on younger children. Wong (1988)/Calabrese et al. (1993) and Vermeer and Frate (1979) are the only studies with children 8 years or older.

A brief review of the representativeness of the key studies' samples with respect to socioeconomic status and racial/ethnic identity suggested that there were some discrepancies between the study subjects and the current U.S. population of children age 0 to <21 years. The single survey response study (Vermeer and Frate (1979)) was specifically targeted toward a predominantly rural black population in a particular county in Mississippi. The tracer element studies are of predominantly white populations, apparently with limited representation from other racial and ethnic groups. The Amherst, Massachusetts study (Calabrese et al. 1989/Barnes 1990) did not publish the study participants' socioeconomic status or racial and ethnic identities. The socioeconomic level of the Davis et al. (1990) studied children was reported to be primarily of middle to high income. Self-reported race and ethnicity of relatives of the children studied (in most cases, they were the parents of the children studied) in Davis et al. (1990) were White (86.5 percent), Asian (6.7 percent), Hispanic (4.8 percent), Native American (1.0 percent), and Other (1.0 percent), and the 91 married or living-as-married respondents identified their spouses as White (86.8 percent), Hispanic (7.7 percent), Asian (4.4 percent), and Other (1.1 percent). Davis and Mirick (2006) did not state the race and ethnicity of the follow-up study participants, who were a subset of the original study participants from Davis et al. (1990). For the Calabrese et al. (1997a) study in Anaconda, Montana, population demographics were not presented in the published article. The study sample appeared to have been drawn from a door-to-door census of Anaconda residents that identified 642 toilet trained children who were less than 72 months of age. Of the 414 children participating in a companion study (out of the 642 eligible children identified), 271 had complete study data for that companion study, and of these 271, 97.4 percent were identified as white and the remaining 2.6 percent were identified as native American, black, Asian and Hispanic (Hwang et al., 1997). The 64 children in the Calabrese et al. (1997a) study apparently were a stratified random sample drawn from the 642 children identified in the door-to-door census. Presumably these children identified as similar races and ethnicities to the Hwang et al. (1997) study children. The Calabrese et al. (1997b) study indicated that 11 of the 12 children studied were white.

5.5 SUMMARY OF SOIL AND DUST INGESTION ESTIMATES FROM KEY STUDIES

Table 5-19 summarizes the soil and dust ingestion estimates from the 9 key studies. For the U.S. tracer element studies, in order to compare estimates that were calculated in a similar manner, the summary is limited to estimates that use the same basic algorithm of ((fecal and urine tracer content) - (food and medication tracer content))/(soil or dust tracer concentration). Note that several of the published reanalyses suggested different variations on these algorithms, or suggest adjustments that should be made for various reasons. However, because individual observations were not available from the studies with reanalyzed data, those reanalyzed estimates were not included in the summary table. Other reanalyses suggested that omitting some of the data according to statistical criteria would be a worthwhile exercise. Due to the current state of the science regarding soil and dust ingestion estimates, U.S. EPA does not advise omitting an individual child's soil or dust ingestion estimate, based on statistical criteria, at this point in time.

There is a wide range of estimated soil and dust ingestion across key studies. Note that some of the soil-pica ingestion estimates from the tracer element studies were consistent with the estimated mean soil ingestion from the survey response study of geophagy behavior. Also note that the biokinetic model comparison methodology's confirmation of central tendency soil and dust ingestion default assumptions corresponded roughly with some of the central tendency tracer element study estimates.

5.6 REFERENCES FOR CHAPTER 5

Agency for Toxic Substances and Disease Registry (ATSDR). (2001) Summary report for the ATSDR soil-pica workshop. ATSDR, Atlanta, GA. March 20, 2001. Available online at: http://www.atsdr.cdc.gov/NEWS/soilpica.html.

Agency for Toxic Substances and Disease Registry (ATSDR) (2006) Toxicological profile for Aluminum (*Draft for Public Comment*). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Anonymous (1969). Nutritional Status - U.S.A. Nutr Rev 27(7): 196-200.

Aufreiter, S.; Hancock, R.G.V.; Mahaney, W.C.; Stambolic-Robb, A.; Sanmugadas, K. (1997) Geochemistry and mineralogy of soils eaten by humans. Int J Food Sci Nutr 48(5) 293-305.

Barltrop, D. (1966) The Prevalence of Pica. Amer J Dis Child 112:116-123.

Barnes, R. (1990) Childhood Soil Ingestion: How Much Dirt Do Kids Eat? Anal Chem 62:1024-1033.

Binder, S.; Sokal, D.; Maughan, D. (1986) Estimating soil ingestion: the use of tracer elements in estimating the amount of soil ingested by young children. Arch Environ Health 41(6):341-345.

Bissé, E.; Epting, T.; Beil, A.; Lindinger, G.; Lang, H.; Wieland, H. (2005) Reference values for serum silicon in adults. Anal Biochem 337:130-135.

Bruhn, C.M.; Pangborn, R.M. (1971) Reported incidence of pica among migrant families. J Am Diet Assoc 58:417-420.

Calabrese, E.J., and Stanek, E.J. (1991) A Guide to Interpreting Soil Ingestion Studies II. Quantitative and QualitativeEvidence of Soil Ingestion. Regul Toxicol Pharmacol 13:278-292.

Calabrese, E.J., and Stanek, E.J. (1992a) Distinguishing outdoor soil ingestion from indoor dust ingestion in a soil picachild. Regul Toxicol Pharmacol 15:83-85.

Calabrese, E.J., and Stanek, E.J. (1992b) What proportion of household dust is derived from outdoor soil? J Soil Contam 1(3):253-263.

Calabrese, E.J., and Stanek, E.J. (1993) Soil pica: not a rare event. J Environ Sci Health A28(2):373-384.

Calabrese, E.J., and Stanek, E.J. (1995) Resolving intertracer inconsistencies in soil ingestion estimation. Environ Health Perspect 103(5):454-456.

Calabrese, E.J.; Barnes, R.; Stanek, E.J. III; Pastides, H.; Gilbert, C.; Veneman, P.; Wang, X.; Lásztity, A.; Kostecki, P.T. (1989) How much soil do young children ingest: an epidemiologic study. In: Petroleum Contaminated Soils, Lewis Publishers, Chelsea, MI. pp. 363-397 and in: Regul Toxicol Pharm 10:123-137.

Calabrese, E.J.; Stanek, E.J.; Gilbert, C.E.; and Barnes, R. (1990) Preliminary adult soil ingestion estimates: Results of a pilot study. Regul Toxicol Pharmacol 12:88-95.

Calabrese, E.J.; Stanek, E.J.; Gilbert, C.E. (1991) Evidence of Soil-Pica behavior and Quantification of Soil Ingested. Hum Exp Toxicol 10:245-249.

Calabrese, E.J.; Stanek, E.J.; Barnes, R.M. (1996) Methodology to estimate the amount and particle size of soil ingested by children: Implications for exposure assessment at waste sites. Regul Toxicol Pharmacol 24: 264-268.

Calabrese, E.J.; Stanek, E.J.; Pekow, P.; Barnes, R.M. (1997a) Soil ingestion estimates for children residing on a Superfund site. Ecotoxicol Environ Saf 36:258-268.

Calabrese, E.J.; Stanek, E.J.; Barnes, R.M. (1997b) Soil ingestion rates in children identified by parental observation as likely high soil ingesters. J Soil Contam 6(3): 271-279.

Carlisle, E. (1980) Biochemical and Morphological Changes Associated with Long Bone Abnormalities in Silicon Deficiency. J Nutr 110:1046-1055.

Clausing, P.; Brunekreef, B.; Van Wïjnen, J.H. (1987) A method for estimating soil ingestion by children. Int Arch Occup Environ Health 59(1):73-82.

Colquitt, P.J. (2002) Do powered toothbrushes contaminate toothpaste with metals? Sci Total Environ 289:25-32.

Cooper, M. 1957) Present Study. Chapter In: Pica: A survey of the historical literature as well as reports from the fields of veterinary medicine and anthropology, the present study of pica in young children, and a discussion of its pediatric and psychological implications. Springfield, IL: Charles C. Thomas.

Corbett, R.W.; Ryan, C.; Weinrich, S.P. (2003) Pica in pregnancy: does it affect pregnancy outcomes? MCM Am J Matern Child Nurs. 28(3):183-189.

Danford, D.E. (1982) Pica and nutrition. Annu Rev Nutr 2:303-322.

Danford, D.E. (1983) Pica and zinc. Zinc Deficiency in Human Subjects, pp. 185-195. New York: Alan R. Liss Inc.

Davis, S. and Mirick, D. (2006) Soil ingestion in children and adults in the same family. J Exp Anal Environ Epidem 16:63-75.

Davis, S.; Waller, P.; Buschbom, R.; Ballou, J.; White, P. (1990) Quantitative estimates of soil ingestion in normal children between the ages of 2 and 7 years: population based estimates using aluminum, silicon, and titanium as soil tracer elements. Arch Environ Health 45:112-122.

Dawson, E.B.; Frey, M.J.; Moore, T.D.; McGanity, W.J. (1978) Relationship of metal metabolism to vascular disease mortality rates in Texas. Am J Clin Nutr 31(7):1188-1197.

Dickens, D. and Ford, R.N. (1942) Geophagy (Dirt Eating) Among Mississippi Negro School Children. Amer Soc Rev 7:59-65.

Dominy, N.J.; Davoust, E.; Minekus, M. (2003) Adaptive function of soil consumption: an in vitro study modeling the human stomach and small intestine. J Exp Biol 207(Pt 2): 319-324.

Geissler, P.W.; Mwaniki, D.L.; Thiong'o, F.; Michaelsen, K.F., Friis, H. (1998) Geophagy, Iron Status and Anaemia Among Primary School Children in Western Kenya. Trop Med Int Health 3(7):529-534.

Glickman, L.T., Chaudry, I.U., Costantino, J., Clack, F.B., Cypess. R.H., Winslow, L. (1981) Pica Patterns,Toxocariasis, and Elevated Blood Lead in Children. Am J Trop Med Hyg 30(1):77-80.

Gulson, B.L.; Mizon, K.J.; Palmer, J.M.; Patison, N.; Law, A.J.; Korsch, M.J.; Mahaffey, K.R.; Donnelly, J.B. (2001) Longitudinal Study of Daily Intake and Excretion of Lead in Newly Born Infants. Environ Res Sec A 85:232-245.

Halsted, J.A. (1968) Geophagia in Man: Its Nature and Nutritional Effects. Am J Clin Nutr 21(12): 1381-1393.

Harris, S.G.; Harper, B.L. (1997) A Native American Exposure Scenario. Risk Anal 17(6):789-795.

Hawley, J.K. (1985) Assessment of Health Risk from Exposure to Contaminated Soil. Risk Anal 5(4): 289-302.

Hertz, H. (1946) Notes on Clay and Starch Eating Among Negroes in a Southern Urban Community. Soc F 25:343-344.

Hogan, K.; Marcus, A.; Smith, R.; White, P. (1998) Integrated exposure uptake biokinetic model for lead in children: empirical comparisons with epidemiologic data. Environ Health Perspect 106(Supp 6): 1557-1567.

Hooda, P.; Henry, C.; Seyoum, T.; Armstrong, L.; and Fowler, M. (2004) The potential impact of soil ingestion on human mineral nutrition. Sci Total Environ 333:74-87.

Hwang, Y.-H.; Bornschein, R.L.; Grote, J.; Menrath, W.; and Roda, S. (1997) Environmental Arsenic Exposure of Children around a Former Copper Smelter Site. Environ Res 72:72-81.

Hyman, S.L.; Fisher, W.; Mercugliano, M.; Cataldo, M.F. (1990) Children With Self-Injurious Behavior. Pediatrics 85:437-441.

ICRP (2002). Basic anatomical and physiological data for use in radiological protection: reference values: ICRP Publication 89. Annals of the ICRP 32 (3-4):1-277.

Johns, T.; Duquette, M. (1991) Detoxification and mineral supplementation as functions of geophagy. Am J Clin Nutr 53:448-456.

Jugdaohsingh, R.; Anderson, S.; Tucker, K.; Elliott, H.; Kiel, D.; Thompson, R.; Powell, J. (2002) Dietary silicon intake and absorption. Am J Clin Nutr 75(5): 887-893.

Kinnell, H.G. (1985) Pica as a Feature of Autism. Br J Psychiatry 147:80-82.

Kissel, J.C., Shirai, J.H., Richter, K.Y., Fenske, R.A. (1998) Empirical Investigation of Hand-to-Mouth Transfer of Soil Bull Environ Contam Toxicol 60:379-86.

Korman, S. (1990) Pica as a presenting symptom in childhood celiac disease. Am J Clin Nutr 51:139-141.

Lacey, E. (1990) Broadening the Perspective of Pica: Literature Review. Public Health Rep 105(1):29-35.

Lourie, R.S.; Layman, E.M.; Millican, F.K. (1963) Why children eat things that are not food. Children 10:143-146.

Manton, W.I.; Angle, C.R.; Stanek, K.L.; Reese, Y.R.; Kuehnemann, T.J. (2000) Acquisition and Retention of Lead by Young Children. Environ Res Sec A 82:60-80.

Marmor, M., Glickman, L., Shofer, F., Faich, L.A., Rosenberg, C., Cornblatt, B., Friedman, S. (1987) *Toxocara canis* Infection of Children: Epidemiologic and Neuropsychologic Findings. Am J Public Health 77:554-559.

Minnich, V.; Okçuoğlu, A.; Tarcon, Y.; Arcasoy, A.; Cin, S.; Yörükoğlu, O.; Renda, F.; Demirağ, B. (1968) Pica in Turkey. Am J Clin Nutr 21(1): 78-86.

Mølhave, L.; Schneider, T.; Kjærgaard, S.K.; Larsen, L.; Norn, S.; Jørgensen, O. (2000) House dust in seven Danish offices. Atmospher Environ 34:4767-4779.

National Academy Press (2000) Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, D.C.: 2000.

National Climatic Data Center (2008). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service. Data Set TD3200: U.S. Cooperative Summary of the Day Data, Daily Surface Data. Accessed online at: http://www.ncdc.noaa.gov/oa/climate/stationlocator.html on March 7 - 13, 2008.

Nelson, S.; Greene, T.; Ernhart, C.B. (1996) *Toxocara canis* Infection in Preschool Age Children: Risk Factors and the Cognitive Development of Preschool Children. Neurotoxicol Teratol 18(2):167-174.

Parnell, C.B.; Jones, D.D.; Rutherford, R.D.; Goforth, K.J. (1986) Physical Properties of Five Grain Dust Types. Environ Health Perspect 66:183-188.

Powell, J.J.; Ainley, C.C.; Harvey, R.S.; Mason, I.M.; Kendall, M.D.; Sankey, E.A.; Dhillon, A.P.; Thompson, R.P. (1996) Characterisation of inorganic microparticles in pigment cells of human gut associated lymphoid tissue. Gut (38):390-395.

Rainville, A.J. (1998) Pica practices of pregnant women are associated with lower maternal hemoglobin level at delivery. J Am Diet Assoc 98(3):293-296.

Robischon, P. (1971) Pica Practice and Other Hand-Mouth Behavior and Children's Developmental Level. Nurs Res 20(1):4-16.

Shacklette, H.T.; Boerngen, J.G. (1984) Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States. United States Geological Survey Professional Paper 1270. Washington, D.C.: U.S. Government Printing Office.

Smulian, J.C.; Motiwala, S.; Sigman, R.K. (1995) Pica in a rural obstetric population. South Med J 88(12):1236-1240.

Shepherd, N.A.; Crocker, P.R.; Smith, A.P.; Levison, D.A. (1987) Exogenous pigment in Peyer's patches. Hum Pathol 18(1):50-54.

Stanek, E.J., and Calabrese, E.J. (1995a) Daily estimates of soil ingestion in children. Environ Health Perspect 103(3):276-285.

Stanek, E.J., and Calabrese, E.J. (1995b) Soil ingestion estimates for use in site evaluations based on the best tracer method. Hum Ecol Risk Assess 1:133-156.

Stanek, E.J., and Calabrese, E.J. (2000) Daily soil ingestion estimates for children at a Superfund site. Risk Anal 20(5): 627-635.

Stanek, E.J.; Calabrese, E.J.; Mundt, K.; Pekow, P.; Yeatts, K.B. (1998) Prevalence of Soil Mouthing/Ingestion among Healthy Children Aged 1 to 6. J Soil Contam 7(2):227-242.

Stanek, E.J.; Calabrese, E.J.; Barnes, R. (1999) Soil ingestion estimates for children in Anaconda using trace element concentrations in different particle size fractions. Human Ecol Risk Assess 5(3): 547-558.

Stanek, E.J.; Calabrese, E.J.; Zorn, M. (2001a) Biasing factors for simple soil ingestion estimates in mass balance studies of soil ingestion. Hum Ecol Risk Assess 7(2): 329-355.

Stanek, E.J.; Calabrese, E.J.; Zorn, M. (2001b) Soil ingestion distributions for Monte Carlo risk assessment in children. Hum Ecol Risk Assess 7(2): 357-368.

USDA. (2008) Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, Web Soil Survey, accessed February 25, 2008.

U.S. DHHS (1981a) U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics. Public Use Data Tape Documentation: Medical History Questionnaire, Ages 1-11, Tape Number 4067. National Health and Nutrition Examination Survey, 1971-1975. May 1981. Hyattsville, MD.

U.S. DHHS (1981b) U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics. Public Use Data Tape Documentation: Medical History Questionnaire, Ages 12-74, Tape Number 4081. National Health and Nutrition Examination Survey, 1971-1975. May 1981. Hyattsville, MD.

U.S. DHHS (1985a) U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics. Public Use Data Tape Documentation: Medical History 6 Months - 11 Years, Tape Number 5010. National Health and Nutrition Examination Survey, 1976-1980. May 1985. Hyattsville, MD.

U.S. DHHS (1985b) U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics. Public Use Data Tape Documentation: Medical History Ages 12-74 Years, Tape Number 5020. National Health and Nutrition Examination Survey, 1976-1980. May 1985. Hyattsville, MD.

U.S. DOC (2008) U.S. Department of Commerce, Bureau of the Census, Population Division. Table 2: Annual Estimates of the Population by Sex and Selected Age Groups for the United States: April 1, 2000 to July 1, 2007 (NC-EST2007-02).

U.S. EPA (1994a) Guidance Manual for the IEUBK Model for Lead in Children. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA 540/R-93/081.

U.S. EPA (1994b) Technical Support Document: Parameters and Equations Used in the Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children (v 0.99d). Washington, D.C.: U.S. Environmental Protection Agency, Technical Review Workgroup for Lead with assistance from the Environmental Criteria and Assessment Office, Research Triangle Park, NC. EPA 9285.7-22.

U.S. EPA. (1996) Soil Screening Guidance: User's Guide. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Publication 9355.4-23.

U.S. EPA. (1997) Exposure Factors Handbook Revised. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/P-95/002F.

U.S. EPA. (2005) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants. Washington, DC.: U.S. Environmental Protection Agency, Office of Research and Development. EPA/630/P-03/003F.

Van Dyck, K.; Robberecht, H.; Van Cauwenburgh, R.; Van Vlaslaer, V.; Deelstra, H. (2000) Indication of silicon essentiality in humans: serum concentrations in Belgian children and adults, including pregnant women. Biol Trace Elem Res 77(1):25-32.

Van Wïjnen, J.H.; Clausing, P.; Brunekreff, B. (1990) Estimated soil ingestion by children. Environ Res 51:147-162.

Vermeer, D.E.; Frate, D.A. (1979) Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. Am J Clin Nutr 32:2129-2135.

Von Lindern, I.; Spalinger, S.; Petroysan, V.; von Braun, M. (2003) Assessing remedial effectiveness through the blood lead:soil/dust lead relationship at the Bunker Hill Superfund Site in the Silver Valley of Idaho. Sci Total Environ 303(1-2): 139-170.

Wilson, M.J. Clay Mineralogical and Related Characteristics of Geophagic Materials. (2003) J Chem Ecol 29(7):1525-1547.

Wong, E.Y., Shirai, J.H., Garlock, T.J., and Kissel, J.C. (2000) Adult proxy responses to a survey of children's dermal soil contact activities. J Exp Anal Environ Epidem 10:509-517.

Wong, M.S. (1988) The Role of Environmental and Host Behavioural Factors in Determining Exposure to Infection with Ascaris lumbricoldes and Trichuris trichiura. Ph.D. Thesis, Faculty of Natural Sciences, University of the West Indies. 1988.

Table 5-3. Soil, Dust and Soil + Dust Ingestion Estimates for Amherst, Massachusetts Study Children

Tracer Element	N	Ingestion (mg/day)				
		Mean	Median	SD	95th Percentile	Maximum
Aluminum						
soil	64	153	29	852	223	6,837
dust	64	317	31	1,272	506	8,462
soil/dust combined	64	154	30	629	478	4,929
Barium						
soil	64	32	-37	1,002	283	6,773
dust	64	31	-18	860	337	5,480
soil/dust combined	64	29	-19	868	331	5,626
Manganese						
soil	64	-294	-261	1,266	788	7,281
dust	64	-1,289	-340	9,087	2,916	20,575
soil/dust combined	64	-496	-340	1,974	3,174	4,189
Silicon						
soil	64	154	40	693	276	5,549
dust	64	964	49	6,848	692	54,870
soil/dust combined	64	483	49	3,105	653	24,900
Vanadium						
soil	62	459	96	1,037	1,903	5,676
dust	64	453	127	1,005	1,918	6,782
soil//dust combined	62	456	123	1,013	1,783	6,736
Yttrium						
soil	62	85	9	890	106	6,736
dust	64	62	15	687	169	5,096
soil/dust combined	62	65	11	717	159	5,269
Zirconium						
soil	62	21	16	209	110	1,391
dust	64	27	12	133	160	789
soil/dust combined	62	23	11	138	159	838
Titanium						
soil	64	218	55	1,150	1,432	6,707
dust	64	163	28	659	1,266	3,354
soil/dust combined	64	170	30	691	1,059	3,597

SD = Standard deviation.

Source: Calabrese et al., 1989.

Table 5-4. Amherst, Massachusetts Soil-Pica Child's Daily Ingestion Estimates by Tracer and by Week (mg/day)

Tracer element	Estimated Soil Ingestion (mg/day)	
	Week 1	Week 2
Al	74	13,600
Ba	458	12,088
Mn	2,221	12,341
Si	142	10,955
Ti	1,543	11,870
V	1,269	10,071
Y	147	13,325
Zr	86	2,695

Source: Calabrese et al., 1991.

Table 5-5. Amherst, Massachusetts Soil-Pica Child's Tracer Ratios

Tracer Pairs		Ratio			Estimated Residual Fecal Tracers of Soil Origin as Predicted by Specific Tracer Ratios (%)
		Soil	Fecal	Dust	
1.	Mn/Ti	208.368	215.241	260.126	87
2.	Ba/Ti	187.448	206.191	115.837	100
3.	Si/Ti	148.117	136.662	7.490	92
4.	V/Ti	14.603	10.261	17.887	100
5.	Ai/Ti	18.410	21.087	13.326	100
6.	Y/Ti	8.577	9.621	5.669	100
7.	Mn/Y	24.293	22.373	45.882	100
8.	Ba/Y	21.854	21.432	20.432	71
9.	Si/Y	17.268	14.205	1.321	81
10.	V/Y	1.702	1.067	3.155	100
11.	Al/Y	2.146	2.192	2.351	88
12.	Mn/Al	11.318	10.207	19.520	100
13.	Ba/Al	10.182	9.778	8.692	73
14.	Si/Al	8.045	6.481	0.562	81
15.	V/Al	0.793	0.487	1.342	100
16.	Si/V	10.143	13.318	0.419	100
17.	Mn/Si	1.407	1.575	34.732	99
18.	Ba/Si	1.266	1.509	15.466	83
19.	Mn/Ba	1.112	1.044	2.246	100

Source: Calabrese and Stanek, 1992.

Table 5-6. Van Wïjnen et al., 1990 Limiting Tracer Method (LTM) Soil Ingestion Estimates for Sample of Dutch Children

Age (years)	Sex	Daycare Centers			Campgrounds		
		N	GM LTM (mg/day)	GSD LTM (mg/day)	N	GM LTM (mg/day)	GSD LTM (mg/day)
Birth to <1	Girls	3	81	1.09	NA	NA	NA
	Boys	1	75	-	NA	NA	NA
1 to <2	Girls	20	124	1.87	3	207	1.99
	Boys	17	114	1.47	5	312	2.58
2 to <3	Girls	34	118	1.74	4	367	2.44
	Boys	17	96	1.53	8	232	2.15
3 to <4	Girls	26	111	1.57	6	164	1.27
	Boys	29	110	1.32	8	148	1.42
4 to <5	Girls	1	180	-	19	164	1.48
	Boys	4	99	1.62	18	136	1.30
All girls		86	117	1.70	36	179	1.67
All boys		72	104	1.46	42	169	1.79
Total		162[a]	111	1.60	78[b]	174	1.73

[a] Age and/or sex not registered for 8 children; one untransformed value = 0.
[b] Age not registered for 7 children; geometric mean LTM value = 140.
N = Number of subjects.
GM = Geometric mean.
LTM = Limiting tracer method.
GSD = Geometric standard deviation.
NA = Not available.

Source: Adapted from Van Wïjnen et al., 1990.

Table 5-7. Estimated Geometric Mean Limiting Tracer Method (LTM) Values of Children Attending Daycare Centers According to Age, Weather Category, and Sampling Period

Weather Category	Age (years)	First Sampling Period		Second Sampling Period	
		N	Estimated Geometric Mean LTM Value (mg/day)	N	Estimated Geometric Mean LTM Value (mg/day)
Bad	<1	3	94	3	67
(>4 days/week	1 to <2	18	103	33	80
precipitation)	2 to <3	33	109	48	91
	4 to <5	5	124	6	109
Reasonable	<1			1	61
(2-3 days/week	1 to <2			10	96
precipitation)	2 to <3			13	99
	3 to <4			19	94
	4 to <5			1	61
Good	<1	4	102		
(<2 days/week	1 to <2	42	229		
precipitation)	2 to <3	65	166		
	3 to <4	67	138		
	4 to <5	10	132		

N = Number of subjects.
LTM = Limiting tracer method.

Source: Van Wïjnen et al., 1990.

Table 5-8. Estimated Soil Ingestion for Sample of Washington State Children [a]

Element	Mean (mg/day)	Median (mg/day)	Standard Error of the Mean (mg/day)	Range (mg/day)[b]
Aluminum	38.9	25.3	14.4	-279.0 to 904.5
Silicon	82.4	59.4	12.2	-404.0 to 534.6
Titanium	245.5	81.3	119.7	-5,820.8 to 6,182.2
Minimum	38.9	25.3	12.2	-5,820.8
Maximum	245.5	81.3	119.7	6,182.2

[a] Excludes three children who did not provide any samples (N=101).
[b] Negative values occurred as a result of correction for non-soil sources of the tracer elements. For aluminum, lower end of range published as 279.0 mg/day in article appears to be a typographical error that omitted the negative sign.

Source: Adapted from Davis et al., 1990.

Table 5-9. Soil Ingestion Estimates for 64 Anaconda Children

Tracer	Estimated Soil Ingestion (mg/day)							
	P1	P50	P75	P90	P95	Max	Mean	SD
Al	-202.8	-3.3	17.7	66.6	94.3	461.1	2.7	95.8
Ce	-219.8	44.9	164.6	424.7	455.8	862.2	116.9	186.1
La	-10,673	84.5	247.9	460.8	639.0	1,089.7	8.6	1,377.2
Nd	-387.2	220.1	410.5	812.6	875.2	993.5	269.6	304.8
Si	-128.8	-18.2	1.4	36.9	68.9	262.3	-16.5	57.3
Ti	-15,736	11.9	398.2	1,237.9	1,377.8	4,066.6	-544.4	2,509.0
Y	-441.3	32.1	85.0	200.6	242.6	299.3	42.3	113.7
Zr	-298.3	-30.8	17.7	94.6	122.8	376.1	-19.6	92.5

P = Percentile.
SD = Standard deviation.
Note: Negative values are a result of limitations in the methodology.

Source: Calabrese et al., 1997a.

Table 5-10. Soil Ingestion Estimates for Massachusetts Child Displaying Soil Pica Behavior (mg/day)

Study day	Al-based estimate	Si-based estimate	Ti-based estimate
1	53	9	153
2	7,253	2,704	5,437
3	2,755	1,841	2,007
4	725	573	801
5	5	12	21
6	1,452	1,393	794
7	238	92	84

Source: Calabrese et al., 1997b.

Table 5-11. Soil Ingestion Estimates for Sample of 12 Washington State Children [a]

Tracer Element	Estimated Soil Ingestion [b] (mg/day)			
	Mean	Median	SD	Maximum
Aluminum	36.7	33.3	35.4	107.9
Silicon	38.1	26.4	31.4	95.0
Titanium	206.9	46.7	277.5	808.3

[a] For some study participants, estimated soil ingestion resulted in a negative value. These estimates have been set to zero mg/day for tabulation and analysis.
[b] Results based on 12 children with complete food, excreta and soil data.
SD = Standard deviation.

Source: Davis and Mirick, 2006.

Table 5-12. Estimated Soil Ingestion for Six High Soil Ingesting Jamaican Children

Child	Month	Estimated soil ingestion (mg/day)
11	1	55
	2	1,447
	3	22
	4	40
12	1	0
	2	0
	3	7,924
	4	192
14	1	1,016
	2	464
	3	2,690
	4	898
18	1	30
	2	10,343
	3	4,222
	4	1,404
22	1	0
	2	-
	3	5,341
	4	0
27	1	48,314
	2	60,692
	3	51,422
	4	3,782

\- = No data.

Source: Calabrese and Stanek, 1993.

Table 5-13. Estimated Daily Soil Ingestion for East Helena, Montana Children

Estimation Method	Mean (mg/day)	Median (mg/day)	Standard Deviation (mg/day)	Range (mg/day)	95th Percentile (mg/day)	Geometric Mean (mg/day)
Aluminum	181	121	203	25-1,324	584	128
Silicon	184	136	175	31-799	578	130
Titanium	1,834	618	3,091	4-17,076	9,590	401
Minimum	108	88	121	4-708	386	65

Source: Binder et al., 1986.

Table 5-14. Estimated Soil Ingestion for Sample of Dutch Nursery School Children

Child	Sample Number	Soil Ingestion as Calculated from Ti (mg/day)	Soil Ingestion as Calculated from Al (mg/day)	Soil Ingestion as Calculated from AIR (mg/day)	Limiting Tracer (mg/day)
1	L3	103	300	107	103
	L14	154	211	172	154
	L25	130	23	-	23
2	L5	131	-	71	71
	L13	184	103	82	82
	L27	142	81	84	81
3	L2	124	42	84	42
	L17	670	566	174	174
4	L4	246	62	145	62
	L11	2,990	65	139	65
5	L8	293	-	108	108
	L21	313	-	152	152
6	L12	1,110	693	362	362
	L16	176	-	145	145
7	L18	11,620	-	120	120
	L22	11,320	77	-	77
8	L1	3,060	82	96	82
9	L6	624	979	111	111
10	L7	600	200	124	124
11	L9	133	-	95	95
12	L10	354	195	106	106
13	L15	2,400	-	48	48
14	L19	124	71	93	71
15	L20	269	212	274	212
16	L23	1,130	51	84	51
17	L24	64	566	-	64
18	L26	184	56	-	56
Arithmetic Mean		1,431	232	129	105

- = No data.

Source: Adapted from Clausing et al., 1987.

Table 5-15. Estimated Soil Ingestion for Sample of Dutch Hospitalized, Bedridden Children

Child	Sample	Soil Ingestion as Calculated from Ti (mg/day)	Soil Ingestion as Calculated from Al (mg/day)	Limiting Tracer (mg/day)
1	G5	3,290	57	57
	G6	4,790	71	71
2	G1	28	26	26
3	G2	6,570	94	84
	G8	2,480	57	57
4	G3	28	77	28
5	G4	1,100	30	30
6	G7	58	38	38
Arithmetic Mean		2,293	56	49

Source: Adapted from Clausing et al., 1987.

Table 5-16. Positive/negative Error (Bias) in Soil Ingestion Estimates in Calabrese et al. (1989) Study: - Effect on Mean Soil Ingestion Estimate (mg/day)[a] -

Tracer	Negative Error						
	Lack of Fecal Sample on Final Study Day	Other Causes[b]	Total Negative Error	Total Positive Error	Net Error	Original Mean	Adjusted Mean
Aluminum	14	11	25	43	+18	153	136
Silicon	15	6	21	41	+20	154	133
Titanium	82	187	269	282	+13	218	208
Vanadium	66	55	121	432	+311	459	148
Yttrium	8	26	34	22	-12	85	97
Zirconium	6	91	97	5	-92	21	113

[a] How to read table: for example, aluminum as a soil tracer displayed both negative and positive error. The cumulative total negative error is estimated to bias the mean estimate by 25 mg/day downward. However, aluminum has positive error biasing the original mean upward by 43 mg/day. The net bias in the original mean was 18 mg/day positive bias. Thus, the original 156 mg/day mean for aluminum should be corrected downward to 136 mg/day.

[b] Values indicate impact on mean of 128-subject-weeks in milligrams of soil ingested per day.

Source: Calabrese and Stanek, 1995.

Table 5-17. Distribution of Average (Mean) Daily Soil Ingestion Estimates per Child for 64 Children[a] (mg/day)

Type of Estimate	Overall	A1	Ba	Mn	Si	Ti	V	Y	Zr
Number of Samples	64	64	33	19	63	56	52	61	62
Mean	179	122	655	1,053	139	271	112	165	23
25th Percentile	10	10	28	35	5	8	8	0	0
50th Percentile	45	19	65	121	32	31	47	15	15
75th Percentile	88	73	260	319	94	93	177	47	41
90th Percentile	186	131	470	478	206	154	340	105	87
95th Percentile	208	254	518	17,374	224	279	398	144	117
Maximum	7,703	4,692	17,991	17,374	4,975	12,055	845	8,976	208

[a] For each child, estimates of soil ingestion were formed on days 4-8 and the mean of these estimates was then evaluated for each child. The values in the column "overall" correspond to percentiles of the distribution of these means over the 64 children. When specific trace elements were not excluded via the relative standard deviation criteria, estimates of soil ingestion based on the specific trace element were formed for 108 days for each subject. The mean soil ingestion estimate was again evaluated. The distribution of these means for specific trace elements is shown.

Source: Stanek and Calabrese, 1995a.

Table 5-18. Estimated Distribution of Individual Mean Daily Soil Ingestion Based on Data for 64 Subjects Projected over 365 Days[a]

Range	1 - 2,268 mg/d[b]
50th Percentile (median)	75 mg/d
90th Percentile	1,190 mg/d
95th Percentile	1,751 mg/d

[a] Based on fitting a log-normal distribution to model daily soil ingestion values.
[b] Subject with pica excluded.

Source: Stanek and Calabrese, 1995a.

Table 5- 19. Summary of Estimates of Soil and Dust Ingestion by Children (0.5-14 years old) from Key Studies (mg/day)

Sample Size	Age (years)	Ingestion medium	Mean	P25	P50	P75	P90	P95	Reference
292	0.1 - <1	Soil	0 to 30 [a]	NR	NR	NR	NR	NR	Van Wijnen et al., 1990
	1 - <5	Soil	0 to 200 [a]	NR	NR	NR	≤300	NR	
101	2-<8	Soil	39 to 246	NR	25 to 81	NR	NR	NR	Davis et al., 1990
		Soil and Dust	65 to 268	NR	52 to 117	NR	NR	NR	
64	1-<4	Soil	-294 to +459	NR	-261 to +96	NR	67 to 1,366	106 to 1,903	Calabrese et al., 1989
		Dust	-1,289 to +964	NR	-340 to +127	NR	91 to 1,700	160 to 2,916	
		Soil and Dust	-496 to +483	NR	-340 to +456	NR	89 to 1,701	159 to 3,174	
12	3-<8	Soil	37 to 207	NR	26 to 47	NR	NR	NR	Davis and Mirick, 2006
64	1-<4	Soil	-544 to +270	-582 - +65	-31 to +220	1 to 411	37 to 1,238	69 to 1,378	Calabrese et al., 1997a
478	<1 - <7	Soil and Dust	113	NR	NR	NR	NR	NR	Hogan et al., 1998
140	1 - 13+	Soil	50,000 [b]	NR	NR	NR	NR	NR	Vermeer and Frate, 1979
52	0.3 - 14	Soil	NR	NR	NR	NR	~1,267	~4,000	Wong (1988)/Calabrese and Stanek (1993)

[a] Geometric mean.
[b] Average includes adults and children.
NR = Not reported.

6 INHALATION RATES

6.1 INTRODUCTION

Ambient and indoor air are potential sources of children's exposure to toxic substances. Children can be exposed to contaminated air during a variety of activities in different environments. Children may be exposed due to sources that contribute pollution to ambient air. Children may also inhale chemicals from the indoor use of various consumer products. Due to their size, physiology, and activity level, the inhalation rates of children differ from those of adults.

Infants and children have a higher resting metabolic rate and oxygen consumption rate per unit of body weight than adults, because of their rapid growth and relatively larger lung surface area per unit of body weight that requires cooling. For example, the oxygen consumption rate for a resting infant between one week and one year of age is 7 milliliters per kilogram of body weight (mL/kg) per minute, while the rate for an adult under the same conditions is 3-5 mL/kg per minute (WHO, 1986). Thus, while greater amounts of air and pollutants are inhaled by adults than children over similar time periods on an absolute basis, the volume of air passing through the lungs of a resting infant is up to twice that of a resting adult on a body weight basis.

The Agency defines exposure as the chemical concentration at the boundary of the body (U.S. EPA, 1992). In the case of inhalation, the situation is complicated by the fact that oxygen exchange with carbon dioxide takes place in the distal portion of the lung. The anatomy and physiology of the respiratory system as well as the characteristics of the inhaled agent diminishes the pollutant concentration in inspired air (potential dose) such that the amount of a pollutant that actually enters the body through the lung (internal dose) is less than that measured at the boundary of the body. A detailed discussion of this concept can be found in *Guidelines for Exposure Assessment* (U.S. EPA, 1992). When constructing risk assessments that concern the inhalation route of exposure, one must be aware of any adjustments that have been employed in the estimation of the pollutant concentration to account for this reduction in potential dose.

Children's inhalation dosimetry and health effects were topics of discussion at a U.S. EPA workshop held in June 2006 (Foos and Sonawane, 2008). Age related differences in lung structure and function, breathing patterns, and how these affect the inhaled dose and the deposition of particles in the lung are important factors in assessing risks from inhalation exposures (Foos et al., 2008). Children may have a lesser nasal contribution to breathing during rest and while performing various activities. The uptake of particles in the nasal airways is also less efficient in children. Thus, the deposition of particles in the lower respiratory tract may be greater (Foos et al., 2008).

Inclusion of this chapter in the Child-Specific Exposure Factors Handbook does not imply that assessors will always need to select and use inhalation rates when evaluating exposure to air contaminants. For example, it is unnecessary to calculate inhaled dose when using dose-response factors from the Integrated Risk Information System (IRIS) (U.S. EPA, 1994), because the IRIS methodology accounts for inhalation rates in the development of "dose-response" relationships. Information in this chapter may be used by toxicologists in their derivation of human equivalent concentrations. When using IRIS for inhalation risk assessments, "dose-response" relationships require only an average air concentration to evaluate health concerns:

- For non-carcinogens, IRIS uses Reference Concentrations (RfCs) which are expressed in concentration units. Hazard is evaluated by comparing the inspired air concentration to the RfC.
- For carcinogens, IRIS uses unit risk values which are expressed in inverse concentration units. Risk is evaluated by multiplying the unit risk by the inspired air concentration.

Detailed descriptions of the IRIS methodology for derivation of inhalation reference concentrations can be found in two methods manuals produced by the Agency (U.S. EPA, 1992; 1994).

The Superfund Program has also updated its approach for determining inhalation risk, eliminating the use of inhalation rates when evaluating exposure to air contaminants (U.S. EPA, 2008). The current methodology recommends that risk assessors use the concentration of the chemical in air as the exposure metric (e.g., mg/m^3), instead of the intake of a contaminant in air based on inhalation rate and body weight (e.g., mg/kg-day).

Recommended inhalation rates (both long- and short-term) are provided in the next section, along with the confidence ratings for these recommendations. These recommendations are based on four key studies identified by U.S. EPA for this factor. Long-term exposure is repeated exposure for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days). Long-term inhalation rates for children (including infants) are presented as daily rates (m^3/day). Short-term exposure is repeated exposure for more than 24 hours, up to 30 days. Short-term inhalation rates are reported for children (including infants) performing various activities in m^3/minute. Following the recommendations, the available studies (both key and relevant studies) on inhalation rates are summarized.

6.2 RECOMMENDATIONS

The recommended inhalation rates for children are based on four recent studies: Brochu et al., 2006; U.S. EPA, 2006; Arcus-Arth and Blaisdell, 2007; and Stifelman, 2007. These studies represent an improvement upon those previously used for recommended inhalation rates in this handbook, because they use a large data set that is representative of the United States as a whole and consider the correlation between body weight and inhalation rate.

The selection of inhalation rates to be used for exposure assessments depends on the age of the exposed population and the specific activity levels of this population during various exposure scenarios. The recommended long-term values for children (including infants) for use in various exposure scenarios are presented in Table 6-1 for the standard U.S. EPA childhood age groups used in this handbook. As shown in Table 6-1, the daily average inhalation rates for long-term exposures for male and female children combined (unadjusted for body weight) range from 3.6 m^3/day for children from birth to <1 month to 16.5 m^3/day for children aged 16 to <21 years. These values represent averages of the inhalation rate data from the four key studies. The 95th percentile values range from 7.1 m^3/day to 27.6 m^3/day for the same age categories. The 95th percentile values represent averages of the inhalation rate data from the three key studies for which 95th percentile values were available for selected age groups (Brochu et al., 2006; U.S. EPA, 2006; Arcus-Arth and Blaisdell, 2007). It should be noted that there may be a high degree of uncertainty associated with the upper percentiles. These values equate to unusually high estimates of caloric intake per day, and are unlikely to be representative of the average child. For example, using Layton's equation (Layton, 1993) for estimating metabolically consistent inhalation rates to calculate caloric equivalence (see Section 6.4.6), the 95th percentile value for 16 to <21 year old children is 4,840 kcal/day. All of the 95th percentile values listed in Table 6-1 may represent unusually high inhalation rates for long-term exposures, even for the upper end of the distribution, but were included in this handbook to provide exposure assessors a sense of the possible range of inhalation rates for children. These values should be used with caution when estimating long-term exposures.

For short-term exposures for children aged 21 years and under, for which activity patterns are known, mean and 95th percentile data are provided in Table 6-2 for males and females combined, in m^3/minute. These values represent averages of the activity level data from the one key study from which short-term inhalation rate data were available (U.S. EPA, 2006).

The confidence ratings for the inhalation rate recommendations are shown in Table 6-3. Multiple percentiles for long- and short-term inhalation rates for both males and females are provided in Tables 6-5 through 6-11 and Table 6-16.

Table 6-1. Recommended Long-Term Exposure (More Than 30 Days) Values for Inhalation (Males and Females Combined).

Age Group	Mean m^3/day	Sources Used for Means	95th Percentile m^3/day	Sources Used for 95th Percentiles	Multiple Percentiles
Birth to <1 month	3.6	a	7.1	a	See Tables 6-5 through 6-11 and 6-16
1 to <3 months	- [b]	-	-	-	
3 to <6 months	4.1	a,c	6.1	a,c	
6 to <12 months	5.4	a,c	8.1	a,c	
1 to <2 years	8.0	a,c,d,e	12.8	a,c,d	
2 to <3 years	9.5	a,d,e	15.9	a,d	
3 to <6 years	10.9	a,d,e	16.2	a,d	
6 to <11 years	12.4	a,d,e	18.7	a,d	
11 to <16 years	15.1	a,d,e	23.5	a,d	
16 to <21 years	16.5	a,d,e	27.6	a,d	

[a] Arcus-Arth and Blaisdell, 2007.
[b] No data for this age group.
[c] Brochu et al., 2006.
[d] U.S. EPA, 2006.
[e] Stifelman, 2007.
Note: Some 95th percentile values may be unusually high, and may not be representative of the average child.

Table 6-2. Recommended Short-Term Exposure (Less Than 30 Days) Values for Inhalation (Males and Females Combined)

Activity Level	Age Group years	Mean m^3/minute	95th Percentile m^3/minute	Multiple Percentiles
Sleep or Nap	Birth to <1 year	3.0E-03	4.6E-03	See Tables 6-11 and 6-12
	1 to <2 years	4.5E-03	6.4E-03	
	2 to <3 years	4.6E-03	6.4E-03	
	3 to <6 years	4.3E-03	5.8E-03	
	6 to <11 years	4.5E-03	6.3E-03	
	11 to <16 years	5.0E-03	7.4E-03	
	16 to <21 years	4.9E-03	7.1E-03	
Sedentary/ Passive	Birth to <1 year	3.1E-03	4.7E-03	
	1 to <2 years	4.7E-03	6.5E-03	
	2 to <3 years	4.8E-03	6.5E-03	
	3 to <6 years	4.5E-03	5.8E-03	
	6 to <11 years	4.8E-03	6.4E-03	
	11 to <16 years	5.4E-03	7.5E-03	
	16 to <21 years	5.3E-03	7.2E-03	
Light Intensity	Birth to <1 year	7.6E-03	1.1E-02	
	1 to <2 years	1.2E-02	1.6E-02	
	2 to <3 years	1.2E-02	1.6E-02	
	3 to <6 years	1.1E-02	1.4E-02	
	6 to <11 years	1.1E-02	1.5E-02	
	11 to <16 years	1.3E-02	1.7E-02	
	16 to <21 years	1.2E-02	1.6E-02	
Moderate Intensity	Birth to <1 year	1.4E-02	2.2E-02	
	1 to <2 years	2.1E-02	2.9E-02	
	2 to <3 years	2.1E-02	2.9E-02	
	3 to <6 years	2.1E-02	2.7E-02	
	6 to <11 years	2.2E-02	2.9E-02	
	11 to <16 years	2.5E-02	3.4E-02	
	16 to <21 years	2.6E-02	3.7E-02	
High Intensity	Birth to <1 year	2.6E-02	4.1E-02	
	1 to <2 years	3.8E-02	5.2E-02	
	2 to <3 years	3.9E-02	5.3E-02	
	3 to <6 years	3.7E-02	4.8E-02	
	6 to <11 years	4.2E-02	5.9E-02	
	11 to <16 years	4.9E-02	7.0E-02	
	16 to <21 years	4.9E-02	7.3E-02	

Source: U.S. EPA, 2006.

Table 6-3. Confidence in Recommendations for Inhalation Rates

General Assessment Factors	Rationale	Rating
Soundness		Medium
Adequacy of Approach	The survey methodology and data analysis was adequate. Measurements were made by indirect methods. The studies analyzed existing primary data.	
Minimal (or defined) Bias	Potential bias within the studies was fairly well documented.	
Applicability and Utility		High
Exposure Factor of Interest	The studies focused on inhalation rates and factors influencing them.	
Representativeness	The studies focused on the U.S. population. A wide range of age groups were included.	
Currency	The studies were published during 2006 and 2007 and represent current exposure conditions.	
Data Collection Period	The data collection period for the studies may not be representative of long-term exposures.	
Clarity and Completeness		Medium
Accessibility	All key studies are available from the peer reviewed literature.	
Reproducibility	The methodologies were clearly presented; enough information was included to reproduce most results.	
Quality Assurance	Information on ensuring data quality in the key studies was limited.	
Variability and Uncertainty		Medium
Variability in Population	In general, the key studies addressed variability in inhalation rates based on age and activity level. However, other factors that may affect inhalation rates (e.g., weight, body mass index [BMI], ethnicity) are not discussed.	
Uncertainty	Multiple sources of uncertainty exist for these studies. Assumptions associated with Energy Expenditure (EE) based estimation procedures are a source of uncertainty in inhalation rate estimates.	
Evaluation and Review		High
Peer Review	Three of the key studies appeared in peer reviewed journals, and one key study is a U.S. EPA peer reviewed report.	
Number and Agreement of Studies	There are four key studies. The results of studies from different researchers are in general agreement.	
Overall Rating		**Medium**

6.3 KEY INHALATION RATE STUDIES

6.3.1 Brochu et al., 2006 - Physiological Daily Inhalation Rates for Free-living Individuals Aged 1 Month to 96 Years, Using Data from Doubly Labeled Water Measurements: A proposal for Air Quality Criteria, Standard Calculations and Health Risk Assessment

Brochu et al. (2006) calculated physiological daily inhalation rates (PDIR) for 2,210 individuals aged 3 weeks to 96 years using the reported disappearance rates of oral doses of doubly labeled water (DLW) (^2H_2O and $H_2{}^{18}O$) in urine, monitored by gas-isotope-ratio mass spectrometry for an aggregate period of more than 30,000 days. DLW data were complemented with indirect calorimetry and nutritional balance measurements.

In the DLW method, the disappearance of the stable isotopes deuterium (^2H) and heavy oxygen-18 (^{18}O) are monitored in urine, saliva, or blood samples over a long period of time (from 7 to 21 days) after subjects receive oral doses of ^2H_2O and $H_2{}^{18}O$. The disappearance rate of ^2H reflects water output and that of ^{18}O represents water output plus carbon dioxide (CO_2) production rates. The CO_2 production rate is then calculated by difference between the two disappearance rates. Total daily energy expenditures (TDEEs) are determined from CO_2 production rates using classic respirometry formulas, in which values for the respiratory quotient ($RQ = CO_{2\,produced}/O_{2\,consumed}$) are derived from the composition of the diet during the period of time of each study. The DLW method also allows for measurement of the energy cost of growth (ECG). TDEE and ECG measurements can be converted into PDIR values using the following equation developed by Layton (1993):

$$PDIR = (TDEE + ECG) \times H \times VQ\ 10^{-3} \qquad \text{(Eqn. 6-1)}$$

where:

PDIR = physiological daily inhalation rates (m^3/day);
TDEE = total daily energy expenditure (kcal/day);
ECG = stored daily energy cost for growth (kcal/day);
H = oxygen uptake factor, volume of 0.21 L of oxygen (at standard temperature and pressure, dry air) consumed to produce 1 kcal of energy expended;
VQ = ventilatory equivalent ratio of the minute volume (V_E) at body temperature pressure saturation) to the oxygen uptake rate (VO_2 at standard temperature and pressure, dry air) $V_E/VO_2 = 27$; and
10^{-3} = conversion factor (L/m^3).

Brochu et al. (2006) calculated daily inhalation rates (expressed in m^3/day and m^3/kg-day) for a variety of age groups and physiological conditions. Published data on BMI, body weight, basal metabolic rate (BMR), ECG, and TDEE measurements (based on DLW method and indirect calorimetry) for subjects aged 2.6 months to 96 years were used. Only the data for children are presented in this handbook. Data for underweight, healthy normal-weight, and overweight/obese individuals were gathered and defined according to BMI cutoffs. Data for newborns were included regardless of BMI values, because they were clinically evaluated as being healthy infants.

Mean inhalation rates for newborns are presented in Table 6-4. Due to the insufficient number of subjects, no distributions were derived for this group. The distribution of daily inhalation rates for normal-weight and overweight/obese individuals by gender and age groups are presented in Tables 6-5 to 6-9.

An advantage of this study is that data are provided for age groups of less than one year. A limitation of this study is that data for individuals with pre-existing medical conditions was lacking.

6.3.2 U.S. EPA, 2006 - Metabolically-derived Human Ventilation Rates: A Revised Approach Based Upon Oxygen Consumption Rates

U.S. EPA (2006) conducted a study to ascertain inhalation rates for children and adults. Specifically, U.S. EPA sought to improve upon the methodology used by Layton (1993) and other studies that relied upon the ventilatory equivalent (VQ) and a linear relationship between oxygen consumption and fitness rate. A revised approach, developed by U.S.

fitness rate. A revised approach, developed by U.S. EPA's National Exposure Research Laboratory (NERL), was used, in which an individual's inhalation rate was derived from his or her assumed oxygen consumption rate. U.S. EPA applied this revised approach using body weight data from the 1999-2002 National Health and Nutrition Examination Survey (NHANES) and metabolic equivalents (METS) data from U.S. EPA's Consolidated Human Activity Database (CHAD). In this database, metabolic cost is given in units of "METS" or "metabolic equivalents of work," an energy expenditure metric used by exercise physiologists and clinical nutritionists to represent activity levels. An activity's METS value represents a dimensionless ratio of its metabolic rate (energy expenditure) to a person's resting, or basal metabolic rate (BMR).

NHANES provided age, gender, and body weight data for 19,022 individuals from throughout the United States. From these data, basal metabolic rate (BMR) was estimated using an age-specific linear equation used in the Exposure Factors Handbook (U.S. EPA, 1997), and in several other studies and reference works.

The CHAD database is a compilation of several databases of human activity patterns. U.S. EPA used one of these studies, the National Human Activity Pattern Survey (NHAPS), as its source for METS values because it was more representative of the entire United States population than the other studies in the database. The NHAPS data set included activity data for 9,196 individuals, each of which provided 24 hours of activity pattern data using a diary-based questionnaire. While NHAPS was identified as the best available data source for activity patterns, there were some shortcomings in the quality of the data. Study respondents did not provide body weights; instead, body weights are simulated using statistical sampling. Also, the NHAPS data extracted from CHAD could not be corrected to account for non-random sampling of study participants and survey days.

NHANES and NHAPS data were grouped into age categories using the standardized age categories presented elsewhere in this handbook, with the exception that children under the age of one year were placed into a single category to preserve an adequate sample size within the category. For each NHANES participant, a "simulated" 24-hour activity pattern was generated by randomly sampling activity patterns from the set of NHAPS participants with the same gender and age category as the NHANES participant. Twenty such patterns were selected at random for each NHANES participant, resulting in 480 hours of simulated activity data for each NHANES participant. The data were then scaled down to a 24-hour time frame to yield an average 24-hour activity pattern for each of the 19,022 NHANES individuals.

Each activity was assigned a METS value based on statistical sampling of the distribution assigned by CHAD to each activity code. For most codes, these distributions were not age-dependent, but age was a factor for some activities for which intensity level varies strongly with age. Using statistical software, equations for METS based on normal, lognormal, exponential, triangular, and uniform distributions were generated as needed for the various activity codes. The METS values were then translated into energy expenditure (EE) by multiplying the METS by the basal metabolic rate (BMR), which was calculated as a linear function of body weight. The oxygen consumption rate (VO_2) was calculated by multiplying EE by H, the volume of oxygen consumed per unit of energy. VO_2 was calculated both as volume per time and as volume per time per unit body weight.

The inhalation rate for each activity within the 24-hour simulated activity pattern for each individual was estimated as a function of VO_2, body weight, age, and gender. Following this, the average inhalation rate was calculated for each individual for the entire 24-hour period, as well as for four separate classes of activities based on METS value (sedentary/passive (METS less than or equal to 1.5), light intensity (METS greater than 1.5 and less than or equal to 3.0), moderate intensity (METS greater than 3.0 and less than or equal to 6.0), and high intensity (METS greater than 6.0). Data for individuals were then used to generate summary tables based on gender and age categories.

Data from this study are presented in Tables 6-10 through 6-15. Tables 6-10 and 6-11 present, for male and female subjects, respectively, summary statistics for daily average inhalation rate by age category on a volumetric (m^3/day) and body-weight adjusted (m^3/day-kg) basis. Table 6-12 presents the mean and 95th percentile values for males, females, and males and females combined. Tables 6-13 and 6-14 present, for male and female subjects, respectively, mean ventilation rates by age category on a volumetric (m^3/min) and body-weight adjusted (m^3/min-kg) basis for the five different activity level ranges described above. Table 6-15 presents the number of hours spent per day at each activity level by males and females.

An advantage of this study is the large sample size. In addition, the datasets used, NHAPS and NHANES, are representative of the U.S. general population. Limitations are that the NHAPS data are 10 years old, there is variability in the 24-hour activity, and there is uncertainty in the METs randomization, all of which were noted by the authors.

6.3.3 Arcus-Arth and Blaisdell, 2007 - Statistical Distributions of Daily Breathing Rates for Narrow Age Groups of Infants and Children

Arcus-Arth and Blaisdell (2007) derived daily breathing rates for narrow age ranges of children using the metabolic conversion method of Layton (1993) and energy intake data adjusted to represent the U.S. population from the Continuing Survey of Food Intake for Individuals (CSFII) 1994-1996, 1998. Normalized (m^3/kg-day) and nonnormalized (m^3/day) breathing rates for children 0-18 years of age were derived using the general equation developed by Layton (1993) to calculate energy-dependent inhalation rates (see Equation 6-2).

$$VE = H \times VQ \times EE \qquad \text{(Eqn. 6-2)}$$

where:

VE = volume of air breathed per day (m^3/day);
H = volume of oxygen consumed to produce 1 kcal of energy (m3/kcal);
VQ = ratio of the volume of air to the volume of oxygen breathed per unit time (unitless); and
EE = energy (kcal) expended per day.

Arcus-Arth and Blaisdell (2007) calculated H values of 0.22 and 0.21 for infants and noninfant children, respectively, using the 1977-1978 NFCS and CSFII data sets. Ventilatory equivalent (VQ) data, including those for infants, were obtained from 13 studies that reported VQ data for children aged 4-8 ears. Separate preadolescent (4-8 years) and adolescent (9-18 years) VQ values were calculated in addition to separate VQ values for adolescent boys and girls. Two-day-averaged daily energy intake (EI) values reported in the CSFII data set were used a surrogate for EE. CSFII records that did not report body weight and those for children who consumed breast milk or were breast fed were excluded from their analyses. The EIs of children 9 years of age and older were multiplied by 1.2, the value calculated by Layton (1993) to adjust for potential bias related to underreporting of dietary intakes by older children. For infants, EI values were adjusted by subtracting the amount of energy put into storage by infants as estimated by Scrimshaw et al. (1996). Self-reported body weights for each individual from the CSFII data set were used to calculate nonnormalized (m^3/day) and normalized (m^3/kg-day) breathing rates, which decreased the variability in the resulting breathing rate data. Daily breathing rates were grouped into three-month age groups for infants, one-year age groups for children 1-18 years of age, and the age groups recommended by U.S. EPA cancer guidelines supplement (U.S. EPA, 2005) to receive greater weighting for mutagenic carcinogens (0 to < 2 years of age, and 2 to < 16 years of age). Data were also presented for adolescent boys and girls, aged 9-18 years (Table 6-16). For each age and age-gender group, Arcus-Arth and Blaisdell (2007) calculated the arithmetic mean, standard error of the mean, percentiles (50th, 90th, and 95th), geometric mean, standard deviation, and best-fit parametric models of the breathing rate distributions. Overall, the CSFII-derived nonnormalized breathing rates progressively increased with age from infancy through 18 years of age, while normalized breathing rates progressively decreased. The data are presented in Table 6-16 in units of m^3/day. There were statistical differences between boys and girls 9-18 years of age, both for these years combined (*p*< 0.00) and for each year of age separately (*p*< 0.05). The authors reasoned that since the fat-free mass (basically muscle mass) of boys typically increases during adolescence, and because fat-free mass is highly correlated to basal metabolism which accounts for the majority of EE, nonnormalized breathing rates for adolescent boys may be expected to increase with increasing age. Table 6-17 presents the mean and 95th percentile values for males and females combined, averaged to fit within the standard EPA age groups.

The CSFII-derived mean breathing rates derived by Arcus-Arth and Blaisdell (2007) were compared to the mean breathing rates estimated in studies that utilized doubly labeled water (DLW) technique EE data that had been coupled with the Layton (1993) method. The infants' CSFII-derived breathing rates were 15 to 27 percent greater than the comparison DLW EE breathing rates while the children's CSFII rates ranged from 23 percent less to 14 percent greater than comparison rates. Thus, the CSFII and comparison rates were quite similar across age groups.

An advantage of this study is that it provides breathing rates specific to narrow age ranges, which can be useful for assessing inhalation dose during periods of greatest susceptibility. However, the study is limited by the potential for misreporting, underestimating, or overestimating of food intake data in the CSFII. In addition to underreporting of food intake by adolescents, EI values for younger children may be under- or overestimated. Overweight children (or their parents) may also underreport food intakes. In addition, adolescents who misreport food intake may have also misreported body weights.

6.3.4 Stifelman, 2007 - Using Doubly-labeled Water Measurements of Human Energy Expenditure to Estimate Inhalation Rates

Stifelman (2007) estimated inhalation rates using DLW energy data. The DLW method administers two forms of stable isotopically labeled water: deuterium-labeled (^2H_2O) and ^{18}oxygen-labeled ($H_2{}^{18}O$). The difference in disappearance rates between the two isotopes represents the energy expended over a period of 1–3 half-lives of the labeled water (Stifelman, 2007). The resulting duration of observation is typically 1–3 weeks, depending on the size and activity level.

The DLW database contains subjects from areas around the world and represents diversity in ethnicity, age, activity, body type, and fitness level. DLW data have been compiled by the Institute of Medicine (IOM) Panel on Macronutrients and the Food and Agriculture Organization of the United Nations (FAO). Stifelman (2007) used the equation of Layton (1993) to convert the recommended energy levels of IOM for the active-very active people to their equivalent inhalation rates. The IOM reports recommend energy expenditure levels organized by gender, age and body size (Stifelman, 2007).

The equivalent inhalation rates are shown in Table 6-18. Shown in Table 6-19 are the mean and 95th percentile values for the IOM "active" energy level category, averaged to fit within the standard EPA age groups. Stifelman (2007) noted that the estimates based on the DLW are consistent with previous findings of Layton (1993) and the Exposure Factors Handbook (U.S. EPA, 1997) and that inhalation rates based on the IOM active classification are consistent with the mean inhalation rate in the handbook.

The advantages of this study are that the inhalation rates were estimated using the DLW data from a large data set. Stifelman (2007) noted that DLW methods are advantageous; the data are robust, measurements are direct and avoid errors associated with indirect measurements (heart rate), subjects are free-living, and the period of observation is longer than what is possible from staged activity measures. Observations over a longer period of time reduce the uncertainties associated with using short duration studies to infer long-term inhalation rates. A limitation with the study is that the inhalation rates that are presented are for active/very active persons only.

6.3.5 Key Studies Combined

In order to provide the recommended long-term inhalation rates shown in Table 6-1**,** data from the four key studies were combined. The data from each study were averaged by gender and grouped according to the standard U.S. EPA childhood age groups used in this handbook, when possible. Mean and 95th percentile inhalation rate values for the four key studies are shown in Tables 6-20 and 6-21, respectively.

6.4 RELEVANT INHALATION RATE STUDIES

6.4.1 International Commission on Radiological Protection (ICRP), 1981 - Report of the Task Group on Reference Man

The International Commission on Radiological Protection (ICRP) (1981) estimated daily inhalation rates for reference children (10 years old), infants (1 year old), and newborn babies by using a time-activity-ventilation approach. This approach for estimating an inhalation rate over a specified period of time was based on calculating a time weighted average of inhalation rates associated with physical activities of varying durations (Table 6-22). ICRP (1981) compiled reference values (Table 6-23) of minute volume/inhalation rates from various literature sources. ICRP (1981) assumed that the daily activities of a reference child (10 yrs) consisted of 8 hours of rest and 16 hours of light activities. It was assumed that a day consisted of 14 hours resting and 10 hours light activity for an infant (1 year). A newborn's daily activities consisted of 23 hours resting and 1 hour light activity. The estimated inhalation rates were 14.8 m^3/day for children (age 10 years), 3.76 m^3/day for infants (age 1 year), and 0.78 m^3/day for newborns (Table 6-22).

A limitation associated with this study is that the validity and accuracy of the inhalation rate data used in the compilation of reference values were not specified. This introduces some degree of uncertainty in the results obtained. Also, the approach used required that assumptions be made regarding the hours spent by various age/gender cohorts in specific activities. These assumptions may over/under-estimate the inhalation rates obtained.

6.4.2 U.S. EPA, 1985 - Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments

The U.S. EPA (1985) compiled measured values of minute ventilation for various age/gender cohorts from early studies. The data compiled by the U.S. EPA (1985) for each age/gender cohorts were obtained at various activity levels (Table 6-24). These levels were categorized as light, moderate, or heavy according to the criteria developed by the U.S. EPA Office of Environmental Criteria and Assessment for the Ozone Criteria Document. These criteria were developed for a reference male adult with a body weight of 70 kg (U.S. EPA, 1985).

Table 6-24 presents a summary of inhalation rates by age and activity level. A description of activities included in each activity level is also presented in Table 6-24. Table 6-24 indicates that at rest, the mean inhalation rate for children, ages 6 and 10 years, is 0.4 m^3/hr. Table 6-25 presents activity pattern data aggregated for three microenvironments by activity level for all age groups. The total average hours spent indoors was 20.4, outdoors was 1.77, and in a transportation vehicle was 1.77. Based on the data presented in Tables 6-24 and 6-25, a daily inhalation rate was calculated for adults and children by using a time-activity-ventilation approach. These data are presented for children in Table 6-26. The average daily inhalation rate for 6 and 10 years old children is 16.74 and 21.02 m^3/day, respectively.

Limitations associated with this study are its age and that many of the values used in the data compilation were from early studies. The accuracy and/or validity of the values used and data collection method were not presented in U.S. EPA (1985). This introduces uncertainty in the results obtained. An advantage of this study is that the data are actual measurement data for a large number of children.

6.4.3 Linn et al., 1992 - Documentation of Activity Patterns in "High-risk" Groups Exposed to Ozone in the Los Angeles Area

Linn et al. (1992) conducted a study that estimated the inhalation rates for "high-risk" subpopulation groups exposed to ozone in their daily activities in the Los Angeles area. The population surveyed consisted of several panels of children. The panels included *Panel 2*: 17 healthy elementary school students (5 males and 12 females, ages 10-12 years); *Panel 3*: 19 healthy high school students (7 males and 12 females, ages 13-17 years); *Panel 6*: 13 young asthmatics (7 males and 6 females, ages 11-16 years).

An initial calibration test was conducted, followed by a training session. Finally, a field study that involved the subjects collecting their own heart rates and diary data was conducted. During the calibration tests, ventilation rate (VR), breathing rate, and heart rate (HR) were measured simultaneously at each exercise level. From the calibration data an equation was developed using linear regression analysis to predict VR from measured HR.

In the field study, each subject recorded in diaries their daily activities, change in locations (indoors, outdoors, or in a vehicle), self-estimated breathing rates during each activity/location, and time spent at each activity/location. Healthy subjects recorded their HR once every 60 seconds using a Heart

Watch, an automated system consisting of a transmitter and receiver worn on the body. Asthmatic subjects recorded their diary information once every hour. Subjective breathing rates were defined as slow (walking at their normal pace), medium (faster than normal walking), and fast (running or similarly strenuous exercise). Table 6-27 presents the calibration and field protocols for self-monitoring of activities for each subject panel.

Table 6-28 presents the mean, 99^{th} percentile, and mean VR at each subjective activity level (slow, medium, fast). The mean and 99th percentile VR were derived from all HR recordings that appeared to be valid, without considering the diary data. Each of the three activity levels was determined from both the concurrent diary data and HR recordings by direct calculation or regression. The authors reported that the diary data showed that on a typical day, most individuals spent most of their time indoors at slow activity level. During slow activity, asthmatic subjects had higher VRs than healthy subjects (Table 6-28). The authors also reported that in every panel the predicted VR correlated significantly with the subjective estimates of activity levels.

A limitation of this study is that calibration data may overestimate the predictive power of HR during actual field monitoring. The wide variety of exercises in everyday activities may result in greater variation of the VR-HR relationship than was calibrated. Another limitation is the small sample size of each subpopulation surveyed. An advantage of this study is that diary data can provide rough estimates of ventilation patterns which are useful in exposure assessments. Another advantage is that inhalation rates were presented for both healthy and asthmatic children.

6.4.4 Spier et al., 1992 - Activity Patterns in Elementary and High School Students Exposed to Oxidant Pollution

Spier et al. (1992) investigated the activity patterns of 17 elementary school students (10-12 years old) and 19 high school students (13-17 years old) in suburban Los Angeles from late September to October (oxidant pollution season). Calibration tests were conducted in supervised outdoor exercise sessions. The exercise sessions consisted of 5 minutes each of rest, slow walking, jogging, and fast walking. HR and VR were measured during the last 2 minutes of each exercise. Individual VR and HR relationships for each individual were determined by fitting a regression line to HR values and log VR values. Each subject recorded their daily activities, changes in location, and breathing rates in diaries for 3 consecutive days. Self-estimated breathing rates were recorded as slow (slow walking), medium (walking faster than normal), and fast (running). HR was recorded once per minute during the 3 days using a Heart Watch. VR values for each self-estimated breathing rate and activity type were estimated from the HR recordings by employing the VR and HR equation obtained from the calibration tests.

The data presented in Table 6-29 represent HR distribution patterns and corresponding predicted VR for each age group during hours spent awake. At the same self-reported activity levels for both age groups, inhalation rates were higher for outdoor activities than for indoor activities. The total number of hours spent indoors was higher for high school students (21.2 hours) than for elementary school students (19.6 hours). The converse was true for outdoor activities: 2.7 hours for high school students and 4.4 hours for elementary school students (Table 6-30).

A limitation of this study is the small sample size. The results may not be representative of all children in these age groups. Another limitation is that the accuracy of the self-estimated breathing rates reported by younger age groups is uncertain. This may affect the validity of the data set generated. An advantage of this study is that inhalation rates were determined for children and adolescents. These data are useful in estimating exposure for the younger population.

6.4.5 Adams, 1993 - Measurement of Breathing Rate and Volume in Routinely Performed Daily Activities, Final Report

Adams (1993) conducted research to accomplish two main objectives: (1) identification of mean and ranges of inhalation rates for various age/gender cohorts and specific activities, and (2) derivation of simple linear and multiple regression equations that could be used to predict inhalation rates through other measured variables: breathing frequency and oxygen consumption. A total of 160 subjects participated in the primary study. For children, there were two age-dependent groups: children 6 to 12.9 years old and adolescents 13 to18.9 years old. An additional 40 children from 6 to 12.9 years old and 12 young children from 3 to 5.9 years old were identified as subjects for pilot testing purposes.

Resting protocols conducted in the laboratory for all age groups consisted of three phases (25 minutes each) of lying, sitting, and standing. The phases were categorized as resting and sedentary activities. Two active protocols— moderate (walking) and heavy (jogging/ running) phases— were performed on a treadmill over a progressive continuum of intensity levels made up of 6-minute intervals at three speeds ranging from slow to moderately fast. All protocols involved measuring VR, HR, f_B (breathing frequency), and VO_2 (oxygen consumption). Measurements were taken in the last 5 minutes of each phase of the resting protocol and the last 3 minutes of the 6-minute intervals at each speed designated in the active protocols.

In the field, all children completed spontaneous play protocols; most protocols were conducted for 30 minutes. All the active field protocols were conducted twice. Results are shown in Tables 6-31 and 6-32.

During all activities in either the laboratory or field protocols, VR for the children's group revealed no significant gender differences. Therefore, VR data presented in Tables 6-33 and 6-34 were categorized by activity type (lying, sitting, standing, walking, and running) for young children and children without regard to gender. These categorized data from Tables 6-33 and 6-32 are summarized as inhalation rates in Tables 6-31 and 6-32. The laboratory protocols are shown in Table 6-31. Table 6-32 presents the mean inhalation rates by group and for moderate activity levels in field protocols. Data were not provided for the light and sedentary activities because the group did not perform for this protocol or the number of subjects was too small for appropriate comparisons. Accurate predictions of inhalation rates across all population groups and activity types were obtained by including body surface area (SA), HR, and breathing frequency in multiple regression analysis (Adams, 1993). Adams (1993) calculated SA from measured height and body weight using the equation:

$$SA = Height^{(0.725)} \times Weight^{(0.425)} \times 71.84 \quad \text{(Eqn. 6-3)}$$

A limitation associated with this study is that the population does not represent the general U.S. population. Also, the classification of activity types (i.e., laboratory and field protocols) into activity levels may bias the inhalation rates obtained for various age/gender cohorts. The estimated rates were based on short-term data and may not reflect long-term patterns.

6.4.6 Layton, 1993 - Metabolically Consistent Breathing Rates for Use in Dose Assessments

Layton (1993) presented a method for estimating metabolically consistent inhalation rates for use in quantitative dose assessments of airborne radionuclides. Generally, the approach for estimating the breathing rate for a specified time frame was to calculate a time-weighted-average of ventilation rates associated with physical activities of varying durations. However, in this study, breathing rates were calculated on the basis of oxygen consumption associated with energy expenditures for short (hours) and long (weeks and months) periods of time, using the following general equation to calculate energy-dependent inhalation rates:

$$V_E = E \times H \times VQ \quad \text{(Eqn. 6-4)}$$

where:

V_E = ventilation rate (m^3/min or m^3/day);
E = energy expenditure rate; [kilojoules/minute (KJ/min) or megajoules/hour (MJ/hr)];
H = volume of oxygen (at standard temperature and pressure, dry air consumed in the production of 1 kilojoule (KJ) of energy expended (L/KJ or m^3/MJ)); and
VQ = ventilatory equivalent (ratio of minute volume (m^3/min) to oxygen uptake (m^3/min)) unitless.

Layton (1993) used two alternative approaches to estimate daily chronic (long term) inhalation rates for different age/gender cohorts of the U.S. population using this methodology.

First Approach

Inhalation rates were estimated by multiplying average daily food energy intakes for different age/gender cohorts, H, and VQ, as shown in the equation above. The average food energy intake data (Table 6-35) are based on approximately 30,000 individuals and were obtained from the 1977-78 USDA-NFCS. The food energy intakes were adjusted upwards by a constant factor of 1.2 for all individuals 9 years and older. This factor compensated for a consistent bias in USDA-NFCS that was attributed to under-reporting of the foods consumed or the methods used to ascertain dietary intakes. Layton (1993) used a weighted average oxygen uptake of 0.05 L O_2/KJ which was determined from data reported in the 1977-78 USDA-NFCS and the second NHANES (NHANES II). The survey sample for NHANES II was approximately 20,000 participants. A VQ of 27 used in the calculations was calculated as the geometric mean of VQ data that were obtained from several studies.

The inhalation rate estimation techniques are shown in footnote (a) of Table 6-36. Table 6-37 presents the daily inhalation rate for each age/gender cohort. The highest daily inhalation rates were 10 m^3/day for children between the ages of 6 and 8 years, 17 m^3/day for males between 15 and 18 years, and 13 m^3/day for females between 9 and 11 years. Inhalation rates were also calculated for active and inactive periods for the various age/gender cohorts.

The inhalation rate for inactive periods was estimated by multiplying the BMR times H times VQ. BMR was defined as "the minimum amount of energy required to support basic cellular respiration while at rest and not actively digesting food" (Layton, 1993). The inhalation rate for active periods was calculated by multiplying the inactive inhalation rate by the ratio of the rate of energy expenditure during active hours to the estimated BMR. This ratio is presented as F in Table 6-36. These data for active and inactive inhalation rates are also presented in Table 6-36. For children, inactive and active inhalation rates ranged from 2.35 to 5.95 m^3/day and from 6.35 to 13.09 m^3/day, respectively.

Second Approach

Inhalation rates were calculated as the product of the BMR of the population cohorts, the ratio of total daily energy expenditure to daily BMR, H, and VQ. The BMR data obtained from the literature were statistically analyzed, and regression equations were developed to predict BMR from body weights of various age/gender cohorts. The statistical data used to develop the regression equations are presented in Table 6-37. The data obtained from the second approach are presented in Table 6-38. Inhalation rates for children (6 months - 10 years) ranged from 7.3 to 9.3 m^3/day for male and 5.6 to 8.6 m^3/day for female children; for older children (10 to 18 years), inhalation rates were 15 m^3/day for males and 12 m^3/day for females. These rates are similar to the daily inhalation rates obtained using the first approach. Also, the inactive inhalation rates obtained from the first approach are lower than the inhalation rates obtained using the second approach. This may be attributed to the BMR multiplier employed in the equation of the second approach to calculate inhalation rates.

Inhalation rates were also obtained for short-term exposures for various age/gender cohorts and five energy-expenditure categories (rest, sedentary, light, moderate, and heavy). BMRs were multiplied by the product of the metabolic equivalent, H, and VQ. The data obtained for short-term exposures are presented in Table 6-39.

This study obtained similar results using two different approaches. The major strengths of this study are that it estimates inhalation rates in different age groups and that the populations are large. Explanations for differences in results due to metabolic measurements, reported diet, or activity patterns are supported by observations reported by other investigators in other studies. Major limitations of this study are (1) the estimated activity pattern levels are somewhat subjective; (2) the explanation that activity pattern differences are responsible for the lower level obtained with the metabolic approach (25 %) compared to the activity pattern approach is not well supported by the data; and (3) different populations were used in each approach, which may have introduced error.

6.4.7 Rusconi et al., 1994 - Reference Values for Respiratory Rate in the First 3 Years of Life

Rusconi et al. (1994) examined a large number of infants and children in Milano, Italy in order to determine the reference values for respiratory rate in children aged 15 days to 3 years. A total of 618 infants and children (336 males and 282 females) who did not have respiratory infections or any severe disease were included in the study. Of the 618, a total of 309 were in good health and were observed in day care centers, while the remaining 309 were seen in hospitals or as outpatients.

Respiratory rates were recorded twice, 30 to 60 minutes apart, listening to breath sounds for 60 seconds with a stethoscope, when the child was awake and calm and when the child was sleeping quietly (sleep not associated with any spontaneous movement, including eye movements or vocalizations) (Table 6-40). The children were assessed for one year in order to determine the repeatability of the recordings, to compare respiratory rate counts obtained by stethoscope and by observation, and to construct reference percentile curves by age in a large number of subjects.

The authors plotted the differences between respiratory rate counts determined by stethoscope at 30- to 60-minute intervals against their mean count in waking and sleeping subjects. The standard deviation of the differences between the two counts was 2.5 and 1.7 breaths/minute, respectively, for waking and sleeping children. This standard deviation yielded 95% repeatability coefficients of 4.9 breaths/minute when the infants and children were awake and 3.3 breaths/minute when they were asleep.

In both waking and sleeping states, the respiratory rate counts determined by stethoscope were found to be higher than those obtained by observation. The mean difference was 2.6 and 1.8 breaths per minute, respectively, in waking and sleeping states. The mean respiratory rate counts were significantly higher in infants and children at all ages when awake and calm than when asleep. A decrease in respiratory rate with increasing age was seen in waking and sleeping infants and children. A scatter diagram of respiratory rate counts by age in waking and sleeping subjects showed that the pattern of respiratory rate decline with age was similar in both states, but it was much faster in the first few months of life. The authors constructed centile curves by first log-transforming the data and then applying a second degree polynormal curve, which allowed excellent fitting to observed data. Figures 6-1 and 6-2 show smoothed percentiles by age in waking and sleeping subjects, respectively. The variability of respiratory rate among subjects was higher in the first few months of life, which may be attributable to biological events that occur during these months, such as maturation of the neurologic control of breathing and changes in lung and chest wall compliance and lung volumes.

An advantage of this study is that it provides distribution data for respiratory rate for children from infancy (less than 2 months) to 36 months old. These data are not U.S. data; U.S. distributions were not available. Although, there is no reason to believe that the respiratory rates for Italian children would be different from that of U.S. children, this study only provided data for a narrow range of activities.

6.4.8 Price et al., 2003 - Modeling Interindividual Variation in Physiological Factors Used in PBPK Models of Humans

Price et al. (2003) developed a database of values for physiological parameters often used in physiologically-based pharmacokinetic models (PBPK). The database consisted of approximately 31,000 records containing information on volumes and masses of selected organs and tissues, blood flows for the organ and tissues, and total resting cardiac output and average inhalation rates. Records were created based on data from the NHANES III survey.

The study authors note that the database provides a source of data for human physiological parameters were the parameter values for an individual are correlated with one another and capture interindividual variation in populations of a specific gender, race, and age range. A computer program, Physiological Parameters for PBPK Modeling (PPPM or P^3M), which is publicly available (The Lifeline Group, 2007), was also developed to randomly retrieve records from the database for groups of individuals of specified age ranges, gender, and ethnicities. Price et al. (2003) recommends that output sets be used as inputs to Monte Carlo-based PBPK models of interindividual variation in dose.

6.5 REFERENCES FOR CHAPTER 6

Adams, W.C. (1993) Measurement of breathing rate and volume in routinely performed daily activities, Final Report. California Air Resources Board (CARB) Contract No. A033-205.June 1993. 185 pgs.

Arcus-Arth, A. and Blaisdell, R. J. (2007) Statistical distributions of daily breathing rates for narrow age groups of infants and children. Risk Anal 27(1):97-110

Brochu, P.; Ducré-Robitaille, J.; Brodeur, J. (2006) Physiological daily inhalation rates for free-living individuals aged 1 month to 96 years, using data from doubly labeled water measurements: a proposal for air quality criteria, standard calculations and health risk assessment. Hum Ecol Risk Assess 12:675-701.

FASEB/LSRO (Federation of American Societies for Experimental Biology, Life Sciences Research Office). (1995) Joint policy on variance estimation and statistical standards on NHANES III and CSFII reports (Appendix III). In: Third Report on Nutrition Monitoringin the United States. Prepared for the Interagency Board for Nutrition Monitoring and Related Research. Washington, DC: U.S. Government Printing Office.

Foos, B., Sonwane, B. (2008) Overview: workshop on children's inhalation dosimetry and health effects for risk assessment. J Toxicol Environ Health Part A 71(3):147-148.

Foos, B.; Marty, M.; Schwartz, J.; Bennett, W.; Moya, J.; Jarabek, A; Salmon, A. (2008) Focusing on children's inhalation dosimetry and health effects for risk assessment: an introduction. J Toxicol Environ Health Part A 71(3):149-165.

International Commission on Radiological Protection. (1981) Report of the task group on reference man. New York: Pergammon Press.

Layton, D.W. (1993) Metabolically consistent breathing rates for use in dose assessments. Health Phys 64(1):23-36.

Linn, W.S.; Shamoo, D.A.; Hackney, J.D. (1992) Documentation of activity patterns in "high-risk" groups exposed to ozone in the Los Angeles area. In: Proceedings of the Second EPA/AWMA Conference on Tropospheric Ozone, Atlanta, Nov. 1991. pp. 701-712. Air and Waste Management Assoc., Pittsburgh, PA.

Price, P.; Conolly, R.; Chaisson, C.; Gross, E.; Young, J.; Mathis, E.; Tedder, D. (2003) Modeling interindividual variation in physiological factors used in PBPK models of humans. Crit Rev Toxicol 33 (5):469-503.

Rusconi, F.; Castagneto, M.; Garliardi, L.; Leo, G.; Pellegatta, A.; Porta, N.; Razon, S.; Braga, M. (1994) Reference values for respiratory rate in the first 3 years of life. Pediatrics 94(3):350-355.

Scrimshaw, N. S.; Waterlow, J. C.; Schurch, B. (Eds.). (1996) Energy and Protein Requirements. Proceedings of an International Dietary and Energy Consultancy Group Workshop; 1994 Oct 31–Nov 4; London, UK: Stockton Press.

Spier, C.E.; Little, D.E.; Trim, S.C.; Johnson, T.R.; Linn, W.S.; Hackney, J.D. (1992) Activity patterns in elementary and high school students exposed to oxidant pollution. J Exp Anal Environ Epidemiol 2(3):277-293.

Stifelman, M. (2007) Using doubly-labeled water measurements of human energy expenditure to estimate inhalation rates. Sci Total Environ 373:585-590.

The Lifeline Group. (2007) Physiological parameters for PBPK modeling™ version 1.3 (P³M™). Accessed May 2007. Available at: http://www.thelifelinegroup.org/p3m/

U.S. EPA. (1985) Development of statistical distributions or ranges of standard factors used in exposure assessments. Washington, DC: Office of Health and Environmental Assessment; EPA Report No. EPA 600/8-85-010. Available from: NTIS, Springfield, VA; PB85-242667.

U.S. EPA. (1992) Guidelines for exposure assessment. Washington, DC: Office of

Research and Development, Office of Health and Environmental Assessments.

U.S. EPA. (1994) Methods for derivation of inhalation reference concentrations and application of inhalation dosimetry. Washington, DC: Office of Health and Environmental Assessment. EPA/600/8-90/066F.

U.S. EPA. (1997) Exposure Factors Handbook. Washington, DC: Office of Research and Development, Office of Health and Environmental Assessment.

U.S. EPA. (2005). Supplemental guidance for assessing susceptibility from early-life exposure to carcinogens. Washington, DC: Risk Assessment Forum. EPA/630/R-03/003F.

U.S. EPA. (2006) Metabolically-derived human ventilation rates: A revised approach based upon oxygen consumption rates. Washington, DC: National Center for Environmental Assessment. External Review Draft. Prepared for USEPA/ORD, Contract No. EP-C-04-027.

U.S. EPA. (2008) Risk Assessment Guidance for Superfund: Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment). Washington, DC: Office of Superfund Remediation and Technology Innovation. Peer Review Draft. Prepared for USEPA, Contract No. 68-W-01-05.

WHO. (1986) Principles for evaluating health risks from chemicals during infancy and early childhood: the need for a special approach. Environmental Health Criteria 59, World Health Organization, International Programme on Chemical Safety.

Table 6-4. Physiological Daily Inhalation Rates for Newborns Aged 1 Month or Less

Age Group	N	Body Weight (kg) Mean ± SD	Physiological Daily Inhalation Rates[e] Mean ± SD	
			(m^3/day)	(m^3/kg-day)
21 days (3 weeks)	13[a,c]	1.2 ± 0.2	0.85 ± 0.17[f]	0.74 ± 0.09[f]
32 days (~ 1 month)	10[b,d]	4.7 ± 0.7	2.45 ± 0.59[g]	0.53 ± 0.10[g]
33 days (~ 1 month)	10[a,d]	4.8 ± 0.3	2.99 ± 0.47[g]	0.62 ±0.09[g]

[a] Formula-fed infants.
[b] Breast-fed infants.
[c] Healthy infants with very low birth weight.
[d] Infants evaluated as being clinically healthy and neither underweight or overweight.
[e] Physiological daily inhalation rates were calculated using the following equation: (TDEE + ECG)*H*(V_E/VO_2)*10^{-3}, where H = 0.21 L of O_2/Kcal, V_E/VO_2 = 27 (Layton, 1993), TDEE = total daily energy expenditure (kcal/day) and ECG = stored daily energy cost for growth (kcal/day).
[f] TDEEs based on nutritional balance measurements during 3-day periods.
[g] TDEEs based on ^2H_2O and $H_2{}^{18}O$ disappearance rates from urine

N = Number of individuals.
SD = Standard deviation.

Source: Brochu et al., 2006.

Table 6-5. Distribution Percentiles of Physiological Daily Inhalation Rates (m^3/day) for Free-living Normal-weight Males and Females Aged 2.6 months to 23 years

Age Group (years)	N	Body Weight[a] (kg) Mean ± SD	Physiological Daily Inhalation Rates[b] (m^3/day)								
			Mean ± SD	Percentile[c]							
				5th	10th	25th	50th	75th	90th	95th	99th
Males											
0.22 to <0.5	32	6.7 ± 1.0	3.38 ± 0.72	2.19	2.46	2.89	3.38	3.87	4.30	4.57	5.06
0.5 to <1	40	8.8 ± 1.1	4.22 ± 0.79	2.92	3.21	3.69	4.22	4.75	5.23	5.51	6.05
1 to <2	35	10.6 ± 1.1	5.12 ± 0.88	3.68	3.99	4.53	5.12	5.71	6.25	6.56	7.16
2 to <5	25	15.3 ± 3.4	7.60 ± 1.28	5.49	5.95	6.73	7.60	8.47	9.25	9.71	10.59
5 to <7	96	19.8 ± 2.1	8.64 ± 1.23	6.61	7.06	7.81	8.64	9.47	10.21	10.66	11.50
7 to <11	38	28.9 ± 5.6	10.59 ± 1.99	7.32	8.04	9.25	10.59	11.94	13.14	13.87	15.22
11 to <23	30	58.6 ± 13.9	17.23 ± 3.67	11.19	12.53	14.75	17.23	19.70	21.93	23.26	25.76
Females											
0.22 to <0.5	53	6.5 ± 0.9	3.26 ± 0.66	2.17	2.41	2.81	3.26	3.71	4.11	4.36	4.81
0.5 to <1	63	8.5 ± 1.0	3.96 ± 0.72	2.78	3.05	3.48	3.96	4.45	4.88	5.14	5.63
1 to <2	66	10.6 ± 1.3	4.78 ± 0.96	3.20	3.55	4.13	4.78	5.43	6.01	6.36	7.02
2 to <5	36	14.4 ± 3.0	7.06 ± 1.16	5.15	5.57	6.28	7.06	7.84	8.54	8.97	9.76
5 to <7	102	19.7 ± 2.3	8.22 ± 1.31	6.06	6.54	7.34	8.22	9.11	9.90	10.38	11.27
7 to <11	161	28.3 ± 4.4	9.84 ± 1.69	7.07	7.68	8.70	9.84	10.98	12.00	12.61	13.76
11 to <23	87	50.0 ± 8.9	13.28 ± 2.60	9.00	9.94	11.52	13.28	15.03	16.61	17.56	19.33

[a] Measured body weight. Normal-weight individuals defined according to the body mass index (BMI) cut-offs.

[b] Physiological daily inhalation rates were calculated using the following equation: (TDEE + ECG)*H*(V_E/VO_2)*10^{-3}, where H = 0.21 L of O_2/Kcal, V_E/VO_2 = 27 (Layton, 1993), TDEE = total daily energy expenditure (kcal/day) and ECG = stored daily energy cost for growth (kcal/day).

[c] Percentiles based on a normal distribution assumption for age groups.

N = Number of individuals.

SD = Standard deviation.

Source: Brochu et al., 2006.

Table 6-6. Mean and 95th Percentile Inhalation Rate Values (m^3/day) for Free-living Normal-weight Males, Females, and Males and Females Combined.

Age Group[a]	N	Mean	95th
Males			
3 to <6 months[b]	32	3.38	4.57
6 to <12 months	40	4.42	5.51
1 to <2 years	35	5.12	6.56
Females			
3 to <6 months[b]	53	3.26	4.36
6 to <12 months	63	3.96	5.14
1 to <2 years	66	4.78	6.36
Males and Females Combined			
3 to <6 months[b]	85	3.32	4.47
6 to <12 months	103	4.09	5.53
1 to <2 years	101	4.95	6.46

[a] No other age groups from Table 6-5 (Brochu et al., 2006) fit into the U.S. EPA age groupings.
[b] Age group from Brochu et al. (2006) was 2.6 to <6 months.
N = Number of individuals.

Source: Brochu et al., 2006.

Table 6-7. Distribution Percentiles of Physiological Daily Inhalation Rates (m^3/day) for Free-living Normal-weight and Overweight/obese Males and Females Aged 4 to 18 years

Age Group (years)	N	Body Weight[a] (kg) Mean ± SD	Physiological Daily Inhalation Rates[b] (m^3/day) Mean ± SD	Percentile[c] 5th	10th	25th	50th	75th	90th	95th	99th
				Males - Normal-weight							
4 to <5.1	77	19.0 ± 1.9	7.90 ± 0.97	6.31	6.66	7.25	7.90	8.56	9.15	9.50	10.16
5.1 to <9.1	52	22.6 ± 3.5	9.14 ± 1.44	6.77	7.29	8.17	9.14	10.11	10.99	11.51	12.49
9.1 to <18.1	36	41.4 ± 12.1	13.69 ± 3.95	7.19	8.63	11.02	13.69	16.35	18.75	20.19	22.88
				Males - Overweight/obese							
4 to <5.1	54	26.5 ± 4.9	9.59 ± 1.26	7.52	7.98	8.74	9.59	10.44	11.21	11.66	12.52
5.1 to <9.1	40	32.5 ± 9.2	10.88 ± 2.49	6.78	7.69	9.20	10.88	12.56	14.07	14.98	16.68
9.1 to <18.1	33	55.8 ± 10.8	14.52 ± 1.98	11.25	11.98	13.18	14.52	15.85	17.06	17.78	19.13
				Females - Normal-weight							
4 to <5.1	82	18.7 ± 2.0	7.41 ± 0.91	5.92	6.25	6.80	7.41	8.02	8.57	8.90	9.52
5.1 to <9.1	151	25.5 ± 4.1	9.39 ± 1.62	6.72	7.31	8.30	9.39	10.48	11.47	12.05	13.16
9.1 to <18.1	124	42.7 ± 11.1	12.04 ± 2.86	7.34	8.38	10.11	12.04	13.97	15.70	16.74	18.68
				Females - Overweight/obese							
4 to <5.1	56	26.1 ± 5.5	8.70 ± 1.13	6.84	7.26	7.94	8.70	9.47	10.15	10.56	11.33
5.1 to <9.1	68	34.6 ± 9.9	10.55 ± 2.23	6.88	7.69	9.05	10.55	12.06	13.41	14.22	15.75
9.1 to <18.1	68	59.2 ± 12.8	14.27 ± 2.70	9.83	10.81	12.45	14.27	16.09	17.73	18.71	20.55

[a] Measured body weight. Normal-weight and overweight/obese males defined according to the body mass index (BMI) cut-offs.

[b] Physiological daily inhalation rates were calculated using the following equation: $(TDEE + ECG)*H*(V_E/VO_2)*10^{-3}$, where H = 0.21 L of O_2/Kcal, $V_E/VO_2 = 27$ (Layton, 1993), TDEE = total daily energy expenditure (kcal/day) and ECG = stored daily energy cost for growth (kcal/day).

[c] Percentiles based on a normal distribution assumption for age groups.

N = Number of individuals.

SD = Standard deviation.

Source: Brochu et al., 2006.

Table 6-8. Distribution Percentiles of Physiological Daily Inhalation Rates per Unit of Body Weight (m^3/kg-day) for Free-living Normal-weight Males and Females Aged 2.6 months to 23 years

Age Group (years)	Physiological Daily Inhalation Rates[a] (m^3/kg-day)								
	Mean ± SD	Percentile[b]							
		5th	10th	25th	50th	75th	90th	95th	99th
Males									
0.22 to <0.5	0.51 ± 0.09	0.36	0.39	0.45	0.51	0.57	0.63	0.66	0.73
0.5 to <1	0.48 ± 0.07	0.36	0.39	0.43	0.48	0.53	0.57	0.60	0.64
1 to <2	0.48 ± 0.06	0.38	0.41	0.44	0.48	0.52	0.56	0.58	0.62
2 to <5	0.44 ± 0.04	0.38	0.39	0.42	0.44	0.47	0.50	0.51	0.54
5 to <7	0.42 ± 0.05	0.34	0.35	0.38	0.42	0.45	0.48	0.49	0.52
7 to <11	0.37 ± 0.06	0.27	0.29	0.33	0.37	0.41	0.45	0.47	0.52
11 to <23	0.30 ± 0.05	0.22	0.24	0.27	0.30	0.33	0.36	0.38	0.41
Females									
0.22 to <0.5	0.50 ± 0.09	0.35	0.39	0.44	0.50	0.57	0.62	0.66	0.72
0.5 to <1	0.46 ± 0.06	0.36	0.38	0.42	0.46	0.51	0.55	0.57	0.61
1 to <2	0.45 ± 0.08	0.33	0.35	0.40	0.45	0.50	0.55	0.58	0.63
2 to <5	0.44 ± 0.07	0.32	0.35	0.39	0.44	0.49	0.53	0.56	0.61
5 to <7	0.40 ± 0.05	0.32	0.33	0.36	0.40	0.43	0.46	0.47	0.51
7 to <11	0.35 ± 0.06	0.25	0.27	0.31	0.35	0.39	0.43	0.45	0.50
11 to <23	0.27 ± 0.05	0.19	0.21	0.24	0.27	0.30	0.33	0.35	0.38

[a] Physiological daily inhalation rates were calculated using the following equation: (TDEE + ECG)*H*(V_E/VO_2)*10^{-3}, where H = 0.21 L of O_2/Kcal, V_E/VO_2 = 27 (Layton, 1993), TDEE = total daily energy expenditure (kcal/day) and ECG = stored daily energy cost for growth (kcal/day).

[b] Percentiles based on a normal distribution assumption for age groups.

SD = Standard deviation.

Source: Brochu et al., 2006.

Table 6-9. Distribution Percentiles of Physiological Daily Inhalation Rates (m^3/kg-day) for Free-living Normal-weight and Overweight/obese Males and Females Aged 4 to 18 years

Age Group (years)	Physiological Daily Inhalation Rates[a] (m^3/kg-day)								
	Mean ± SD	Percentile[b]							
		5th	10th	25th	50th	75th	90th	95th	99th
Males - Normal-weight									
4 to <5.1	0.42 ± 0.04	0.35	0.36	0.39	0.42	0.45	0.47	0.49	0.52
5.1 to <9.1	0.41 ± 0.06	0.31	0.34	0.37	0.41	0.45	0.48	0.50	0.54
9.1 to <18.1	0.33 ± 0.05	0.26	0.27	0.30	0.33	0.37	0.40	0.41	0.45
Males - Overweight/obese									
4 to <5.1	0.37 ± 0.04	0.30	0.31	0.34	0.37	0.40	0.42	0.44	0.47
5.1 to <9.1	0.35 ± 0.08	0.22	0.25	0.29	0.35	0.40	0.45	0.47	0.53
9.1 to <18.1	0.27 ± 0.04	0.20	0.22	0.24	0.27	0.29	0.32	0.33	0.36
Females - Normal-weight									
4 to <5.1	0.40 ± 0.05	0.32	0.34	0.37	0.40	0.43	0.46	0.48	0.51
5.1 to <9.1	0.37 ± 0.06	0.27	0.29	0.33	0.37	0.41	0.45	0.47	0.52
9.1 to <18.1	0.29 ± 0.06	0.20	0.22	0.25	0.29	0.33	0.36	0.38	0.42
Females - Overweight/obese									
4 to <5.1	0.34 ± 0.04	0.27	0.28	0.31	0.34	0.37	0.40	0.41	0.44
5.1 to <9.1	0.32 ± 0.07	0.21	0.23	0.27	0.32	0.36	0.40	0.43	0.47
9.1 to <18.1	0.25 ± 0.05	0.17	0.18	0.21	0.25	0.28	0.31	0.33	0.36

[a] Physiological daily inhalation rates were calculated using the following equation: (TDEE + ECG)*H*(V_E/VO_2)*10^{-3}, where H = 0.21 L of O_2/Kcal, V_E/VO_2 = 27 (Layton, 1993), TDEE = total daily energy expenditure (kcal/day) and ECG = stored daily energy cost for growth (kcal/day).

[b] Percentiles based on a normal distribution assumption for age groups.

SD = Standard deviation.

Source: Brochu et al., 2006.

Table 6-10. Descriptive Statistics for Daily Average Inhalation Rate in Males, by Age Category[a]

Age Group	N	Daily Average Inhalation Rate, Unadjusted for Body Weight (m^3/day) Mean	Percentiles 5th	10th	25th	50th	75th	90th	95th	Maximum
Birth to <1 year	419	8.76	4.77	5.70	7.16	8.70	10.43	11.93	12.69	17.05
1 to < 2 years	308	13.49	9.73	10.41	11.65	13.11	15.02	17.03	17.89	24.24
2 to < 3 years	261	13.23	9.45	10.20	11.43	13.19	14.49	16.27	17.71	28.17
3 to <6 years	540	12.65	10.42	10.87	11.40	12.58	13.64	14.63	15.41	19.52
6 to <11 years	940	13.42	10.08	10.69	11.73	13.09	14.73	16.56	17.72	24.97
11 to <16 years	1337	15.32	11.41	12.11	13.27	14.79	16.81	19.54	21.21	28.54
16 to <21 years	1241	17.22	12.60	13.41	14.48	16.63	19.16	21.94	23.38	39.21
Age Group	N	Daily Average Inhalation Rate, Adjusted for Body Weight (m^3/day-kg) Mean	Percentiles 5th	10th	25th	50th	75th	90th	95th	Maximum
Birth to <1 year	419	1.09	0.91	0.94	1.00	1.09	1.16	1.26	1.29	1.48
1 to < 2 years	308	1.19	0.96	1.02	1.09	1.17	1.26	1.37	1.48	1.73
2 to < 3 years	261	0.95	0.78	0.82	0.87	0.94	1.01	1.09	1.13	1.36
3 to <6 years	540	0.70	0.52	0.56	0.61	0.69	0.78	0.87	0.92	1.08
6 to <11 years	940	0.44	0.32	0.34	0.38	0.43	0.50	0.55	0.58	0.81
11 to <16 years	1337	0.29	0.21	0.22	0.25	0.28	0.32	0.36	0.38	0.51
16 to <21 years	1241	0.23	0.17	0.18	0.20	0.23	0.25	0.28	0.30	0.40

[a] Individual daily averages are weighted by their 4-year sampling weights as assigned within NHANES 1999-2002 when calculating the statistics in this table. Inhalation rate was estimated using a multiple linear regression model.

N = Number of individuals.

BW = Body weight.

Source: U.S. EPA, 2006.

Table 6-11. Descriptive Statistics for Daily Average Inhalation Rate in Females, by Age Category[a]

Age Group	N	Daily Average Inhalation Rate, Unadjusted for Body Weight (m^3/day)								
		Mean	Percentiles							Maximum
			5th	10th	25th	50th	75th	90th	95th	
Birth to <1 year	415	8.53	4.84	5.48	6.83	8.41	9.78	11.65	12.66	26.26
1 year	245	13.31	9.08	10.12	11.24	13.03	14.64	17.45	18.62	24.77
2 years	255	12.74	8.91	10.07	11.38	12.60	13.96	15.58	16.37	23.01
3 to <6 years	543	12.16	9.87	10.38	11.20	12.02	13.01	14.03	14.93	19.74
6 to <11 years	894	12.41	9.99	10.35	11.01	11.95	13.42	15.13	16.34	20.82
11 to <16 years	1,451	13.44	10.47	11.11	12.04	13.08	14.54	16.25	17.41	26.58
16 to <21 years	1,182	13.59	9.86	10.61	11.78	13.20	15.02	17.12	18.29	30.11
Age Group	N	Daily Average Inhalation Rate, Adjusted for Body Weight (m^3/day-kg)								
		Mean	Percentiles							Maximum
			5th	10th	25th	50th	75th	90th	95th	
Birth to <1 year	415	1.14	0.91	0.97	1.04	1.13	1.24	1.33	1.38	1.60
1 year	245	1.20	0.98	1.01	1.10	1.18	1.30	1.41	1.47	1.73
2 years	255	0.96	0.82	0.84	0.89	0.96	1.01	1.07	1.11	1.23
3 to <6 years	543	0.69	0.48	0.54	0.60	0.68	0.77	0.88	0.92	1.12
6 to <11 years	894	0.43	0.28	0.31	0.36	0.43	0.49	0.55	0.58	0.75
11 to <16 years	1,451	0.25	0.19	0.20	0.22	0.25	0.28	0.31	0.34	0.47
16 to <21 years	1,182	0.21	0.16	0.17	0.19	0.21	0.24	0.27	0.28	0.36

[a] Individual daily averages are weighted by their 4-year sampling weights as assigned within NHANES 1999-2002 when calculating the statistics in this table. Inhalation rate was estimated using a multiple linear regression model.

N = Number of individuals.

Source: U.S. EPA, 2006.

Table 6-12. Mean and 95th Percentile Inhalation Rate Values (m^3/day) for Males, Females and Males and Females Combined

Age Group[a]	N	Mean	95th
Males			
Birth to <1 year	419	8.76	12.69
1 to <2 years	308	13.49	17.89
2 to <3 years	261	13.23	17.71
3 to <6 years	540	12.65	15.41
6 to <11 years	940	16.42	17.72
11 to <16 years	1,337	15.32	21.21
16 to <21 years	1,241	17.22	23.38
Females			
Birth to <1 year	415	8.53	12.66
1 to <2 years	245	13.31	18.62
2 to <3 years	255	12.74	16.37
3 to <6 years	543	12.16	14.93
6 to <11 years	894	12.41	16.34
11 to <16 years	1,451	13.44	17.41
16 to <21 years	1,182	13.59	18.29
Males and Females Combined			
Birth to <1 year	834	8.65	12.68
1 to <2 years	553	13.40	18.26
2 to <3 years	516	12.99	17.04
3 to <6 years	1,083	12.41	15.17
6 to <11 years	1,834	12.92	17.03
11 to <16 years	2,788	14.38	19.31
16 to <21 years	2423	15.41	20.84

[a] No other age groups from Tables 6-9 and 6-10 (U.S. EPA, 2006) fit into the EPA age groupings.
N = Number of individuals.

Source: U.S. EPA, 2006.

Table 6-13. Descriptive Statistics for Average Ventilation Rate[a] While Performing Activities Within the Specified Activity Category, for Males by Age Category

Age Group	N	Average Ventilation Rate (m^3/min), Unadjusted for Body Weight									Average Ventilation Rate (m^3/min-kg), Adjusted for Body Weight								
		Mean	Percentiles							Maximum	Mean	Percentiles							Maximum
			5th	10th	25th	50th	75th	90th	95th			5th	10th	25th	50th	75th	90th	95th	
Sleep or nap (Activity ID = 14500)																			
Birth to <1 year	419	3.08E-03	1.66E-03	1.91E-03	2.45E-03	3.00E-03	3.68E-03	4.35E-03	4.77E-03	7.19E-03	3.85E-04	2.81E-04	3.01E-04	3.37E-04	3.80E-04	4.27E-04	4.65E-04	5.03E-04	6.66E-04
1 year	308	4.50E-03	3.11E-03	3.27E-03	3.78E-03	4.35E-03	4.95E-03	5.90E-03	6.44E-03	1.00E-02	3.95E-04	2.95E-04	3.13E-04	3.45E-04	3.84E-04	4.41E-04	4.91E-04	5.24E-04	6.26E-04
2 years	261	4.61E-03	3.01E-03	3.36E-03	3.94E-03	4.49E-03	5.21E-03	6.05E-03	6.73E-03	8.96E-03	3.30E-04	2.48E-04	2.60E-04	2.89E-04	3.26E-04	3.62E-04	4.05E-04	4.42E-04	5.38E-04
3 to <6 years	540	4.36E-03	3.06E-03	3.30E-03	3.76E-03	4.29E-03	4.86E-03	5.54E-03	5.92E-03	7.67E-03	2.43E-04	1.60E-04	1.74E-04	1.98E-04	2.37E-04	2.79E-04	3.14E-04	3.50E-04	4.84E-04
6 to <11 years	940	4.61E-03	3.14E-03	3.39E-03	3.83E-03	4.46E-03	5.21E-03	6.01E-03	6.54E-03	9.94E-03	1.51E-04	1.02E-04	1.09E-04	1.25E-04	1.48E-04	1.74E-04	2.00E-04	2.15E-04	3.02E-04
11 to <16 years	1,337	5.26E-03	3.53E-03	3.78E-03	4.34E-03	5.06E-03	5.91E-03	6.94E-03	7.81E-03	1.15E-02	9.80E-05	6.70E-05	7.20E-05	8.10E-05	9.40E-05	1.10E-04	1.29E-04	1.41E-04	2.08E-04
16 to <21 years	1,241	5.31E-03	3.55E-03	3.85E-03	4.35E-03	5.15E-03	6.09E-03	6.92E-03	7.60E-03	1.28E-02	7.10E-05	4.70E-05	5.20E-05	6.10E-05	6.90E-05	8.00E-05	9.00E-05	9.80E-05	1.47E-04
Sedentary & Passive Activities (METS ≤ 1.5 -- Includes Sleep or Nap)																			
Birth to <1 year	419	3.18E-03	1.74E-03	1.99E-03	2.50E-03	3.10E-03	3.80E-03	4.40E-03	4.88E-03	7.09E-03	3.97E-04	3.03E-04	3.17E-04	3.51E-04	3.91E-04	4.37E-04	4.70E-04	4.98E-04	6.57E-04
1 year	308	4.62E-03	3.17E-03	3.50E-03	3.91E-03	4.49E-03	5.03E-03	5.95E-03	6.44E-03	9.91E-03	4.06E-04	3.21E-04	3.31E-04	3.63E-04	3.97E-04	4.48E-04	4.88E-04	5.25E-04	6.19E-04
2 years	261	4.79E-03	3.25E-03	3.66E-03	4.10E-03	4.69E-03	5.35E-03	6.05E-03	6.71E-03	9.09E-03	3.43E-04	2.74E-04	2.86E-04	3.09E-04	3.40E-04	3.69E-04	4.05E-04	4.46E-04	5.10E-04
3 to <6 years	540	4.58E-03	3.47E-03	3.63E-03	4.07E-03	4.56E-03	5.03E-03	5.58E-03	5.82E-03	7.60E-03	2.55E-04	1.78E-04	1.93E-04	2.15E-04	2.50E-04	2.88E-04	3.27E-04	3.46E-04	4.54E-04
6 to <11 years	940	4.87E-03	3.55E-03	3.78E-03	4.18E-03	4.72E-03	5.40E-03	6.03E-03	6.58E-03	9.47E-03	1.60E-04	1.13E-04	1.18E-04	1.35E-04	1.57E-04	1.80E-04	2.09E-04	2.18E-04	2.89E-04
11 to <16 years	1,337	5.64E-03	4.03E-03	4.30E-03	4.79E-03	5.43E-03	6.26E-03	7.20E-03	7.87E-03	1.11E-02	1.05E-04	7.70E-05	8.00E-05	8.80E-05	1.01E-04	1.18E-04	1.35E-04	1.42E-04	1.95E-04
16 to <21 years	1,241	5.76E-03	4.17E-03	4.42E-03	4.93E-03	5.60E-03	6.43E-03	7.15E-03	7.76E-03	1.35E-02	7.70E-05	5.50E-05	6.00E-05	6.80E-05	7.60E-05	8.50E-05	9.50E-05	1.02E-04	1.32E-04
Light Intensity Activities (1.5 < METS ≤ 3.0)																			
Birth to <1 year	419	7.94E-03	4.15E-03	5.06E-03	6.16E-03	7.95E-03	9.57E-03	1.08E-02	1.19E-02	1.55E-02	9.88E-04	7.86E-04	8.30E-04	8.97E-04	9.72E-04	1.07E-03	1.17E-03	1.20E-03	1.44E-03
1 year	308	1.16E-02	8.66E-03	8.99E-03	9.89E-03	1.14E-02	1.29E-02	1.44E-02	1.58E-02	2.11E-02	1.02E-03	8.36E-04	8.59E-04	9.18E-04	1.01E-03	1.10E-03	1.22E-03	1.30E-03	1.49E-03
2 years	261	1.17E-02	8.52E-03	9.14E-03	9.96E-03	1.14E-02	1.30E-02	1.47E-02	1.53E-02	1.90E-02	8.37E-04	6.83E-04	7.16E-04	7.61E-04	8.26E-04	8.87E-04	9.95E-04	1.03E-03	1.18E-03
3 to <6 years	540	1.14E-02	9.20E-03	9.55E-03	1.02E-02	1.11E-02	1.23E-02	1.34E-02	1.40E-02	1.97E-02	6.33E-04	4.41E-04	4.80E-04	5.44E-04	6.26E-04	7.11E-04	7.94E-04	8.71E-04	1.08E-03
6 to <11 years	940	1.16E-02	8.95E-03	9.33E-03	1.02E-02	1.13E-02	1.28E-02	1.46E-02	1.56E-02	2.18E-02	3.84E-04	2.67E-04	2.86E-04	3.24E-04	3.77E-04	4.37E-04	4.93E-04	5.29E-04	7.09E-04
11 to <16 years	1,337	1.32E-02	9.78E-03	1.03E-02	1.13E-02	1.28E-02	1.47E-02	1.64E-02	1.87E-02	2.69E-02	2.46E-04	1.76E-04	1.87E-04	2.09E-04	2.38E-04	2.82E-04	3.11E-04	3.32E-04	4.42E-04
16 to <21 years	1,241	1.34E-02	1.00E-02	1.05E-02	1.15E-02	1.30E-02	1.50E-02	1.70E-02	1.80E-02	2.91E-02	1.79E-04	1.37E-04	1.44E-04	1.56E-04	1.78E-04	1.99E-04	2.18E-04	2.30E-04	3.32E-04

Table 6-13. Descriptive Statistics for Average Ventilation Rate[a] While Performing Activities Within the Specified Activity Category, for Males by Age Category (continued)

Age Group	N	Average Ventilation Rate (m^3/min), Unadjusted for Body Weight									Average Ventilation Rate (m^3/min-kg), Adjusted for Body Weight								
		Mean	Percentiles							Maximum	Mean	Percentiles							Maximum
			5th	10th	25th	50th	75th	90th	95th			5th	10th	25th	50th	75th	90th	95th	
Moderate Intensity Activities (3.0 < METS ≤ 6.0)																			
Birth to <1 year	419	1.45E-02	7.41E-03	8.81E-03	1.15E-02	1.44E-02	1.70E-02	2.01E-02	2.25E-02	3.05E-02	1.80E-03	1.40E-03	1.49E-03	1.62E-03	1.78E-03	1.94E-03	2.18E-03	2.28E-03	3.01E-03
1 year	308	2.14E-02	1.45E-02	1.59E-02	1.80E-02	2.06E-02	2.41E-02	2.69E-02	2.89E-02	3.99E-02	1.88E-03	1.41E-03	1.50E-03	1.65E-03	1.82E-03	2.02E-03	2.34E-03	2.53E-03	3.23E-03
2 years	261	2.15E-02	1.54E-02	1.67E-02	1.84E-02	2.08E-02	2.41E-02	2.69E-02	2.97E-02	5.09E-02	1.55E-03	1.21E-03	1.28E-03	1.40E-03	1.54E-03	1.66E-03	1.84E-03	2.02E-03	2.29E-03
3 to <6 years	540	2.10E-02	1.63E-02	1.72E-02	1.87E-02	2.06E-02	2.29E-02	2.56E-02	2.71E-02	3.49E-02	1.17E-03	8.05E-04	8.83E-04	9.99E-04	1.12E-03	1.31E-03	1.56E-03	1.68E-03	2.10E-03
6 to <11 years	940	2.23E-02	1.64E-02	1.72E-02	1.93E-02	2.16E-02	2.50E-02	2.76E-02	2.95E-02	4.34E-02	7.36E-04	5.03E-04	5.45E-04	6.18E-04	7.14E-04	8.34E-04	9.58E-04	1.04E-03	1.43E-03
11 to <16 years	1,337	2.64E-02	1.93E-02	2.05E-02	2.26E-02	2.54E-02	2.92E-02	3.38E-02	3.69E-02	5.50E-02	4.91E-04	3.59E-04	3.75E-04	4.18E-04	4.73E-04	5.52E-04	6.35E-04	6.81E-04	1.06E-03
16 to <21 years	1,241	2.90E-02	2.03E-02	2.17E-02	2.45E-02	2.80E-02	3.17E-02	3.82E-02	4.21E-02	6.74E-02	3.87E-04	2.81E-04	2.96E-04	3.34E-04	3.80E-04	4.31E-04	4.86E-04	5.18E-04	7.11E-04
High Intensity (METS > 6.0)																			
Birth to <1 year	183	2.75E-02	1.51E-02	1.73E-02	2.06E-02	2.78E-02	3.25E-02	3.84E-02	4.22E-02	5.79E-02	3.48E-03	2.70E-03	2.93E-03	3.10E-03	3.46E-03	3.81E-03	4.14E-03	4.32E-03	5.08E-03
1 year	164	4.03E-02	2.83E-02	3.17E-02	3.47E-02	3.98E-02	4.43E-02	5.16E-02	5.59E-02	6.07E-02	3.52E-03	2.52E-03	2.89E-03	3.22E-03	3.57E-03	3.91E-03	4.11E-03	4.34E-03	4.86E-03
2 years	162	4.05E-02	2.82E-02	2.97E-02	3.45E-02	4.06E-02	4.62E-02	5.19E-02	5.51E-02	9.20E-02	2.89E-03	2.17E-03	2.34E-03	2.58E-03	2.87E-03	3.20E-03	3.43E-03	3.54E-03	4.30E-03
3 to <6 years	263	3.90E-02	2.95E-02	3.14E-02	3.40E-02	3.78E-02	4.32E-02	4.89E-02	5.22E-02	6.62E-02	2.17E-03	1.55E-03	1.66E-03	1.81E-03	2.11E-03	2.50E-03	2.73E-03	2.98E-03	3.62E-03
6 to <11 years	637	4.36E-02	3.07E-02	3.28E-02	3.58E-02	4.19E-02	4.95E-02	5.66E-02	6.24E-02	8.99E-02	1.41E-03	9.36E-04	1.03E-03	1.19E-03	1.38E-03	1.59E-03	1.83E-03	1.93E-03	2.68E-03
11 to <16 years	1,111	5.08E-02	3.43E-02	3.68E-02	4.15E-02	4.91E-02	5.74E-02	6.63E-02	7.29E-02	1.23E-01	9.50E-04	6.35E-04	6.96E-04	7.90E-04	9.09E-04	1.09E-03	1.27E-03	1.36E-03	1.98E-03
16 to <21 years	968	5.32E-02	3.60E-02	3.83E-02	4.35E-02	5.05E-02	5.93E-02	7.15E-02	8.30E-02	1.30E-01	7.11E-04	4.75E-04	5.27E-04	5.99E-04	6.91E-04	8.02E-04	9.17E-04	9.97E-04	1.94E-03

a An individual's ventilation rate for the given activity category equals the weighted average of the individual's activity-specific ventilation rates for activities falling within the category, estimated using a multiple linear regression model, with weights corresponding to the number of minutes spent performing the activity. Numbers in these two columns represent averages, calculated across individuals in the specified age category, of these weighted averages. These are weighted averages, with the weights corresponding to the 4-year sampling weights assigned within NHANES 1999-2002.

N = Number of individuals.

MET = Metabolic equivalent.

Source: U.S. EPA, 2006.

Table 6-14. Descriptive Statistics for Average Ventilation Rate[a] While Performing Activities Within the Specified Activity Category, for Females by Age Category

Age Group	N	Average Ventilation Rate (m^3/min), Unadjusted for Body Weight									Average Ventilation Rate (m^3/min-kg), Adjusted for Body Weight								
		Mean	Percentiles							Maximum	Mean	Percentiles							Maximum
			5th	10th	25th	50th	75th	90th	95th			5th	10th	25th	50th	75th	90th	95th	
Sleep or nap (Activity ID = 14500)																			
Birth to <1 year	415	2.92E-03	1.54E-03	1.72E-03	2.27E-03	2.88E-03	3.50E-03	4.04E-03	4.40E-03	8.69E-03	3.91E-04	2.80E-04	3.01E-04	3.35E-04	3.86E-04	4.34E-04	4.79E-04	5.17E-04	7.39E-04
1 year	245	4.59E-03	3.02E-03	3.28E-03	3.76E-03	4.56E-03	5.32E-03	5.96E-03	6.37E-03	9.59E-03	4.14E-04	3.15E-04	3.29E-04	3.61E-04	4.05E-04	4.64E-04	5.21E-04	5.36E-04	6.61E-04
2 years	255	4.56E-03	3.00E-03	3.30E-03	3.97E-03	4.52E-03	5.21E-03	5.76E-03	6.15E-03	9.48E-03	3.42E-04	2.58E-04	2.71E-04	2.93E-04	3.33E-04	3.91E-04	4.25E-04	4.53E-04	4.94E-04
3 to <6 years	543	4.18E-03	2.90E-03	3.20E-03	3.62E-03	4.10E-03	4.71E-03	5.22E-03	5.73E-03	7.38E-03	2.38E-04	1.45E-04	1.63E-04	1.95E-04	2.33E-04	2.75E-04	3.20E-04	3.53E-04	5.19E-04
6 to <11 years	894	4.36E-03	2.97E-03	3.17E-03	3.69E-03	4.24E-03	4.93E-03	5.67E-03	6.08E-03	8.42E-03	1.51E-04	8.90E-05	9.70E-05	1.20E-04	1.46E-04	1.76E-04	2.11E-04	2.29E-04	2.97E-04
11 to <16 years	1,451	4.81E-03	3.34E-03	3.57E-03	3.99E-03	4.66E-03	5.39E-03	6.39E-03	6.99E-03	9.39E-03	9.00E-05	5.90E-05	6.50E-05	7.50E-05	8.70E-05	1.02E-04	1.18E-04	1.30E-04	1.76E-04
16 to <21 years	1,182	4.40E-03	2.78E-03	2.96E-03	3.58E-03	4.26E-03	5.05E-03	5.89E-03	6.63E-03	1.23E-02	6.90E-05	4.40E-05	4.70E-05	5.70E-05	6.70E-05	8.00E-05	9.30E-05	1.02E-04	1.52E-04
Sedentary & Passive Activities (METS ≤ 1.5 -- Includes Sleep or Nap)																			
Birth to <1 year	415	3.00E-03	1.60E-03	1.80E-03	2.32E-03	2.97E-03	3.58E-03	4.11E-03	4.44E-03	9.59E-03	4.02E-04	2.97E-04	3.16E-04	3.52E-04	3.96E-04	4.46E-04	4.82E-04	5.19E-04	7.19E-04
1 year	245	4.71E-03	3.26E-03	3.44E-03	3.98E-03	4.73E-03	5.30E-03	5.95E-03	6.63E-03	9.50E-03	4.25E-04	3.35E-04	3.48E-04	3.76E-04	4.18E-04	4.69E-04	5.12E-04	5.43E-04	6.42E-04
2 years	255	4.73E-03	3.34E-03	3.53E-03	4.19E-03	4.67E-03	5.25E-03	5.75E-03	6.22E-03	9.42E-03	3.55E-04	2.85E-04	2.96E-04	3.20E-04	3.48E-04	3.91E-04	4.20E-04	4.42E-04	4.85E-04
3 to <6 years	543	4.40E-03	3.31E-03	3.49E-03	3.95E-03	4.34E-03	4.84E-03	5.29E-03	5.73E-03	7.08E-03	2.51E-04	1.64E-04	1.79E-04	2.11E-04	2.48E-04	2.84E-04	3.28E-04	3.58E-04	4.89E-04
6 to <11 years	894	4.64E-03	3.41E-03	3.67E-03	4.04E-03	4.51E-03	5.06E-03	5.88E-03	6.28E-03	8.31E-03	1.60E-04	9.90E-05	1.10E-04	1.31E-04	1.57E-04	1.85E-04	2.12E-04	2.34E-04	2.93E-04
11 to <16 years	1,451	5.21E-03	3.90E-03	4.16E-03	4.53E-03	5.09E-03	5.68E-03	6.53E-03	7.06E-03	9.07E-03	9.70E-05	7.10E-05	7.50E-05	8.30E-05	9.50E-05	1.09E-04	1.23E-04	1.33E-04	1.74E-04
16 to <21 years	1,182	4.76E-03	3.26E-03	3.56E-03	4.03E-03	4.69E-03	5.32E-03	6.05E-03	6.60E-03	1.18E-02	7.50E-05	5.30E-05	5.70E-05	6.30E-05	7.40E-05	8.50E-05	9.60E-05	1.04E-04	1.41E-04
Light Intensity Activities (1.5 < METS ≤ 3.0)																			
Birth to <1 year	415	7.32E-03	3.79E-03	4.63E-03	5.73E-03	7.19E-03	8.73E-03	9.82E-03	1.08E-02	1.70E-02	9.78E-04	7.91E-04	8.17E-04	8.80E-04	9.62E-04	1.05E-03	1.18E-03	1.23E-03	1.65E-03
1 year	245	1.16E-02	8.59E-03	8.80E-03	1.00E-02	1.12E-02	1.29E-02	1.52E-02	1.58E-02	2.02E-02	1.05E-03	8.45E-04	8.68E-04	9.49E-04	1.04E-03	1.14E-03	1.25E-03	1.27E-03	1.64E-03
2 years	255	1.20E-02	8.74E-03	9.40E-03	1.03E-02	1.17E-02	1.32E-02	1.56E-02	1.63E-02	2.36E-02	8.97E-04	7.30E-04	7.63E-04	8.19E-04	8.93E-04	9.64E-04	1.04E-03	1.10E-03	1.26E-03
3 to <6 years	543	1.09E-02	8.83E-03	9.04E-03	9.87E-03	1.07E-02	1.17E-02	1.29E-02	1.38E-02	1.64E-02	6.19E-04	4.48E-04	4.84E-04	5.37E-04	5.99E-04	6.98E-04	7.83E-04	8.28E-04	1.02E-03
6 to <11 years	894	1.11E-02	8.51E-03	9.02E-03	9.79E-03	1.08E-02	1.20E-02	1.35E-02	1.47E-02	2.22E-02	3.82E-04	2.52E-04	2.70E-04	3.15E-04	3.76E-04	4.42E-04	5.03E-04	5.39E-04	7.10E-04
11 to <16 years	1,451	1.20E-02	9.40E-03	9.73E-03	1.06E-02	1.18E-02	1.31E-02	1.47E-02	1.58E-02	2.21E-02	2.25E-04	1.63E-04	1.74E-04	1.96E-04	2.17E-04	2.49E-04	2.84E-04	3.05E-04	3.96E-04
16 to <21 years	1,182	1.11E-02	8.31E-03	8.73E-03	9.64E-03	1.08E-02	1.23E-02	1.38E-02	1.49E-02	2.14E-02	1.74E-04	1.29E-04	1.38E-04	1.54E-04	1.73E-04	1.93E-04	2.13E-04	2.24E-04	2.86E-04

Table 6-14. Descriptive Statistics for Average Ventilation Rate[a] While Performing Activities Within the Specified Activity Category, for Females by Age Category (continued)

AgeGroup	N	Average Ventilation Rate (m^3/min), Unadjusted for Body Weight									Average Ventilation Rate (m^3/min-kg), Adjusted for Body Weight								
		Mean	Percentiles							Maximum	Mean	Percentiles							Maximum
			5th	10th	25th	50th	75th	90th	95th			5th	10th	25th	50th	75th	90th	95th	
Moderate Intensity Activities (3.0 < METS ≤ 6.0)																			
Birth to <1 year	415	1.40E-02	7.91E-03	9.00E-03	1.12E-02	1.35E-02	1.63E-02	1.94E-02	2.23E-02	4.09E-02	1.87E-03	1.47E-03	1.52E-03	1.67E-03	1.85E-03	2.01E-03	2.25E-03	2.40E-03	2.83E-03
1 year	245	2.10E-02	1.56E-02	1.63E-02	1.79E-02	2.01E-02	2.35E-02	2.71E-02	2.93E-02	3.45E-02	1.90E-03	1.52E-03	1.62E-03	1.73E-03	1.87E-03	2.02E-03	2.24E-03	2.37E-03	3.24E-03
2 years	255	2.13E-02	1.42E-02	1.56E-02	1.82E-02	2.15E-02	2.39E-02	2.76E-02	2.88E-02	3.76E-02	1.60E-03	1.27E-03	1.31E-03	1.44E-03	1.58E-03	1.75E-03	1.92E-03	2.02E-03	2.59E-03
3 to <6 years	543	2.00E-02	1.53E-02	1.63E-02	1.78E-02	1.98E-02	2.16E-02	2.38E-02	2.59E-02	3.29E-02	1.14E-03	7.92E-04	8.53E-04	9.64E-04	1.11E-03	1.31E-03	1.45E-03	1.56E-03	1.93E-03
6 to <11 years	894	2.10E-02	1.60E-02	1.68E-02	1.85E-02	2.04E-02	2.30E-02	2.61E-02	2.81E-02	4.31E-02	7.23E-04	4.62E-04	5.12E-04	5.98E-04	7.15E-04	8.38E-04	9.42E-04	1.01E-03	1.37E-03
11 to <16 years	1,451	2.36E-02	1.82E-02	1.95E-02	2.08E-02	2.30E-02	2.54E-02	2.84E-02	3.14E-02	4.24E-02	4.41E-04	3.17E-04	3.38E-04	3.80E-04	4.31E-04	4.92E-04	5.51E-04	6.11E-04	9.86E-04
16 to <21 years	1,182	2.32E-02	1.66E-02	1.76E-02	1.96E-02	2.24E-02	2.61E-02	3.03E-02	3.20E-02	5.25E-02	3.65E-04	2.67E-04	2.82E-04	3.10E-04	3.51E-04	4.07E-04	4.63E-04	4.94E-04	6.50E-04
High Intensity (METS > 6.0)																			
Birth to <1 year	79	2.42E-02	1.24E-02	1.33E-02	1.72E-02	2.25E-02	2.93E-02	3.56E-02	4.07E-02	7.46E-02	3.26E-03	2.53E-03	2.62E-03	2.89E-03	3.23E-03	3.63E-03	3.96E-03	4.08E-03	5.02E-03
1 year	55	3.65E-02	2.59E-02	2.62E-02	3.04E-02	3.61E-02	4.20E-02	4.73E-02	4.86E-02	7.70E-02	3.38E-03	2.57E-03	2.75E-03	2.97E-03	3.24E-03	3.71E-03	4.16E-03	4.87E-03	4.88E-03
2 years	130	3.76E-02	2.90E-02	3.05E-02	3.23E-02	3.64E-02	4.08E-02	4.81E-02	5.14E-02	7.30E-02	2.80E-03	2.20E-03	2.31E-03	2.48E-03	2.81E-03	3.13E-03	3.36E-03	3.48E-03	3.88E-03
3 to <6 years	347	3.45E-02	2.70E-02	2.82E-02	3.00E-02	3.33E-02	3.76E-02	4.32E-02	4.47E-02	5.66E-02	1.98E-03	1.36E-03	1.51E-03	1.69E-03	1.90E-03	2.19E-03	2.50E-03	2.99E-03	3.24E-03
6 to <11 years	707	3.94E-02	2.86E-02	3.01E-02	3.37E-02	3.80E-02	4.41E-02	5.05E-02	5.46E-02	8.29E-02	1.33E-03	8.85E-04	9.67E-04	1.12E-03	1.33E-03	1.52E-03	1.72E-03	1.81E-03	2.22E-03
11 to <16 years	1,170	4.66E-02	3.11E-02	3.38E-02	3.88E-02	4.53E-02	5.29E-02	6.08E-02	6.63E-02	1.02E-01	8.79E-04	5.89E-04	6.25E-04	7.12E-04	8.53E-04	1.01E-03	1.18E-03	1.31E-03	2.05E-03
16 to <21 years	887	4.41E-02	2.87E-02	3.06E-02	3.65E-02	4.27E-02	5.02E-02	5.82E-02	6.34E-02	1.09E-01	6.96E-04	4.52E-04	4.96E-04	5.67E-04	6.86E-04	7.93E-04	9.16E-04	1.00E-03	1.50E-03

[a] An individual's ventilation rate for the given activity category equals the weighted average of the individual's activity-specific ventilation rates for activities falling within the category, estimated using a multiple linear regression model, with weights corresponding to the number of minutes spent performing the activity. Numbers in these two columns represent averages, calculated across individuals in the specified age category, of these weighted averages. These are weighted averages, with the weights corresponding to the 4-year sampling weights assigned within NHANES 1999-2002.

N = Number of individuals.

MET = Metabolic equivalent.

Source: U.S. EPA, 2006.

Table 6-15. Descriptive Statistics for Duration of Time (hours/day) Spent Performing Activities Within the Specified Activity Category, by Age and Gender Categories[a]

AgeGroup	N	Duration (hours/day) Spent at Activity – Males									N	Duration (hours/day) Spent at Activity – Females								
		Mean	Percentiles							Maximum		Mean	Percentiles							Maximum
			5th	10th	25th	50th	75th	90th	95th				5th	10th	25th	50th	75th	90th	95th	
Sleep or nap (Activity ID = 14500)																				
Birth to <1 year	419	13.51	12.63	12.78	13.19	13.53	13.88	14.24	14.46	15.03	415	12.99	12.00	12.16	12.53	12.96	13.44	13.82	14.07	14.82
1 year	308	12.61	11.89	12.15	12.34	12.61	12.89	13.13	13.29	13.79	245	12.58	11.59	11.88	12.29	12.63	12.96	13.16	13.31	14.55
2 years	261	12.06	11.19	11.45	11.80	12.07	12.39	12.65	12.75	13.40	255	12.09	11.45	11.68	11.86	12.08	12.34	12.57	12.66	13.48
3 to <6 years	540	11.18	10.57	10.70	10.94	11.18	11.45	11.63	11.82	12.39	543	11.13	10.45	10.70	10.92	11.12	11.38	11.58	11.75	12.23
6 to <11 years	940	10.18	9.65	9.75	9.93	10.19	10.39	10.59	10.72	11.24	894	10.26	9.55	9.73	10.01	10.27	10.54	10.74	10.91	11.43
11 to <16 years	1337	9.38	8.84	8.94	9.15	9.38	9.61	9.83	9.95	10.33	1451	9.57	8.82	8.97	9.27	9.55	9.87	10.17	10.31	11.52
16 to <21 years	1241	8.69	7.91	8.08	8.36	8.67	9.03	9.34	9.50	10.44	1182	9.08	8.26	8.44	8.74	9.08	9.39	9.79	10.02	11.11
Sedentary & Passive Activities (METS ≤ 1.5 -- Includes Sleep or Nap)																				
Birth to <1 year	419	14.95	13.82	14.03	14.49	14.88	15.44	15.90	16.12	17.48	415	14.07	12.86	13.05	13.53	14.08	14.54	15.08	15.49	16.14
1 year	308	14.27	13.22	13.33	13.76	14.25	14.74	15.08	15.38	16.45	245	14.32	13.02	13.25	13.73	14.31	14.88	15.36	15.80	16.40
2 years	261	14.62	13.52	13.67	14.11	14.54	15.11	15.60	15.77	17.28	255	14.86	13.81	13.95	14.44	14.81	15.32	15.78	16.03	16.91
3 to <6 years	540	14.12	13.01	13.18	13.54	14.03	14.53	15.26	15.62	17.29	543	14.27	12.88	13.15	13.56	14.23	14.82	15.43	15.85	17.96
6 to <11 years	940	13.51	12.19	12.45	12.86	13.30	13.85	14.82	15.94	19.21	894	13.97	12.49	12.74	13.22	13.82	14.50	15.34	16.36	18.68
11 to <16 years	1337	13.85	12.39	12.65	13.06	13.61	14.30	15.41	16.76	18.79	1451	14.19	12.38	12.76	13.34	14.05	14.82	15.87	16.81	19.27
16 to <21 years	1241	13.21	11.39	11.72	12.32	13.08	13.97	14.83	15.44	18.70	1182	13.58	11.80	12.17	12.79	13.52	14.29	15.08	15.67	16.96
Light Intensity Activities (1.5 < METS ≤ 3.0)																				
Birth to <1 year	419	5.30	2.97	3.25	3.71	4.52	7.29	8.08	8.50	9.91	415	6.00	3.49	3.70	4.26	5.01	8.43	9.31	9.77	10.53
1 year	308	5.52	2.68	2.89	3.37	4.31	8.23	9.04	9.73	10.90	245	5.61	2.83	2.94	3.46	4.39	8.28	9.03	9.39	10.57
2 years	261	5.48	3.06	3.26	3.85	4.58	7.58	8.83	9.04	9.92	255	5.78	3.20	3.54	4.29	5.33	7.48	8.46	8.74	9.93
3 to <6 years	540	6.60	3.86	4.25	5.16	6.20	8.26	9.31	9.70	10.74	543	6.25	3.78	4.10	4.79	5.84	7.86	8.84	9.38	10.32
6 to <11 years	940	7.62	5.07	5.57	6.63	7.63	8.72	9.78	10.12	11.59	894	7.27	4.63	5.46	6.33	7.17	8.34	9.42	9.79	11.06
11 to <16 years	1337	7.50	4.48	5.59	6.75	7.67	8.51	9.19	9.63	10.91	1451	7.55	4.89	5.62	6.75	7.67	8.55	9.27	9.57	10.85
16 to <21 years	1241	7.13	4.37	4.97	6.00	7.02	8.29	9.43	10.03	11.50	1182	6.98	4.60	5.08	5.91	6.85	7.96	9.16	9.57	12.29

Table 6-15. Descriptive Statistics for Duration of Time (hours/day) Spent Performing Activities Within the Specified Activity Category, by Age and Gender Categories[a] (continued)

Age Group	N	Mean	Duration (hours/day) Spent at Activity – Males: Percentiles 5th	10th	25th	50th	75th	90th	95th	Maximum	N	Mean	Duration (hours/day) Spent at Activity – Females: Percentiles 5th	10th	25th	50th	75th	90th	95th	Maximum
Moderate Intensity Activities (3.0 < METS ≤ 6.0)																				
Birth to <1 year	419	3.67	0.63	0.97	1.74	4.20	5.20	5.80	6.21	7.52	415	3.91	0.53	0.74	1.10	4.87	5.77	6.27	6.54	7.68
1 year	308	4.04	0.45	0.59	1.14	5.29	6.06	6.61	6.94	7.68	245	4.02	0.52	0.73	1.08	5.14	6.10	7.00	7.37	8.07
2 years	261	3.83	0.59	0.76	1.23	4.74	5.37	5.82	6.15	7.40	255	3.27	0.50	0.78	1.22	4.01	4.88	5.35	5.57	6.93
3 to <6 years	540	3.15	0.55	0.75	1.30	3.80	4.52	5.11	5.32	6.30	543	3.35	0.70	0.89	1.61	3.88	4.71	5.29	5.65	7.58
6 to <11 years	940	2.66	0.65	0.92	1.65	2.68	3.57	4.36	4.79	5.95	894	2.57	0.65	0.95	1.82	2.66	3.41	3.95	4.32	6.10
11 to <16 years	1337	2.35	0.88	1.09	1.66	2.30	3.02	3.62	3.89	5.90	1451	2.01	0.89	1.08	1.45	1.96	2.51	3.03	3.28	4.96
16 to <21 years	1241	3.35	1.13	1.42	2.19	3.45	4.37	5.24	5.59	6.83	1182	3.26	1.27	1.48	2.21	3.39	4.24	4.74	5.07	6.68
High Intensity (METS > 6.0)																				
Birth to <1 year	183	0.20	0.00	0.00	0.01	0.14	0.28	0.50	0.59	0.96	79	0.17	0.03	0.05	0.09	0.14	0.21	0.33	0.40	0.58
1 year	164	0.31	0.01	0.01	0.03	0.22	0.56	0.78	0.93	1.52	55	0.22	0.03	0.05	0.09	0.18	0.35	0.40	0.43	0.48
2 years	162	0.10	0.00	0.01	0.03	0.05	0.14	0.25	0.33	0.48	130	0.15	0.00	0.01	0.03	0.08	0.16	0.48	0.65	1.01
3 to <6 years	263	0.27	0.02	0.03	0.04	0.13	0.33	0.75	1.16	1.48	347	0.19	0.01	0.02	0.05	0.10	0.22	0.46	0.73	1.43
6 to <11 years	637	0.32	0.01	0.01	0.03	0.13	0.38	1.10	1.50	3.20	707	0.24	0.02	0.03	0.06	0.12	0.26	0.67	0.98	1.71
11 to <16 years	1111	0.38	0.03	0.04	0.10	0.21	0.47	1.03	1.34	2.35	1170	0.30	0.03	0.04	0.08	0.19	0.40	0.66	0.96	3.16
16 to <21 years	968	0.40	0.03	0.04	0.14	0.27	0.53	0.99	1.29	2.59	887	0.24	0.01	0.03	0.08	0.18	0.34	0.51	0.60	1.61

[a] Individual measures are weighted by their 4-year sampling weights as assigned within NHANES 1999-2002 when calculating the statistics in this table. Ventilation rate was estimated using a multiple linear regression model.
N = Number of individuals.
MET =Metabolic equivalent.

Source: U.S. EPA, 2006.

Table 6-16. Nonnormalized Daily Inhalation Rates (m^3/day) Derived Using Layton's (1993) Method and CSFII Energy Intake Data

Age	Sample Size (Nonweighted)	Mean	SEM	Percentiles 50th	90th	95th	SE of 95th percentile
Infancy							
0-2 months	182	3.63	0.14	3.30	5.44	7.10	0.64
3-5 months	294	4.92	0.14	4.56	6.86	7.72	0.48
6-8 months	261	6.09	0.15	5.67	8.38	9.76	0.86
9-11 months	283	7.41	0.20	6.96	10.21	11.77	-
0-11 months	1,020	5.70	0.10	5.32	8.74	9.95	0.55
Children							
1 year	934	8.77	0.08	8.30	12.19	13.79	0.25
2 years	989	9.76	0.10	9.38	13.56	14.81	0.35
3 years	1,644	10.64	0.10	10.28	14.59	16.03	0.27
4 years	1,673	11.40	0.09	11.05	15.53	17.57	0.23
5 years	790	12.07	0.13	11.56	15.72	18.26	0.47
6 years	525	12.25	0.18	11.95	16.34	17.97	0.87
7 years	270	12.86	0.21	12.51	16.96	19.06	1.27
8 years	253	13.05	0.25	12.42	17.46	19.02	1.08
9 years	271	14.93	0.29	14.45	19.68	22.45[a]	1.35
10 years	234	15.37	0.35	15.19	20.87	22.90[a]	1.02
11 years	233	15.49	0.32	15.07	21.04	23.91[a]	1.62
12 years	170	17.59	0.54	17.11	25.07[a]	29.17[a]	1.61
13 years	194	15.87	0.44	14.92	22.81[a]	26.23[a]	1.11
14 years	193	17.87	0.62	15.90	25.75[a]	29.45[a]	4.38
15 years	185	18.55	0.55	17.91	28.11[a]	29.93[a]	1.79
16 years	201	18.34	0.54	17.37	27.56	31.01	2.07
17 years	159	17.98	0.96	15.90	31.42[a]	36.69[a]	-
18 years	135	18.59	0.78	17.34	28.80[a]	35.24[a]	4.24
Adolescent Boys							
9-18 years	983	19.27	0.28	17.96	28.78	32.82	1.39
Adolescent Girls							
9-18 years	992	14.27	0.22	13.99	21.17	23.30	0.61
U.S. EPA Cancer Guidelines' Age Groups with Greater Weighting							
0 through 1 year	1,954	7.50	0.08	7.19	11.50	12.86	0.17
2 through 15 years	7,624	14.09	0.12	13.13	20.99	23.88	0.50

[a] FASEB/LSRO (1995) convention, adopted by CSFII, denotes a value that might be less statistically reliable than other estimates due to small cell size.

\- Denotes unable to calculate.

SEM = Standard error of the mean.

SE = Standard error.

Source: Arcus-Arth and Blaisdell, 2007.

Table 6-17. Mean and 95th Percentile Inhalation Rate Values (m^3/day) for Males and Females Combined

Age Group[a]	Sample Size	Mean	95th
Birth to <1 month[b]	182	3.63	7.10
3 to <6 months	294	4.92	7.72
6 to <12 months[c]	544	6.75	10.77
1 to <2 years	934	8.77	13.79
2 to <3 years	989	9.76	14.81
3 to <6 years[d]	4,107	11.37	17.29
6 to <11 years[e]	1,553	13.69	20.28
11 to <16 years[f]	975	17.07	27.74
16 to <21 years[g]	495	18.31	34.32

[a] No other age groups from Table 6-14 (Arcus-Arth and Blaisdell, 2007) fit into the U.S. EPA age groupings.
[b] Age group from Arcus-Arth and Blaisdell (2007) was 0-2 months.
[c] Age groups of 6-8 months and 9-11 months from Arcus-Arth and Blaisdell (2007) were averaged.
[d] Age groups of 3, 4 and 5 years from Arcus-Arth and Blaisdell (2007) were averaged.
[e] Age groups of 6, 7, 8, 9 and 10 years from Arcus-Arth and Blaisdell (2007) were averaged.
[f] Age groups of 11, 12, 13, 14 and 15 years from Arcus-Arth and Blaisdell (2007) were averaged.
[g] Age groups of 16, 17 and 18 years from Arcus-Arth and Blaisdell (2007) were averaged.

Source: Arcus-Arth and Blaisdell, 2007.

Table 6-18. Summary of Institute of Medicine Energy Expenditure Recommendations for Active and Very Active People with Equivalent Inhalation Rates

Age Years	Males		Females	
	Energy Expenditure (kcal/day)	Inhalation Rate (m^3/day)	Energy Expenditure (kcal/day)	Inhalation Rate (m^3/day)
<1	607	3.4	607	3.4
1	869	4.9	869	4.9
2	1050	5.9	977	5.5
3	1,485—1,683	8.4—9.5	1,395—1,649	7.9—9.3
4	1,566—1,783	8.8—10.1	1,475—1,750	8.3—9.9
5	1,658—1,894	9.4—10.7	1,557—1,854	8.8—10.5
6	1,742—1,997	9.8—11.3	1,642—1,961	9.3—11.1
7	1,840—2,115	10.4—11.9	1,719—2,058	9.7—11.6
8	1,931—2,225	10.9—12.6	1,810—2,173	10.2—12.3
9	2,043—2,359	11.5—13.3	1,890—2,273	10.7—12.8
10	2,149—2,486	12.1—14.0	1,972—2,376	11.1—13.4
11	2,279—2,640	12.9—14.9	2,071—2,500	11.7—14.1
12	2,428—2,817	13.7—15.9	2,183—2,640	12.3—14.9
13	2,618—3,038	14.8—17.2	2,281—2,762	12.9—15.6
14	2,829—3,283	16.0—18.5	2,334—2,831	13.2—16.0
15	3,013—3,499	17.0—19.8	2,362—2,870	13.3—16.2
16	3,152—3,663	17.8—20.7	2,368—2,883	13.4—16.3
17	3,226—3,754	18.2—21.2	2,353—2,871	13.3—16.2
18	2,823—3,804	18.4—21.5	2,336—2,858	13.2—16.1
19—30	3,015—3,490	17.0—19.7	2,373—2,683	13.4—15.2
31—50	2,862—3,338	16.2—18.9	2,263—2,573	12.8—14.5
51—70	2,671—3,147	15.1—17.8	2,124—2,435	12.0—13.8

Source: Stifelman, 2007.

Table 6-19. Mean Inhalation Rate Values (m^3/day) for Males, Females, and Males and Females Combined.[a]

Age Group[b]	Males	Females	Combined
Birth to <1 year	3.4	3.4	3.4
1 to <2 years	4.9	4.9	4.9
2 to <3 years	5.9	5.5	5.7
3 to <6 years[c]	9.2	8.3	8.8
6 to <11 years[d]	10.9	10.2	10.6
11 to <16 years[e]	14.9	12.7	13.8
16 to <21 years[f]	18.2	13.3	15.8

[a] Inhalation rates are for IOM Physical Activity Level (PAL) category "active"; the total number of subjects for all PAL categories was 3007.
[b] No other age groups from Table 6-15 (Stifelman, 2007) fit into the EPA age groupings.
[c] Age groups of 3, 4, and 5 years from Stifelman, 2007 were averaged.
[d] Age groups of 6, 7, 8, 9 and 10 years from Stifelman, 2007 were averaged.
[e] Age groups of 11, 12, 13, 14 and 15 years from Stifelman, 2007 were averaged.
[f] Age groups of 16, 17 and 18 years from Stifelman, 2007 were averaged.

Source: Stifelman, 2007.

Table 6-20. Mean Inhalation Rate Values (m^3/day) from Key Studies for Males and Females Combined

Age Group	U.S. EPA (2006)		Brochu et al. (2006)		Arcus-Arth and Blaisdell (2007)		Stifelman (2007)		Combined Key Studies	
	N[a]	Mean	N	Mean	N	Mean	N	Mean	N	Mean
Birth to <1 month	-[b]	-	-	-	182	3.63	-	-	182	3.63
1 to <3 months	-	-	-	-	-	-	-	-	-	-
3 to <6 months	-	-	85	3.32	294	4.92	-	-	379	4.12
6 to <12 months	-	-	103	4.09	544	6.75	-	-	647	5.42
Birth to <1 year	834	8.65	-	-	--	--	-	3.40	834	6.03
1 to <2 years	553	13.40	101	4.95	934	8.77	-	4.90	1,588	8.01
2 to <3 years	516	12.99	-	-	989	9.76	-	5.70	1,505	9.48
3 to <6 years	1,083	12.41	-	-	4,107	11.37	-	8.77	5,190	10.85
6 to <11 years	1,834	12.92	-	-	1,553	13.69	-	10.57	3,387	12.39
11 to <16 years	2,788	14.38	-	-	975	17.07	-	13.78	3,763	15.08
16 to <21 years	2,423	15.41	-	-	495	18.31	-	15.75	2,918	16.48

a Number of individuals; the total number of subjects for Stifelman (2007) was 3,007.
b No data from this study for this age group.

Table 6-21. 95th Percentile Inhalation Rate Values (m^3/day) from Key Studies for Males and Females Combined

Age Group	U.S. EPA (2006)		Brochu et al. (2006)		Arcus-Arth and Blaisdell (2007)		Stifelman (2007)		Combined Key Studies	
	N[a]	95th	N	95th	N	95th	N	95th	N	95th
Birth to <1 month	-[b]	-	-	-	182	7.10	-	-	182	7.10
1 to <3 months	-	-	-	-	-	-	-	-	-	-
3 to <6 months	-	-	85	4.47	294	7.72	-	-	379	6.09
6 to <12 months	-	-	103	5.33	544	10.77	-	-	647	8.05
Birth to <1 year	834	12.68	-	-	-	-	-	-	834	12.68
1 to <2 years	553	18.26	101	6.46	934	13.79	-	-	1,588	12.84
2 to <3 years	516	17.04	-	-	989	14.81	-	-	1,505	15.93
3 to <6 years	1,083	15.17	-	-	4,107	17.29	-	-	5,190	16.23
6 to <11 years	1,834	17.03	-	-	1,553	20.28	-	-	3,387	18.66
11 to <16 years	2,788	19.31	-	-	975	27.74	-	-	3,763	23.53
16 to <21 years	2,423	20.84	-	-	495	34.32	-	-	2,918	27.58

a Number of individuals; the total number of subjects for Stifelman (2007) was 3,007.
b No data from this study for this age group.

Table 6-22. Daily Inhalation Rates Estimated From Daily Activities[a]

Subject	Inhalation Rate (m^3/hour)		Daily Inhalation Rate (DIR)[b] (m^3/day)
	Resting	Light Activity	
Child (10 years)	0.29	0.78	14.8
Infant (1 year)	0.09	0.25	3.76
Newborn	0.03	0.09	0.78

[a] Assumptions made were based on 8 hours resting and 16 hours light activity for adults and children (10 yrs); 14 hours resting and 10 hours light activity for infants (1 yr); 23 hours resting and 1 hour light activity for newborns.

[b]
$$DIR = \frac{1}{T}\sum_{i=1}^{K} IR_i t_i$$

DIR = Daily Inhalation Rate
IR_i = Corresponding inhalation rate at i^{th} activity
t_i = Hours spent during the i^{th} activity
k = Number of activity periods
T = Total time of the exposure period (i.e., a day)

Source: ICRP, 1981.

Table 6-23. Selected Inhalation Rate Values During Different Activity Levels Obtained From Various Literature Sources

Subject	W (kg)	Resting			Light Activity			Heavy Work			Maximal Work During Exercise		
		f	VT	V*	f	VT	V*	f	VT	V*	f	VT	V*
Adolescent													
male, 14-16 y		16	330	5.2							53	2520	113
male, 14-15 y	59.4												
female, 14-16 y		15	300	4.5									
female, 14-15 y; 164.9 cm L	56										52	1870	88
Children													
10 y; 140 cm L		16	300	4.8	24	600	14						
males, 10-11 y	36.5										58	1330	71
males, 10-11 y; 140.6 cm L	32.5										61	1050	61
females, 4-6 y	20.8										70	600	40
females, 4-6 y; 111.6 cm L	18.4										66	520	34
Infant, 1 y		30	48	1.4[a]									
Newborn	2.5	34	15	0.5									
20 hrs-13 wk	2.5-5.3										68[b]	51[a,b]	3.5[b]
9.6 hrs	3.6	25	21	0.5									
6.6 days	3.7	29	21	0.6									

W = Body weights; f = frequency (breaths/min); VT = tidal volume (ml); V* = minute volume (l/min); cm L = length/height; y = years of age; wk = week.
[a] Calculated from V* = f x VT.
[b] Crying.

Source: ICRP, 1981.

Table 6-24. Summary of Human Inhalation Rates for Children by Activity Level (m^3/hour)[a]

	N[b]	Resting[c]	N[b]	Light[d]	N[b]	Moderate[e]	N[b]	Heavy[f]
Child, 6 years	8	0.4	16	0.8	4	2	5	2.3
Child, 10 years	10	0.4	40	1	29	3.2	43	3.9

[a] Values of inhalation rates for children (male and female) presented in this table represent the mean of values reported for each activity level in 1985.
[b] Number of observations at each activity level.
[c] Includes watching television, reading, and sleeping.
[d] includes most domestic work, attending to personal needs and care, hobbies, and conducting minor indoor repairs and home improvements.
[e] Includes heavy indoor cleanup, performance of major indoor repairs and alterations, and climbing stairs.
[f] Includes vigorous physical exercise and climbing stairs carrying a load.

Source: Adapted from U.S. EPA, 1985.

Table 6-25. Activity Pattern Data Aggregated for Three Microenvironments by Activity Level for All Age Groups

Microenvironment	Activity Level	Average Hours Per Day in Each Microenvironment at Each Activity Level
Indoors	Resting	9.82
	Light	9.82
	Moderate	0.71
	Heavy	0.10
	TOTAL	20.4
Outdoors	Resting	0.51
	Light	0.51
	Moderate	0.65
	Heavy	0.12
	TOTAL	1.77
In Transportation Vehicle	Resting	0.86
	Light	0.86
	Moderate	0.05
	Heavy	0.0012
	TOTAL	1.77

Source: Adapted from U.S. EPA, 1985.

Table 6-26. Summary of Daily Inhalation Rates Grouped by Age and Activity Level

Subject	Daily Inhalation Rate (m^3/day)[a]				Total Daily IR[b] (m^3/day)
	Resting	Light	Moderate	Heavy	
Child, 6 years	4.47	8.95	2.82	0.50	16.74
Child, 10 years	4.47	11.19	4.51	0.85	21.02

[a] Daily inhalation rate was calculated using the following equation:

$$IR = \frac{1}{T} \sum_{i=1}^{K} IR_i t_i$$

IR_i = Inhalation rate at i^{th} activity (Table 6-13 and 6-14)
t_i = Hours spent per day during i^{th} activity (Table 6-15)
k = Number of activity periods
T = Total time of the exposure period (e.g., a day)

[b] Total daily inhalation rate was calculated by summing the specific activity (resting, light, moderate, heavy) and dividing them by the total amount of time spent on all activities.

Source: Generated using the data from U.S. EPA (1985) as shown in Tables 6-24 and 6-25.

Table 6-27. Calibration and Field Protocols for Self-monitoring of Activities Grouped by Subject Panels

Panel	Calibration Protocol	Field Protocol
Panel 2 - Healthy Elementary School Students - 5 male, 12 female, ages 10-12	Outdoor exercises each consisted of 20 minute rest, slow walking, jogging and fast walking	Saturday, Sunday and Monday (school day) in early autumn; heart rate recordings and activity diary during waking hours and during sleep.
Panel 3 - Healthy High School Students - 7 male, 12 female, ages 13-17	Outdoor exercises each consisted of 20 minute rest, slow walking, jogging and fast walking	Same as Panel 2, however, no heart rate recordings during sleep for most subjects.
Panel 6 - Young Asthmatics - 7 male, 6 female, ages 11-16	Laboratory exercise tests on bicycles and treadmills	Summer monitoring for 2 successive weeks, including 2 controlled exposure studies with few or no observable respiratory effects.

Source: Linn et al., 1992.

Table 6-28. Subject Panel Inhalation Rates by Mean VR, Upper Percentiles, and Self-estimated Breathing Rates

Panel Number and Description	N[a]	Inhalation Rates (m^3/hour)				
		Mean VR	99th Percentile VR	Mean VR at Activity Levels[b]		
				Slow	Medium	Fast
Healthy						
2 - Elementary School Students	17	0.90	1.98	0.84	0.96	1.14
3 - High School Students	19	0.84	2.22	0.78	1.14	1.62
Asthmatics						
6 - Elementary and High School Students	13	1.20	2.40	1.20	1.20	1.50

a Number of individuals in each survey panel.
b Some subjects did not report medium and/or fast activity. Group means were calculated from individual means (i.e., give equal weight to each individual who recorded any time at the indicated activity level).
VR = Ventilation rate.

Source: Linn et al., 1992.

Table 6-29. Distribution of Predicted Inhalation Rates by Location and Activity Levels for Elementary and High School Students

Age (years)	Student	Location	Activity Level	% Recorded Time[a]	Inhalation Rates (m^3/hour)			
					Mean ± SD	Percentile Rankings[b]		
						1[st]	50[th]	99.9th
10-12	EL[c] (N[d]=17)	Indoors	slow	49.6	0.84 ± 0.36	0.18	0.78	2.34
			medium	23.6	0.96 ± 0.36	0.24	0.84	2.58
			fast	2.4	1.02 ± 0.60	0.24	0.84	3.42
		Outdoors	slow	8.9	0.96 ± 0.54	0.36	0.78	4.32
			medium	11.2	1.08 ± 0.48	0.24	0.96	3.36
			fast	4.3	1.14 ± 0.60	0.48	0.96	3.60
13-17	HS[c] (N[d]=19)	Indoors	slow	70.7	0.78 ± 0.36	0.30	0.72	3.24
			medium	10.9	0.96 ± 0.42	0.42	0.84	4.02
			fast	1.4	1.26 ± 0.66	0.54	1.08	6.84[e]
		Outdoors	slow	8.2	0.96 ± 0.48	0.42	0.90	5.28
			medium	7.4	1.26 ± 0.78	0.48	1.08	5.70
			fast	1.4	1.44 ± 1.08	0.48	1.02	5.94

[a] Recorded time averaged about 23 hr per elementary school student and 33 hours per high school student over 72-hour periods.
[b] Geometric means closely approximated 50th percentiles; geometric standard deviations were 1.2-1.3 for HR,1.5-1.8 for VR.
[c] Elementary school student or high school student.
[d] Number of students that participated in survey.
[e] Highest single value.
SD = Standard deviation.

Source: Spier et al., 1992.

Table 6-30. Average Hours Spent Per Day in a Given Location and Activity Level for Elementary and High School Students

Students	Location	Activity Level			Total Time Spent (hours/day)
		Slow	Medium	Fast	
Elementary school, ages 10-12 years (N=17)	Indoors	16.3	2.9	0.4	19.6
	Outdoors	2.2	1.7	0.5	4.4
High school, ages 13-17 years (N=19)	Indoors	19.5	1.5	0.2	21.2
	Outdoors	1.2	1.3	0.2	2.7

N = Number of students that participated in survey.

Source: Spier et al., 1992.

Table 6-31. Summary of Average Inhalation Rates (m^3/hour) by Age Group and Activity Levels for Laboratory Protocols

Age Group	Activity Level				
	Resting[a]	Sedentary[b]	Light[c]	Moderate[d]	Heavy[e]
Young Children (3-5.9 years) Average inhalation rate (m^3/hour) (N=12, gender not specified)	0.37	0.40	0.65	DNP[f]	DNP[f]
Children (6-12.9 years) Average inhalation rate (m^3/hour) (N=40, 20 male and 20 female)	0.45	0.47	0.95	1.74	2.23

[a] Resting defined as lying (see Table 6-33 for original data).
[b] Sedentary defined as sitting and standing (see Table 6-33 for original data).
[c] Light defined as walking at speed level 1.5 - 3.0 mph (see Table 6-33 for original data).
[d] Moderate defined as fast walking (3.3 - 4.0 mph) and slow running (3.5 - 4.0 mph) (see Table 6-33 for original data).
[e] Heavy defined as fast running (4.5 - 6.0 mph) (see Table 6-33 for original data).
[f] Group did not perform (DNP) this protocol or N was too small for appropriate mean comparisons. All young children did not run.

Source: Adapted from Adams, 1993.

Table 6-32. Summary of Average Inhalation Rates (m^3/hour) by Age Group And Activity Levels in Field Protocols

Age Group	Moderate Activity[a]
Young Children (3-5.9 years) Average inhalation rate (m^3/hour) (N=12, gender not specified)	0.68
Children (6-12.9 years) Average inhalation rate (m^3/hour) (N=40, 20 male and 20 female)	1.07

[a] Moderate activity was defined as play.
N = Number of individuals.

Source: Adams, 1993.

Table 6-33. Mean Minute Inhalation Rate (m^3/minute) by Group and Activity for Laboratory Protocols

Activity	Young Children[a]	Children[a]
Lying	6.19E-03	7.51E-03
Sitting	6.48E-03	7.28E-03
Standing	6.76E-03	8.49E-03
Walking		
1.5 mph	1.03E-02	DNP[b]
1.875 mph	1.05E-02	DNP
2.0 mph	DNP	1.41E-02
2.25 mph	1.17E-02	DNP
2.5 mph	DNP	1.56E-02
3.0 mph	DNP	1.78E-02
3.3 mph	DNP	DNP
4.0 mph	DNP	DNP
Running		
3.5 mph	DNP	2.68E-02
4.0 mph	DNP	3.12E-02
4.5 mph	DNP	3.72E-02
5.0 mph	DNP	DNP
6.0 mph	DNP	DNP

[a] Young Children, male and female 3-5.9 years old; Children, male and female 6-12.9 years old.
[b] Group did not perform (DNP) this protocol or N was too small for appropriate mean comparisons.

Source: Adams , 1993.

Table 6-34. Mean Minute Inhalation Rate (m^3/minute) by Group and Activity for Field Protocols

Activity	Young Children[a]	Children[a]
Play	1.13E-02	1.89E-02

[a] Young children, male and female 3-5.9 years old; children, male and female 6-12.9 years old.

Source: Adams, 1993.

Table 6-35. Comparisons of Estimated Basal Metabolic Rates (BMR) with Average Food-energy Intakes (EFD) for Individuals Sampled in the 1977-78 NFCS

Cohort/Age (years)	Body Weight (kg)	BMR[a]		Energy Intake (EFD)		Ratio EFD[d]/BMR
		MJ/day[b]	Kcal/day[c]	MJ/day	Kcal/day	
Males and Females						
< 1	7.6	1.74	416	3.32	793	1.90
1 to 2	13	3.08	734	5.07	1209	1.65
3 to 5	18	3.69	881	6.14	1466	1.66
6 to 8	26	4.41	1053	7.43	1774	1.68
Males						
9 to 11	36	5.42	1293	8.55	2040	1.58
12 to 14	50	6.45	1540	9.54	2276	1.48
15 to 18	66	7.64	1823	10.80	2568	1.41
Females						
9 to 11	36	4.91	1173	7.75	1849	1.58
12 to 14	49	5.64	1347	7.72	1842	1.37
15 to 18	56	6.03	1440	7.32	1748	1.21

[a] Calculated from the appropriate age and gender-based BMR equations given in Table 6-37.
[b] MJ/day - mega joules/day.
[c] Kcal/d - kilo calories/day.
[d] Food energy intake (Kcal/day) or (MJ/day).

Source: Layton, 1993.

Table 6-36. Daily Inhalation Rates Calculated from Food-energy Intakes

Cohort/Age (years)	L[b]	Daily Inhalation Rate[c] (m^3/day)	Sleep (hours)	MET[a] Value		Inhalation Rates	
				A[d]	F[e]	Inactive[f] (m^3/day)	Active[f] (m^3/day)
Males and Females							
<1	1	4.5	11	1.9	2.7	2.35	6.35
1 to 2	2	6.8	11	1.6	2.2	4.16	9.15
3 to 5	3	8.3	10	1.7	2.2	4.98	10.96
6 to 8	3	10	10	1.7	2.2	5.95	13.09
Males							
9 to 11	3	14	9	1.9	2.5	7.32	18.3
12 to 14	3	15	9	1.8	2.2	8.71	19.16
15 to 18	4	17	8	1.7	2.1	10.31	21.65
Females							
9 to 11	3	13	9	1.9	2.5	6.63	16.58
12 to 14	3	12	9	1.6	2.0	7.61	15.22
15 to 18	4	12	8	1.5	1.7	8.14	13.84

[a] MET = Metabolic equivalent.

[b] L = Number of years for each age cohort.

[a] Daily inhalation rate was calculated by multiplying the EFD values (see Table 6-35) by H × VQ for subjects under 9 years of age and by 1.2 × H × VQ (for subjects 9 years of age and older (see text for explanation), where EFD = Food energy intake (Kcal/day) or (MJ/day), H = Oxygen uptake = 0.05 LO_2/KJ or 0.21 LO_2/Kcal, and VQ = Ventilation equivalent = 27 = geometric mean of VQs (unitless).

[d] For individuals 9 years of age and older, A was calculated by multiplying the ratio for EFD/BMR (unitless) (Table 6-35) by the factor 1.2 (see text for explanation).

[e] F = (24 × A - S)/(24 - S) (unitless), ratio of the rate of energy expenditure during active hours to the estimated BMR (unitless), where S = Number of hours spent sleeping each day.

[f] Inhalation rate for inactive periods was calculated as BMR × H × VQ, and for active periods by multiplying the inactive inhalation rate by F (see footnote c); BMR values are from Table 6-35, where BMR = basal metabolic rate (MJ/day) or (kg/hr).

Source: Layton, 1993.

Table 6-37. Statistics of the Age/gender Cohorts Used to Develop Regression Equations for Predicting Basal Metabolic Rates (BMR)

Gender, Age (years)	BMR		CV	Body Weight (kg)	N	BMR Equation[a]	r
	MJ d^{-1}	SD					
Males							
Under 3	1.51	0.92	0.61	6.6	162	0.249 bw - 0.127	0.95
3 to < 10	4.14	0.50	0.12	21	338	0.095 bw + 2.110	0.83
10 to < 18	5.86	1.17	0.20	42	734	0.074 bw + 2.754	0.93
Females							
Under 3	1.54	0.92	0.59	6.9	137	0.244 bw - 0.130	0.96
3 to < 10	3.85	0.49	0.13	21	413	0.085 bw + 2.033	0.81
10 to < 18	5.04	0.78	0.15	38	575	0.056 bw + 2.898	0.8

[a] Body weight (bw) in kg.
SD = Standard deviation.
CV = Coefficient of variation (SD/mean).
N = Number of observations.
r = Coefficient of correlation.

Source: Layton, 1993.

Table 6-38. Daily Inhalation Rates Obtained from the Ratios of Total Energy Expenditure to Basal Metabolic Rate (BMR)

Gender/Age (years)	Body Weight[a] (kg)	BMR[b] (MJ/day)	VQ	A[c]	H (m^3O_2/MJ)	Inhalation Rate, V_E (m^3/day)[d]
Males						
0.5 to <3	14	3.4	27	1.6	0.05	7.3
3 to <10	23	4.3	27	1.6	0.05	9.3
10 to <18	53	6.7	27	1.7	0.05	15
Females						
0.5 to <3	11	2.6	27	1.6	0.05	5.6
3 to <10	23	4.0	27	1.6	0.05	8.6
10 to <18	50	5.7	27	1.5	0.05	12

[a] Body weight was based on the average weights for age/gender cohorts in the U.S. population.

[b] The BMRs (basal metabolic rate) are calculated using the respective body weights and BMR equations (see Table 6-36).

[c] The values of the BMR multiplier (EFD/BMR) for those 18 years and older were derived from the Basiotis et al. (1989) study: Male = 1.59, Female = 1.38. For males and females under 10 years old, the mean BMR multiplier used was 1.6. For males and females aged 10 to < 18 years, the mean values for A given in Table 6-36 for 12-14 years and 15-18 years, age brackets for males and females were used: male = 1.7 and female = 1.5.

[d] Inhalation rate = BMR x A x H x VQ; VQ = ventilation equivalent and H = oxygen uptake.

Source: Layton, 1993.

Table 6-39. Inhalation Rates for Short-term Exposures

Gender/Age (years)	Body Weight (kg)[a]	BMR[b] (MJ/day)	Activity Type				
			Rest	Sedentary	Light	Moderate	Heavy
			MET (BMR Multiplier)				
			1	1.2	2[c]	4[d]	10[e]
			Inhalation Rate (m^3/minute)[f,g]				
Males							
0.5 to <3	14	3.40	3.2E-03	3.8E-03	6.4E-03	1.3E-02	–[h]
3 to <10	23	4.30	4.0E-03	4.8E-03	8.1E-03	1.6E-02	–[h]
10 to <18	53	6.70	6.3E-03	7.5E-03	1.3E-02	2.5E-02	6.3E-02
Females							
0.5 to <3	11	2.60	2.4E-03	2.9E-03	4.9E-03	1.0E-02	–[h]
3 to <10	23	4.00	3.8E-03	4.5E-03	7.5E-03	1.5E-02	–[h]
10 to <18	50	5.70	5.3E-03	6.4E-03	1.1E-02	2.1E-02	5.3E-02

[a] Body weights were based on average weights for age/gender cohorts of the U.S. population

[b] The BMRs for the age/gender cohorts were calculated using the respective body weights and the BMR equations (Table 6-37).

[c] Range = 1.5 - 2.5.

[d] Range = 3 - 5.

[e] Range = >5 - 20.

[f] The inhalation rate was calculated as IR = BMR (MJ/day) × H (0.05 L/KJ) × MET × VQ (27) × (day/1440 min)

[g] Original data were presented in L/min. Conversion to m^3/min was obtained as follows: $\frac{m^3}{1000L} \times \frac{L}{min}$

[h] The maximum possible MET sustainable for more than 5 minutes does not reach 10 for females and males until age 13 and 12, respectively. Therefore, a METs of 10 is not possible for this age category.

Source: Layton, 1993.

Table 6-40. Mean, Median, and SD of Inhalation Rate According to Waking or Sleeping in 618 Infants and Children Grouped in Classes of Age

Age (months)	N	Inhalation Rate (breaths/min)			
		Waking		Sleeping	
		Mean ± SD	Median	Mean ± SD	Median
<2	104	48.0 ± 9.1	47	39.8 ± 8.7	39
2 to <6	106	44.1 ± 9.9	42	33.4 ± 7.0	32
6 to <12	126	39.1 ± 8.5	38	29.6 ± 7.0	28
12 to <18	77	34.5 ± 5.8	34	27.2 ± 5.6	26
18 to <24	65	32.0 ± 4.8	32	25.3 ± 4.6	24
24 to <30	79	30.0 ± 6.2	30	23.1 ± 4.6	23
30 to 36	61	27.1 ± 4.1	28	21.5 ± 3.7	21

SD = Standard deviation.
N = Number of individuals.

Source: Rusconi et al., 1994.

Figure 6-1. 5th, 10th, 25th, 50th, 75th, 90th, and 95th Smoothed Centiles by Age in Awake Subjects (RR = respiratory rate). Source: Rusconi et al., 1994.

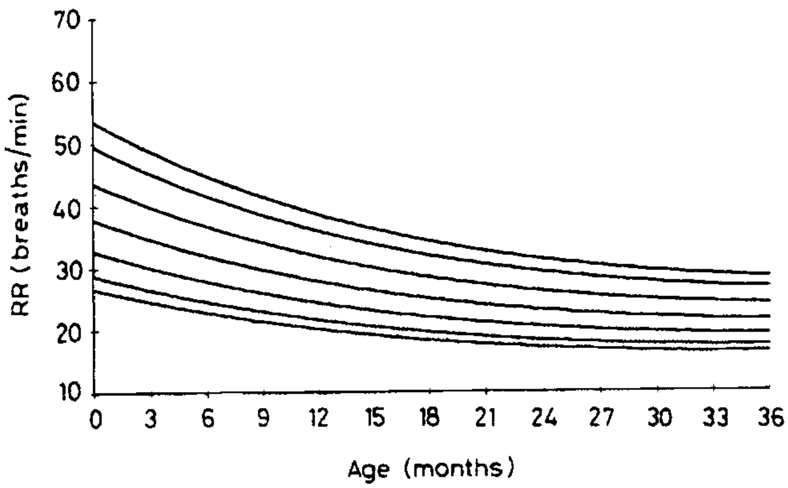


Figure 6-2. 5th, 10th, 25th, 50th, 75th, 90th, and 95th Smoothed Centiles by Age in Asleep Subjects (RR = respiratory rate). Source: Rusconi et al., 1994.

7 DERMAL EXPOSURE FACTORS

7.1 INTRODUCTION

Dermal exposure can occur during a variety of activities in different environmental media and microenvironments (U.S. EPA, 1992a; 1992b; 2004). These include:

- Water (e.g., bathing, washing, swimming);
- Soil (e.g., outdoor recreation, gardening, construction);
- Sediment (e.g., wading, fishing);
- Liquids (e.g., use of commercial products);
- Vapors/fumes (e.g., use of commercial products); and
- Indoor dust (e.g., carpets, floors, counter tops).

Children may be more highly exposed to environmental toxicants through dermal routes than adults. For instance, children may crawl, roll or sit on surfaces treated with chemicals (i.e., carpets and floors) and play with objects such as toys where residues may settle. Children also are more likely to wear less clothing than adults. As a result, children may have higher dermal contact with contaminated media. In addition, young children who wear diapers may be exposed for long periods of time to chemical components of lotions and other products used for diapering. Children also have a higher surface area relative to body weight compared to adults. The surface-area-to-body weight ratio for newborn infants is more than two times greater than that for adults (Cohen-Hubal et al., 1999). Therefore, the dose relative to body weight would be greater for a child than for an adult with an equal amount of skin exposure to a chemical.

This chapter focuses on measurements of body surface area and dermal adherence of solids to the skin. These are only two of a several parameters that influence dermal absorption. Other factors include the concentration of chemical in contact with the skin, characteristics of the chemical (i.e., lipophilicity, polarity, volatility, solubility), the site of application (i.e., the thickness of the stratum corneum varies over parts of the body), absorption of chemical through the skin and factors that affect absorption (i.e, thickness, age, condition), and the amount of chemical delivered to the target organ. For guidance on how to use skin surface area and dermal adherence factors, as well as these other factors to assess dermal exposure, readers are referred to *Dermal Exposure Assessment: Principles and Applications* (U.S. EPA, 1992b) and *Risk Assessment Guidelines for Superfund (RAGs) Part E* (U.S. EPA, 2004). Frequency and duration of contact also affect dermal exposure. Information on activity factors is presented in Chapter 17 of this handbook.

Surface area of the skin can be determined using measurement or estimation techniques. Coating, triangulation, and surface integration are direct measurement techniques that have been used to measure total body surface area and the surface area of specific body parts. The coating method consists of coating either the whole body or specific body regions with a substance of known density and thickness. Triangulation consists of marking the area of the body into geometric figures, then calculating the figure areas from their linear dimensions. Surface integration is performed by using a planimeter and adding the areas. The results of studies conducted using these various techniques have been summarized in *Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments* (U.S. EPA, 1985). Because of the difficulties associated with direct measurements of body surface area, the existing direct measurement data are limited and dated. However, several researchers have developed methods for estimating body surface area from measurements of other body dimensions (DuBois and DuBois, 1916; Boyd, 1935; Gehan and George, 1970). Generally, these formulas are based on the observation that body weight and height are correlated with surface area and are derived using multiple regression techniques. U.S. EPA (1985) evaluated the various formulas for estimating total body surface area. A discussion and comparison of formulas are presented in Appendix 7A. The key studies on body surface area that are presented in Section 7.3 of this chapter are based on these formulas, and weight and height data from the National Health and Nutrition Examination Survey (NHANES).

Several field studies have been conducted to estimate the adherence of solids to skin. These field studies consider factors such as activity, gender, age, field conditions, and clothing worn. These studies are presented in Section 7.4 of this chapter.

The recommendations for skin surface area and dermal adherence of solids to skin are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on key studies identified by U.S. EPA for these factors. Following the recommendations, the two key studies on skin surface area and the three key studies on dermal adherence of solids to skin are summarized. Relevant data on these factors are also presented to provide added perspective on the state-of-knowledge pertaining to dermal exposure factors.

7.2 RECOMMENDATIONS

7.2.1 Body Surface Area

The recommended mean and 95th percentile total body surface area values for children are summarized in Table 7-1. If gender-specific data or data for percentiles other than the mean or 95th percentile are needed, the reader is referred to Tables 7-7 through 7-9 of this chapter. The recommendations for total body surface area are based on the U.S. EPA analysis of NHANES 1999-2006 data and are presented for the standard age groupings recommended by U.S. EPA (2005) for male and female children combined. The U.S. EPA analysis of NHANES 1999-2006 data uses correlations with body weight and height for deriving skin surface area (see Section 7.3.1.2 and Appendix 7A). NHANES 1999-2006 used a statistically-based survey design which should ensure that the data are reasonably representative of the general population. The recommendations for the percentage of total body surface area represented by individual body parts are based on data from U.S. EPA (1985), and are presented in Table 7-2 (See Section 7.3.1). Table 7-2 also provides age-specific body part surface areas (m^2) that were obtained by multiplying the mean body part percentages by the total body surface areas presented in Table 7-1. If gender-specific data or data for percentiles other than the mean and 95th percentile are needed, the body part percentages in Table 7-2 may be applied to the total skin surface area data in Tables 7-7 through 7-9. Table 7-3 presents the confidence ratings for the recommendations for body surface area.

For swimming and bathing scenarios, past exposure assessments have assumed that 75 to 100 percent of the skin surface is exposed (U.S. EPA, 1992b). More recent guidance recommends assuming 100 percent exposure for these scenarios (U.S. EPA, 2004). For other exposure scenarios, it is reasonable to assume that clothing reduces the contact area. However, while it is generally assumed that adherence of solids to skin occurs to only the areas of the body not covered by clothing, it is important to understand that soil and dust particles can get under clothing and be deposited on skin to varying degrees depending on the protective properties of the clothing. Likewise, liquids may soak through clothing and contact covered areas of the skin. Assessors should consider these possibilities for the scenario of concern and select skin areas that are judged appropriate.

7.2.2 Adherence of Solids to Skin

The adherence factor (AF) describes the amount of material that adheres to the skin per unit of surface area. Although most research in this area has focused on soils, a variety of other solid residues can accumulate on skin, including household dust, sediments and commercial powders. Studies on soil adherence have shown that: 1) soil properties influence adherence; 2) soil adherence varies considerably across different parts of the body; and 3) soil adherence varies with activity (U.S. EPA, 2004). It is recommended that exposure assessors use adherence data derived from testing that matches the exposure scenario of concern in terms of solid type, exposed body parts, and activities, as closely as possible. Assessors should refer to the activities described in Table 7-12 to select those that best represent the exposure scenarios of concern and use the corresponding adherence values from Table 7-13. Table 7-12 lists the age ranges covered by each study. This may be used as a general guide to the ages covered by these data. Recommended mean AF values are summarized in Table 7-4 according to common activities involving children. Insufficient data were available to develop distributions or probability functions for these values. Also, the small number of subjects in these studies prevented the development of recommendations for the specific age groups recommended by U.S. EPA (2005).

RAGS Part E (U.S. EPA, 2004) recommends that scenario-specific adherence values be weighted according to the body parts exposed. Weighted adherence factors may be estimated according to the following equation:

$$AF_{wtd} = \frac{(AF_1)(SA_1) + (AF_2)(SA_2) + \ldots (AF_i)(SA_i)}{SA_1 + SA_2 + \ldots SA_i}$$

(Eqn. 7-1)

where:

AF_{wtd} = weighted adherence factor;
AF = adherence factor; and
SA = surface area.

For the purposes of this calculation, the surface area of the face may be assumed to be 1/3 that of the head, forearms may be assumed to represent 45 percent of the arms and lower legs may be assumed to represent 40 percent of the legs (U.S. EPA, 2004).

The recommended dermal AFs represent the amount of material on the skin at the time of measurement. U.S. EPA (1992b) recommends interpreting AFs as representative of contact events. Assuming that the amount of solids measured on the skin represents accumulation between washings, and that people wash at least once per day, these adherence values can be interpreted as daily contact rates (U.S. EPA, 1992b). The rate of solids accumulation on skin over time has not been well studied, but probably occurs fairly quickly. Therefore, pro-rating the adherence values for exposure time periods of less than one day is not recommended.

The confidence ratings for these AF recommendations are shown in Table 7-5. It should be noted that while the recommendations are based on the best available estimates of activity-specific adherence, they are based on limited data from studies that have focused primarily on soil. Therefore, they have a high degree of uncertainty and considerable judgment must be used when selecting them for an assessment. It should also be noted that the skin adherence studies have not considered the influence of skin moisture on adherence. Skin moisture varies depending on a number of factors, including activity level and ambient temperature/humidity. It is uncertain how well this variability has been captured in the dermal adherence studies.

Table 7-1. Recommended Values for Total Body Surface Area, Males and Females Combined

Age Group	Mean	95th Percentile	Multiple Percentiles	Source
	m²			
Birth to <1 month	0.29	0.34	See Tables 7-7, 7-8, and 7-9	U.S. EPA Analysis of NHANES 1999-2006 data
1 to <3 months	0.33	0.38		
3 to <6 months	0.38	0.44		
6 to <12 months	0.45	0.51		
1 to <2 years	0.53	0.61		
2 to <3 years	0.61	0.70		
3 to <6 years	0.76	0.95		
6 to <11 years	1.08	1.48		
11 to <16 years	1.59	2.06		
16 to <21 years	1.84	2.33		

Table 7-2. Recommended Values for Surface Area of Body Parts

Age Group	Head	Trunk	Arms	Hands	Legs	Feet	Source
	Mean Percent of Total Surface Area						
Birth to <1 month	18.2	35.7	13.7	5.3	20.6	6.5	U.S. EPA, 1985
1 to <3 months	18.2	35.7	13.7	5.3	20.6	6.5	
3 to <6 months	18.2	35.7	13.7	5.3	20.6	6.5	
6 to <12 months	18.2	35.7	13.7	5.3	20.6	6.5	
1 to <2 years	16.5	35.5	13.0	5.7	23.1	6.3	
2 to <3 years	14.2	38.5	11.8	5.3	23.2	7.1	
3 to <6 years	13.7	31.7	14.2	5.9	27.3	7.3	
6 to <11 years	12.6	34.7	12.7	5.0	27.9	7.2	
11 to <16 years	9.4	33.7	12.9	5.3	31.3	7.5	
16 to <21 years	7.8	32.2	15.3	5.4	32.2	7.1	
	Mean Surface Area by Body Part[a] m^2						
Birth to <1 month	0.053	0.104	0.040	0.015	0.060	0.019	U.S. EPA Analysis of NHANES 1999-2006 data and U.S. EPA, 1985
1 to <3 months	0.060	0.118	0.045	0.017	0.068	0.021	
3 to <6 months	0.069	0.136	0.052	0.020	0.078	0.025	
6 to <12 months	0.082	0.161	0.062	0.024	0.093	0.029	
1 to <2 years	0.087	0.188	0.069	0.030	0.122	0.033	
2 to <3 years	0.087	0.235	0.072	0.032	0.142	0.043	
3 to <6 years	0.104	0.241	0.108	0.045	0.207	0.055	
6 to <11 years	0.136	0.375	0.137	0.054	0.301	0.078	
11 to <16 years	0.149	0.536	0.205	0.084	0.498	0.119	
16 to <21 years	0.144	0.592	0.282	0.099	0.592	0.131	
	95^{th} Percentile Surface Area by Body Part[b] m^2						
Birth to <1 month	0.062	0.121	0.047	0.018	0.070	0.022	U.S. EPA Analysis of NHANES 1999-2006 data and U.S. EPA, 1985
1 to <3 months	0.069	0.136	0.052	0.020	0.078	0.025	
3 to <6 months	0.080	0.157	0.060	0.023	0.091	0.029	
6 to <12 months	0.093	0.182	0.070	0.027	0.105	0.033	
1 to <2 years	0.101	0.217	0.079	0.035	0.141	0.038	
2 to <3 years	0.099	0.270	0.083	0.037	0.162	0.050	
3 to <6 years	0.130	0.301	0.135	0.056	0.259	0.069	
6 to <11 years	0.186	0.514	0.188	0.074	0.413	0.107	
11 to <16 years	0.194	0.694	0.266	0.109	0.645	0.155	
16 to <21 years	0.182	0.750	0.356	0.126	0.750	0.165	

[a] Calculated as mean percentage of body part times mean total body surface area.

[b] Calculated as mean percentage of body part times 95^{th} percentile total body surface area.

Note: Surface area values reported in m^2 can be converted to cm^2 by multiplying by 10,000 cm^2/m^2.

Table 7-3. Confidence in Recommendations for Body Surface Area

General Assessment Factors	Rationale	Rating
Soundness		Medium
Adequacy of Approach	Total surface area estimates were based on algorithms developed using direct measurements and data from NHANES surveys. The methods used for developing these algorithms were adequate. The NHANES data and the secondary data analyses to estimate total surface areas were appropriate. NHANES included a large sample sizes; sample size varied with age. Body part percentages were based on direct measurements from a limited number of subjects.	
Minimal (or Defined) Bias	The data used to develop the algorithms for estimating surface area from height and weight data were limited. NHANES collected physical measurements of weight and height. Body part data were based on direct measurements from a limited number of subjects.	
Applicability and Utility		Medium
Exposure Factor of Interest	The key studies were directly relevant to surface area estimates.	
Representativeness	The direct measurement data used to develop the algorithms for estimating total body surface area from weight and height may not be representative of the U.S. population. However, NHANES height and weight data were collected using a complex, stratified, multi-stage probability cluster sampling design intended to be representative of the U.S. population. The sample used to derive body part percentages of total surface was not representative of U.S. population.	
Currency	The U.S. EPA analysis used the most current data at the time both studies were conducted. The data on body part percentages were dated; however, the age of the data is not expected to affect its utility.	
Data Collection Period	The U.S. EPA analysis was based on four NHANES data sets covering 1999-2006.	
Clarity and Completeness		Medium
Accessibility	The U.S. EPA analysis of the NHANES data is unpublished, but available upon request. U.S. EPA (1985) is a U.S. EPA-published report.	
Reproducibility	The methodology was clearly presented; enough information was included to reproduce the results.	
Quality Assurance	Quality assurance of NHANES data was good; quality control of secondary data analysis was not well described.	

Table 7-3. Confidence in Recommendations for Body Surface Area (continued)

General Assessment Factors	Rationale	Rating
Variability and Uncertainty		Medium
Variability in Population	The full distributions were given for total surface area.	
Uncertainty	A source of uncertainty in total surface areas resulted from the limitations in data used to develop the algorithms for estimating total surface from height and weight. Because of the small sample size, there is uncertainty in the body part percentage estimates.	
Evaluation and Review		Medium
Peer Review	The NHANES surveys received a high level of peer review. The U.S. EPA analysis was not published in a peer-reviewed journal.	
Number and Agreement of Studies	There is one key study for total surface area and one key study for the surface area of body parts.	
Overall Rating		**Medium** for Total Surface Area and **Low** for Surface Area of Individual Body Parts

Table 7-4. Recommended Values for Mean Solids Adherence to Skin

	Face	Arms	Hands	Legs	Feet	Source
	mg/cm^2					
Residential (indoors)[a]	-	0.0041	0.011	0.0035	0.010	Holmes et al., 1999
Daycare (indoors & outdoors)[b]	-	0.024	0.099	0.020	0.071	Holmes et al., 1999
Outdoor sports[c]	0.012	0.011	0.11	0.031	-	Kissel et al., 1996a
Indoor sports[d]	-	0.0019	0.0063	0.0020	0.0022	Kissel et al., 1996a
Activities with soil[e]	0.054	0.046	0.17	0.051	0.20	Holmes et al., 1999
Playing in mud[f]	-	11	47	23	15	Kissel et al., 1996a
Playing in sediment[g]	0.040	0.17	0.49	0.70	21	Shoaf et al., 2005

[a] Based on weighted average of geometric mean soil loadings for 2 groups of children (ages 3 to13 years; N = 10) playing indoors.

[b] Based on weighted average of geometric mean soil loadings for 4 groups of daycare children (ages 1 to 6.5 years; N = 21) playing both indoors and outdoors.

[c] Based on geometric mean soil loadings of 6 children (ages ≥8 years) and 1 adult engaging in Tae Kwon Do.

[d] Based on geometric mean soil loadings of 8 children (ages 13 to 15 years) playing soccer.

[e] Based on weighted average of geometric mean soil loadings for gardeners and archeologists (ages 16 to 35 years).

[e] Based on weighted average of geometric mean solids loading of 2 groups of children (age 9 to 14 years; N= 12) playing in mud.

[f] Based on geometric mean solids loading of 9 children (ages 7 to 12 years) playing in tidal flats.

\- = No data.

Table 7-5. Confidence in Recommendations for Solids Adherence to Skin		
General Assessment Factors	Rationale	Rating
Soundness		Medium
Adequacy of Approach	The approach was adequate; the skin rinsing technique is widely employed for purposes similar to this. Small sample sizes (4 to 9 children) were used in the studies; the key studies directly measured soil adherence to skin.	
Minimal (or Defined) Bias	The studies attempted to measure soil adherence for selected activities and conditions. The number of activities and study participants was limited.	
Applicability and Utility		Low
Exposure Factor of Interest	The studies were relevant to the factor of interest; the goal was to determine soil adherence to skin.	
Representativeness	The soil/dust studies were limited to the State of Washington and the sediment study was limited to Rhode Island. The data may not be representative of other locales.	
Currency	The studies were published between 1996 and 2005	
Data Collection Period	Short-term data were collected. Seasonal factors may be important, but have not been studied adequately.	
Clarity and Completeness		Medium
Accessibility	Articles were published in widely circulated journals/reports.	
Reproducibility	The reports clearly describe the experimental methods, and enough information was provided to allow for the study to be reproduced.	
Quality Assurance	Quality control was not well described.	
Variability and Uncertainty		Low
Variability in Population	Variability in soil adherence is affected by many factors including soil properties, activity and individual behavior patterns. Not all age groups were represented in the sample.	
Uncertainty	The estimates are highly uncertain; the soil adherence values were derived from a small number of observations for a limited set of activities.	
Evaluation and Review		Medium
Peer Review	The studies were reported in peer reviewed journal articles.	
Number and Agreement of Studies	There are three key studies that evaluated different activities in children.	
Overall Rating		**Low**

7.3 SURFACE AREA

7.3.1 Key Body Surface Area Studies

7.3.1.1 *U.S. EPA, 1985 - Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments*

The U.S. EPA (1985) summarized the direct measurements of the surface area of children's body parts provided by Boyd (1935) and Van Graan (1969) as a percentage of total surface area. A total of 21 children less than 18 years of age were included. These percentages are presented in Table 7-6. Because of the small sample size, it is unclear how accurately these estimates represent averages for the age groups. Note that the proportion of total body surface area contributed by the head decreases from childhood to adulthood, whereas the proportion contributed by the leg increases.

7.3.1.2 *U.S. EPA Analysis of NHANES 1999-2006 Data*

The U.S. EPA estimated total body surface areas for children in U.S. EPA's standard age categories, using the empirical relationship shown in Appendix 7A and U.S. EPA (1985), and body weight and height data from the 1999-2006 NHANES. NHANES is conducted annually by the Center for Disease Control (CDC), National Center of Health Statistics (NCHS). The survey's target population is the civilian, noninstitutionalized U.S. population. The NHANES 1999-2006 survey was conducted on a nationwide probability sample of approximately 40,000 persons for all ages, of which approximately 20,000 were children. The survey is designed to obtain nationally representative information on the health and nutritional status of the population of the United States through interviews and direct physical examinations. A number of anthropometrical measurements were taken for each participant in the study, including body weight and height. Unit nonresponse to the household interview was 19 percent, and an additional 4 percent did not participate in the physical examinations (including body weight measurements).

The NHANES 1999-2006 survey includes over-sampling of low-income persons, adolescents 12-19 years, persons 60+ years of age, African Americans, and Mexican Americans. Sample data were assigned weights to account both for the disparity in sample sizes for these groups and for other inadequacies in sampling, such as the presence of non-respondents. Because the U.S. EPA utilized four NHANES data sets in its analysis (NHANES 1999-2000, 2001-2002, 2003-2004, and 2005-2006), sample weights were developed for the combined data set in accordance with CDC guidance from the NHANES' web site (http://www.cdc.gov/nchs/about/major/nhanes/nhanes2005-2006/faqs05_06.htm#question%2012).

Table 7-7 presents the mean and percentile estimates of body surface area by age category for male and female children, combined. Tables 7-8 and 7-9 present mean and percentiles of body surface area by age category for male and female children, respectively. An advantage of using the NHANES datasets to derive surface area estimates is that data are available for infants from birth and older. In addition, the NHANES data are nationally representative and remain the principal source of body weight and height data collected nationwide from a large number of subjects. It should be noted that in the NHANES surveys height measurements for children under 2 years of age were based on recumbent length while standing height information was collected for children aged 2 years and older. Some studies have reported differences between recumbent length and standing height measurements for the same individual, ranging from 0.5 to 2 cm, with recumbent length being the larger of the two measurements (Buyken et al., 2005). The use of height data obtained from two different types of height measurements to estimate surface area of children may potentially introduce errors into the estimates.

7.3.2 Relevant Body Surface Area Studies

7.3.2.1 *Phillips et al., 1993 - Distributions of Total Skin Surface Area to Body Weight Ratios*

Phillips et al. (1993) observed a strong correlation (0.986) between body surface area and body weight and studied the effect of using these factors as independent variables in the lifetime average daily dose (LADD) equation (See Chapter 1). The authors suggested that, because of the correlation between these two variables, the use of body surface area to body weight (SA/BW) ratios in human exposure assessments may be more appropriate than treating these factors as independent variables. Direct measurement data from the scientific literature were used to calculate SA/BW ratios for two age groups of children (infants aged 0 to 2 years and children aged 2.1 to 17.9 years). These ratios were calculated by dividing body surface areas by corresponding body weights for the 401 individuals analyzed by Gehan and George (1970) and summarized by U.S. EPA (1985). Distributions of SA/BW ratios were developed, and summary statistics were calculated for the two age groups and the combined data set.

Summary statistics for the two children's age groups are presented in Table 7-10. The shapes of these SA/BW distributions were determined using D'Agostino's test, as described in D'Agostino et al. (1990). The results indicate that the SA/BW ratios for infants are lognormally distributed. SA/BW ratios for children were neither normally nor lognormally distributed. According to Phillips et al. (1993), SA/BW ratios may be used to calculate LADDs by replacing the body surface area factor in the numerator of the LADD equation with the SA/BW ratio and eliminating the body weight factor in the denominator of the LADD equation.

The effect of gender and age on SA/BW distribution was also analyzed by classifying the 401 observations by gender and age. Statistical analyses indicated no significant differences between SA/BW ratios for males and females. SA/BW ratios were found to decrease with increasing age. The advantage of this study is that it studied correlations between surface area and body weight. However, data could not be broken out by finer age categories.

7.3.2.2 *Wong et al., 2000 - Adult Proxy Responses to a Survey of Children's Dermal Soil Contact Activities*

Wong et al. (2000) reported on two surveys that gathered information on activity patterns related to dermal contact with soil. The first of these national phone surveys (also reported on by Garlock et al., 1999) was conducted in 1996 using random digit dialing. Information about children was gathered from adults over the age of 18, and obtained information on 211 children. For older children (those between the ages of 5 and 17 years), information was gathered on their participation in "gardening and yardwork," "outdoor sports," and "outdoor play activities." For children less than 5 years old, information was gathered on "outdoor play activities," including whether the activity occurred on a playground or yard with "bare dirt or mixed grass and dirt" surfaces. Information on the types of clothing worn while participating in these play activities during warm weather months (April though October) was obtained. The results of this survey indicate that most children wore short pants, a dress or skirt, short sleeve shirts, no socks, and leather or canvas shoes during the outdoor play activities of interest. Using the survey data on clothing and total body surface area data from U.S. EPA (1985), estimates were made of the skin area exposed (expressed as percentages of total body surface area) associated with various age ranges and activities. These estimates are provided in Table 7-11.

7.4 ADHERENCE OF SOLIDS TO SKIN

7.4.1 Key Adherence of Solids to Skin Studies

7.4.1.1 *Kissel et al., 1996a - Field Measurements of Dermal Soil Loading Attributable to Various Activities: Implications for Exposure Assessment*

Kissel et al. (1996a) collected direct measurements of soil loading on the surface of the skin of volunteers, before and after activities expected to result in soil contact. Soil adherence associated with the following indoor and outdoor activities were estimated: greenhouse gardening, tae kwon do karate, soccer, rugby, reed gathering, irrigation installation, truck farming, and playing in mud. Skin surface areas monitored included hands, forearms, lower legs, faces and/or feet (Kissel et al., 1996a).

Several of the activities studied by Kissel et al. (1996a) involved children, as shown in Table 7-12. A group of young male soccer players (Soccer) was monitored before and after 40 minutes of practice on a field consisting of half grass and half bare earth. Six children were monitored after 10 and 20 minutes of playing in the mud at a lake with an exposed shoreline (Kids-in-mud No. 1 and No. 2). For indoor activities, soil loadings were estimated from six children and one adult practicing tae kwon do (Tae Kwon Do); the activity lasted 90 minutes including a 30-min warm up. Information on activity duration, sample size and clothing worn by participants is provided in Table 7-12. The subjects' body surfaces (forearms, hands, lower legs for all sample groups; faces and/or feet pairs in some sample groups) were washed before and after the monitored activities. Paired samples were pooled into single ones. The mass recovered was converted to soil loading using allometric models of surface area.

Geometric means for post-activity soil adherence by activity and body region for the four groups of volunteers evaluated are presented in Table 7-13. Children playing in the mud had the highest soil loadings among the groups evaluated. The results also indicate that, in general, the amount of soil adherence to the hands is higher than for other parts of the body during the same activity.

An advantage of this study is that it provides information on soil adherence to various body parts resulting from unscripted activities. However, the study authors noted that, because the activities were unstaged, "control of variables such as specific behaviors within each activity, clothing worn by participants, and duration of activity was limited." In addition, soil adherence values were estimated based on a small number of observations and very young children and indoor activities were under-represented in the study.

7.4.1.2 *Holmes et al., 1999 - Field Measurements of Dermal Loadings in Occupational and Recreational Activities*

Holmes et al. (1999) collected pre- and post-activity soil loadings on various body parts of individuals within groups engaged in various occupational and recreational activities. These groups included: children at a daycare center (Daycare Kids), children playing indoors in a residential setting (Indoor Kids), individuals (aged 16 to 35) removing historical artifacts from a site (Archeologists), and individuals (aged 16 to 35) performing gardening work (Gardeners). This study was conducted as a follow up to previous field sampling of soil adherence on individuals participating in various activities (Kissel et al., 1996a). For this round of sampling, soil loading data were collected utilizing the same methods used and described in Kissel et al. (1996a). Information regarding the groups studied and their observed activities is presented in Table 7-12.

The daycare children studied were all at one location, and measurements were taken on three different days. The children freely played both indoors in the house and outdoors in the backyard. The backyard was described as having a grass lawn, shed, sand box, and wood chip box. In this setting, the children engaged in typical activities including: playing with toys and each other, wrestling, sleeping, and eating. The number of children within each day's group and the clothing worn is described in Table 7-12. The five children measured on the first day were washed first thing in the morning to establish a preactivity level. They were next washed at noon to determine the postactivity soil loading for the morning (Daycare Kids No. 1a). The same children were washed once again at the close of the day for measurement of soil adherence from the afternoon play activities (Daycare Kids No. 1b). For the second observation day (Daycare Kids No. 2), postactivity data were collected for five children. All the activities on this day occurred indoors. For the third daycare group (Daycare Kids No. 3), four children were studied.

On two separate days, children playing indoors in a home environment were monitored. The first group (Indoor Kids No. 1) had four children while the second group (Indoor Kids No. 2) had six children. The play area was described by the authors as being primarily carpeted. The clothing worn by the children within each day's group is described in Table 7-12.

Seven individuals (Archeologists), ages 16 to 35 years, were monitored while excavating, screening, sorting, and cataloging historical artifacts from an ancient Native American site during a single event. Eight volunteers (Gardeners), ages 16 to 35 years, were monitored while performing gardening activities (i.e., weeding, pruning, digging small irrigation trenches, picking and cleaning fruit). The clothing worn by these groups is described in Table 7-12.

The geometric means and standard deviations of the postactivity soil adherence for each group of individuals and for each body part are summarized in Table 7-13. According to the authors, variations in the soil loading data from the daycare participants reflect differences in the weather and access to the outdoors.

An advantage of this study is that it provides a supplement to soil loading data collected in a previous round of studies (Kissel et al., 1996a). Also, the data support the assumption that hand loading can be used as a conservative estimate of soil loading on other body surfaces for the same activity. The activities studied represent normal child play both indoors and outdoors, as well as different combinations of clothing. The small number of participants is a disadvantage of this study. Also, the children studied and the activity setting may not be representative of the U.S. population.

7.4.1.3 *Shoaf et al., 2005 - Child Dermal Sediment Loads Following Play in a Tide Flat*

The purpose of this study was to obtain sediment adherence data for children playing in a tidal flat (Shoreline Play). The study was conducted on one day in late September 2003 at a tidal flat in Jamestown, Rhode Island. Nine subjects (three females and six males) ages 7 to 12 years old participated in the study. Information on activity duration, sample size and clothing worn by participants is provided in Table 7-12. Participants' parents completed questionnaires regarding their child's typical activity patterns during tidal flat play, exposure frequency and duration, clothing choices, bathing practices and clothes laundering.

This study reported direct measurements of sediment loadings on five body parts (face, forearms, hands, lower legs, and feet) after play in a tide flat. Each of nine subjects participated in two timed sessions and pre- and post-activity sediment loading data were collected. Geometric mean (geometric standard deviations) dermal loadings (mg/cm^2) on the face, forearm, hands, lower legs, and feet for the combined sessions, as shown in Table 7-13, were 0.04 (2.9), 0.17 (3.1), 0.49 (8.2), 0.70 (3.6) and 21 (1.9), respectively.

The primary advantage of this study is that it provides adherence data specific to children and sediments which had previously been largely unavailable. Results will be useful to risk assessors considering exposure scenarios involving child activities at a coastal shoreline or tidal flat. The limited number of participants (9) and sampling during just one day and at one location, make extrapolation to other situations uncertain.

7.4.2 Relevant Adherence of Solids to Skin Studies

7.4.2.1 *Kissel et al., 1996b - Factors Affecting Soil Adherence to Skin in Hand-press Trials: Investigation of Soil Contact and Skin Coverage*

Kissel et al. (1996b) conducted soil adherence experiments using five soil types obtained locally in the Seattle, WA, area: sand, 2 types of loamy sand, sandy loam, and silt loam. All soils were analyzed by hydrometer (settling velocity) to determine composition. Clay content ranged from 0.5 to 7.0 percent. Organic carbon content, determined by combustion, ranged from 0.7 to 4.6 percent. Soils were dry-sieved to obtain particle size ranges of <150, 150-250, and >250 µm. For each soil type, the amount of soil adhering to an adult female hand, using both sieved and unsieved soils, was determined by measuring the soil sample weight before and after the hand was pressed into a pan containing the test soil. Loadings were estimated by dividing the recovered soil mass by total hand area, although loading occurred primarily on only one side of the hand. Results showed that generally, soil adherence to hands was directly correlated with moisture content, inversely correlated with particle size, and independent of clay content or organic carbon content. The advantage of this study is that it provides information on how soil type can affect adherence to the skin. However, the soil adherence data are for a single subject and the data are limited to five soil samples.

7.4.2.2 *Kissel et al., 1998 - Investigation of Dermal Contact with Soil in Controlled Trials*

Kissel et al. (1998) measured dermal exposure to soil from staged activities conducted in a greenhouse. A fluorescent marker was mixed in soil so that soil contact for a particular skin surface area could be identified. The subjects, which included a group of children, were video-imaged under a long-wave ultraviolet (UV) light before and after soil contact. In this manner, soil contact on hands, forearms, lower legs, and faces was assessed by presence of fluorescence. In addition to fluorometric data, gravimetric measurements for preactivity and postactivity were obtained from the different body parts examined.

The studied group of children played for 20 minutes in a soil bed of varying moisture content representing wet and dry soils. Three trials with children were conducted, each representing a different clothing/soil moisture scenario. For wet soils, both combinations of long sleeves and long pants, and short sleeves and short pants were tested. For dry soil, only short sleeves and short pants were worn during play. Clothing was laundered after each trial. The parameters describing each of these trials are summarized in Table 7-14. Before each trial, each child was washed in order to obtain a preactivity or background gravimetric measurement.

For wet soil, postactivity fluorescence results indicated that the hand had a much higher fractional coverage than other body surfaces (see Figure 7-1). No fluorescence was detected on the forearms or lower legs of children dressed in long sleeves and pants. As shown in Figure 7-2, postactivity gravimetric measurements showed higher soil loading on hands and much lower amounts on other body surfaces, as was observed with fluorescence data. According to Kissel et al. (1998), the relatively low loadings observed on non-hand body parts may be a result of a more limited area of contact for the body part rather than lower localized loadings. The highest soil loading observed was a geometric mean dermal loading of 0.7 mg/cm^2, found on the children's hands following play in wet soil. Mean loadings were lower on hands in the dry soil trial and on lower legs, forearms, and faces in both the wet and dry soil trials. Higher loadings were observed for all body surfaces with the higher moisture content soils.

This report is valuable in showing soil loadings from soils of different moisture content and providing evidence that dermal exposure to soil is not uniform for various body surfaces. This study also provides some evidence of the protective effect of clothing. Disadvantages of the study include the small number of study participants and a short activity duration.

7.5 REFERENCES FOR CHAPTER 7

Boyd, E. (1935) The growth of the surface area of the human body. Minneapolis, MN: University of Minnesota Press.

Buyken, A.E.; Hahn, S.; Kroke, A. (2005) Differences between recumbent length and stature measurement in groups of 2- and 3-y-old children and its relevance for the use of European body mass index references. Int J Obes 29:24-28.

Cohen-Hubal, E.A.; Sheldon, L.S.; Burke, J.M.; McLundy, T.R.; Berry, M.R.; Rigas, M.L.; Zartarian, V.G.; Freeman, N.C.G. (1999) Children's exposure assessment: A review of factors influencing children's exposure, and the data available to characterize and assess that exposure. Research Triangle Park, NC: U.S. EPA, National Exposure Research Laboratory.

D'Agostino, R.B.; Belanger, A.; D'Agostino, R.B. Jr. A suggestion for using powerful and informative tests of normality. The American Statistician 44(4):316-321.

Dubois, D.; Dubois, E.F. (1916) A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med 17:863-871.

Garlock, T.J.; Shirai, J.H.; Kissel, J.C. (1999) Adult responses to a survey of soil contact related behaviors. J Expo Anal Environ Epidemiol 9:134-142.

Gehan, E.; George, G.L. (1970) Estimation of human body surface area from height and weight. Cancer Chemother Rep 54(4):225-235.

George, S.L.; Gehan, E.A.; Haycock, G.B.; Schwartz, G.J. (1979) Letters to the editor. J Pediatr 94(2):342.

Holmes, Jr., K.K.; Shirai, J.H.; Richter, K.Y.; Kissel, J.C. (1999) Field measurement of dermal loadings in occupational and recreational activities. Environ Res Section A 80:148-157.

Kissel, J.C.; Richter, K.; Fenske, R. (1996a) Field measurements of dermal soil loading attributable to various activities: Implications for exposure assessment. Risk Anal 16(1):116-125.

Kissel, J.C.; Richter, K.; Duff, R.; Fenske, R. (1996b) Factors affecting soil adherence to skin in hand-press trials. Bull Environ Contam Toxicol 56:722-728.

Kissel, J.C.; Shirai, J.H.; Richter, K.Y.; Fenske, R.A. (1998) Investigation of dermal contact with soil in controlled trials. J Soil Contam 7(6): 737-752.

Phillips, L.J.; Fares, R.J.; Schweer, L.G. (1993) Distributions of total skin surface area to body weight ratios for use in dermal exposure assessments. J Expo Anal Environ Epidemiol 3(3):331-338.

Shoaf, M.B.; Shirai, J.H.; Kedan, G.; Schaum, J.; Kissel, J.C. (2005) Child dermal sediment loads following play in a tide flat. J Expo Anal Environ Epidemiol 15:407-412.

U.S. EPA (1985) Development of statistical distributions or ranges of standard factors used in exposure assessments. Washington, DC: Office of Research and Development, Office of Health and Environmental Assessment. EPA 600/8-85-010. Available from: NTIS, Springfield, VA. PB85-242667.

U.S. EPA (1992a) Guidelines for exposure assessment. Federal Register. FR 57:104:22888-22938. May 29, 1992.

U.S. EPA (1992b) Dermal exposure assessment: principles and applications. Washington, DC: Office of Research and Development, Office of Health and Environmental Assessment/OHEA. U.S. EPA/600/8-9-91.

U.S. EPA (2004) Risk assessment guidance for Superfund (RAGS): Volume I, Human Health

Evaluation Manual, Part E. Washington, DC. EPA/540/R/99/005.

U.S. EPA (2005) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants. U.S. Environmental Protection Agency, Washington, DC. EPA/630/P-03/003F. November 2005.

Van Graan, C.H. (1969) The determination of body surface area. S Afr Med J 43(31):952-959.

Wong, E.Y.; Shirai, J.H.; Garlock, T.J.; Kissel, J.C. (2000) Adult proxy responses to a survey of children's dermal soil contact activities. J Expo Anal Environ Epidemiol 10:509-517.

Table 7-6. Percentage of Total Body Surface Area by Body Part For Children
Males and Females Combined

Age (years)	N M:F	Percent of Total											
		Head		Trunk		Arms		Hands		Legs		Feet	
		Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max
< 1	2:0	18.2	18.2-18.3	35.7	34.8-36.6	13.7	12.4-15.1	5.3	5.2-5.4	20.6	18.2-22.9	6.5	6.5-6.6
1 < 2	1:1	16.5	16.5-16.5	35.5	34.5-36.6	13.0	12.8-13.1	5.7	5.6-5.8	23.1	22.1-24.0	6.3	5.8-6.7
2 < 3	1:0	14.2		38.5		11.8		5.3		23.2		7.1	
3 < 4	0:5	13.6	13.3-14.0	31.9	29.9-32.8	14.4	14.2-14.7	6.1	5.8-6.3	26.8	26.0-28.6	7.2	6.8-7.9
4 < 5	1:3	13.8	12.1-15.3	31.5	30.5-32.4	14.0	13.0-15.5	5.7	5.2-6.6	27.8	26.0-29.3	7.3	6.9-8.1
5 < 6													
6 < 7	1:0	13.1		35.1		13.1		4.7		27.1		6.9	
7 < 8													
8 < 9													
9 < 10	0:2	12.0	11.6-12.5	34.2	33.4-34.9	12.3	11.7-12.8	5.3	5.2-5.4	28.7	28.5-28.8	7.6	7.4-7.8
10 < 11													
11 < 12													
12 < 13	1:0	8.7		34.7		13.7		5.4		30.5		7.0	
13 <14	1:0	10.0		32.7		12.1		5.1		32.0		8.0	
14 < 15													
15 < 16													
16 < 17	1:0	8.0		32.7		13.1		5.7		33.6		6.9	
17 < 18	1:0	7.6		31.7		17.5		5.1		30.8		7.3	

N = Number of subjects, (M:F = males:females).
Min. = Minimum percent.
Max. = Maximum percent.

Source: U.S. EPA, 1985.

Table 7-7. Mean and Percentile Skin Surface Area (m^2) Derived from U.S. EPA Analysis of NHANES 1999-2006 Males and Females Combined											
Age Group	N	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	154	0.29	0.24	0.25	0.26	0.27	0.29	0.31	0.31	0.33	0.34
1 to <3 months	281	0.33	0.27	0.29	0.29	0.31	0.33	0.35	0.37	0.37	0.38
3 to <6 months	488	0.38	0.33	0.34	0.35	0.36	0.38	0.40	0.42	0.43	0.44
6 to <12 months	923	0.45	0.38	0.39	0.40	0.42	0.45	0.48	0.49	0.50	0.51
1 to <2 years	1159	0.53	0.45	0.46	0.47	0.49	0.53	0.56	0.58	0.59	0.61
2 to <3 years	1122	0.61	0.52	0.54	0.55	0.57	0.61	0.64	0.67	0.68	0.70
3 to <6 years	2303	0.76	0.61	0.64	0.66	0.68	0.74	0.81	0.85	0.89	0.95
6 to <11 years	3590	1.08	0.81	0.85	0.88	0.93	1.05	1.21	1.31	1.36	1.48
11 to <16 years	5294	1.59	1.19	1.25	1.31	1.4	1.57	1.75	1.86	1.94	2.06
16 to <21 years	4843	1.84	1.47	1.53	1.58	1.65	1.80	1.99	2.10	2.21	2.33

N = Number of observations.

Source: U.S. EPA Analysis of NHANES 1999-2006 data.

Table 7-8. Mean and Percentile Skin Surface Area (m^2) Derived from U.S. EPA Analysis of NHANES 1999-2006 Males											
Age Group	N	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	85	0.29	0.24	0.25	0.26	0.27	0.29	0.31	0.33	0.34	0.36
1 to <3 months	151	0.33	0.28	0.29	0.30	0.31	0.34	0.36	0.37	0.37	0.38
3 to <6 months	255	0.39	0.34	0.35	0.36	0.37	0.39	0.41	0.42	0.43	0.44
6 to <12 months	471	0.45	0.39	0.41	0.42	0.43	0.46	0.48	0.49	0.50	0.51
1 to <2 years	620	0.53	0.46	0.47	0.48	0.50	0.53	0.57	0.58	0.59	0.62
2 to <3 years	548	0.62	0.54	0.56	0.56	0.58	0.62	0.65	0.67	0.68	0.70
3 to <6 years	1150	0.76	0.61	0.64	0.66	0.69	0.75	0.82	0.86	0.89	0.95
6 to <11 years	1794	1.09	0.82	0.86	0.89	0.94	1.06	1.21	1.29	1.34	1.46
11 to <16 years	2593	1.61	1.17	1.23	1.28	1.39	1.60	1.79	1.90	1.99	2.12
16 to <21 years	2457	1.94	1.61	1.66	1.7	1.76	1.91	2.08	2.22	2.30	2.42

N = Number of observations.

Source: U.S. EPA Analysis of NHANES 1999-2006 data.

Table 7-9. Mean and Percentile Skin Surface Area (m^2) Derived from U.S. EPA Analysis of NHANES 1999-2006
Females

Age Group	N	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	69	0.28	0.24	0.25	0.26	0.27	0.28	0.30	0.30	0.31	0.33
1 to <3 months	130	0.32	0.27	0.28	0.29	0.30	0.31	0.35	0.36	0.37	0.37
3 to <6 months	233	0.38	0.32	0.33	0.34	0.35	0.38	0.40	0.40	0.41	0.43
6 to <12 months	452	0.44	0.38	0.39	0.40	0.41	0.44	0.47	0.48	0.49	0.51
1 to <2 years	539	0.52	0.44	0.46	0.47	0.48	0.52	0.56	0.57	0.58	0.59
2 to <3 years	574	0.60	0.51	0.53	0.54	0.56	0.59	0.63	0.66	0.67	0.70
3 to <6 years	1153	0.75	0.61	0.64	0.66	0.68	0.74	0.80	0.84	0.88	0.94
6 to <11 years	1796	1.08	0.80	0.85	0.87	0.92	1.04	1.21	1.33	1.39	1.51
11 to <16 years	2701	1.57	1.20	1.28	1.34	1.42	1.55	1.69	1.8	1.88	2.00
16 to <21 years	2386	1.73	1.42	1.47	1.51	1.57	1.69	1.85	1.98	2.06	2.17

N = Number of observations.

Source: U.S. EPA Analysis of NHANES 1999-2006 data.

Table 7-10. Descriptive Statistics For Surface Area/Body Weight (SA/BW) Ratios (m^2/kg)

Age (years)	Mean	Range Min-Max	SD	SE	Percentiles						
					5th	10th	25th	50th	75th	90th	95th
0 to 2	0.064	0.042-0.114	0.011	0.001	0.047	0.051	0.056	0.062	0.072	0.0784	0.0846
2.1 to 17.9	0.042	0.027-0.067	0.008	0.001	0.029	0.033	0.038	0.042	0.045	0.0501	0.0594

SD = Standard deviation.
SE = Standard error of the mean.

Source: Phillips et al., 1993.

Table 7-11. Estimated Skin Surface Exposed During Warm Weather Outdoor Activities

	Skin Area Exposed (% of total body surface area)		
	Play	Gardening/yardwork	Organized Team Sport
Age (years)	<5	5-17	5-17
N	41	437	65
Mean	38.0	33.8	29.0
Median	36.5	33.0	30.0
SD	6.0	8.3	10.5

N = Number of observations.
SD = Standard deviation.

Source: Wong et al., 2000.

Table 7-12. Summary of Field Studies

Activity	Month	Event[a] (hrs)	N	M	F	Age (years)	Conditions	Clothing	Study
Indoor									
Tae Kwon Do	Feb.	1.5	7	6	1	8-42	Carpeted floor	All in long sleeve-long pants martial arts uniform, sleeves rolled back, barefoot	Kissel et al., 1996a
Indoor Kids No. 1	Jan.	2	4	3	1	6-13	Playing on carpeted floor	3 of 4 short pants, 2 of 4 short sleeves, socks, no shoes	Holmes et al., 1999
Indoor Kids No. 2	Feb.	2	6	4	2	3-13	Playing on carpeted floor	5 of 6 long pants, 5 of 6 long sleeves, socks, no shoes	
Daycare Kids No. 1a	Aug.	3.5	6	5	1	1-6.5	Indoors: linoleum surface; Outdoors: grass, bare earth, barked area	4 of 6 in long pants, 5 of 6 short sleeves, socks, shoes	
Daycare Kids No. 1b	Aug.	4	6	5	1	1-6.5	Indoors: linoleum surface; Outdoors: grass, bare earth, barked area	4 of 6 long pants, 5 of 6 short sleeves, 3 of 6 barefoot all afternoon, others barefoot half the afternoon	
Daycare Kids No. 2[b]	Sept.	8	5	4	1	1-4	Indoors: low napped carpeting, linoleum surfaces	4 of 5 long pants, 3 of 5 long sleeves, all barefoot for part of the day	
Daycare Kids No. 3	Nov.	8	4	3	1	1-4.5	Indoors: linoleum surface, Outside: grass, bare earth, barked area	All long pants, 3 of 4 long sleeves, socks and shoes	
Outdoor									
Soccer	Nov.	0.67	8	8	0	13-15	Half grass-half bare earth	6 of 8 long sleeves, 4 of 8 long pants, 3 of 4 short pants and shin guards	Kissel et al., 1996a
Kids-in-mud No. 1	Sept.	0.17	6	5	1	9-14	Lake shoreline	All in short sleeve T-shirts, shorts, barefoot	
Kids-in-mud No. 2	Sept.	0.33	6	5	1	9-14	Lake shoreline	All in short sleeve T-shirts, shorts, barefoot	
Gardeners	Aug.	4	8	1	7	16-35	Weeding, pruning, digging a trench	6 of 8 long pants, 7 of 8 short sleeves, 1 sleeveless, socks, shoes, intermittent use of gloves	Holmes et al., 1999
Archeologists	July	11.5	7	3	4	16-35	Digging with trowel, screening dirt, sorting	6 of 7 short pants, all short sleeves, 3 no shoes or socks, 2 sandals	
Shoreline Play	Sept.	0.33-1.0	9	6	3	7-12	Tidal flat	No shirt or short sleeve T-shirts, shorts, barefoot	Shoaf et al., 2005

[a] Event duration.
[b] Activities were confined to the house.
N = Number of subjects.
M = Male.
F = Female.

Table 7-13. Geometric Mean and Geometric Standard Deviations of Solids Adherence by Activity and Body Region[a]

Activity	N	Post-activity Dermal Solids Loadings (mg/cm^2)				
		Hands	Arms	Legs	Faces	Feet
Indoor						
Tae Kwon Do	7	0.0063 1.9	0.0019 4.1	0.0020 2.0		0.0022 2.1
Indoor Kids No. 1	4	0.0073 1.9	0.0042 1.9	0.0041 2.3		0.012 1.4
Indoor Kids No. 2	6	0.014 1.5	0.0041 2.0	0.0031 1.5		0.0091 1.7
Daycare Kids No. 1a	6	0.11 1.9	0.026 1.9	0.030 1.7		0.079 2.4
Daycare Kids No. 1b	6	0.15 2.1	0.031 1.8	0.023 1.2		0.13 1.4
Daycare Kids No. 2	5	0.073 1.6	0.023 1.4	0.011 1.4		0.044 1.3
Daycare Kids No. 3	4	0.036 1.3	0.012 1.2	0.014 3.0		0.0053 5.1
Outdoor						
Soccer	8	0.11 1.8	0.011 2.0	0.031 3.8	0.012 1.5	
Kids-in-mud No. 1	6	35 2.3	11 6.1	36 2.0		24 3.6
Kids-in-mud No. 2	6	58 2.3	11 3.8	9.5 2.3		6.7 12.4
Gardeners	8	0.20 1.9	0.050 2.1	0.072 --	0.058 1.6	0.17 --
Archeologists	7	0.14 1.3	0.041 1.9	0.028 4.1	0.050 1.8	0.24 1.4
Shoreline Play	9	0.49 8.2	0.17 3.1	0.70 3.6	0.04 2.9	21 1.9

[a] Means are presented above the standard deviations. The standard deviations generally exceed the means by large amounts indicating high variability in the data.

N = Number of subjects.

Sources: Kissel et al., 1996a; Holmes et al., 1999; Shoaf et al., 2005.

Table 7-14. Summary of Controlled Greenhouse Trials - Children Playing

Activity	Ages (years)	Duration (min)	Soil Moisture (%)	Clothing[a]	N	Male	Female
Playing	8 to 12	20	17-18	L	4	3	1
			16-18	S	9	5	4
			3-4	S	5	3	2

[a] L, long sleeves and long pants; S, short sleeves and short pants.
N = Number of subjects.

Source: Kissel et al., 1998.

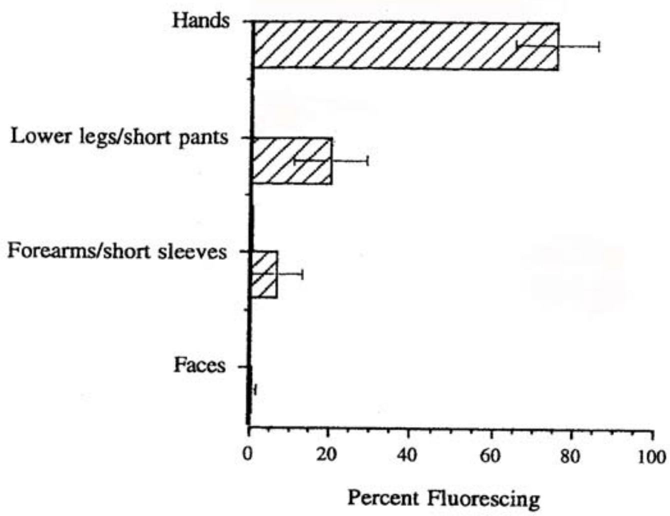


Figure 7-1. Skin Coverage as Determined by Fluorescence vs. Body Part for Children Playing in Wet Soils (bars are arithmetic means and corresponding 95% confidence intervals)

Source: Kissel et al., 1998.

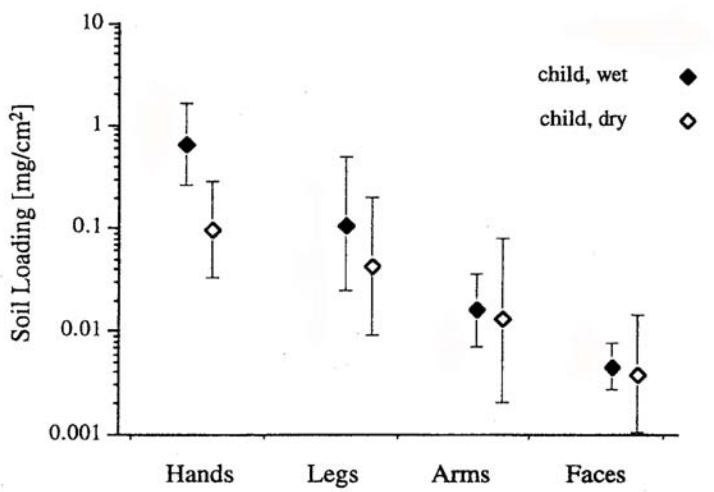


Figure 7-2. Gravimetric Loading vs. Body Part for Children Playing in Wet and Dry Soils (symbols are geomettric means and 95% confidence intervals)

Source: Kissel et al., 1998.

APPENDIX 7A

FORMULAS FOR TOTAL BODY SURFACE AREA

APPENDIX 7A - FORMULAS FOR TOTAL BODY SURFACE AREA

Most formulas for estimating surface area (SA) relate height to weight to surface area. The following formula was proposed by Gehan and George (1970):

$$SA = KW^{2/3} \quad \text{(Eqn. 7A-1)}$$

where:

SA = surface area in square meters;
W = weight in kg; and
K = constant.

While the above equation has been criticized because human bodies have different specific gravities and because the surface area per unit volume differs for individuals with different body builds, it gives a reasonably good estimate of surface area.

A formula published in 1916 that still finds wide acceptance and use is that of DuBois and DuBois (1916). Their model can be written:

$$SA = a_0 H^{a_1} W^{a_2} \quad \text{(Eqn. 7A-2)}$$

where:

SA = surface area in square meters;
H = height in centimeters; and
W = weight in kg.

The values of a_0 (0.007182), a_1 (0.725), and a_2 (0.425) were estimated from a sample of only nine individuals for whom surface area was directly measured. Boyd (1935) stated that the Dubois formula was considered a reasonably adequate substitute for measuring surface area. Nomograms for determining surface area from height and mass presented in Volume I of the Geigy Scientific Tables (1981) are based on the DuBois and DuBois formula. In addition, a computerized literature search conducted for this report identified several articles written in the last 10 years in which the DuBois and DuBois formula was used to estimate body surface area.

Boyd (1935) developed new constants for the DuBois and DuBois model based on 231 direct measurements of body surface area found in the literature. These data were limited to measurements of surface area by coating methods (122 cases), surface integration (93 cases), and triangulation (16 cases). The subjects were Caucasians of normal body build for whom data on weight, height, and age (except for exact age of adults) were complete. Resulting values for the constants in the DuBois and DuBois model were a_0 = 0.01787, a_1 = 0.500, and a_2 = 0.4838. Boyd also developed a formula based exclusively on weight, which was inferior to the DuBois and DuBois formula based on height and weight.

Gehan and George (1970) proposed another set of constants for the DuBois and DuBois model. The constants were based on a total of 401 direct measurements of surface area, height, and weight of all postnatal subjects listed in Boyd (1935). The methods used to measure these subjects were coating (163 cases), surface integration (222 cases), and triangulation (16 cases).

Gehan and George (1970) used a least-squares method to identify the values of the constants. The values of the constants chosen are those that minimize the sum of the squared percentage errors of the predicted values of surface area. This approach was used because the importance of an error of 0.1 square meter depends on the surface area of the individual. Gehan and George (1970) used the 401 observations summarized in Boyd (1935) in the least-squares method. The following estimates of the constants were obtained: a_0 = 0.02350, a_1 = 0.42246, and a_2 = 0.51456. Hence, their equation for predicting SA is:

$$SA = 0.02350\ H^{0.42246} W^{0.51456} \quad \text{(Eqn. 7A-3)}$$

or in logarithmic form:

$$\ln SA = -3.75080 + 0.42246 \ln H + 0.51456 \ln W \quad \text{(Eqn. 7A-4)}$$

where:

SA = surface area in square meters;
H = height in centimeters; and
W = weight in kg.

This prediction explains more than 99 percent of the variations in surface area among the 401 individuals measured (Gehan and George, 1970).

The equation proposed by Gehan and George (1970) was determined by the U.S. EPA (1985) as the best choice for estimating total body surface area. However, the paper by Gehan and George gave insufficient information to estimate the standard error about the regression. Therefore, the 401 direct measurements of children and adults (i.e., Boyd, 1935) were reanalyzed in U.S. EPA (1985) using the formula of Dubois and Dubois (1916) and the Statistical Processing System (SPS) software package to obtain the standard error.

The Dubois and Dubois (1916) formula uses weight and height as independent variables to predict total body surface area (SA), and can be written as:

$$SA_i = a_0 H_i^{a_1} W_i^{a_2} e_i \qquad \text{(Eqn. 7A-5)}$$

or in logarithmic form:

$$\ln(SA)_i = \ln a_0 + a_1 \ln H_i + a_2 \ln W_i + \ln e_i \qquad \text{(Eqn. 7A-6)}$$

where:

SA_i	=	surface area of the i-th individual (m^2);
H_i	=	height of the i-th individual (cm);
W_i	=	weight of the i-th individual (kg);
a_0, a_1, and a_2 and	=	parameters to be estimated;
e_i	=	a random error term with mean zero and constant variance.

Using the least squares procedure for the 401 observations, the following parameter estimates and their standard errors were obtained:

a_0 = -3.73 (0.18), a_1 = 0.417 (0.054), a_2 = 0.517 (0.022)

The model is then:

$$SA = 0.0239\, H^{0.417} W^{0.517} \qquad \text{(Eqn. 7A-7)}$$

or in logarithmic form:

$$\ln SA = 3.73 + 0.417 \ln H + 0.517 \ln W \qquad \text{(Eqn. 7A-8)}$$

with a standard error about the regression of 0.00374. This model explains more than 99 percent of the total variation in surface area among the observations, and is identical to two significant figures with the model developed by Gehan and George (1970).

When natural logarithms of the measured surface areas are plotted against natural logarithms of the surface predicted by the equation, the observed surface areas are symmetrically distributed around a line of perfect fit, with only a few large percentage deviations. Only five subjects differed from the measured value by 25 percent or more. Because each of the five subjects weighed less than 13 pounds, the amount of difference was small. Eighteen estimates differed from measurements by 15 to 24 percent. Of these, 12 weighed less than 15 pounds each, 1 was overweight (5 feet 7 inches, 172 pounds), 1 was very thin (4 feet 11 inches, 78 pounds), and 4 were of average build. Since the same observer measured surface area for these 4 subjects, the possibility of some bias in measured values cannot be discounted (Gehan and George 1970).

Gehan and George (1970) also considered separate constants for different age groups: less than 5 years old, 5 years old to less than 20 years old, and greater than 20 years old. The different values for the constants are presented in Table 7A-1.

The surface areas estimated using the parameter values for all ages were compared to surface areas estimated by the values for each age group for subjects at the 3rd, 50th, and 97th percentiles of weight and height. Nearly all differences in surface area estimates were less than 0.01 square meter, and the largest difference was 0.03 m^2 for an 18-year-old at the 97th percentile. The authors concluded that there is no advantage in using separate values of a_0, a_1, and a_2 by age interval.

Haycock et al. (1978) without knowledge of the work by Gehan and George (1970), developed values for the parameters a_0, a_1, and a_2 for the DuBois and DuBois model. Their interest in making the DuBois and DuBois model more accurate resulted from their work in pediatrics and the fact that DuBois and DuBois (1916) included only one child in their study group, a severely undernourished girl who weighed only 13.8 pounds at age 21 months. Haycock et al. (1978) used their own geometric method for estimating surface area from 34 body measurements for 81 subjects. Their study included newborn infants (10 cases), infants (12 cases), children (40 cases), and adult members of the medical and secretarial staffs of 2 hospitals (19 cases). The subjects all had grossly normal body structure, but the sample included subjects of widely varying physique ranging from thin to obese. Black, Hispanic, and white children were included in their sample. The values of the model parameters were solved for the relationship between surface area and height and weight by multiple regression analysis. The least squares best fit for this equation yielded the following values for the three coefficients: a_0 = 0.024265, a_1 = 0.3964, and a_2 = 0.5378. The result was the following equation for estimating surface area:

$$SA = 0.024265 H^{0.3964} W^{0.5378} \qquad \text{(Eqn. 7A-9)}$$

expressed logarithmically as:

$$\ln SA = \ln 0.024265 + 0.3964 \ln H + 0.5378 \ln W \qquad \text{(Eqn. 7A-10)}$$

The coefficients for this equation agree remarkably with those obtained by Gehan and George (1970) for 401 measurements.

George et al. (1979) agree that a model more complex than the model of DuBois and DuBois for estimating surface area is unnecessary. Based on samples of direct measurements by Boyd (1935) and Gehan and George (1970), and samples of geometric estimates by Haycock et al. (1978), these authors have obtained parameters for the DuBois and DuBois model that are different than those originally postulated in 1916. The DuBois and DuBois model can be written logarithmically as:

$$\ln SA = \ln a_0 + a_1 \ln H + a_2 \ln W \qquad \text{(Eqn. 7A-11)}$$

The values for a_0, a_1, and a_2 obtained by the various authors discussed in this section are presented in Table 7A-2.

The agreement between the model parameters estimated by Gehan and George (1970) and Haycock et al. (1978) is remarkable in view of the fact that Haycock et al. (1978) were unaware of the previous work. Haycock et al. (1978) used an entirely different set of subjects, and used geometric estimates of surface area rather than direct measurements. It has been determined that the Gehan and George model is the formula of choice for estimating total surface area of the body since it is based on the largest number of direct measurements.

Sendroy and Cecchini (1954) proposed a method of creating a *nomogram*, a diagram relating height and weight to surface area. However, they do not give an explicit model for calculating surface area. The nomogram was developed empirically based on 252 cases, 127 of which were from the 401 direct measurements reported by Boyd (1935). In the other 125 cases the surface area was estimated using the linear method of DuBois and DuBois (1916). Because the Sendroy and Cecchini method is graphical, it is inherently less precise and less accurate than the formulas of other authors discussed above.

REFERENCES FOR APPENDIX 7A

Boyd, E. (1935) The growth of the surface area of the human body. Minneapolis, MN: University of Minnesota Press.

Dubois, D.; Dubois, E.F. (1916) A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med 17:863-871.

Gehan, E.; George, G.L. (1970) Estimation of human body surface area from height and weight. Cancer Chemother Rep 54(4):225-235.

Geigy Scientific Tables (1981) Nomograms for determination of body surface area from height and mass. Lentner, C. (ed.). CIBA-Geigy Corporation, West Caldwell, NJ. pp. 226-227.

Haycock, G.B.; Schwartz, G.J.; Wisotsky, D.H. (1978) Geometric method for measuring body surface area: A height-weight formula validated in infants, children, and adults. J Pediatr 93(1):62-66.

Sendroy, J.; Cecchini, L.P. (1954) Determination of human body surface area from height and weight. J Appl Physiol 7(1):3-12.

Table 7A-1. Estimated Parameter Values for Different Age Intervals

Age Group	Number of persons	a_0	a_1	a_2
All ages	401	0.02350	0.42246	0.51456
<5 years old	229	0.02667	0.38217	0.53937
≥5 to <20 years old	42	0.03050	0.35129	0.54375
≥20 years old	30	0.01545	0.54468	0.46336

Table 7A-2. Summary of Surface Area Parameter Values for the Dubois and Dubois Model

Author (year)	Number of persons	a_0	a_1	a_2
DuBois and DuBois (1916)	9	0.007184	0.725	0.425
Boyd (1935)	231	0.01787	0.500	0.4838
Gehan and George (1970)	401	0.02350	0.42246	0.51456
Haycock et al. (1978)	81	0.024265	0.3964	0.5378

8 BODY WEIGHT STUDIES

8.1 INTRODUCTION

The average daily dose (ADD) is a dose that is typically normalized to the average body weight of the exposed population. If exposure occurs only during childhood years, the average child body weight during the exposure period should be used to estimate risk (U.S. EPA, 1989).

The purpose of this section is to describe a key published study on body weight for children in the general U.S. population, as described in Section 1.5 of this handbook. The recommendations for body weight are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on one key study identified by U.S. EPA for this factor. Following the recommendations, the key study on body weight is summarized. Relevant data on body weight are also provided. Since childhood obesity is a growing concern and may increase the risk of chronic diseases during adulthood, information on body mass index (BMI) and height are also provided.

8.2 RECOMMENDATIONS

The recommended values for body weight are summarized in Table 8-1. Table 8-2 presents the confidence ratings for body weight recommendations. The recommended values represent mean body weights in kilograms for the age groups recommended by U.S. EPA in *Guidance for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). Use of upper percentile body weight values are not routinely recommended for calculating ADDs because inclusion of an upper percentile value in the denominator of the ADD equation would be a non-conservative approach. However, distributions of body weight data are provided in section 8.3 of this chapter. These distributions may be useful if probabilistic methods are used to assess exposure. Also, if gender-specific data are needed, or if data for finer age bins are needed, the reader should refer to the tables in Section 8.3.

Table 8-1. Recommended Values for Body Weight			
Age Group	Mean kg	Multiple Percentiles	Source
Birth to <1 month	4.8	Tables 8-3 through 8-5	U.S. EPA analysis of NHANES, 1999-2006 data
1 to <3 months	5.6		
3 to <6 months	7.4		
6 to <12 months	9.2		
1 to <2 years	11.4		
2 to <3 years	13.8		
3 to <6 years	18.6		
6 to <11 years	31.8		
11 to <16 years	56.8		
16 to <21 years	71.6		

Table 8-2. Confidence in Recommendations for Body Weight		
General Assessment Factors	Rationale	Rating
Soundness		High
Adequacy of Approach	The survey methodology and secondary data analysis analysis was adequate. NHANES consisted of a large sample size; sample size varied with age. Direct measurements were taken during a physical examination.	
Minimal (or Defined) Bias	No significant biases were apparent.	
Applicability and Utility		High
Exposure Factor of Interest	The key study is directly relevant to body weight.	
Representativeness	NHANES was a nationally representative sample of the U.S. population; participants are selected using a complex, stratified, multi-stage probability cluster sampling design.	
Currency	The U.S. EPA analysis used the most current NHANES data.	
Data Collection Period	The U.S. EPA analysis was based on 4 data sets of NHANES data covering 1999-2006.	
Clarity and Completeness		High
Accessibility	NHANES data are available from NCHS; the U.S. EPA analysis of the NHANES data is available upon request.	
Reproducibility	The methods used were well-described; enough information was provided to allow for reproduction of results.	
Quality Assurance	Quality assurance of NHANES data was good; quality control of secondary data analysis was not well described.	
Variability and Uncertainty		High
Variability in Population	The full distributions were given in the key study.	
Uncertainty	No significant uncertainties were apparent in the NHANES data, nor in the secondary analyses of the data.	
Evaluation and Review		Medium
Peer Review	NHANES received a high level of peer review. The U.S. EPA analysis was not published in a peer-reviewed journal.	
Number and Agreement of Studies	The number of studies is 1.	
Overall Rating		**High**

8.3 KEY BODY WEIGHT STUDY

8.3.1 U.S. EPA analysis of NHANES 1999-2006 data

The U.S. EPA analyzed data from the 1999-2006 National Health and Nutrition Examination Survey (NHANES) to generate distributions of body weight for various age ranges of children. NHANES is conducted annually by the Center for Disease Control (CDC), National Center of Health Statistics (NCHS). The survey's target population is the civilian, noninstitutionalized U.S. population. The NHANES 1999-2006 survey was conducted on a nationwide probability sample of approximately 40,000 persons for all ages, of which approximately 20,000 were children. The survey is designed to obtain nationally representative information on the health and nutritional status of the population of the United States through interviews and direct physical examinations. A number of anthropometric measurements, including body weight, were taken for each participant in the study. Unit non-response to the household interview was 19 percent, and an additional 4 percent did not participate in the physical examinations (including body weight measurements).

The NHANES 1999-2006 survey includes over-sampling of low-income persons, adolescents 12-19 years, persons 60+ years of age, African Americans and Mexican Americans. Sample data were assigned weights to account both for the disparity in sample sizes for these groups and for other inadequacies in sampling, such as the presence of non-respondents. Because the U.S. EPA utilized four NHANES data sets in its analysis (NHANES 1999-2000, 2001-2002, 2003-2004, and 2005-2006) sample weights were developed for the combined data set in accordance with CDC guidance from the NHANES' website (http://www.cdc.gov/nchs/about/major/nhanes/nhanes2005-2006/faqs05_06.htm#question%2012).

Using the data and the weighting factors from the four NHANES data sets, U.S. EPA calculated body weight statistics for the standard age categories. The mean value for a given group was calculated using the following formula:

$$\bar{x} = \frac{\sum_i w_i x_i}{\sum_i w_i} \qquad \text{(Eqn. 8-1)}$$

where:

$\bar{x}$ = sample mean;
x_i = the i^{th} observation;
w_i = sample weight assigned to observation x_i.

Percentile values were generated by first calculating the sum of the weights for all observations in a given group and multiplying this sum by the percentile of interest (e.g., multiplying by 0.25 to determine the 25th percentile). The observations were then ordered from least to greatest, and each observation was assigned a cumulative weight, equal to its own weight plus all weights listed before the observation. The first observation listed with a cumulative weight greater than the value calculated for the percentile of interest was selected.

Table 8-3 presents the body weight means and percentiles, by age category, for male and female children, combined. Tables 8-4 and 8-5 present the body weight means and percentiles for male and female children, respectively.

The advantage of this study is that it provides body weight distributions for children at ages ranging from infancy to young adults. A limitation of the study is that the data in Tables 8-3 to 8-5 may underestimate current body weights due to an observed upward trend in body weights (Ogden et al., 2004). However, the NHANES data are nationally representative and remain the principal source of body weight data collected nationwide from a large number of subjects.

8.4 RELEVANT BODY WEIGHT STUDIES

8.4.1 National Center for Health Statistics, 1987 - Anthropometric reference data and prevalence of overweight, United States, 1976-80

This study used anthropometric measurement data for body weight for the U.S. population that were collected by NCHS as part of the second National Health and Nutrition Examination Survey (NHANES II). NHANES II began in February 1976 and was completed in February 1980. The survey was conducted on a nationwide probability sample of 27,801 persons aged 6 months to 74 years from the civilian, noninstitutionalized population of the United States. A total of 20,322 individuals in the sample were interviewed and examined, resulting in a response rate of 73.1 percent. The sample was selected so that certain subgroups thought to be at high risk of malnutrition (persons with low incomes, preschool children, and the elderly) were over sampled. The estimates were weighted to reflect national population estimates. The weighting was accomplished by inflating examination results for each subject by the reciprocal of selection probabilities, adjusted to account for those who were not examined, and-post stratifying by race, age, and sex.

NHANES II collected standard body measurements of sample subjects, including height and weight, that were made at various times of the day and in different seasons of the year. This technique was used because an individual's weight may vary between winter and summer and may fluctuate with patterns of food and water intake and other daily activities (NCHS, 1987). NCHS (1987) provided descriptive statistics of the body weight data. Means and percentiles, by age category, are presented in Table 8-6 for males, and in Table 8-7 for females.

The advantages of the study are that it is nationally representative and provides data for various age groups of children, beginning at 2 months of age. The limitation of the study is the age of the data.

8.4.2 Burmaster and Crouch, 1997 - Lognormal distributions for body weight as a function of age for males and females in the United States, 1976-1980

Burmaster and Crouch (1997) performed data analysis to fit normal and lognormal distributions to the body weights of females and males aged 9 months to 70 years. The data used in this analysis were from the second survey of the National Center for Health Statistics, NHANES II, which was based on a national probability sample of 27,801 persons 6 months to 74 years of age in the U.S. (Burmaster and Crouch 1997). The NHANES II data had been statistically adjusted for non-response and probability of selection, and stratified by age, sex, and race to reflect the entire U.S. population prior to reporting. Burmaster and Crouch (1997) conducted exploratory and quantitative data analyses and fit normal and lognormal distributions to percentiles of body weights of children and teens, as a function of age. Cumulative distribution functions were plotted for female and male body weights on both linear and logarithmic scales.

Burmaster and Crouch (1997) used "maximum likelihood" estimation to fit lognormal distributions to the data. Linear and quadratic regression lines were fitted to the data. A number of goodness-of-fit measures were conducted on the data generated. The investigators found that lognormal distributions gave strong fits to the data for each gender across all age groups. The statistics for the lognormal probability plots for female and male children aged 9 months to 20 years are presented in Tables 8-8 and 8-9, respectively. These data can be used for further analyses of body weight distribution (i.e., application of Monte Carlo analysis).

The advantage of this study is that NHANES data were used for the analysis and the data are representative nationally. It also provides statistics for probability plot regression analyses for females and males from 6 months to 20 years old. However, the analysis is based on an older set of NHANES data.

8.4.3 U.S. EPA, 2000 - Body weight estimates on NHANES III Data

U.S. EPA's Office of Water has estimated body weights for children by age and gender using data from NHANES III, which was conducted from 1988 to 1994. NHANES III collected body weight data for approximately 15,000 children between the ages of 2 months and 17 years. Table 8-10 presents the body weight estimates in kilograms by age and gender. Table 8-11 shows the body weight estimates for infants under the age of 3 months.

The limitations of this analysis are that data were not available for infants under 2 months old, and that the data are roughly 14 to 20 years old. With the upward trends in body weight from NHANES II (1976-1980) to NHANES III, which may still be valid, the data in Tables 8-10 and 8-11 may underestimate current body weights. However, the data are national in scope and represent the general children's population.

8.4.4 Kuczmarski et al., 2002 - 2000 CDC growth charts for the United States: methods and development

NCHS published growth charts for infants, birth to 36 months of age, and children and adolescents, 2 to 20 years of age (Kuczmarski et al., 2002). Growth charts were developed with data from five national health examination surveys: National Health Examination Survey (NHES) II (1963-65) for ages 6-11 years, NHES

III (1966-70) for ages 12-17 years, National Health and Nutrition Examination Survey (NHANES) I (1971-74) for ages 1-17 years, NHANES II (1976-80) beginning at 6 months of age, and NHANES III (1988-94) beginning at 2 months of age. Data from these national surveys were pooled because no single survey had enough observations to develop these charts. For the infant charts, a limited number of additional data points were obtained from other sources where national data were either not available or insufficient. Birth weights <1,500 grams were excluded when generating the charts for weights and lengths. Also, the length-for-age charts exclude data from NHANES III for ages <3.5 months. Supplemental birth certificate data from the U.S. vital statistics were used in the weight-for-age charts and supplemental birth certificate data from Wisconsin and Missouri vital statistics, CDC Pediatric Nutrition Surveillance System data were used for ages 0.5, 1.5, 2.5, 3.5, and 4.5 months for the length-for-age charts. The Missouri and Wisconsin birth certificate data were also used to supplement the surveys for the weight-for-length charts. Table 8-12 presents the percentiles of weight by gender and age. Figures 8-1 and 8-2 present weight by age percentiles for boys and girls, aged birth to 36 months, respectively. Figures 8-3 and 8-4 present weight by length percentiles for boys and girls, respectively. Figures 8-5 and 8-6 provide the Body Mass Index (BMI) for boys and girls aged 2 to 20 years old.

A limitation of this analysis is that trends in the weight data cannot be assessed because data from various years were combined. The advantages of this analysis are that it is based on a nationally representative sample of the U.S. population and it provides body weight on a month-by-month basis up to 36 months of age, as well as BMI data for children through age 20 years.

8.4.5 Ogden et al., 2004 - Mean body weight, height, and body mass index, United States 1960-2002

Ogden et al. (2004) analyzed trends in body weight measured by the National Health Examination Surveys II and III (NHES II and III), the National Health and Nutrition Examination Surveys I, II, and III (NHANES I, II, and III), and NHANES 1999-2002. The surveys covered the period from 1960 to 2002. Table 8-13 presents the measured body weights for various age groups as measured in NHES and NHANES. Tables 8-14 and 8-15 present the mean height and BMI data for the same population, respectively. The BMI data were calculated as weight in kilograms divided by the square of height in meters. Population means were calculated using sample weights to account for variation in sampling for certain subsets of the U.S. population, non-response, and non-coverage (Ogden et al., 2004). The data indicate that mean body weight has increased over the period analyzed.

There is some uncertainty inherent in such an analysis, however, because of changes in sampling methods during the 42 year time span covered by the studies. Because this study is based on an analysis of NHANES data, its limitations are the same as those for that study. However, it serves to illustrate the importance of the use of timely data when analyzing body weight.

8.4.6 Freedman et al., 2006 - Racial and ethnic differences in secular trends for childhood BMI, weight, and height

Freedman et al. (2006) examined sex and race/ethnicity differences in secular trends for childhood BMI, overweight, weight, and height in the United States using data from NHANES I (1971 to 1974), NHANES II (1976- 1980), NHANES III (1988 to 1994) and NHANES 1999-2002. The analyses included children 2 to 17 years olds. Persons with missing weight or height information were excluded from the analyses (Freedman et al., 2006). The authors categorized the data across the four examinations and presented the data for non-Hispanic White, non-Hispanic Black, or Mexican American. Freedman et al. (2006) excluded other categories of race/ethnicity such as other Hispanics, because the sample sizes were small. Height and weight data were obtained for each survey and BMI was calculated as weight in kilograms divided by height in meters square. Sex specific z-scores and percentiles of weight-for-age, height-for-age, and BMI-for-age were calculated. Childhood overweight was defined as BMI-for-age $\geq 95^{th}$ percentile and childhood obesity was defined as children with a BMI-for-age $\geq 99^{th}$ percentile.

In the analyses, sample weights were used to account for differential probabilities, non-selection, non response, and non-coverage. The sample sizes used in the analyses by age, race and survey are presented in Table 8-16. Mean BMI levels are provided in Table 8-17 and the prevalence of overweight and obesity is shown in Table 8-18. Table 8-17 shows that in 1971-1974 survey total population, Mexican American children had the highest mean BMI level (18.6 kg/m^2). However the greatest increase throughout the survey occurred among Black children increasing from 17.8 to 20 kg/m^2 (Freedman et al., 2006). Table 8-18 shows that 2 to 5 year old White children had slightly larger increases in overweight, but among the older children, the largest increases were among the Black and Mexican American children (Freedman et al., 2006). Overall, in most sex-age groups, Mexican Americans experienced the greater increase in BMI and overweight than what was experienced by Black and White Children (Freedman et al., 2006). Black children experienced larger secular increases in BMI, weight, and height than did White children (Freedman et al., 2006). According to Freedman et al. (2006) racial/ethnicity differences were less marked in the 2 to 5 years old children.

The advantages of the study are that the sample size is large and the analysis was designed to represent the general population of the racial and ethnic groups studied. The disadvantage is that some ethnic population groups were excluded because of small sample sizes.

8.4.7 Martin et al., 2007 - Births: final data for 2005

Martin et al.(2007) provided statistics on the percentage of live births categorized as having low or very low birth weights in the U.S. Low birth weight was defined as <2,500 grams (<5 pounds 8 ounces) and very low birth weight was defined as <1,500 grams (<3 pounds 4 ounces). The data used in the analysis were from birth certificates registered in all states and the District of Columbia for births occurring in 2005. Data were presented for maternal demographic characteristics including race ethnicity: non-Hispanic White, non-Hispanic Black, and Hispanic.

The numbers of live births within various weight ranges, and the percentages of live births with low or very low birth weights are presented in Table 8-19. The percentage of live births with low birth weights was 8.2, and the percentage of very low birth weights was 1.5 in 2005. Non-Hispanic Blacks had the highest percentage of low birth weights (14.0 percent) and very low birth weights (3.3 percent). Martin et al. (2007) also provided statistics on the numbers and percentages of pre-term live births in the U.S. Of the 4,138,349 live births in the U.S. in 2005, 522,913 were defined as pre-term (i.e., less than 37 weeks gestation). A total of 43.3 percent of these pre-term infants had low birth weights an 11.3 percent had very low birth weights. The advantage of this data set is that it is nationally representative and provides data for infants.

8.4.8 Portier et al., 2007 - Body weight distributions for risk assessment

Portier et al. (2007) provided age-specific distributions of body weight based on NHANES II, III, and IV data. The number of observations in these surveys was 20,322, 33,311, and 9,965, respectively. Portier et al. (2007) computed the means and standard deviations of body weight as back transformations of the weighted means and standard deviations of natural log-transformed body weights. Body weight distributions were computed by gender and various age brackets (Portier et al., 2007). The estimated mean body weights are shown in Tables 8-20, 8-21, and 8-22 using NHANES II, III, and IV data, respectively. The sample size (N) shown in the tables is the observed number of individuals and not the expected population size (sum of the sample weights) in each age category (Portier et al., 2007). The authors noted that the age groups are defined as starting at the birth month and include the next eleven months (i.e., age group 2 includes children 24-35 months at the time of the health assessment). Table 8-23 provides estimates for age groups that are often considered in risk assessments (Portier et al., 2007). The authors concluded that the data show changes in the average body weight over time and that the changes are not constant for all ages. The reader is referred to Portier et al. (2007) for equations suggested by the authors to be used when performing risk assessments where shifts and changes in body weight distributions need factoring in.

The advantages of this study are that it represents the U.S. general population, it provides distribution data, and can be used for trend analysis. In addition, the data are provided for both genders and for single-year age groups. The study results are also based on a large sample size.

8.4.9 Kahn and Stralka, 2008 - Estimated daily average per capita water ingestion by child and adult age categories based on USDA's 1994-96 and 1998 Continuing Survey of Food Intakes

As part of an analysis of water ingestion, Kahn and Stralka (2008) provided body weight distributions for children. The analysis was based on self reported body weights from the 1994 - 1996, 1998 Continuing Survey of Food Intake Among Individuals (CSFII). The average body weight across all individuals was 65 kilograms. According to Kahn and Stralka (2008), 10 kilograms, which is often used as the default body weight for babies, is the 95th value of the distribution of body weight for children in the 3 to <6 months category. The median weight is 9 kilograms for the 6 to 12 month age category and 11 kilograms for the 1 to 2 year old category (Kahn and Stralka, 2008). The body weight distributions are presented in Table 8-24 and the intervals around the mean and 90th and 95th percentiles are presented in Table 8-25.

The advantages of the study are its large sample size and that it is representative of the U.S. population for the age groups presented. A limitation of the study is that the data are based on self reporting from the participants.

8.5 RELEVANT FETAL WEIGHT STUDIES

8.5.1 Brenner et al., 1976 - A Standard of Fetal Growth for the United States of America

Brenner et al. (1976) determined fetal weights for 430 fetuses aborted at 8 to 20 weeks of gestation and for 30,772 liveborn infants delivered at 21 to 44 weeks of gestation. Gestational age for the aborted fetuses was determined through a combination of the physician's estimate of uterine size and the patient's stated last normal menstrual period. Data were not used when these two estimates differed by more than 2 weeks. To determine fetal growth, the fetuses were weighed and measured (crown-to-rump and crown-to heel lengths). All abortions were legally performed at Memorial Hospital, University of North Carolina at Chapel Hill from 1972 to 1975. For the liveborn infants, data were analyzed from single birth deliveries with the infant living at the onset of labor, among pregnancies not complicated by pre-eclampsia, diabetes or other disorders. Infants were weighed on a balance scale immediately after delivery. The liveborn infants were delivered at MacDonald House, University Hospitals of Cleveland, Ohio from 1962 to 1969.

Percentiles for fetal weight were calculated from the data at each week of gestation and are shown in Table 8-26. The resulting percentile curves were smoothed with two-point weighted means. Variables associated with significant differences in fetal weight in the latter part of pregnancy (after 34-38 weeks of gestation) included maternal parity and race, and fetal gender.

The advantage of this study is the large sample size. Limitations of the study are that the data were collected more than 30 years ago in only two U.S. states. In addition, a number of variables which may affect fetal weight (i.e., maternal smoking, disease, nutrition, and addictions) were not evaluated in this study.

8.5.2 Doubilet et al., 1997 - Improved Birth Weight Table for Neonates Developed from Gestations Dated by Early Ultrasonography

Doubilet et al. (1997) matched a database of obstetrical ultrasonograms over a period of 5 years from 1988 to 1993 to birth records for 3,718 infants (1,857 males and 1,861 females). The study population included 1,514 Whites, 770 Blacks, 1,256 Hispanics, and 178 who were either unclassified, or classified as "other." Birth weights were obtained from hospital records and a gestational age was assigned based on the earliest first trimester sonogram. The database was screened for possible outliers, defined as infants with birth weights that exceeded 5000 grams. Labor and delivery records and mother-infant medical records were retrieved to correct any errors in data entry for infants with birth weights exceeding 5000 grams. The mean gestational age at initial sonogram was 9.5 ± 2.3 weeks. Regression analysis techniques were used to derive weight tables for neonates at each gestational age for 25 weeks of gestation onward. Weights for each gestational age were found to conform to a natural logarithm distribution. Polynomial equations were derived from the regression analysis to estimate mean weight by gestational age for males, females, and males and females combined. Table 8-27 provides the distribution of neonatal weights by gestational age from 25 weeks of gestation onward.

8.6 REFERENCES FOR CHAPTER 8

Brenner, W.E.; Edelman, D.A.; Hendricks, C.H. (1976) A standard of fetal growth for the United States of America. Am J Obstet Gynecol 1:126(5):555-64.

Burmaster, D.E.; Crouch, E.A.C. (1997) Lognormal distributions for body weight as a function of age for males and females in the United States, 1976-1980. Risk Anal 17(4):499-505.

Doubilet, P.M.; Benson, C.B.; Nadel, A.S.; Ringer, S.A. (1997) Improved birth weight table for neonates developed from gestations dated by early ultrasonography. J Ultrasound Med 16:241-249.

Freedman, D.; Kettel, K.; Serdula, M.; Ogden, C.; Dietz, W. (2006) Racial and ethnic differences in secular trends for childhood BMI, weight, and height. Obesity 14(2):301:307.

Kahn, H.; Stralka, K. (2008) Estimated daily average per capita water ingestion by child and adult age categories based on USDA's 1994-96 and 1998 continuing survey of food intakes (CSFII). J Expo Sci Environ Epidemiol (2008) 1-9.

Kuczmarski, R.J.; Ogden, C.L.; Guo, S.S.; Grummer-Strawn, L.; Flegal, K., et al. (2000) CDC growth charts for the United States: methods and development. National Center for Health Statistics. Vital Health Stat. 11(246)2002.

LSRO (1995) Third report on nutrition monitoring in the United States: Volume 1. Prepared by: Federation of American Societies for Experimental Biology, Life Sciences Research Office for the Interagency Board for Nutrition Monitoring and Related Research. Washington, D.C.: U.S. Government Printing Office.

Martin, J.; Hamilton, B.; Sutton, P.; Ventura, S.; Fay, M.; et al. (2007) Births: final data for 2005. CDC National Vital Statistics Report, Volume 56. No. 6.

National Center for Health Statistics (NCHS). (1987) Anthropometric reference data and prevalence of overweight, United States, 1976-80. Data from the National Health and Nutrition Examination Survey, Series 11, No. 238. Hyattsville, MD: U.S. Department of Health and Human Services, Public Health Service, National Center for Health Statistics. DHHS Publication No. (PHS) 87-1688.

Ogden, C.L.; Fryar, C.D.; Carroll, M.D.; Flegal, K. M. (2004) Mean Body Weight, Height, and Body Mass Index, United States 1960-2002. Advance Data from Vital and Health Statistics, No. 347, October 27, 2004. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Portier K.; Tolson, J.; Roberts, S. (2007) Body weight distributions for risk assessment. Risk Anal 27(1)11-26.

U.S. EPA (1989) Risk assessment guidance for Superfund, Volume I: Human health evaluation manual. Washington, DC: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/1-89/002.

U.S. EPA (2000) Memorandum entitled: Body weight estimates on NHANES III data, revised, Contract 68-C-99-242, Work Assignment 0-1 from Bob Clickner, Westat Inc. to Helen Jacobs, U.S. EPA dated March 3, 2000.

U.S. EPA (2005) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants (2005). Washington, D.C.: U.S. Environmental Protection Agency, EPA/630/P-03/003F.

Table 8-3. Mean and Percentile Body Weights (kilograms) Derived from NHANES 1999-2006, Males and Females Combined

Age Group	N	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	158	4.8	3.6	3.9	4.1	4.2	4.8	5.1	5.5	5.8	6.2
1 to <3 months	284	5.9	4.5	4.7	4.9	5.2	5.9	6.6	6.9	7.1	7.3
3 to <6 months	489	7.4	5.7	6.1	6.3	6.7	7.3	8.0	8.4	8.7	9.1
6 to <12 months	927	9.2	7.1	7.5	7.9	8.3	9.1	10.1	10.5	10.8	11.3
1 to <2 years	1176	11.4	8.9	9.3	9.7	10.3	11.3	12.4	13.0	13.4	14.0
2 to <3 years	1144	13.8	10.9	11.5	11.9	12.4	13.6	14.9	15.8	16.3	17.1
3 to <6 years	2318	18.6	13.5	14.4	14.9	15.8	17.8	20.3	22.0	23.6	26.2
6 to <11 years	3593	31.8	19.7	21.3	22.3	24.4	29.3	36.8	42.1	45.6	52.5
11 to <16 years	5297	56.8	34.0	37.2	40.6	45.0	54.2	65.0	73.0	79.3	88.8
16 to <21 years	4851	71.6	48.2	52.0	54.5	58.4	67.6	80.6	90.8	97.7	108.0

Source: U.S. EPA Analysis of NHANES 1999-2006 data.

Table 8-4. Mean and Percentile Body Weights (kilograms) for Males Derived from NHANES 1999-2006

Age Group	N	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	88	4.9	3.6	3.6	4.0	4.4	4.8	5.5	5.8	6.2	6.8
1 to <3 months	153	6.0	4.6	5.0	5.1	5.4	6.1	6.8	7.0	7.2	7.3
3 to <6 months	255	7.6	5.9	6.4	6.6	6.9	7.5	8.2	8.6	8.8	9.1
6 to <12 months	472	9.4	7.3	7.9	8.2	8.5	9.4	10.3	10.6	10.8	11.5
1 to <2 years	632	11.6	9.0	9.7	10.0	10.5	11.5	12.6	13.2	13.5	14.3
2 to <3 years	558	14.1	11.4	12.0	12.2	12.8	14.0	15.2	15.9	16.4	17.0
3 to <6 years	1158	18.8	13.5	14.4	14.9	15.9	18.1	20.8	22.6	23.8	26.2
6 to <11 years	1795	31.9	20.0	21.8	22.9	24.8	29.6	36.4	41.2	45.2	51.4
11 to <16 years	2593	57.6	33.6	36.3	38.9	44.2	55.5	66.5	75.5	81.2	91.8
16 to <21 years	2462	77.3	54.5	57.6	60.0	63.9	73.1	86.0	96.8	104.0	113.0

Source: U.S. EPA Analysis of NHANES 1999-2006 data.

Table 8-5. Mean and Percentile Body Weights (kilograms) for Females Derived from NHANES 1999-2006

Age Group	N	Mean	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	70	4.6	3.6	4.0	4.1	4.2	4.6	4.9	5.0	5.2	5.9
1 to <3 months	131	5.7	4.3	4.6	4.74	5.1	5.5	6.4	6.6	6.9	7.3
3 to <6 months	234	7.2	5.5	5.9	6.2	6.4	7.2	7.9	8.2	8.4	9.0
6 to <12 months	455	9.0	7.1	7.3	7.6	8.0	8.9	9.8	10.3	10.6	11.2
1 to <2 years	544	11.1	8.7	9.1	9.4	10.0	11.1	12.2	12.9	13.2	13.7
2 to <3 years	586	13.5	10.5	11.0	11.5	12.1	13.2	14.6	15.5	16.2	17.1
3 to <6 years	1160	18.3	13.5	14.3	14.7	15.6	17.5	19.7	21.3	23.2	26.2
6 to <11 years	1798	31.7	19.3	20.9	22.0	23.9	29.0	37.3	43.1	46.7	53.4
11 to <16 years	2704	55.9	34.9	38.6	41.6	45.7	53.3	62.8	70.7	76.5	86.3
16 to <21 years	2389	65.9	46.2	48.6	51.1	54.5	61.5	73.3	83.4	89.9	99.7

Source: U.S. EPA Analysis of NHANES 1999-2006 data.

Table 8-6. 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]

Age Group	Number of Persons Examined	Mean (kg)	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	-	-	-	-	-	-	-	-	-	-	-
1 to <2 months	-	-	-	-	-	-	-	-	-	-	-
2 to <3 months	103	6.6	5.3	5.5	5.7	5.9	6.8	7.2	7.6	7.8	8.4
3 to <6 months	287	7.7	6.3	6.6	6.7	7.0	7.7	8.4	8.9	9.2	9.6
6 to <12 months	589	9.4	7.5	7.9	8.1	8.6	9.4	10.2	10.6	10.9	11.4
1 to <2 years	613	11.7	9.4	9.8	10.1	10.8	11.7	12.6	13.1	13.7	14.5
2 to <3 years	627	13.7	11.4	11.8	12.2	12.6	13.6	14.6	15.2	15.8	16.5
3 to <6 years	1556	18.0	13.7	14.6	14.9	15.7	17.5	19.7	21.0	22.0	24.0
6 to <11 years	1373	30.7	19.5	21.1	22.1	24.0	28.5	35.2	40.5	43.5	48.7
11 to <16 years	1037	55.2	34.0	36.5	38.7	42.8	53.0	63.0	69.4	74.8	84.3
16 to <21 years	890	71.8	54.1	56.6	58.3	61.8	68.7	77.9	84.3	89.7	101.0

[a] Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.
\- No data available for infants less than two months old.

Source: National Center for Health Statistics, 1987.

Table 8-7. 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]

Age Group	Number of Persons Examined	Mean (kg)	Percentiles								
			5th	10th	15th	25th	50th	75th	85th	90th	95th
Birth to <1 month	-	-	-	-	-	-	-	-	-	-	-
1 to <2 months	-	-	-	-	-	-	-	-	-	-	-
2 to <3 months	131	6.0	4.7	5.1	5.2	5.6	6.0	6.5	7.1	7.3	7.8
3 to <6 months	269	7.1	5.8	5.9	6.1	6.4	7.1	7.7	7.9	8.4	8.7
6 to <12 months	574	8.8	7.2	7.5	7.7	8.0	8.7	9.4	10.1	10.4	10.8
1 to <2 years	617	11.0	9.1	9.4	9.6	9.9	10.9	11.9	12.6	12.9	13.4
2 to <3 years	597	13.4	10.8	11.2	11.6	12.1	13.2	14.6	15.4	15.6	16.3
3 to <6 years	1658	18.0	13.3	14.0	14.5	15.4	17.2	19.7	21.1	22.6	25.1
6 to <11 years	1321	30.6	19.0	20.5	21.3	23.4	28.9	35.0	39.6	44.3	50.2
11 to <16 years	1144	53.2	34.1	37.2	40.4	45.2	51.6	60.0	67.2	70.6	78.2
16 to <21 years	1001	62.2	46.7	48.2	49.7	52.2	58.9	68.3	74.7	80.8	92.6

[a] Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.
- No data available for infants less than two months old.

Source: National Center for Health Statistics, 1987.

Table 8-8. Statistics for Probability Plot Regression Analyses:
Females Body Weights 6 Months to 20 Years of Age

Age Midpoint (years)	Lognormal Probability Plots Linear Curve	
	μ_2[a]	σ_2[a]
0.75	2.16	0.145
1.5	2.38	0.129
2.5	2.56	0.112
3.5	2.69	0.136
4.5	2.83	0.134
5.5	2.98	0.164
6.5	3.10	0.174
7.5	3.19	0.174
8.5	3.31	0.156
9.5	3.46	0.214
10.5	3.57	0.199
11.5	3.71	0.226
12.5	3.82	0.213
13.5	3.92	0.215
14.5	3.99	0.187
15.5	4.00	0.156
16.5	4.05	0.167
17.5	4.08	0.165
18.5	4.07	0.147
19.5	4.10	0.149

[a] μ_2, σ_2 - correspond to the mean and standard deviation, respectively, of the lognormal distribution of body weight (kg).

Source: Burmaster and Crouch, 1997.

Table 8-9. Statistics for Probability Plot Regression Analyses: Males Body Weights 6 Months to 20 Years of Age

Age Midpoint (years)	Lognormal Probability Plots Linear Curve	
	μ_2[a]	σ_2[a]
0.75	2.23	0.132
1.5	2.46	0.119
2.5	2.60	0.120
3.5	2.75	0.114
4.5	2.87	0.133
5.5	2.98	0.138
6.5	3.13	0.145
7.5	3.21	0.151
8.5	3.33	0.181
9.5	3.43	0.165
10.5	3.59	0.195
11.5	3.69	0.252
12.5	3.78	0.224
13.5	3.88	0.215
14.5	4.02	0.181
15.5	4.09	0.159
16.5	4.20	0.168
17.5	4.19	0.167
18.5	4.25	0.159
19.5	4.26	0.154

[a] μ_2, σ_2 - correspond to the mean and standard deviation, respectively, of the lognormal distribution of body weight (kg).

Source: Burmaster and Crouch, 1997.

Table 8-10. Body Weight Estimates (kilograms) by Age and Gender, U.S. Population Derived From NHANES III (1988-94)

Age Group	Sample Size	Population	Male and Female		Male		Female	
			Median	Mean	Median	Mean	Median	Mean
2 to 6 months	1,020	1,732,702	7.4	7.4	7.6	7.7	7.0	7.0
7 to 12 months	1,072	1,925,573	9.4	9.4	9.7	9.7	9.1	9.1
1 year	1,258	3,935,114	11.3	11.4	11.7	11.7	10.9	11.0
2 years	1,513	4,459,167	13.2	12.9	13.5	13.1	13.0	12.5
3 years	1,309	4,317,234	15.3	15.1	15.5	15.2	15.1	14.9
4 years	1,284	4,008,079	17.2	17.1	17.2	17.0	17.3	17.2
5 years	1,234	4,298,097	19.6	19.4	19.7	19.3	19.6	19.4
6 years	750	3,942,457	21.3	21.7	21.5	22.1	20.9	21.3
7 years	736	4,064,397	25.0	25.5	25.4	25.5	24.1	25.6
8 years	711	3,863,515	27.4	28.1	27.2	28.4	27.9	27.9
9 years	770	4,385,199	31.8	32.7	32.0	32.3	31.1	33.0
10 years	751	3,991,345	35.2	35.6	35.9	36.0	34.3	35.2
11 years	754	4,270,211	40.6	41.5	38.8	40.0	43.4	42.8
12 years	431	3,497,661	47.2	46.9	48.1	49.1	45.7	48.6
13 years	428	3,567,181	53.0	55.1	52.6	54.5	53.7	55.9
14 years	415	4,054,117	56.9	61.1	61.3	64.5	53.7	57.9
15 years	378	3,269,777	59.6	62.8	62.6	66.9	57.1	59.2
16 years	427	3,652,041	63.2	65.8	66.6	69.4	56.3	61.6
17 years	410	3,719,690	65.1	67.5	70.0	72.4	60.7	62.2
1 and older	31,311	251,097,002	66.5	64.5	73.9	89.0	80.8	80.3
1 to 3 years	4,080	12,711,515	13.2	13.1	13.4	13.4	13.0	12.9
1 to 14 years	12,344	56,653,796	24.9	29.9	25.1	30.0	24.7	29.7
15 to 44 years	10,393	118,430,653	70.8	73.5	77.5	80.2	63.2	67.3

Source: U.S. EPA, 2000.

Table 8-11. Body Weight Estimates (in kilograms) by Age, U.S. Population Derived From NHANES III (1988-94)

Age Group	Sample Size	Population	Male and Female		
			Median	Mean	95% CI
2 Months	243	408,837	6.3	6.3	6.1-6.4
3 Months	190	332,823	7.0	6.9	6.7-7.1
3 Months and Younger	433	741,660	6.6	6.6	6.4-6.7

CI = Confidence Interval.

Source: U.S. EPA, 2000.

Table 8-12. Observed Mean, Standard Deviation and Selected Percentiles for Weight (kilograms) by Gender and Age: Birth to 36 Months

Age Group	Mean	SD	Percentile					
			10th	25th	50th	75th	90th	95th
Boys								
Birth	3.4	0.6	2.7	3.1	3.4	3.8	4.1	4.3
0 < 1 months	–	–	–	–	–	–	–	–
1< 2 months	–	–	–	–	–	–	–	–
2 < 3 months	6.5	0.8	5.6	5.8	6.7	6.9	7.4	7.5
3 < 4 months	7.0	0.9	5.9	6.5	7.0	7.5	8.2	8.5
4 < 5 months	7.2	0.8	6.3	6.7	7.2	7.7	8.0	8.4
5 < 6 months	7.9	0.9	6.7	7.5	7.8	8.6	9.4	9.6
6 < 7 months	8.4	1.1	7.3	7.6	8.4	9.0	10.2	10.7
7 < 8 months	8.6	1.1	7.1	7.8	8.6	9.5	10.1	10.4
8 < 9 months	9.3	1.1	7.9	8.6	9.2	10.1	10.5	11.0
9 < 10 months	9.3	0.9	8.2	8.6	9.3	10.0	10.8	10.9
10 < 11 months	9.5	1.1	8.3	8.7	9.3	10.1	11.3	11.5
11 < 12 months	10.0	1.0	8.7	9.5	10.0	10.6	11.1	11.6
12 < 15 months	10.6	1.2	9.2	9.8	10.6	11.3	12.1	12.4
15 < 18 months	11.4	1.9	9.9	10.5	11.3	12.0	12.8	13.5
18 < 21 months	12.1	1.5	10.4	11.0	11.9	12.7	13.9	15.5
21 < 24 months	12.4	1.3	10.9	11.6	12.4	13.1	14.4	14.7
24 < 30 months	13.1	1.7	11.3	12.1	12.9	14.1	15.1	15.9
30 < 36 months	14.0	1.5	12.0	13.0	13.8	14.7	16.0	16.6
Girls								
Birth	3.3	0.5	2.6	3.0	3.3	3.6	3.9	4.1
0 < 1 months	–	–	–	–	–	–	–	–
1< 2 months	–	–	–	–	–	–	–	–
2 < 3 months	5.4	0.5	4.8	5.0	5.6	5.9	6.0	–
3 < 4 months	6.3	0.7	5.6	5.8	6.3	6.8	7.4	7.8
4 < 5 months	6.7	0.9	5.8	6.1	6.6	7.4	8.0	8.3
5 < 6 months	7.3	0.9	6.3	6.7	7.1	7.7	8.5	8.8
6 < 7 months	7.7	0.8	6.6	7.1	7.6	8.1	8.9	9.0
7 < 8 months	8.0	1.4	6.7	7.4	7.8	8.6	9.4	9.8
8 < 9 months	8.3	0.9	7.3	7.8	8.3	8.9	9.4	9.8
9 < 10 months	8.9	0.9	7.8	8.1	8.7	9.4	10.1	10.5
10 < 11 months	9.0	1.1	7.8	8.4	9.0	9.5	10.4	10.9
11 < 12 months	9.3	1.0	7.9	8.6	9.2	10.1	10.6	10.9
12 < 15 months	9.8	1.1	8.5	9.1	9.8	10.4	11.3	11.6
15 < 18 months	10.4	1.1	9.1	9.7	10.3	11.2	11.8	12.0
18 < 21 months	11.1	1.4	9.6	10.2	11.0	11.9	12.8	13.5
21 < 24 months	11.8	1.3	10.1	10.9	11.8	12.8	13.5	13.9
24 < 30 months	12.5	1.5	10.8	11.5	12.4	13.3	14.5	15.1
30 < 36 months	13.6	1.7	11.8	12.5	13.4	14.52	15.7	16.4

- No data available.

Source: Kuczmarski et al. 2002.

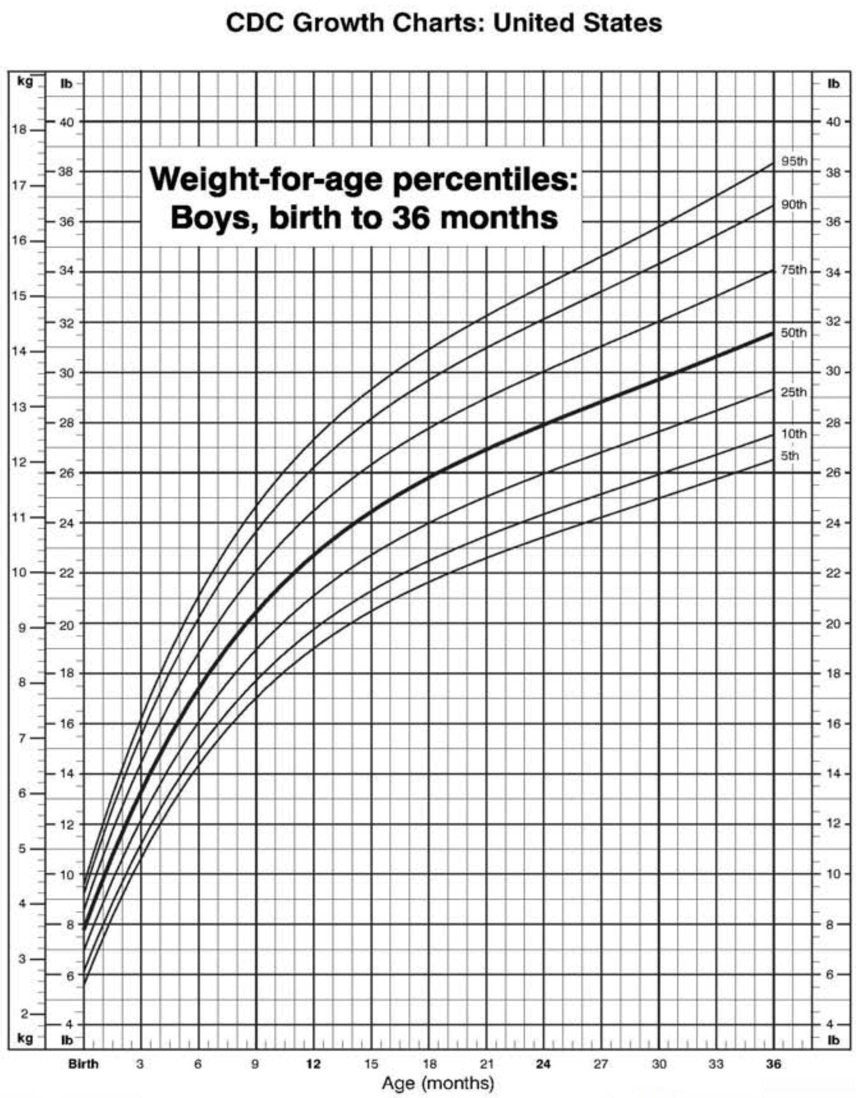


Figure 8-1. Weight by Age Percentiles for Boys Aged Birth to 36 Months

Source: Kuczmarski et al., 2002.

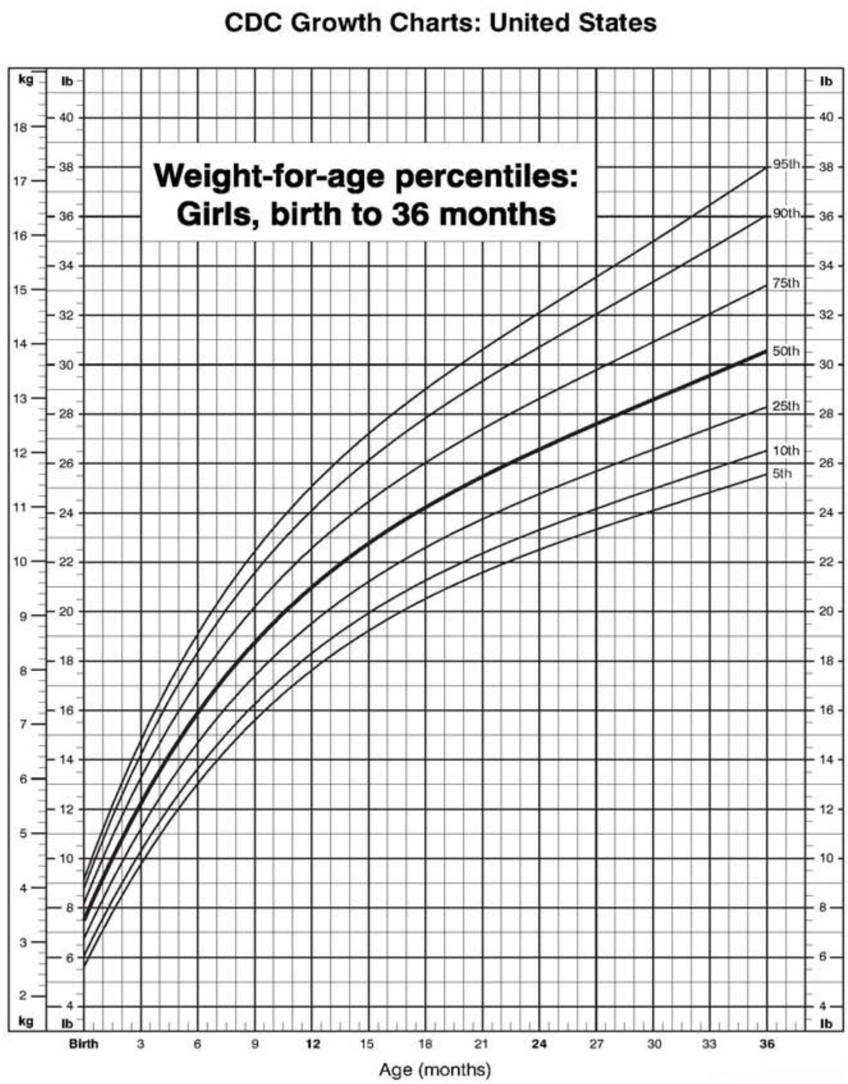


Figure 8-2. Weight by Age Percentiles for Girls Aged Birth to 36 Months

Source: Kuczmarski et al., 2002.

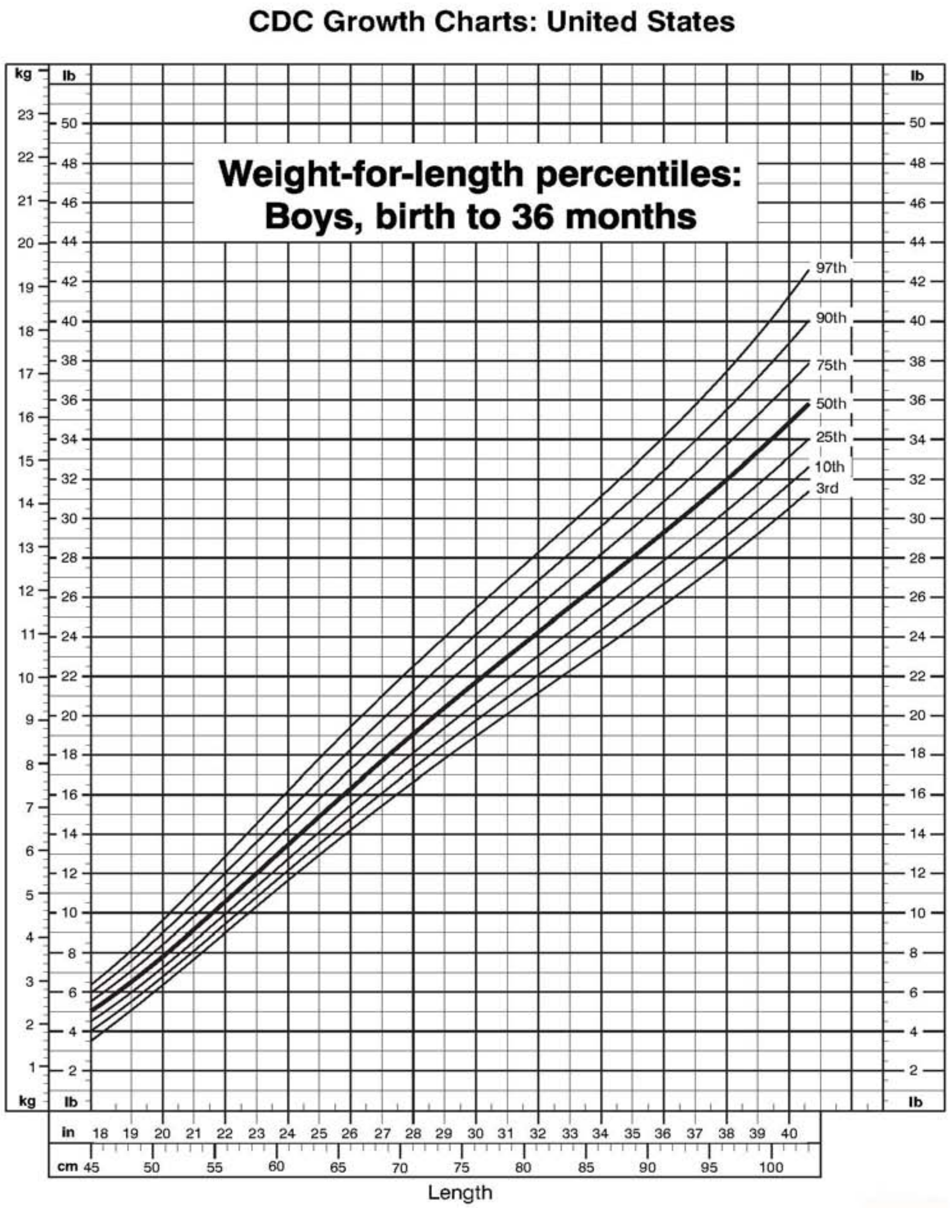


Figure 8-3. Weight by Length Percentiles for Boys Aged Birth to 36 Months

Source: Kuczmarski et al., 2002.

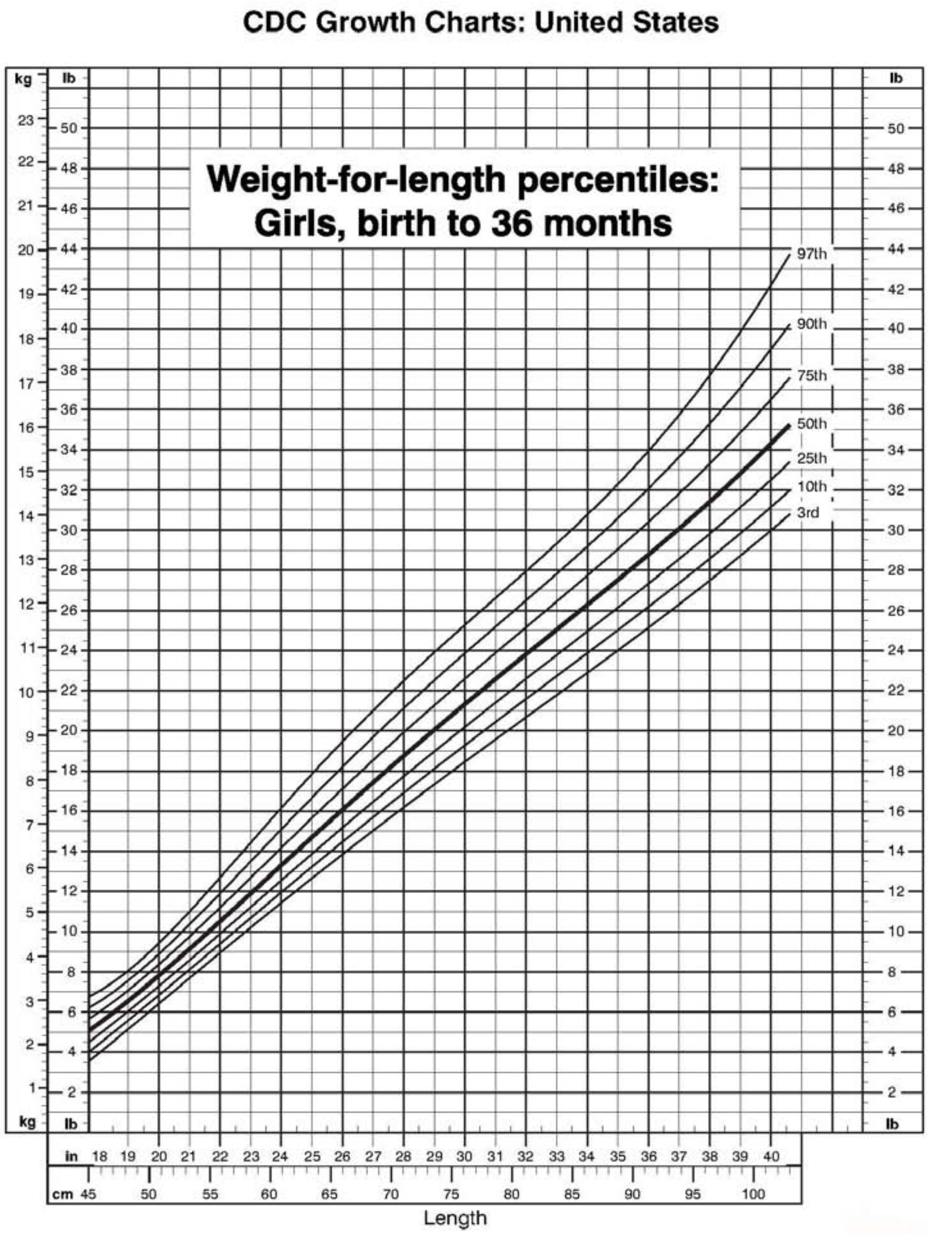


Figure 8-4. Weight by Length Percentiles for Girls Aged Birth to 36 Months

Source: Kuczmarski et al., 2002.

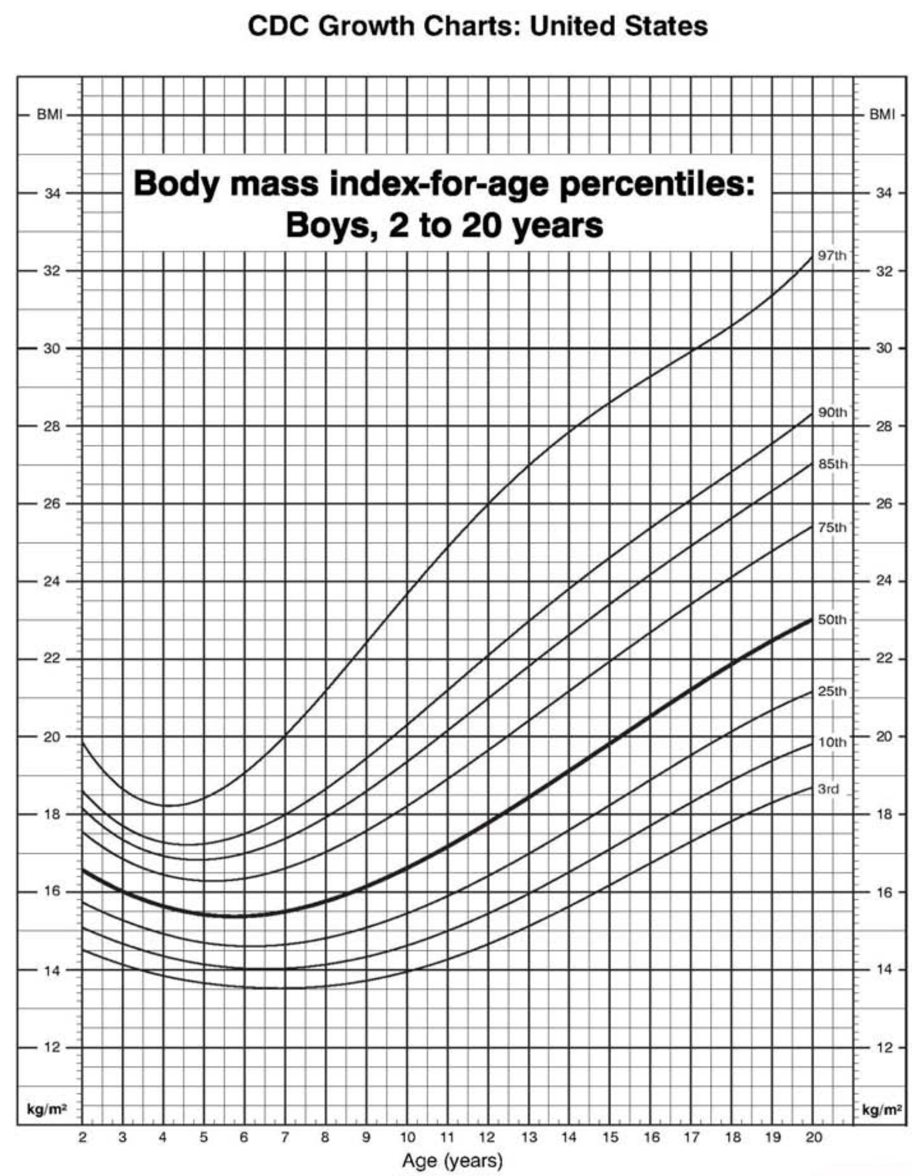


Figure 8-5. Body Mass Index-for-Age Percentiles: Boys, 2 to 20 Years

Source: Kuczmarski et al., 2002.

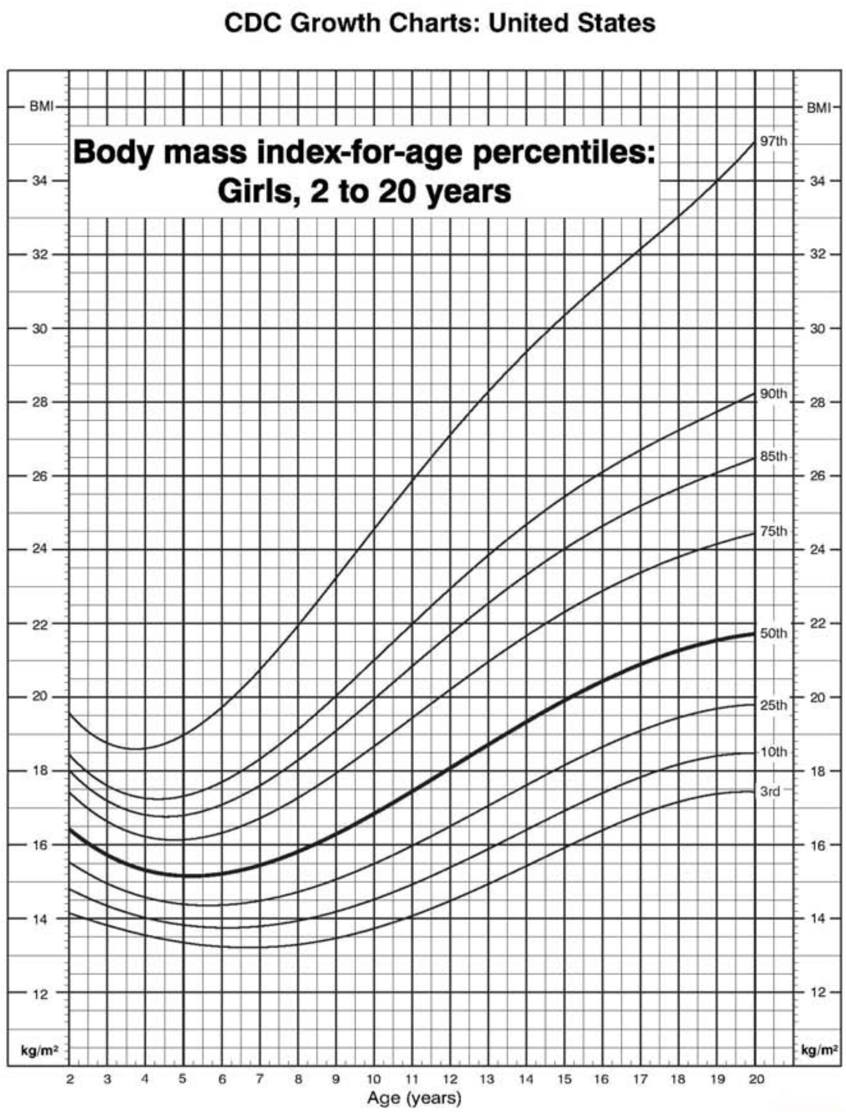


Figure 8-6. Body Mass Index-for-Age Percentiles: Girls, 2 to 20 Years

Source: Kuczmarski et al., 2002.

Table 8-13. Mean Body Weight (kilograms) by Age and Gender Across Multiple Surveys

Gender and Age (years)	NHES II, 1963-65			NHES III, 1966-70			NHANES I, 1971-74			NHANES II, 1976-80			NHANES III, 1988-94			NHANES 1999-2002		
	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
Male																		
2	-	-	-	-	-	-	298	13.6	0.2	370	13.4	0.1	644	13.6	0.1	262	13.7	0.1
3	-	-	-	-	-	-	308	15.6	0.1	421	15.5	0.1	516	15.8	0.2	216	15.9	0.2
4	-	-	-	-	-	-	304	17.7	0.1	405	17.6	0.1	549	17.6	0.2	179	18.5	0.2
5	-	-	-	-	-	-	273	20.2	0.2	393	19.7	0.1	497	20.1	0.2	147	21.3	0.5
6	575	22.0	0.1	-	-	-	179	22.0	0.3	146	22.8	0.4	283	23.2	0.6	182	23.5	0.4
7	632	24.7	0.2	-	-	-	164	24.9	0.4	150	24.9	0.4	269	26.3	0.4	185	27.2	0.4
8	618	27.8	0.2	-	-	-	152	26.4	0.3	145	28.0	0.6	266	30.2	0.8	214	32.7	1.0
9	603	31.2	0.4	-	-	-	169	31.6	0.8	141	30.7	0.6	281	34.4	1.0	174	36.0	0.7
10	576	33.7	0.3	-	-	-	184	34.2	0.6	165	36.2	0.7	297	37.3	0.9	187	38.6	0.8
11	595	38.2	0.3	-	-	-	178	38.8	0.8	153	39.7	0.9	281	42.5	0.9	182	43.7	1.1
12	-	-	-	643	42.9	0.4	200	44.0	0.8	147	44.1	1.0	203	49.1	1.1	299	50.4	1.3
13	-	-	-	626	50.0	0.5	174	49.9	1.0	165	49.5	1.2	187	54.0	1.0	298	53.9	1.9
14	-	-	-	618	56.7	0.6	174	56.3	0.9	188	56.4	0.9	188	64.1	3.6	266	63.9	1.6
15	-	-	-	613	61.6	0.4	171	60.3	1.2	180	61.2	1.0	187	66.9	1.9	283	68.3	1.1
16	-	-	-	556	64.8	0.6	169	66.9	1.3	180	66.5	1.2	194	68.7	1.6	306	74.4	1.4
17	-	-	-	458	68.1	0.4	176	68.6	1.1	183	66.7	0.8	196	72.9	1.3	313	75.6	1.4
18	-	-	-	-	-	-	124	74.3	1.3	156	71.1	1.2	176	71.3	1.7	284	75.6	1.1
19	-	-	-	-	-	-	136	72.6	1.3	150	71.8	0.8	168	73.0	2.2	270	78.2	1.3
Female																		
2	-	-	-	-	-	-	272	13.0	0.1	330	12.8	0.1	624	13.2	0.1	248	13.3	0.1
3	-	-	-	-	-	-	292	15.0	0.2	367	14.8	0.1	587	15.4	0.1	178	15.2	0.2
4	-	-	-	-	-	-	281	16.8	0.2	388	16.8	0.2	537	17.9	0.3	191	17.9	0.3
5	-	-	-	-	-	-	314	19.7	0.3	369	19.4	0.3	554	20.2	0.2	186	20.6	0.6
6	536	21.5	0.2	-	-	-	176	21.6	0.3	150	21.9	0.4	272	22.6	0.6	171	22.4	0.5
7	609	24.2	0.2	-	-	-	169	24.3	0.4	154	24.6	0.5	274	26.4	0.8	196	25.9	0.5
8	613	27.5	0.2	-	-	-	152	27.5	0.5	125	27.5	0.4	248	29.9	0.6	184	31.9	1.2
9	581	31.4	0.4	-	-	-	171	32.0	0.6	154	31.7	0.7	280	34.4	1.2	183	35.4	0.7
10	584	35.2	0.4	-	-	-	197	33.8	0.6	128	35.7	0.6	258	37.9	1.2	164	40.0	1.0
11	525	39.8	0.4	-	-	-	166	41.2	0.8	143	41.4	0.9	275	44.1	1.1	194	47.9	1.3
12	-	-	-	547	46.6	0.4	177	46.7	1.0	146	46.1	0.9	236	49.0	1.2	316	52.0	1.1
13	-	-	-	582	50.5	0.5	198	51.8	1.0	155	50.9	1.2	220	55.8	1.6	321	57.7	1.4
14	-	-	-	586	54.2	0.4	184	54.6	1.0	181	54.3	1.0	218	58.5	1.4	324	59.9	1.0
15	-	-	-	503	56.5	0.5	167	56.6	0.9	144	55.0	0.8	191	58.1	1.1	266	61.1	1.7
16	-	-	-	536	58.1	0.7	171	56.8	1.1	167	57.7	0.9	208	61.3	1.4	273	63.0	1.2
17	-	-	-	442	57.6	0.6	150	59.5	1.6	134	59.6	1.0	201	62.4	1.2	256	61.7	1.2
18	-	-	-	-	-	-	141	58.2	1.1	156	59.0	1.0	175	61.2	1.9	243	65.2	1.5
19	-	-	-	-	-	-	130	59.5	1.4	158	59.8	1.0	177	63.2	1.9	225	67.9	1.2

- Data not available.
N = Number of individuals.
SE = Standard error.

Source: Ogden et al., 2004.

Table 8-14. Mean Height (centimeters) by Age and Gender Across Multiple Surveys

Gender and Age (years)	NHES II, 1963-65			NHES III, 1966-70			NHANES I, 1971-74			NHANES II, 1976-80			NHANES III, 1988-94			NHANES 1999-2002		
	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
Male																		
2	-	-	-	-	-	-	298	91.1	0.4	350	91.1	0.2	589	90.9	0.2	254	91.2	0.3
3	-	-	-	-	-	-	308	98.5	0.3	421	98.7	0.3	513	98.8	0.3	222	98.6	0.3
4	-	-	-	-	-	-	304	106.0	0.3	405	105.5	0.4	551	105.2	0.4	183	106.5	0.4
5	-	-	-	-	-	-	273	112.8	0.3	393	112.3	0.3	497	112.3	0.3	156	113.0	0.5
6	575	118.9	0.2	-	-	-	179	118.1	0.6	146	119.1	0.5	283	118.9	0.7	188	119.2	0.5
7	632	124.5	0.3	-	-	-	164	125.0	0.5	150	124.5	0.5	270	125.9	0.6	187	126.2	0.6
8	618	130.0	0.3	-	-	-	152	129.0	0.5	145	129.6	0.7	269	131.3	0.6	217	1325.	0.7
9	603	135.5	0.4	-	-	-	169	135.1	0.6	141	135.0	0.6	280	137.7	0.7	177	138.1	0.4
10	576	140.2	0.3	-	-	-	184	140.0	0.5	165	141.3	0.6	297	142.0	1.1	188	141.4	0.6
11	595	145.5	0.3	-	-	-	178	146.3	0.7	153	145.5	0.6	285	147.4	0.7	187	148.7	0.9
12	-	-	-	643	152.3	0.4	200	152.8	0.7	147	152.5	0.7	207	155.5	1.1	301	154.8	0.7
13	-	-	-	626	159.8	0.4	174	159.3	0.8	165	158.3	0.8	190	161.6	0.8	298	160.1	0.8
14	-	-	-	618	166.7	0.5	174	166.7	0.6	188	166.8	0.6	191	169.0	0.9	267	168.5	0.9
15	-	-	-	613	171.4	0.3	171	170.8	0.9	180	171.2	0.7	188	172.8	1.0	287	173.8	0.6
16	-	-	-	556	174.3	0.4	169	175.0	0.8	180	173.4	0.5	197	175.0	0.9	310	175.3	0.6
17	-	-	-	458	175.6	0.4	176	176.9	0.5	183	174.8	0.5	196	176.5	0.9	317	175.3	0.6
18	-	-	-	-	-	-	124	176.6	0.7	156	177.3	0.6	176	177.3	1.0	289	176.4	0.7
19	-	-	-	-	-	-	136	176.5	0.9	150	176.1	0.5	169	175.5	0.6	275	176.7	0.6
Female																		
2	-	-	-	-	-	-	272	90.1	0.3	314	89.4	0.3	564	89.7	0.2	233	90.1	0.4
3	-	-	-	-	-	-	292	97.7	0.3	367	97.1	0.2	590	98.2	0.2	187	97.6	0.5
4	-	-	-	-	-	-	281	104.2	0.4	388	104.2	0.4	535	105.1	0.3	195	105.9	0.5
5	-	-	-	-	-	-	314	112.2	0.4	369	111.2	0.4	557	112.2	0.5	190	112.4	0.7
6	536	117.8	0.3	-	-	-	176	118.2	0.5	150	117.9	0.6	274	117.9	0.6	172	117.1	0.7
7	609	123.5	0.2	-	-	-	169	124.6	0.7	154	123.4	0.7	275	124.3	0.7	200	124.4	0.5
8	613	129.4	0.3	-	-	-	152	129.2	0.6	125	129.5	0.5	247	131.1	0.6	184	130.9	0.6
9	581	135.5	0.3	-	-	-	171	135.9	0.5	154	134.1	0.5	282	136.6	0.7	189	136.9	0.7
10	584	140.9	0.3	-	-	-	197	140.1	0.8	128	141.7	0.6	262	142.7	0.6	164	143.3	0.9
11	525	147.3	0.3	-	-	-	166	148.2	0.8	143	147.4	0.7	275	150.2	0.7	194	151.4	0.7
12	-	-	-	547	46.6	0.3	177	154.6	0.6	146	143.8	0.6	239	155.5	0.7	318	156.0	0.7
13	-	-	-	582	50.5	0.3	198	158.9	0.5	155	158.7	0.5	225	159.9	0.9	324	159.1	0.6
14	-	-	-	586	54.2	0.3	184	160.8	0.6	181	160.7	0.7	224	161.2	0.7	326	161.8	0.6
15	-	-	-	503	56.5	0.5	167	163.6	0.6	144	163.3	0.5	195	162.8	0.6	271	162.0	0.6
16	-	-	-	536	58.1	0.3	171	161.7	0.5	167	162.8	0.5	214	163.0	0.7	275	161.9	0.5
17	-	-	-	442	57.6	0.3	150	162.1	0.9	134	163.5	0.6	201	163.6	0.6	258	163.2	0.6
18	-	-	-	-	-	-	141	164.7	0.5	156	162.8	0.5	175	163.2	0.9	249	163.0	0.5
19	-	-	-	-	-	-	130	163.1	0.5	158	163.2	0.4	178	163.4	0.7	231	163.1	0.7

- Data not available.
N = Number of individuals.
SE = Standard error.

Source: Ogden et al., 2004.

Table 8-15. Mean Body Mass Index (BMI) by Age and Gender Across Multiple Surveys

Gender and Age (years)	NHES II, 1963-65			NHES III, 1966-70			NHANES I, 1971-74			NHANES II, 1976-80			NHANES III, 1988-94			NHANES 1999-2002		
	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
Male																		
2	-	-	-	-	-	-	298	16.3	0.1	350	16.2	0.1	588	16.5	0.1	225	16.6	0.1
3	-	-	-	-	-	-	308	16.0	0.1	421	15.9	0.1	512	16.1	0.2	209	16.2	0.1
4	-	-	-	-	-	-	304	15.7	0.1	405	15.8	0.1	547	15.9	0.1	178	16.3	0.2
5	-	-	-	-	-	-	273	15.6	0.1	393	15.6	0.1	495	15.9	0.1	147	16.5	0.3
6	575	15.6	0.1	-	-	-	179	15.7	0.2	146	16.0	0.2	282	16.3	0.3	182	16.4	0.2
7	632	15.9	0.1	-	-	-	164	15.8	0.2	150	16.0	0.2	269	16.5	0.2	185	17.0	0.2
8	618	16.3	0.1	-	-	-	152	15.8	0.2	145	16.5	0.2	266	17.3	0.4	214	18.4	0.4
9	603	16.9	0.2	-	-	-	169	17.1	0.3	141	16.8	0.2	279	18.0	0.7	174	18.7	0.3
10	576	17.1	0.1	-	-	-	184	17.3	0.2	165	18.0	0.3	297	18.4	0.3	187	19.1	0.3
11	595	17.9	0.1	-	-	-	178	18.0	0.3	153	18.6	0.3	280	19.4	0.3	182	19.6	0.4
12	-	-	-	643	18.4	0.1	200	18.7	0.2	147	18.8	0.3	203	20.1	0.3	299	20.7	0.4
13	-	-	-	626	19.4	0.1	174	19.6	0.3	165	19.5	0.4	187	20.5	0.3	298	20.7	0.5
14	-	-	-	618	20.2	0.2	174	20.2	0.3	188	20.2	0.2	188	22.3	1.1	266	22.3	0.4
15	-	-	-	613	20.9	0.1	171	20.5	0.3	180	20.8	0.3	187	22.3	0.5	283	22.5	0.3
16	-	-	-	556	21.3	0.1	169	21.8	0.3	180	22.0	0.3	194	22.3	0.5	306	24.1	0.4
17	-	-	-	458	22.1	0.1	176	21.9	0.3	183	21.8	0.2	196	23.4	0.4	313	24.5	0.4
18	-	-	-	-	-	-	124	23.7	0.3	156	22.6	0.4	176	22.6	0.5	284	24.2	0.3
19	-	-	-	-	-	-	136	23.3	0.5	150	23.1	0.3	168	23.7	0.6	269	24.9	0.4
Female																		
2	-	-	-	-	-	-	272	15.9	0.1	314	16.1	0.1	562	16.5	0.1	214	16.4	0.1
3	-	-	-	-	-	-	292	15.7	0.1	367	15.6	0.1	582	15.9	0.1	173	16.0	0.1
4	-	-	-	-	-	-	281	15.5	0.1	388	15.5	0.1	533	16.0	0.2	190	15.9	0.2
5	-	-	-	-	-	-	314	15.5	0.1	369	15.6	0.1	554	15.9	0.1	186	16.1	0.3
6	536	115.4	0.1	-	-	-	176	15.4	0.1	150	15.6	0.2	272	16.1	0.3	170	16.2	0.2
7	609	15.8	0.1	-	-	-	169	15.6	0.2	154	16.1	0.2	274	16.9	0.3	196	16.6	0.2
8	613	16.4	0.1	-	-	-	152	16.4	0.2	125	16.3	0.2	247	17.3	0.3	184	18.3	0.5
9	581	17.0	0.1	-	-	-	171	17.2	0.2	154	17.5	0.3	280	18.2	0.5	183	18.7	0.3
10	584	17.6	0.2	-	-	-	197	17.1	0.2	128	17.7	0.3	258	18.4	0.4	163	19.3	0.3
11	525	18.2	0.2	-	-	-	166	18.6	0.3	143	18.9	0.3	275	19.4	0.4	194	20.7	0.4
12	-	-	-	547	19.2	0.1	177	19.5	0.4	146	19.3	0.3	236	20.2	0.5	315	21.2	0.4
13	-	-	-	582	19.9	0.1	198	20.4	0.3	155	20.1	0.4	220	21.8	0.6	321	22.6	0.4
14	-	-	-	586	20.8	0.1	184	21.1	0.3	181	21.0	0.3	218	22.4	0.5	324	22.9	0.4
15	-	-	-	503	21.4	0.2	167	21.1	0.3	144	20.6	0.3	191	21.9	0.4	266	23.2	0.5
16	-	-	-	536	21.9	0.2	171	21.7	0.3	167	21.8	0.3	208	23.0	0.5	273	24.0	0.4
17	-	-	-	442	21.7	0.2	150	22.6	0.5	134	22.3	0.4	201	23.3	0.5	255	23.1	0.4
18	-	-	-	-	-	-	141	21.5	0.3	156	22.3	0.4	175	22.9	0.6	243	24.4	0.5
19	-	-	-	-	-	-	130	22.5	0.6	158	22.4	0.3	177	23.7	0.8	225	25.5	0.4

\- Data not available.
N = Number of individuals.
SE = Standard error.

Source: Ogden et al., 2004.

Table 8-16. Sample Sizes by Age, Sex, Race, and Examination

Age Group	Sex	Race[a]	NHANES Examination			
			I (1971-1974)	II (1976-1980)	III (1988-1994)	1999-2002
Overall			6431 (10.3)[b]	6395 (10.6)	9610 (9.9)	6710 (10.1)
2 to 5 years	Boys	White	829 (3.9)	1082 (4.1)	605 (4.0)	226 (3.9)
		Black	286 (3.9)	273 (4.1)	693 (3.9)	234 (4.0)
		Mexican American	51 (3.8)	105 (4.2)	732 (4.0)	231 (3.9)
	Girls	White	772 (4.0)	1028 (4.0)	639 (4.0)	235 (4.1)
		Black	297 (4.0)	234 (4.0)	684 (3.9)	222 (4.0)
		Mexican American	56 (4.1)	102 (4.2)	800 (3.9)	238 (4.1
6 to 11 years	Boys	White	711 (9.1)	667 (9.0)	446 (8.9)	298 (8.9)
		Black	249 (9.0)	137 (9.0)	584 (9.0)	371 (9.0)
		Mexican American	51 (9.0)	60 (9.2)	565 (9.0)	384 (9.0)
	Girls	White	722 (9.1)	631 (9.1)	428 (9.1)	293 (8.9)
		Black	268 (9.0)	155 (9.0)	538 (9.0)	363 (9.1)
		Mexican American	45 (8.9)	40 (9.3)	581 (8.9)	361 (9.0)
12 to 17 years	Boys	White	764 (14.9)	786 (15.1)	282 (14.9)	449 (14.9)
		Black	252 (14.9)	155 (15.1)	412 (15.0)	543 (14.9)
		Mexican American	42 (15.0)	49 (15.0)	406 (15.0)	648 (15.0)
	Girls	White	749 (15.0)	695 (15.1)	344 (15.0)	456 (14.9)
		Black	251 (14.8)	159 (15.0)	450 (14.9)	528 (14.8)
		Mexican American	36 (14.9)	37 (15.2)	421 (14.8)	631 (14.9)

[a] Race was recoded in the first two examinations (using data concerning ancestry/national origin) to create comparable categories in all surveys.

[b] Mean ages are shown in parentheses.

Source: Freeman et al., 2006.

Table 8-17. Mean BMI (kg/m^2) Levels and Change in the Mean Z-Scores by Race-Ethnicity and Sex								
		Examination Year[a]				Increase in Mean z-score From 1971-1974 to 1999-2002		
	Race	1971-1974	1976-1980	1988-1994	1999-2002	BMI	Weight	Height
Overall	White	18.0[b]	18.0	18.8	19.0	+0.33	+0.36	+0.20
	Black	17.8	18.2	19.1	20.0	+0.61	+0.63	+0.31
	Mexican-American	18.6	18.8	19.5	20.1	+0.32	+0.52	+0.39
Sex								
Boys	White	17.9	18.0	18.8	19.0	+0.37	+0.42	+0.25
	Black	17.7	17.8	18.8	19.6	+0.53	+0.58	+0.32
	Mexican-American	18.6	18.9	19.4	20.3	+0.38	+0.67	+0.57
Girls	White	18.0	18.0	18.7	19.0	+0.30	+0.32	+0.16
	Black	17.9	18.6	19.5	20.4	+0.71	+0.69	+0.30
	Mexican-American	18.5	18.6	19.6	19.9	+0.25	+0.35	+0.21
Age (years)								
2 to 5	White	15.8	15.7	16.0	16.2	+0.21	+0.22	+0.13
	Black	15.8	15.7	15.9	16.2	+0.34	+0.32	+0.18
	Mexican-American	16.5	16.2	16.5	16.5	-0.02	+0.29	+0.43
6 to 11	White	16.7	16.9	17.6	17.9	+0.42	+0.47	+0.30
	Black	16.5	17.1	17.9	18.7	+0.67	+0.69	+0.36
	Mexican-American	16.9	17.7	18.5	18.8	+0.50	+0.65	+0.41
12 to 17	White	20.7	20.6	21.8	22.0	+0.32	+0.35	+0.15
	Black	20.4	20.9	22.4	23.7	+0.72	+9,77	+0.33
	Mexican-American	21.6	21.5	22.6	24.0	+0.37	+0.55	+0.34

[a] Secular trends for BMI, BMI-for-age, weight-for-age, and height-for-age were each statistically significant at the 0.001 level. Trends in BMI, BMI-for-age, and weight also differed ($p < 0.001$) by race.

[b] Mean BMI levels have been adjusted for differences in age and sex across exams.

Source: Freedman et al., 2006.

Table 8-18. Prevalence of Overweight and Obesity[a] Among Children

			Examination year				Increase in Prevalence From 1971-1974 to 1999-2002	
		Race	1971-1974	1976-1980	1988-1994	1999-2002	Overweight	Obesity
Overall		White	5% (1)[b]	5% (1)	9% (2)	12% (3)	+8	+2
		Black	6% (1)	7% (2)	12% (3)	18% (5)	+12	+4
		Mexican-American	8% (1)	10% (1)	14% (4)	21% (5)	+12	+4
Sex								
	Boys	White	5% (1)	5% (1)	10% (2)	13% (4)	+8	+3
		Black	6% (2)	5% (1)	11% (3)	16% (5)	+10	+3
		Mexican-American	8% (1)	12% (1)	15% (4)	24% (4)	+16	+6
	Girls	White	5% (1)	5% (1)	9% (2)	12% (2)	+7	+1
		Black	6% (1)	9% (2)	14% (3)	21% (6)	+14	+5
		Mexican-American	8% (2)	7% (0)	14% (3)	17% (4)	+9	+2
Age (years)								
	2 to 5	White	4% (1)	3% (1)	5% (1)	9% (3)	+5	+2
		Black	7% (3)	4% (0)	8% (3)	9% (4)	+2	+1
		Mexican-American	10% (5)	11% (3)	12% (5)	13% (5)	+3	0
	6 to 11	White	4% (0)	6% (1)	11% (3)	13% (4)	+10	+3
		Black	4% (0)	9% (3)	15% (3)	20% (5)	+15	+4
		Mexican-American	6% (0)	11% (0)	17% (4)	22% (5)	+16	+5
	12 to 17	White	6% (1)	4% (0)	11% (2)	13% (2)	+7	+1
		Black	8% (1)	8% (1)	13% (3)	22% (6)	+14	+5
		Mexican-American	9% (0)	8% (1)	14% (2)	25% (5)	+15	+5

[a] Overweight is defined as a BMI ≥ 95th percentile or ≥ 30 kg/m^2; obesity is defined as a BMI ≥ 99th percentile or ≥ 40 kg/m^2.
[b] Values are percentage of overweight children (percentage of obese children).

Source: Freedman et al., 2006.

Table 8-19. Numbers of Live Births by Weight and Percentages of Live Births with Low and Very Low Birth Weights, by Race and Hispanic Origin of Mother: United States, 2005

	All Races[a]	Non-Hispanic White[b]	Non-Hispanic Black[b]	Hispanic[c]
Total Births	4,138,349	2,279,768	583,759	985,505
Weight (grams)	Number of Live Births			
< 500	6,599	2,497	2,477	1,212
500-999	23,864	10,015	8,014	4,586
1,000-1,499	31,325	14,967	8,573	5,988
1,500-1,999	66,453	33,687	15,764	12,710
2,000-2,499	210,324	104,935	46,846	43,300
2,500-2,999	748,042	364,726	144,803	176,438
3,000-3,499	1,596,944	857,136	221,819	399,295
3,500-3,999	1,114,887	672,270	108,698	266,338
4,000-4499	289,098	167,269	22,149	64,704
4,500-4999	42,119	27,541	3,203	9,167
>5,000	4,715	2,840	405	1,174
Not stated	3,979	1,885	1,008	593
Percent of Total				
Low Birth Weight[d]	8.2	7.3	14.0	6.9
Very Low Birth Weight[e]	1.5	1.2	3.3	1.2

[a] All Races includes White, Black, and races other than White and Black and origin not stated.
[b] Race categories are consistent with the 1977 Office of Management and Budget standards.
[c] Hispanic includes all persons of Hispanic origin of any race.
[d] Low birth weight is birth weight less than 2,500 grams (5 lb 8 oz).
[e] Very low birth weight is birth weight less than 1,500grams (3 lb 4 oz).

Source: Martin et al., 2007.

Table 8-20. Estimated Mean Body Weights of Males and Females by Single-Year Age Groups Using NHANES II Data

Age Group[a]	Males (kg)			Females (kg)			Overall (kg)		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
0 to 1 year	9.4	1.3	179	8.8	1.3	177	9.1	1.2	356
1 to 2 years	11.8	1.6	370	10.8	1.4	336	11.3	1.5	706
2 to 3 years	13.6	1.8	375	13.0	1.5	336	13.3	1.6	711
3 to 4 years	15.6	1.9	418	14.9	2.1	366	15.2	1.8	784
4 to 5 years	17.8	2.4	404	17.0	2.3	396	17.4	2.4	800
5 to 6 years	19.8	2.8	397	19.6	3.2	364	19.7	2.8	761
6 to 7 years	23.0	3.7	133	22.1	3.9	135	22.5	3.6	268
7 to 8 years	25.1	3.8	148	24.7	4.6	157	24.8	3.8	305
8 to 9 years	28.2	5.6	147	27.8	4.8	123	28.1	5.6	270
9 to 10 years	31.1	5.8	145	31.8	7.3	149	31.4	5.9	294
10 to 11 years	36.4	7.2	157	36.1	7.7	136	36.2	7.1	293
11 to 12 years	40.2	9.8	155	41.8	10.1	140	41.0	9.9	295
12 to 13 years	44.2	9.8	145	46.4	10.1	147	45.4	10.0	292
13 to 14 years	49.8	11.4	173	50.9	11.2	162	50.4	11.5	335
14 to 15 years	57.1	10.7	186	54.7	10.7	178	55.9	10.5	364
15 to 16 years	61.0	10.4	184	55.1	9.0	145	58.0	9.9	329
16 to 17 years	67.1	11.7	178	58.1	9.6	170	62.4	10.9	348
17 to 18 years	66.7	11.3	173	59.6	10.4	134	63.3	10.7	307
18 to 19 years	71.0	12.0	164	59.0	10.2	170	64.6	10.9	334
19 to 20 years	71.7	11.3	148	60.1	10.1	158	65.3	10.3	306
20 to 21 years	71.6	12.0	114	60.5	10.7	162	65.2	10.9	276

[a] Data were converted from ages in months to ages in years. For instance, age 1–2 years represents ages from 12 to 23 months.
SD = Standard Deviation.
N = Number of individuals.

Source: Portier et al., 2007.

Table 8-21. Estimated Mean Body Weights of Males and Females by Single-Year Age Groups Using NHANES III Data

Age Group[a]	Males (kg)			Females (kg)			Overall (kg)		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
0 to 1 years	8.5	1.5	902	7.8	1.6	910	8.17	1.7	1,812
1 to 2 years	11.6	1.5	660	10.9	1.4	647	11.2	1.5	1,307
2 to 3 years	13.6	1.5	644	13.2	1.8	624	13.4	1.8	1,268
3 to 4 years	15.8	2.3	516	15.4	2.2	587	15.6	2.2	1,103
4 to 5 years	17.6	2.4	549	17.9	3.2	537	17.8	3.2	1,086
5 to 6 years	20.1	3.0	497	20.2	3.5	554	20.2	3.5	1,051
6 to 7 years	23.2	5.0	283	22.6	4.7	272	22.9	4.8	555
7 to 8 years	26.3	5.0	269	26.3	6.2	274	26.4	6.2	543
8 to 9 years	30.1	6.9	266	29.8	6.7	248	30.0	6.7	514
9 to 10 years	34.4	7.9	281	34.3	9.0	280	34.4	9.0	561
10 to 11 years	37.3	8.6	297	37.9	9.5	258	37.7	9.4	555
11 to 12 years	42.5	10.5	281	44.2	10.5	275	43.4	10.3	556
12 to 13 years	49.1	11.1	203	49.1	11.6	236	49.1	11.7	439
13 to 14 years	54.0	12.9	187	55.7	13.2	220	54.8	13.0	407
14 to 15 years	63.7	17.1	188	58.3	11.8	220	60.6	12.2	408
15 to 16 years	66.8	14.9	187	58.3	10.1	197	61.7	10.7	384
16 to 17 years	68.6	14.9	194	61.5	12.8	215	65.2	13.6	409
17 to 18 years	72.7	13.3	196	62.4	11.9	217	67.6	12.9	413
18 to 19 years	71.2	14.3	176	61.5	14.2	193	66.4	15.3	369
19 to 20 years	73.0	12.8	168	63.6	14.5	193	68.3	15.6	361
20 to 21 years	72.5	13.4	149	61.7	12.9	180	66.1	13.8	329

[a] Data were converted from ages in months to ages in years. For instance, age 1–2 years represents ages from 12 to 23 months.
SD = Standard Deviation.
N = Number of individuals.

Source: Portier et al., 2007.

Table 8-22. Estimated Mean Body Weights of Males and Females by Single-Year Age Groups Using NHANES IV Data

Age Group[a]	Males (kg)			Females (kg)			Overall (kg)		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
0 to 1 year	9.3	1.8	116	9.3	1.5	101	9.3	1.5	217
1 to 2 years	11.3	1.4	144	11.5	1.9	98	11.4	1.8	242
2 to 3 years	13.7	2.0	130	13.3	1.9	113	13.5	2.0	243
3 to 4 years	16.4	2.3	105	15.2	2.1	77	15.9	2.2	182
4 to 5 years	18.8	2.6	95	18.1	3.2	87	18.5	3.3	182
5 to 6 years	20.2	3.3	65	20.7	4.9	92	20.6	4.9	157
6 to 7 years	22.9	4.3	94	22.0	4.5	74	22.5	4.6	168
7to 8 years	28.1	5.6	100	26.0	6.2	82	27.4	6.5	182
8 to 9 years	31.9	8.6	100	30.8	7.2	89	31.3	7.3	189
9 to 10 years	36.1	7.5	76	36.0	8.4	84	36.2	8.5	160
10 to 11 years	39.5	9.0	92	39.4	10.2	84	39.5	10.2	176
11 to 12 years	42.0	10.2	84	47.2	12.2	97	44.6	11.6	181
12 to 13 years	49.4	12.7	158	51.6	12.3	160	50.3	11.9	318
13 to 14 years	54.9	16.2	161	59.8	15.3	156	56.9	14.6	317
14 to 15 years	65.1	19.9	137	59.9	13.3	158	61.5	13.7	295
15 to 16 years	68.2	15.7	142	63.4	13.9	126	65.9	14.4	268
16 to 17 years	72.5	18.6	153	63.4	16.0	142	68.0	17.1	295
17 to 18 years	75.4	17.9	146	59.9	11.9	128	66.6	13.2	274
18 to 19 years	74.8	15.9	131	65.0	15.2	139	70.2	16.4	270
19 to 20 years	80.1	17.2	129	68.7	17.4	132	74.6	19.0	261
20 to 21 years	80.0	15.5	37	66.3	15.5	44	74.3	17.4	81

[a] Data were converted from ages in months to ages in years. For instance, age 1–2 years represents ages from 12 to 23 months.
SD = Standard Deviation.
N = Number of individuals.

Source: Portier et al., 2007.

Table 8-23. Estimated Body Weights of Typical Age Groups of Interest in U.S. EPA Risk Assessments[a]

Age Group	NHANES	Males (kg)			Females (kg)			Overall (kg)		
		Mean	SD	N	Mean	SD	N	Mean	SD	N
1 to 6 years	II	17.0	4.6	2,097	16.3	4.7	1,933	16.7	4.5	4,030
	III	16.9	4.7	3,149	16.5	4.9	3,221	16.8	5.0	6,370
	IV	17.1	4.9	633	17.5	5.0	541	17.3	5.0	1,174
7 to 16 years	II	45.2	17.6	1,618	43.9	15.9	1,507	44.8	17.5	3,125
	III	49.3	20.9	2,549	46.8	18.0	2,640	47.8	18.4	5,189
	IV	47.9	20.1	1,203	47.9	19.2	1,178	47.7	19.1	2,381

[a] Estimates were weighted using the sample weights provided with each survey.
SD = Standard Deviation.
N = Number of individuals.

Source: Portier et al., 2007.

Table 8-24. Estimated Percentile Distribution of Body Weight by Fine Age Categories Derived From 1994-96, 1998 CSFII

Weight (kilograms)

Age Group	Sample Size	Mean	Percentile 1st	5th	10th	25th	50th	75th	90th	95th	99th
Birth to 1 month	88	4	1[a]	2[a]	3[a]	3	3	4	4[a]	5[a]	5[a]
1 to <3 months	245	5	2[a]	3[a]	4	4	5	6	6	7[a]	8[a]
3 to <6 months	411	7	4[a]	5	5	6	7	8	9	10	12[a]
6 to <12 months	678	9	6[a]	7	7	8	9	10	11	12	13[a]
1 to <2 years	1,002	12	8[a]	9	9	10	11	13	14	15	19[a]
2 to <3 years	994	14	10[a]	10	11	12	14	16	18	19	22[a]
3 to <6 years	4,112	18	11	13	13	16	18	20	23	25	32
6 to <11 years	1,553	30	16[a]	18	20	23	27	35	41	45	57[a]
11 to <16 years	975	54	29[a]	33	36	44	52	61	72	82	95[a]
16 to <18 years	360	67	41[a]	46[a]	50	56	63	73	86	100[a]	114[a]
18 to <21 years	383	69	45[a]	48[a]	51	58	66	77	89	100[a]	117[a]

[a] Sample size does meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).

Source: Kahn and Stralka, 2008.

Table 8-25. Estimated Percentile Distribution of Body Weight By Fine Age Categories With Confidence Interval

Weight (Kilograms)										
Age Group	Sample Size	Mean			90th Percentile			95th Percentile		
		Estimate	90% CI		Estimate	90% BI		Estimate	90% BI	
			Lower Bound	Upper Bound		Lower Bound	Upper Bound		Lower Bound	Upper Bound
Birth to 1 month	88	4	3	4	4[a]	4[a]	5[a]	5[a]	5[a]	5[a]
1 to <3 months	245	5	5	5	6	6	7	7[a]	7	7
3 to <6 months	411	7	7	7	9	9	9	10	10	10
6 to <12 months	678	9	9	9	11	11	11	12	12	12
1 to <2 years	1,002	12	12	12	14	14	15	15	15	16
2 to <3 years	994	14	14	14	18	17	18	19	18	19
3 to <6 years	4,112	18	18	18	23	23	23	25	25	25
6 to <11 years	1,553	30	29	30	41	41	43	45	44	48
11 to <16 years	975	54	53	55	72	70	75	82	81	84
16 to <18 years	360	67	66	68	86	84	95	100[a]	95[a]	109[a]
18 to <21 years	383	69	68	70	89	88	95	100[a]	95[a]	104[a]

a Sample size does meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States"(Vol. I). Interval estimates may involve aggregation of variance estimation units when data are too sparse to support estimation of variance.

CI = Confidence interval.

BI = Percentile intervals estimated using percentile bootstrap method with 1,000 bootstrap replications.

Source: Kahn and Stralka, 2008.

Table 8-26. Fetal Weight (grams) Percentiles Throughout Pregnancy

Gestational Age (weeks)	Number of Women	10th	25th	50th	75th	90th
8	6	–[a]	–	6.1[b]	–	–
9	7	–	–	7.3[b]	–	–
10	15	–	–	8.1[b]	–	–
11	13	–	–	11.9[b]	–	–
12	18	–	11	21	34	–
13	43	–	23	35	55	–
14	61	–	3,405	51	77	–
15	63	–	51	77	108	–
16	59	–	80	117	151	–
17	36	–	125	166	212	–
18	58	–	172	220	298	–
19	31	–	217	283	394	–
20	21	–	255	325	460	–
21	43	280	330	410	570	860
22	69	320	410	480	630	920
23	71	370	460	550	690	990
24	74	420	530	640	780	1,080
25	48	490	630	740	890	1,180
26	86	570	730	860	1,020	1,320
27	76	660	840	990	1,160	1,470
28	91	770	980	1,150	1,350	1,660
29	88	890	1,100	1,310	1,530	1,890
30	128	1,030	1,260	1,460	1,710	2,100
31	113	1,180	1,410	1,630	1,880	2,290
32	210	1,310	1,570	1,810	2,090	2,500
33	242	1,480	1,720	2,010	2,280	2,690
34	373	1,670	1,910	2,220	2,510	2,880
35	492	1,870	2,130	2,430	2,730	3,090
36	1,085	2,190	2,470	2,650	2,950	3,290
37	1,798	2,310	2,580	2,870	3,160	3,470
38	3,908	2,510	2,770	3,030	3,320	3,610
39	5,413	2,680	2,910	3,170	3,470	3,750
40	10,586	2,750	3,010	3,280	3,590	3,870
41	3,399	2,800	3,070	3,360	3,680	3,980
42	1,725	2,830	3,110	3,410	3,740	4,060
43	507	2,840	3,110	3,420	3,780	4,100
44	147	2,790	3,050	3,390	3,770	4,110

[a] Data not available.

[b] Median fetal weights may be overestimated. They were derived from only a small proportion of the fetuses delivered at these weeks' gestation.

Source: Brenner et al., 1976.

Table 8-27. Neonatal Weight by Gestational Age for Males and Females Combined

Gestational Age (weeks)	Weight (g)						
	5th	10th	25th	50th	75th	90th	95th
25	450	490	564	660	772	889	968
26	523	568	652	760	885	1,016	1,103
27	609	660	754	875	1,015	1,160	1,257
28	707	765	870	1,005	1,162	1,322	1,430
29	820	884	1,003	1,153	1,327	1,504	1,623
30	947	1,020	1,151	1,319	1,511	1,706	1,836
31	1,090	1,171	1,317	1,502	1,713	1,928	2,070
32	1,249	1,338	1,499	1,702	1,933	2,167	2,321
33	1,422	1,519	1,696	1,918	2,169	2,421	2,587
34	1,608	1,714	1,906	2,146	2,416	2,687	2,865
35	1,804	1,919	2,125	2,383	2,671	2,959	3,148
36	2,006	2,129	2,349	2,622	2,927	3,230	3,428
37	2,210	2,340	2,572	2,859	3,177	3,493	3,698
38	2,409	2,544	2,786	3,083	3,412	3,736	3,947
39	2,595	2,735	2,984	3,288	3,622	3,952	4,164
40	2,762	2,904	3,155	3,462	3,798	4,127	4,340
41	2,900	3,042	3,293	3,597	3,930	4,254	4,462
42	3,002	3,142	3,388	3,685	4,008	4,322	4,523
43	3,061	3,195	3,432	3,717	4,026	4,324	4,515

Source: Doubilet et al., 1997.

9 INTAKE OF FRUITS AND VEGETABLES

9.1 INTRODUCTION

The American food supply is generally considered to be one of the safest in the world. Nevertheless, fruits and vegetables may become contaminated with toxic chemicals by several different pathways. Ambient pollutants from the air may be deposited on or absorbed by the plants, or dissolved in rainfall or irrigation waters that contact the plants. Pollutants may also be absorbed through plant roots from contaminated soil and ground water. The addition of pesticides, soil additives, and fertilizers may also result in contamination of fruits and vegetables. To assess exposure through this pathway, information on fruit and vegetable ingestion rates is needed.

Children's exposure from contaminated fruits and vegetables may differ from that of adults because of differences in the types and amounts of food eaten. Also, for many foods, the intake per unit body weight is greater for children than for adults. Common fruits and vegetables eaten by children include apple juice, fresh apples, orange juice, fresh pears, fresh peaches, carrots, fresh bananas, succulent garden peas, and succulent garden beans (Goldman, 1995).

A variety of terms may be used to define intake of fruits and vegetables (e.g., consumer-only intake, per capita intake, total fruit intake, total vegetable intake, as-consumed intake, dry weight intake). These terms are defined below to assist the reader in interpreting and using the intake rates that are appropriate for the exposure scenario being assessed.

Consumer-only intake is defined as the quantity of fruits and vegetables consumed by children during the survey period. These data are generated by averaging intake across only the children in the survey who consumed these food items. Per capita intake rates are generated by averaging consumer-only intakes over the entire population of children (including those children that reported no intake). In general, per capita intake rates are appropriate for use in exposure assessments for which average dose estimates for children are of interest because they represent both children who ate the foods during the survey period and children who may eat the food items at some time, but did not consume them during the survey period. Per capita intake, therefore, represents an average across the entire population of interest, but does so at the expense of underestimating consumption for the subset of the population that consumed the food in question. Total fruit intake refers to the sum of all fruits consumed in a day including canned, dried, frozen, and fresh fruits. Likewise, total vegetable intake refers to the sum of all vegetables consumed in a day including canned, dried, frozen, and fresh vegetables.

Intake rates may be expressed on the basis of the as-consumed weight (e.g., cooked or prepared) or on the uncooked or unprepared weight. As-consumed intake rates are based on the weight of the food in the form that it is consumed and should be used in assessments where the basis for the contaminant concentrations in foods is also indexed to the as-consumed weight. The food ingestion values provided in this chapter are expressed as as-consumed intake rates because this is the fashion in which data were reported by survey respondents. This is of importance because concentration data to be used in the dose equation are often measured in uncooked food samples. It should be recognized that cooking can either increase or decrease food weight. Similarly, cooking can increase the mass of contaminant in food (due to formation reactions, or absorption from cooking oils or water) or decrease the mass of contaminant in food (due to vaporization, fat loss or leaching). The combined effects of changes in weight and changes in contaminant mass can result in either an increase or decrease in contaminant concentration in cooked food. Therefore, if the as-consumed ingestion rate and the uncooked concentration are used in the dose equation, dose may be under-estimated or over-estimated. Ideally, after-cooking food concentrations should be combined with the as-consumed intake rates. In the absence of data, it is reasonable to assume that no change in contaminant concentration occurs after cooking. It is important for the assessor to be aware of these issues and choose intake rate data that best match the concentration data that are being used. For more information on cooking losses and conversions necessary to account for such losses, the reader is referred to Chapter 13 of this handbook.

Sometimes contaminant concentrations in food are reported on a dry weight basis. When these data are used in an exposure assessment, it is recommended that dry-weight intake rates also be used. Dry-weight food concentrations and intake rates are based on the weight of the food consumed after the moisture content has been removed. For information on converting the intake rates presented in this chapter to dry weight intake rates, the reader is referred to Section 9.4.

The purpose of this chapter is to provide intake data for fruits and vegetables among children. The recommendations for fruit and vegetable ingestion rates are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on the key study identified by U.S. EPA for this factor. Following the recommendations, the key study on fruit and vegetable ingestion is summarized. Relevant data on ingestion of fruits and vegetables are also provided. These data are presented to provide the reader with added perspective on the current state-of-knowledge pertaining to ingestion of fruits and vegetables.

9.2 RECOMMENDATIONS

Table 9-1 presents a summary of the recommended values for per capita and consumer-only intake of fruits and vegetables, on an as-consumed basis. Confidence ratings for the fruit and vegetable intake recommendations for general population children are provided in Table 9-2.

The U.S. EPA analysis of data from the 1994-96 and 1998 Continuing Survey of Food Intake by Individuals (CSFII) was used in selecting recommended intake rates for general population children. The U.S. EPA analysis was conducted using age groups that differed slightly from U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). However, for the purposes of the recommendations presented here, data were placed in the standardized age categories closest to those used in the analysis. Also, the CSFII data on which the recommendations are based are short-term survey data and may not necessarily reflect the long-term distribution of average daily intake rates. However, for broad categories of food (i.e., total fruits and total vegetables), because they are eaten on a daily basis throughout the year with minimal seasonality, the short term distribution may be a reasonable approximation of the long-term distribution, although it will display somewhat increased variability. This implies that the upper percentiles shown here may tend to overestimate the corresponding percentiles of the true long-term distribution. It should also be noted that because these recommendations are based on 1994-96 and 1998 CSFII data, they may not reflect the most recent changes that may have occurred in consumption patterns. More current data from the National Health and Nutrition Survey (NHANES) will be incorporated as the data become available and are analyzed.

Table 9-1. Recommended Values for Intake of Fruits and Vegetables, As Consumed[a]

Age Group	Per Capita		Consumers Only		Multiple Percentiles	Source
	Mean	95th Percentile	Mean	95th Percentile		
	g/kg-day	g/kg-day	g/kg-day	g/kg-day		
Total Fruits						
Birth to 1 year	5.7	21	10	26	See Tables 9-3 and 9-4	U.S. EPA Analysis of CSFII, 1994-96 and 1998.
1 to <2 years	6.2	19	6.9	19		
2 to < 3 years	6.2	19	6.9	19		
3 to <6 years	4.6	14	5.1	15		
6 to <11 years	2.4	8.8	2.7	9.3		
11 to <16 years	0.8	3.5	1.1	3.8		
16 to <21 years	0.8	3.5	1.1	3.8		
Total Vegetables						
Birth to 1 year	4.5	15	6.2	16	See Tables 9-3 and 9-4	U.S. EPA Analysis of CSFII, 1994-96 and 1998.
1 to <2 years	6.9	17	6.9	17		
2 to <3 years	6.9	17	6.9	17		
3 to <6 years	5.9	15	5.9	15		
6 to <11 years	4.1	9.9	4.1	9.9		
11 to <16 years	2.9	6.9	2.9	6.9		
16 to <21 years	2.9	6.9	2.9	6.9		
Individual Fruits and Vegetables - See Tables 9-5 and 9-6						

[a] Analysis was conducted using slightly different age groups than those recommended in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005). Data were placed in the standardized age categories closest to those used in the analysis.

Table 9-2. Confidence in Recommendations for Intake of Fruits and Vegetables		
General Assessment Factors	Rationale	Rating
Soundness		High for total fruits and vegetables, low for some individual fruits and vegetables with small sample size
Adequacy of Approach	The survey methodology and data analysis was adequate. The survey sampled more than 11,000 individuals up to age 18 years. However, samples size for some individual fruits and vegetables for some of the age groups are small. An analysis of primary data was conducted.	
Minimal (or Defined) Bias	No physical measurements were taken. The method relied on recent recall of fruits and vegetables eaten.	
Applicability and Utility		Medium
Exposure Factor of Interest	The key study was directly relevant to fruit and vegetable intake.	
Representativeness	The data were demographically representative of the U.S. population (based on stratified random sample).	
Currency	Data were collected between 1994 and 1998.	
Data Collection Period	Data were collected for two non-consecutive days.	
Clarity and Completeness		High
Accessibility	The CSFII data are publicly available.	
Reproducibility	The methodology used was clearly described; enough information was included to reproduce the results.	
Quality Assurance	Quality assurance of the CSFII data was good; quality control of the secondary data analysis was not well described.	
Variability and Uncertainty		Medium
Variability in Population	Full distributions were provided for total fruits and total vegetables. Means were provided for individuals fruits and vegetables.	
Uncertainty	Data collection was based on recall of consumption for a 2-day period; the accuracy of using these data to estimate long-term intake (especially at the upper percentiles) is uncertain. However, use of short-term data to estimate chronic ingestion can be assumed for broad categories of foods such as total fruits and total vegetables. Uncertainty is likely to be greater for individual fruits and vegetables.	

Table 9-2. Confidence in Recommendations for Intake of Fruits and Vegetables (continued)

General Assessment Factors	Rationale	Rating
Evaluation and Review		Medium
Peer Review	The USDA CSFII survey received a high level of peer review. The U.S. EPA analysis of these data has not been peer reviewed outside the Agency.	
Number and Agreement of Studies	There was 1 key study.	
Overall Rating		**High** confidence in the averages; **Low** for some individual fruits and vegetables with small sample size **Low** confidence in the long-term upper percentiles

9.3 INTAKE STUDIES

The primary source of recent information on consumption rates of fruits and vegetables among children is the U.S. Department of Agriculture's (USDA) CSFII. Data from the 1994-96 CSFII and the 1998 Children's supplement to the 1994-96 CSFII have been used in various studies to generate children's consumer-only and per capita intake rates for both individual fruits and vegetables and total fruits and vegetables. The CSFII is a series of surveys designed to measure the kinds and amounts of foods eaten by Americans. The CSFII 1994-96 was conducted between January 1994 and January 1997 with a target population of non-institutionalized individuals in all 50 states and Washington, D.C. In each of the 3 survey years, data were collected for a nationally representative sample of individuals of all ages. The CSFII 1998 was conducted between December 1997 and December 1998 and surveyed children 9 years of age and younger. It used the same sample design as the CSFII 1994-96 and was intended to be merged with CSFII 1994-96 to increase the sample size for children. The merged surveys are designated as CSFII 1994-96, 1998. Additional information on these surveys can be obtained at http://www.ars.usda.gov/Services/docs.htm?docid=14531.

The CSFII 1994-96, 1998 collected dietary intake data through in-person interviews on 2 non-consecutive days. The data were based on 24-hour recall. A total of 21,662 individuals provided data for the first day; of those individuals, 20,607 provided data for a second day. Over 11,000 of the sample persons represented children up to 18 years of age. The 2-day response rate for the 1994-1996 CSFII was approximately 76 percent. The 2-day response rate for CSFII 1998 was 82 percent.

The CSFII 1994-96, 98 surveys were based on a complex multistage area probability sample design. The sampling frame was organized using 1990 U.S. population census estimates, and the stratification plan took into account geographic location, degree of urbanization, and socioeconomic characteristics. Several sets of sampling weights are available for use with the intake data. By using appropriate weights, data for all fours years of the surveys can be combined. USDA recommends that all 4 years be combined in order to provide an adequate sample size for children.

9.3.1 Key Fruits and Vegetables Intake Study

9.3.1.1 *U.S. EPA Analysis of CSFII 1994-96, 1998*

For many years, the U.S. EPA's Office of Pesticide Programs (OPP) has used food consumption data collected by the U.S. Department of Agriculture (USDA) for its dietary risk assessments. Most recently, OPP, in cooperation with USDA's Agricultural Research Service (ARS), used data from the 1994-96, 1998 CSFII to develop the Food Commodity Intake Database (FCID). CSFII data on the foods people reported eating were converted to the quantities of agricultural commodities eaten. "Agricultural commodity" is a term used by U.S. EPA to mean plant (or animal) parts consumed by humans as food; when such items are raw or unprocessed, they are referred to as "raw agricultural commodities." For example, an apple pie may contain the commodities apples, flour, fat, sugar and spices. FCID contains approximately 553 unique commodity names and 8-digit codes. The FCID commodity names and codes were selected and defined by U.S. EPA and were based on the U.S. EPA Food Commodity Vocabulary (http://www.epa.gov/pesticides/foodfeed/).

The fruit and vegetable items/groups selected for the U.S. EPA analysis included total fruits and total vegetables, and individual fruits such as: apples, bananas, peaches, pears, strawberries, citrus fruits, pome fruit, stone fruit, and tropical fruits; and individual vegetables such as: asparagus, beets, broccoli, cabbage, carrots, corn, cucumbers, lettuce, okra, onions, peas, peppers, pumpkin, beans, tomatoes, white potatoes, bulb vegetables, fruiting vegetables, leafy vegetables, legumes, and small stalk stem vegetables. Appendix 9A presents the food codes and definitions used to determine the various fruits and vegetables used in the analysis. Intake rates for these food items/groups represent intake of all forms of the product (e.g., both home produced and commercially produced). Children who provided data for two days of the survey were included in the intake estimates. Individuals who did not provide information on body weight or for whom identifying information was unavailable were excluded from the analysis. Two-day average intake rates were calculated for all individuals in the database for each of the food items/groups.

These average daily intake rates were divided by each individual's reported body weight to generate intake rates in units of grams per kilogram of body weight per day (g/kg-day). The data were weighted according to the four-year, two-day sample weights provided in the 1994-96, 1998 CSFII to adjust the data for the sample population to reflect the national population.

Summary statistics were generated on both a per capita and a consumer only basis. For per capita intake, both users and non-users of the food item were included in the analysis. Consumer only intake rates were calculated using data for only those individuals who ate the food item of interest during the survey period. Intake data from the CSFII were based on as-consumed (i.e., cooked or prepared) forms of the food items/groups. Summary statistics, including: number of observations, percentage of the population consuming the fruits or vegetables being analyzed, mean intake rate, and standard error of the mean intake rate were calculated for total fruits, total vegetables, and selected individual fruits and vegetables. Percentiles of the intake rate distribution (i.e., 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, 99th, and 100th percentile) were also provided for total fruits and total vegetables. Data were provided for the following age groups of children: birth to <1 year, 1 to <2 years, 3 to <5 years, 6 to <12 years, and 13 to <19 years. Because these data were developed for use in U.S. EPA's pesticide registration program, the age groups used are slightly different than those recommended in U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005).

Table 9-3 presents as-consumed per capita intake data for total fruits and vegetables in g/kg-day; as-consumed consumer only intake data for total fruits and vegetables in g/kg-day are provided in Table 9-4. Table 9-5 provides per capita intake data for individual fruits and vegetables and Table 9-6 provides consumer only intake data for individual fruits and vegetables.

It should be noted that the distribution of average daily intake rates generated using short-term data (e.g., 2-day) do not necessarily reflect the long-term distribution of average daily intake rates. The distributions generated from short-term and long-term data will differ to the extent that each individual's intake varies from day to day; the distributions will be similar to the extent that individuals' intakes are constant from day to day. Day-to-day variation in intake among individuals will be high for fruits and vegetables that are highly seasonal and for fruits and vegetables that are eaten year-round, but that are not typically eaten every day. For these fruits and vegetables, the intake distribution generated from short-term data will not be a good reflection of the long-term distribution. On the other hand, for broad categories of foods (e.g., total fruits and total vegetables) that are eaten on a daily basis throughout the year, the short-term distribution may be a reasonable approximation of the true long-term distribution, although it will show somewhat more variability. In this chapter, distributions are provided only for broad categories of fruits and vegetables (i.e., total fruits and total vegetables). Because of the increased variability of the short-term distribution, the short-term upper percentiles shown here may overestimate the corresponding percentiles of the long-term distribution. For individual foods, only the mean, standard error, and percent consuming are provided.

The strengths of U.S. EPA's analysis are that it provides distributions of intake rates for various age groups of children, normalized by body weight. The analysis uses the 1994-96, 1998 CSFII data set which was designed to be representative of the U.S. population. The data set includes four years of intake data combined, and is based on a two-day survey period. As discussed above, short-term dietary data may not accurately reflect long-term eating patterns and may under-represent infrequent consumers of a given food. This is particularly true for the tails (extremes) of the distribution of food intake. Also, the analysis was conducted using slightly different age groups than those recommended in U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). However, given the similarities in the age groups used, the data should provide suitable intake estimates for the age groups of interest.

9.3.2 Relevant Fruit and Vegetable Intake Studies

9.3.2.1 *USDA, 1999 - Food and Nutrient Intakes by Children 1994-96, 1998, Table Set 17*

USDA (1999) calculated national probability estimates of food and nutrient intake by children based on all 4 years of the CSFII (1994-96 and 1998) for children age 9 years and under, and on CSFII 1994-96 only for individuals age 10 years and over. Sample weights were used to adjust for non-response, to match the sample to the U.S. population in terms of demographic characteristics, and to equalize intakes over the 4 quarters of the year and the 7 days of the week. A total of 503 breast-fed children were excluded from the estimates, but both consumers and non-consumers were included in the analysis.

USDA (1999) provided data on the mean per capita quantities (grams) of various food products/groups consumed per individual for one day, and the percent of individuals consuming those foods in one day of the survey. Tables 9-7 through 9-10 present data on the mean quantities (grams) of fruits and vegetables consumed per individual for one day, and the percentage of survey individuals consuming fruits and vegetables on that survey day. Data on mean intakes or mean percentages are based on respondents' day-1 intakes.

The advantage of the USDA (1999) study is that it uses the 1994-96, 98 CSFII data set, which includes four years of intake data, combined, and includes the supplemental data on children. These data are expected to be generally representative of the U.S. population and they include data on a wide variety of fruits and vegetables. The data set is one of a series of USDA data sets that are publicly available. One limitation of this data set is that it is based on a one-day, and short-term dietary data may not accurately reflect long-term eating patterns. Other limitations of this study are that it only provides mean values of food intake rates, consumption is not normalized by body weight, and presentation of results is not consistent with U.S. EPA's recommended age groups.

9.3.2.2 *Smiciklas-Wright et al., 2002 - Foods Commonly Eaten in the United States: Quantities Consumed per Eating Occasion and in a Day, 1994-1996*

Using data gathered in the 1994-96 USDA CSFII, Smiciklas-Wright et al. (2002) calculated distributions for the quantities of fruits and vegetables consumed per eating occasion by members of the U.S. population (i.e., serving sizes). The estimates of serving size were based on data obtained from 14,262 respondents, ages 2 years and above, who provided 2 days of dietary intake information. A total of 4,939 of these respondents were children, ages 2 to 19 years of age. Only dietary intake data from users of the specified food were used in the analysis (i.e., consumers only data).

Table 9-1 presents serving size data for selected fruits and vegetables. These data are presented on an as-consumed basis (grams) and represent the quantity of fruits and vegetables consumed per eating occasion. These estimates may be useful for assessing acute exposures to contaminants in specific foods, or other assessments where the amount consumed per eating occasion is necessary. Only the mean and standard deviation serving size data and percent of the population consuming the food during the 2-day survey period are presented in this handbook. Percentiles of serving sizes of the foods consumed by these age groups of the U.S. population can be found in Smiciklas-Wright et al. (2002).

The advantages of using these data are that they were derived from the USDA CSFII and are representative of the U.S. population. The analysis conducted by Smiciklas-Wright et al. (2002) accounted for individual foods consumed as ingredients of mixed foods. Mixed foods were disaggregated via recipe files so that the individual ingredients could be grouped together with similar foods that were reported separately. Thus, weights of foods consumed as ingredients were combined with weights of foods reported separately to provide a more thorough representation of consumption. However, it should be noted that since the recipes for the mixed foods consumed were not provided by the respondents, standard recipes were used. As a result, the estimates of quantity consumed for some food types are based on assumptions about the types and quantities of ingredients consumed as part of mixed foods. This study used data from the 1994 to 1996 CSFII; data from the 1998 children's supplement were not included.

9.3.2.3 *Fox et al., 2004 - Feeding Infants and Toddlers study: What Foods Are Infants and Toddlers Eating*

Fox et al. (2004) used data from the Feeding Infants and Toddlers study (FITS) to assess food consumption patterns in infants and toddlers. The FITS was sponsored by Gerber Products Company and was conducted to obtain current information on food and nutrient intakes of children, ages 4 to 24 months old, in the 50 states and the District of Columbia. The FITS is described in detail in Devaney et al. (2004). FITS was based on a random sample of 3,022 infants and toddlers for which dietary intake data were collected by telephone from their parents or caregivers between March and July 2002. An initial recruitment and household interview was conducted, followed by an interview to obtain information on intake based on 24-hour recall. The interview also addressed growth, development and feeding patterns. A second dietary recall interview was conducted for a subset of 703 randomly selected respondents. The study over-sampled children in the 4 to 6 and 9 to 11 months age groups; sample weights were adjusted for non-response, over-sampling, and under-coverage of some subgroups. The response rate for the FITS was 73 percent for the recruitment interview. Of the recruited households, there was a response rate of 94 percent for the dietary recall interviews (Devaney et al., 2004). The characteristics of the FITS study population is shown in Table 9-12.

Fox et al. (2004) analyzed the first set of 24-hour recall data collected from all study participants. For this analysis, children were grouped into six age categories: 4 to 6 months, 7 to 8 months, 9 to 11 months, 12 to 14 months, 15 to 18 months, and 19 to 24 months. Table 9-13 provides the percentage of infants and toddlers consuming different types of vegetables at least once in a day. The percentages of children eating any type of vegetable ranged from 39.9 percent for 4 to 6 month olds to 81.6 percent for 19 to 24 month olds. Table 9-14 provides the top five vegetables consumed by age group. Some of the highest percentages ranged from baby food carrots (9.6 percent) in the 4 to 6 month old group to french fries (25.5 percent) in the 19 to 24 month old group. Table 9-15 provides the percentage of children consuming different types of fruit at least once per day. The percentages of children eating any type of fruit ranged from 41.9 percent to 4 to 6 month olds to 77.2 percent for 12 to 14 month olds. Table 9-16 provides information on the top five fruits eaten by infants and toddlers at least once per day. The highest percentages were for bananas among infants 9 to 24 months, and baby food applesauce among infants 4 to 8 months old.

The advantages of this study were that the study population represented the U.S. population and the sample size was large. One limitation of the analysis done by Fox et al. (2004) was that only frequency data were provided; no information on actual intake rates was included. In addition, Devaney et al. (2004) noted several limitations associated with the FITS data. For the FITS, a commercial list of infants and toddlers was used to obtain the sample used in the study. Since many of the households could not be located and did not have children in the target population, a lower response rate than would have occurred in a true national sample was obtained (Devaney et al., 2004). In addition, the sample was likely from a higher socioeconomic status when compared with all U.S. infants in this age group (4 to 24 months old) and the use of a telephone survey may have omitted lower-income households without telephones (Devaney et al., 2004).

9.3.2.4 *Ponza et al., 2004 - Nutrient Food Intakes and Food Choices of Infants and Toddlers Participating in WIC*

Ponza et al. (2004) conducted a study using selected data from the FITS to assess feeding patterns, food choices and nutrient intake of infants and toddlers participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). Ponza et al. (2004) evaluated FITS data for the following age groups: 4 to 6 months (N = 862), 7 to 11 months (N = 1,159) and 12 to 24 months (N= 996). The total sample size described by WIC participants and non-participants is shown in Table 9-17.

The foods consumed were analyzed by tabulating the percentage of infants who consumed specific foods/food groups per day (Ponza et al., 2004).

Weighted data were used in all of the analyses used in the study (Ponza et al., 2004). Table 9-17 presents the demographic data for WIC participants and non-participants. Table 9-18 provides information on the food choices for the infants and toddlers studied. There was little difference in vegetable choices among WIC participants and non-participants (Table 9-18). However, there were some differences for fruits.

An advantage of this study is that it had a relatively large sample size and was representative of the U.S. general population of infants and children. A limitation of the study is that intake values for foods were not provided. Other limitations are those associated with the FITS data, as described previously in Section 9.3.2.3.

9.3.2.5 *Menella et al., 2006 - Feeding Infants and Toddlers Study: The Types of Foods Fed to Hispanic Infants and Toddlers*

Menella et al. (2006) investigated the types of food and beverages consumed by Hispanic infants and toddlers in comparison to the non-Hispanic infants and toddlers in the United States. The FITS 2002 data for children between 4 and 24 months of age were used for the study. The data represent a random sample of 371 Hispanic and 2,367 non-Hispanic infants and toddlers (Menella et al., 2006). Menella et al. (2006) grouped the infants as follows: 4 to 5 months (N = 84 Hispanic; 538 non-Hispanic), 6 to 11 months (N = 163 Hispanic and 1,228 non-Hispanic), and 12 to 24 months (N = 124 Hispanic and 871 non-Hispanic) of age.

Table 9-19 provides the percentages of Hispanic and non-Hispanic infants and toddlers consuming fruits and vegetables. In most instances the percentages consuming the different types of fruits and vegetables were similar. However, 4 to 5 month old Hispanic infants were more likely to eat fruits than non-Hispanic infants in this age group. Table 9-20 provides the top five fruits and vegetables consumed and the percentage of children consuming these foods at least once in a day. Apples and bananas were the foods with the highest percent consuming for both the Hispanic and non-Hispanic study groups. Potatoes and carrots were the vegetables with the highest percentage of infants and toddlers consuming in both study groups.

The advantage of the study is that it provides information on food preferences for Hispanic and non-Hispanic infants and toddlers. A limitation is that the study did not provide food intake data, but provided frequency of use data instead. Other limitations are those noted previously in Section 9.3.2.3 for the FITS data.

9.3.2.6 *Fox et al., 2006 - Average Portion of Foods Commonly Eaten by Infants and Toddlers in the United States*

Fox et al. (2006) estimated average portion sizes consumed per eating occasion by children 4 to 24 months of age who participated in the Feeding Infants and Toddlers Study (FITS). The FITS is a cross-sectional study designed to collect and analyze data on feeding practices, food consumption, and usual nutrient intake of U.S. infants and toddlers and is described in Section 9.3.2.3 of this chapter. It included a stratified random sample of 3,022 children between 4 and 24 months of age.

Using the 24-hour recall data, Fox et al. (2006) derived average portion sizes for major food groups, including fruits and vegetables. Average portion sizes for select individual foods within these major groups were also estimated. For this analysis, children were grouped into six age categories: 4 to 5 months, 6 to 8 months, 9 to 11 months, 12 to 14 months, 15 to 18 months, and 19 to 24 months. Tables 9-21 and 9-22 present the average portion sizes for fruits and vegetables for infants and toddlers, respectively.

9.4 CONVERSION BETWEEN WET AND DRY WEIGHT INTAKE RATES

The intake data presented in this chapter are reported in units of wet weight (i.e., as-consumed fruits and vegetables consumed per day or per eating occasion). However, data on the concentration of contaminants in fruits and vegetables may be reported in units of either wet or dry weight.(e.g., mg contaminant per gram-dry-weight of fruits and vegetables.) It is essential that exposure assessors be aware of this difference so that they may ensure consistency between the units used for intake rates and those used for concentration data (i.e., if the contaminant concentration is measured in dry weight of fruits and vegetables, then the dry weight units should be used for their intake values).

If necessary, wet weight (e.g., as-consumed) intake rates may be converted to dry weight intake rates using the moisture content percentages presented in Table 9-23 and the following equation:

$$IR_{dw} = IR_{ww}\left[\frac{100-W}{100}\right] \qquad \text{(Eqn. 9-1)}$$

where:

IR_{dw}	=	dry weight intake rate;
IR_{ww}	=	wet weight intake rate; and
W	=	percent water content

Alternatively, dry weight residue levels in fruits and vegetables may be converted to wet weight residue levels for use with wet weight (e.g., as-consumed) intake rates as follows:

$$C_{ww} = C_{dw}\left[\frac{100-W}{100}\right] \qquad \text{(Eqn. 9-2)}$$

where:

C_{ww}	=	wet weight intake rate;
C_{dw}	=	dry weight intake rate; and
W	=	percent water content.

The moisture data presented in Table 9-23 are for selected fruits and vegetables taken from USDA (2007).

9.5 REFERENCES FOR CHAPTER 9

Devaney, B.; Kalb, L.; Briefel, R.; Zavitsky-Novak, T.; Clusen, N.; Ziegler, P. (2004) Feeding infants and toddlers study: overview of the study design. J Am Diet Assoc 104(Suppl 1): S8-S13.

Fox, M.K.; Pac, S.; Devaney, B.; Jankowski, L. (2004) Feeding Infants and Toddlers Study: what foods are infants and toddlers eating. J Am Diet Assoc 104 (Suppl):S22-S30.

Fox, M.K.; Reidy, K.; Karwe, V.; Ziegler, P. (2006) Average portions of foods commonly eaten by infants and toddlers in the United States. J Am Diet Assoc 106 (Suppl 1):S66-S76.

Goldman, L. (1995) Children - unique and vulnerable. Environmental risks facing children and recommendations for response. Environ Health Perspect 103(6):13-17.

Mennella, J.; Ziegler, P.; Briefel, R.; Novak, T. (2006) Feeding Infants and Toddlers Study: the types of foods fed to Hispanic infants and toddlers. J Am Diet Assoc 106 (Suppl 1): S96-S106.

Ponza, M.; Devaney, B.; Ziegler, P.; Reidy, K.; Squatrito, C. (2004) Nutrient intakes and food choices of infants and toddlers participating in WIC. J Am Diet Assoc 104 (Suppl): S71-S79.

Smiciklas-Wright, H.; Mitchell, D.C.; Mickle, S.J.; Cook, A.J.; Goldman, J.D. (2002) Foods commonly eaten in the United States: Quantities consumed per eating occasion and in a day, 1994-1996. U.S. Department of Agriculture NFS Report No. 96-5, pre-publication version, 252 pp.

USDA. (1999) Food and nutrient intakes by children 1994-96, 1998: Table Set 17. Beltsville, MD: Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture.

USDA (2007) USDA National Nutrient Database for Standard Reference, Release 20. Agricultural Research Service Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl

U.S. EPA. (2005) Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants. U.S. Environmental Protection Agency, Washington, D.C., EPA/630/P-03/003F.

Table 9-3. Per Capita Intake of Fruits and Vegetables (g/kg-day as consumed)														
Age Group	N	Percent Consuming	Mean	SE	Percentiles									
					1st	5th	10th	25th	50th	75th	90th	95th	99th	100th
Fruits														
Birth to 1 year	1,486	56.4	5.7	0.3	0.0	0.0	0.0	0.0	1.5	9.6	17.1	21.3	32.2	73.8
1 to 2 years	2,096	89.5	6.2	0.2	0.0	0.0	0.0	0.5	4.7	9.4	14.6	18.5	26.4	44.0
3 to 5 years	4,391	90.0	4.6	0.1	0.0	0.0	0.0	0.2	3.2	7.0	11.4	14.4	22.3	45.5
6 to 12 years	2,089	88.3	2.4	0.1	0.0	0.0	0.0	0.1	1.3	3.3	6.4	8.8	14.3	25.0
13 to 19 years	1,222	73.2	0.8	0.1	0.0	0.0	0.0	0.0	0.1	1.1	2.4	3.5	6.9	12.8
Vegetables														
Birth to 1 year	1,486	72.1	4.5	0.2	0.0	0.0	0.0	0.0	2.7	7.4	12.2	14.8	25.3	56.8
1 to 2 years	2,096	99.7	6.9	0.2	0.0	0.7	1.5	3.2	5.6	9.3	13.9	17.1	26.5	58.2
3 to 5 years	4,391	100.0	5.9	0.1	0.0	0.8	1.4	2.8	4.7	7.7	11.7	14.7	23.4	50.9
6 to 12 years	2,089	99.9	4.1	0.1	0.1	0.6	1.0	1.8	3.2	5.3	7.8	9.9	17.4	53.7
13 to 19 years	1,222	100.0	2.9	0.1	0.0	0.4	0.7	1.4	2.4	3.8	5.5	6.9	11.4	29.5

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 9-4. Consumer Only Intake of Fruits and Vegetables (g/kg-day as consumed)

Age Group	N	Mean	SE	Percentiles									
				1st	5th	10th	25th	50th	75th	90th	95th	99th	100th
Fruits													
Birth to 1 year	830	10.1	0.4	0.0	0.4	1.2	3.7	8.5	14.4	20.4	26.4	34.7	73.8
1 to 2 years	1,878	6.9	0.2	0.0	0.0	0.1	2.2	5.4	10.1	15.3	19.0	27.1	44.0
3 to 5 years	3,957	5.1	0.1	0.0	0.0	0.0	1.0	3.8	7.5	11.9	15.0	22.8	45.5
6 to 12 years	1,846	2.7	0.1	0.0	0.0	0.0	0.3	1.7	3.7	6.7	9.3	14.8	25.0
13 to 19 years	898	1.1	0.1	0.0	0.0	0.0	0.0	0.5	1.5	2.9	3.7	7.6	12.8
Vegetables													
Birth to 1 year	1,062	6.2	0.3	0.0	0.1	0.1	2.0	4.9	9.4	13.4	16.1	26.4	56.8
1 to 2 years	2,090	6.9	0.2	0.0	0.7	1.5	3.2	5.6	9.3	13.9	17.1	26.5	58.2
3 to 5 years	4,389	5.9	0.1	0.0	0.8	1.4	2.8	4.7	7.7	11.7	14.7	23.4	50.9
6 to 12 years	2,087	4.1	0.1	0.1	0.6	1.0	1.8	3.2	5.3	7.8	9.9	17.4	53.7
13 to 19 years	1,222	2.9	0.1	0.0	0.4	0.7	1.4	2.4	3.8	5.5	6.9	11.4	29.5

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 9-5. Per Capita Intake of Individual Fruits and Vegetables (g/kg-day as consumed)

Age Group	N	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE
		Apples			Asparagus			Bananas			Beans		
Birth to 1 year	1,486	34.6	2.32	0.13	0.21	0.01	0.00	40.68	1.24	0.06	21.6	0.43	0.04
1 to 2 years	2,096	44.8	1.79	0.09	0.77	0.02	0.01	62.76	1.77	0.09	46.8	0.76	0.04
3 to 5 years	4,391	44.6	1.64	0.05	0.54	0.01	0.00	60.74	0.93	0.04	43.0	0.52	0.02
6 to 12 years	2,089	38.2	0.83	0.05	0.66	0.01	0.00	57.69	0.38	0.03	38.8	0.32	0.02
13 to 19 years	1,222	22.5	0.20	0.02	0.56	0.00	0.00	42.09	0.13	0.02	55.4	0.15	0.02
		Beets			Berries and Small Fruit			Broccoli			Bulb Vegetables		
Birth to 1 year	1,486	0.4	0.01	0.01	16.5	0.13	0.02	3.5	0.07	0.02	33.4	0.07	0.01
1 to 2 years	2,096	0.7	0.01	0.00	66.2	0.91	0.05	12.0	0.25	0.03	93.3	0.30	0.01
3 to 5 years	4,391	0.8	0.01	0.00	72.7	0.72	0.03	10.7	0.18	0.01	95.8	0.27	0.01
6 to 12 years	2,089	0.8	0.01	0.00	73.4	0.40	0.03	11.0	0.14	0.02	97.3	0.21	0.01
13 to 19 years	1,222	0.7	0.00	0.00	97.7	0.19	0.01	8.3	0.06	0.01	12.3	0.11	0.02
		Cabbage			Carrots			Citrus Fruits			Corn		
Birth to 1 year	1,486	1.0	0.01	0.00	12.3	0.17	0.03	2.5	0.07	0.02	46.0	0.48	0.03
1 to 2 years	2,096	8.0	0.06	0.01	46.8	0.41	0.02	15.5	0.47	0.05	96.5	1.13	0.05
3 to 5 years	4,391	8.9	0.07	0.01	46.2	0.34	0.02	18.2	0.50	0.03	98.7	1.24	0.03
6 to 12 years	2,089	9.5	0.06	0.01	44.4	0.22	0.01	16.0	0.26	0.02	98.9	0.87	0.03
13 to 19 years	1,222	9.0	0.04	0.01	40.3	0.11	0.01	12.3	0.11	0.02	95.7	0.43	0.02

Table 9-5. Per Capita Intake of Individual Fruits and Vegetables (g/kg-day as consumed) (continued)

Age Group	N	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE
		Cucumbers			Cucurbits			Fruiting Vegetables			Leafy Vegetables		
Birth to 1 year	1,486	1.7	0.00	0.00	14.0	0.45	0.04	25.50	0.32	0.04	44.2	0.29	0.05
1 to 2 years	2,096	20.5	0.11	0.01	31.3	0.72	0.06	92.14	1.56	0.06	82.1	0.71	0.04
3 to 5 years	4,391	29.3	0.16	0.02	38.7	0.83	0.07	95.38	1.46	0.03	86.9	0.67	0.02
6 to 12 years	2,089	32.6	0.14	0.02	39.9	0.54	0.06	95.87	1.05	0.03	89.5	0.55	0.03
13 to 19 years	1,222	41.3	0.11	0.03	46.7	0.32	0.08	96.08	0.79	0.03	90.3	0.43	0.02
		Legumes			Lettuce			Okra			Onions		
Birth to 1 year	1,486	51.7	1.21	0.06	1.1	0.00	0.00	0.2	0.00	0.00	32.8	0.07	0.01
1 to 2 years	2,096	96.9	1.30	0.08	23.3	0.14	0.01	1.3	0.01	0.00	93.0	0.29	0.01
3 to 5 years	4,391	98.3	0.85	0.06	33.4	0.21	0.01	0.8	0.01	0.00	95.6	0.26	0.01
6 to 12 years	2,089	98.1	0.48	0.03	41.7	0.22	0.01	1.3	0.01	0.00	96.8	0.20	0.01
13 to 19 years	1,222	94.9	0.27	0.02	55.2	0.22	0.02	0.8	0.00	0.00	97.3	0.18	0.01
		Peaches			Pears			Peas			Peppers		
Birth to 1 year	1,486	24.4	0.85	0.08	15.9	0.73	0.07	29.5	0.47	0.04	15.6	0.01	0.00
1 to 2 years	2,096	50.7	0.47	0.04	17.2	0.40	0.04	28.3	0.34	0.03	77.5	0.05	0.01
3 to 5 years	4,391	55.4	0.26	0.02	16.6	0.26	0.03	20.5	0.21	0.02	84.6	0.05	0.00
6 to 12 years	2,089	54.7	0.14	0.02	17.5	0.14	0.01	17.2	0.12	0.01	85.1	0.05	0.00
13 to 19 years	1,222	39.1	0.06	0.01	5.9	0.03	0.01	14.0	0.07	0.01	84.8	0.04	0.00

Table 9-5. Per Capita Intake of Individual Fruits and Vegetables (g/kg-day as consumed) (continued)

Age Group	N	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE
		Pome Fruit			Pumpkins			Root Tuber Vegetables			Stalk, Stem Vegetables		
Birth to 1 year	1,486	40.0	3.04	0.17	0.3	0.00	0.00	61.7	2.60	0.15	1.9	0.01	0.00
1 to 2 years	2,096	52.0	2.19	0.10	0.7	0.01	0.00	99.6	3.38	0.09	13.2	0.06	0.01
3 to 5 years	4,391	51.7	1.90	0.06	0.9	0.01	0.00	100.0	2.96	0.07	10.9	0.04	0.00
6 to 12 years	2,089	47.9	0.97	0.06	1.8	0.01	0.00	100.0	2.09	0.07	10.7	0.03	0.01
13 to 19 years	1,222	26.5	0.23	0.02	1.3	0.01	0.00	99.9	1.36	0.06	16.6	0.03	0.01
		Strawberries			Stone Fruit			Tomatoes			Tropical Fruits		
Birth to 1 year	1,486	6.8	0.02	0.00	29.20	1.15	0.10	21.5	0.30	0.03	42.2	1.31	0.07
1 to 2 years	2,096	33.5	0.19	0.03	53.62	0.60	0.04	80.7	1.50	0.05	70.1	1.97	0.10
3 to 5 years	4,391	37.1	0.14	0.01	57.45	0.38	0.02	85.7	1.40	0.03	69.7	1.10	0.04
6 to 12 years	2,089	37.3	0.10	0.01	56.83	0.23	0.02	86.9	1.00	0.03	67.0	0.50	0.04
13 to 19 years	1,222	26.8	0.05	0.01	41.08	0.09	0.01	90.2	0.74	0.03	54.5	0.19	0.02
		White Potatoes											
Birth to 1 year	1,486	39.9	0.64	0.07									
1 to 2 years	2,096	91.2	1.95	0.08									
3 to 5 years	4,391	95.1	1.75	0.06									
6 to 12 years	2,089	93.9	1.21	0.06									
13 to 19 years	1,222	92.6	0.93	0.05									

SE = Standard error.
Note: Data for fruits and vegetables for which only small percentages of the population reported consumption may be less reliable than data for fruits and vegetables with higher percentages consuming.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 9-6. Consumer Only Intake of Individual Fruits and Vegetables (g/kg-day as consumed)

Age Group	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
	Apples			Asparagus			Bananas			Beans		
Birth to 1 year	496	6.71	0.31	3	2.59	1.16	605	3.04	0.12	313	2.00	0.16
1 to 2 years	947	4.00	0.15	19	1.99	0.54	1,328	2.82	0.12	996	1.63	0.08
3 to 5 years	1,978	3.68	0.08	23	1.37	0.32	2,746	1.54	0.06	1,909	1.22	0.04
6 to 12 years	792	2.17	0.12	13	1.77	0.43	1,214	0.66	0.05	833	0.82	0.05
13 to 19 years	271	0.90	0.06	4	0.56	0.08	511	0.30	0.04	472	0.49	0.03
	Beets			Berries and Small Fruits			Broccoli			Bulb Vegetables		
Birth to 1 year	6	1.42	0.87	229	0.81	0.07	49	2.09	0.33	489	0.22	0.02
1 to 2 years	13	0.98	0.32	1,396	1.38	0.06	242	2.11	0.16	1,957	0.32	0.01
3 to 5 years	36	0.90	0.20	3,166	0.99	0.04	475	1.67	0.09	4,207	0.28	0.01
6 to 12 years	16	0.66	0.33	1,523	0.54	0.04	213	1.29	0.16	2,040	0.22	0.01
13 to 19 years	9	0.20	0.12	679	0.27	0.03	102	0.69	0.07	1,194	0.20	0.01
	Cabbage			Carrots			Citrus Fruits			Corn		
Birth to 1 year	15	0.61	0.41	179	1.39	0.20	37	2.79	0.53	671	1.05	0.07
1 to 2 years	160	0.73	0.11	999	0.87	0.05	336	3.06	0.20	2,027	1.17	0.05
3 to 5 years	369	0.78	0.07	2,048	0.74	0.03	751	2.75	0.15	4,334	1.26	0.03
6 to 12 years	190	0.63	0.11	904	0.50	0.03	324	1.60	0.12	2,064	0.88	0.03
13 to 19 years	106	0.40	0.06	482	0.27	0.02	157	0.90	0.15	1,176	0.45	0.01

Table 9-6. Consumer Only Intake of Individual Fruits and Vegetables (g/kg-day as consumed) (continued)

Age Group	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
	Cucumbers			Cucurbits			Fruiting Vegetables			Leafy Vegetables		
Birth to 1 year	25	0.28	0.11	213	3.19	0.29	371	1.24	0.11	639	0.65	0.11
1 to 2 years	439	0.52	0.05	682	2.29	0.17	1,927	1.70	0.06	1,729	0.87	0.05
3 to 5 years	1,266	0.56	0.05	1,694	2.15	0.17	4,180	1.53	0.03	3,815	0.77	0.03
6 to 12 years	667	0.43	0.06	833	1.34	0.15	2,014	1.10	0.03	1,860	0.62	0.03
13 to 19 years	500	0.26	0.06	563	0.69	0.16	1,176	0.82	0.03	1,101	0.47	0.02
	Legumes			Lettuce			Okra			Onions		
Birth to 1 year	754	2.34	0.11	15	0.17	0.02	4	1.50	0.54	481	0.22	0.02
1 to 2 years	2,037	1.34	0.08	481	0.58	0.04	29	0.64	0.19	1,948	0.31	0.01
3 to 5 years	4,308	0.86	0.06	1,415	0.62	0.03	34	1.16	0.32	4,200	0.27	0.01
6 to 12 years	2,045	0.49	0.03	858	0.53	0.02	21	0.62	0.15	2,030	0.21	0.01
13 to 19 years	1,168	0.29	0.02	669	0.40	0.03	12	0.43	0.13	1,190	0.19	0.01
	Peaches			Pears			Peas			Peppers		
Birth to 1 year	344	3.47	0.28	217	4.55	0.28	417	1.60	0.09	224	0.05	0.01
1 to 2 years	1,067	0.93	0.08	354	2.33	0.16	609	1.21	0.06	1,627	0.06	0.01
3 to 5 years	2,461	0.48	0.03	711	1.59	0.12	888	1.02	0.07	3,706	0.06	0.00
6 to 12 years	1,150	0.26	0.03	382	0.81	0.07	346	0.68	0.06	1,784	0.05	0.01
13 to 19 years	480	0.15	0.03	72	0.45	0.09	168	0.48	0.06	1,041	0.05	0.00

Table 9-6. Consumer Only Intake of Individual Fruits and Vegetables (g/kg-day as consumed) (continued)

Age Group	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
	Pome Fruit			Pumpkins			Root Tuber Vegetables			Stalk, Stem Vegetables		
Birth to 1 year	572	7.60	0.34	3	1.06	0.71	916	4.21	0.19	24	0.56	0.22
1 to 2 years	1,097	4.21	0.13	15	1.08	0.51	2,087	3.40	0.09	272	0.48	0.05
3 to 5 years	2,291	3.68	0.08	36	0.56	0.10	4,388	2.96	0.07	502	0.38	0.03
6 to 12 years.	1,012	2.03	0.10	37	0.52	0.11	2,089	2.09	0.07	218	0.32	0.04
13 to 19 years	320	0.87	0.06	14	0.42	0.16	1,221	1.36	0.06	190	0.20	0.03
	Strawberries			Stone Fruit			Tomatoes			Tropical Fruits		
Birth to 1 year	96	0.26	0.06	418	3.95	0.25	315	1.42	0.13	630	3.09	0.12
1 to 2 years	729	0.57	0.08	1,130	1.13	0.08	1,684	1.86	0.06	1,476	2.81	0.12
3 to 5 years	1,710	0.38	0.03	2,556	0.66	0.03	3,764	1.63	0.03	3,106	1.57	0.05
6 to 12 years.	783	0.28	0.02	1,194	0.41	0.03	1,832	1.15	0.03	1,407	0.75	0.05
13 to 19 years	326	0.18	0.03	508	0.21	0.03	1,098	0.82	0.03	652	0.35	0.04
	White Potatoes											
Birth to 1 year	577	1.60	0.15									
1 to 2 years	1,918	2.14	0.09									
3 to 5 years	4,147	1.84	0.06									
6 to 12 years.	1,963	1.29	0.06									
13 to 19 years	1,131	1.01	0.05									

SE = Standard error.
Note: Data for fruits and vegetables for which only small percentages of the population reported consumption may be less reliable than data for fruits and vegetables with higher percentages consuming.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 9-7. Mean Quantities of Vegetables Consumed Daily by Sex and Age, Per Capita (g/day)

Age Group	Sample Size	Total	White Potatoes		Dark Green Vegetables	Deep Yellow Vegetables	Tomatoes	Lettuce, lettuce-based salads	Green beans	Corn, green peas, lima beans	Other vegetables
			Total	Fried							
Males and Females											
Under 1 year	1,126	57	9	1	2	19	1[a]	[a,b]	6	5	16
1 year	1,016	79	26	11	5	9	7	1	8	9	16
2 years	1,102	87	32	17	4	5	11	2	7	10	17
1 to 2 years	2,118	83	29	14	5	7	9	1	7	9	17
3 years	1,831	91	34	17	5	5	13	2	5	11	16
4 years	1,859	97	37	19	6	5	11	3	5	12	18
5 years	884	103	44	22	4	6	12	3	6	12	17
3 to 5 years	4,574	97	38	20	5	5	12	3	5	11	17
5 years and under	7,818	88	31	16	4	7	10	2	6	10	17
Males											
6 to 9 years	787	110	47	26	4	5	16	5	5	11	16
6 to 11 yers	1,031	115	50	27	5	5	16	5	5	11	18
12 to 19 years	737	176	85	44	6	6	28	12	3[a]	10	25
Females											
6 to 9 years	704	110	42	22	5	4	14	6	5	13	21
6 to 11 years	969	116	46	25	5	4	15	7	5	12	22
12 to 19 years	732	145	61	31	9	4	18	12	4	8	28
Males and Females											
9 years and under	9,309	97	37	19	4	6	12	3	6	11	18
19 years and under	11,287	125	53	27	6	6	17	7	5	10	22

[a] Estimate is not statistically reliable due to small samples size reporting intake.
[b] Value less than 0.5, but greater than 0.

Note: Consumption amounts shown are representative of the first day of each participant's survey response.

Source: USDA, 1999.

Table 9-8. Percentage of Individuals Consuming Vegetables, by Sex and Age (%)											
Age Group	Sample Size	Total	White Potatoes		Dark Green Vegetables	Deep Yellow Vegetables	Tomatoes	Lettuce, lettuce-based salads	Green beans	Corn, green peas, lima beans	Other vegetables
			Total	Fried							
Males and Females											
Under 1 year	1,126	47.2	12.3	4.3	2.3	20.5	1.8	0.2[a]	7.8	8.5	14.8
1 year	1,016	73.3	40.4	25.2	6.4	13.3	18.0	3.9	13.7	17.6	19.4
2 years	1,102	78.4	46.7	34.5	7.6	10.5	30.8	7.5	11.5	15.0	22.3
1 to 2 years	2,118	75.9	43.6	29.9	7.0	11.8	24.6	5.7	12.6	16.2	20.9
3 years	1,831	80.5	46.7	34.7	7.0	10.7	34.1	8.3	10.1	14.6	24.7
4 years	1,859	80.7	47.3	34.8	7.2	12.0	33.0	10.0	9.0	16.4	26.5
5 years	884	83.0	50.7	38.3	4.6	13.3	36.5	13.4	10.4	16.1	28.8
3 to 5 years	4,574	81.4	48.2	35.9	6.3	12.0	34.5	10.6	9.9	15.7	26.7
5 years and under	7,818	75.4	42.3	30.1	6.1	13.0	27.2	7.6	10.5	15.0	23.3
Males											
6 to 9 years	787	78.8	47.9	38.0	6.3	12.5	38.2	13.1	7.8	15.0	29.7
6 to 11 years	1,031	79.3	48.7	38.4	6.1	12.4	38.7	13.9	6.7	13.8	30.8
12 to 19 years	737	78.2	49.5	38.6	3.6	8.0	43.0	23.8	3.5	7.4	33.2
Females											
6 to 9 years	704	80.5	48.2	36.3	5.9	11.9	33.8	15.8	8.4	15.9	26.6
6 to 11 years	969	81.7	50.8	38.9	5.4	11.4	33.5	17.1	7.8	15.1	29.2
12 to 19 years	732	79.5	46.4	34.6	7.0	10.6	35.3	25.1	4.4	7.4	34.5
Males and Females											
9 years and under	9,309	77.1	44.6	32.9	6.1	12.7	30.7	10.3	9.6	15.2	25.2
19 years and under	11,287	78.3	46.8	35.3	5.6	11.2	34.6	16.6	7.0	11.9	29.4

[a] Estimate is not statistically reliable due to small samples size reporting intake.
Note: Percentages shown are representative of the first day of each participant's survey response.

Source: USDA, 1999.

Table 9-9. Mean Quantities of Fruits Consumed Daily by Sex and Age, Per Capita (g/day)

Age Group	Sample Size	Total	Citrus Fruits and Juices		Dried fruits	Other fruits, mixtures, and juices					
			Total	Juices		Total	Apples	Bananas	Melons and berries	Other fruits and mixtures (mainly fruit)	Non-citrus juices and nectars
Males and Females											
Under 1 year	1,126	131	4	4	-[a,b]	126	14	10	1[a]	39	61
1 year	1,016	267	47	42	2	216	22	23	8	29	134
2 years	1,102	276	65	56	2	207	27	20	10	20	130
1 to 2 years	2,118	271	56	49	2	212	24	22	9	24	132
3 years	1,831	256	61	51	1	191	27	18	13	24	110
4 years	1,859	243	62	52	1	177	31	17	14	22	92
5 years	884	218	55	44	-[a,b]	160	31	14	13	24	78
3 to 5 years	4,574	239	59	49	1	176	30	16	13	23	93
5 years and under	7,818	237	52	44	1	182	26	17	10	26	103
Males											
6 to 9 years	787	194	58	51	-[a,b]	133	32	11	21	20	50
6 to 11 years	1,031	183	67	60	-[a,b]	113	28	11	16	19	40
12 to 19 years	737	174	102	94	1[a]	70	13	8	11[a]	10	29
Females											
6 to 9 years	704	180	63	54	1[a]	113	23	10	10	25	46
6 to 11 years	969	169	64	54	-[a,b]	103	21	8	8	23	42
12 to 19 years	732	157	72	67	-[a,b]	83	13	5	15	14	35
Males and Females											
9 years and under	9,309	217	55	47	1	159	27	15	12	24	81
19 years and under	11,287	191	70	62	1	118	21	11	12	19	56

[a] Estimate is not statistically reliable due to small samples size reporting intake.
[b] Value less than 0.5, but greater than 0.

Note: Consumption amounts shown are representative of the first day of each participant's survey response

Source: USDA, 1999.

Table 9-10. Percentage of Individuals Consuming, Fruits by Sex and Age (%)

Age Group	Sample Size	Total	Citrus Fruits and Juices		Dried fruits	Other fruits, mixtures, and juices					
			Total	Juices		Total	Apples	Bananas	Melons and berries	Other fruits and mixtures (mainly fruit)	Non-citrus juices and nectars
Males and Females											
Under 1 year	1,126	59.7	3.6	2.7	0.4[a]	59.0	15.7	13.3	1.8	29.9	33.0
1 year	1,016	81.0	23.6	19.0	5.9	73.0	23.4	25.1	6.9	26.5	43.2
2 years	1,102	76.6	30.6	23.4	5.3	64.7	24.0	20.2	8.5	19.4	37.0
1 to 2 years	2,118	78.8	27.2	21.3	5.6	68.8	23.7	22.6	7.7	22.9	40.0
3 years	1,831	74.5	27.9	21.4	4.1	64.2	22.4	17.5	7.8	20.1	33.3
4 years	1,859	72.6	28.0	21.8	3.0	62.1	23.7	15.7	7.6	20.0	30.8
5 years	884	67.6	26.9	19.5	1.3[a]	56.9	21.9	12.6	7.4	19.0	24.5
3 to 5 years	4,574	71.6	27.6	20.9	2.8	61.0	22.7	15.3	7.6	19.7	29.5
5 years and under	7,818	72.6	24.6	18.8	3.5	63.5	22.2	17.6	6.9	22.0	33.5
Males											
6 to 9 years	787	59.0	24.8	20.5	0.8[a]	49.1	20.3	8.7	7.3	16.8	15.5
6 to 11 years	1,031	56.5	25.2	21.6	1.1[a]	44.2	18.2	8.0	6.6	15.4	12.7
12 to 19 years	737	44.5	24.7	21.7	1.0[a]	27.1	8.2	6.0	4.1	7.1	8.2
Females											
6 to 9 years	704	64.9	27.9	22.3	1.5[a]	50.4	17.3	8.8	7.4	20.4	17.3
6 to 11 years	969	62.1	27.7	21.5	1.1[a]	47.2	16.2	7.3	7.4	19.0	14.9
12 to 19 years	732	45.6	22.4	18.1	1.1[a]	30.2	8.2	4.4	6.0	11.3	9.7
Males and Females											
9 years and under	9,309	68.3	25.2	19.8	2.5	58.0	20.9	14.0	7.1	20.6	26.7
19 years and under	11,287	57.8	24.8	20.1	1.8	44.4	15.2	9.7	6.2	15.5	17.9

[a] Estimate is not statistically reliable due to small samples size reporting intake.

Note: Percentages shown are representative of the first day of each participant's survey response.

Source: USDA, 1999.

Table 9-11. Quantity (as consumed) of Fruits and Vegetables Consumed Per Eating Occasion and Percentage of Individuals Using These Foods in Two Days

Food category	Quantity consumed per eating occasion (grams)											
	2 to 5 years			6 to 11 years			12 to 19 years					
	Male and Female (N = 2,109)			Male and Female (N = 1,432)			Male (N = 696)			Female (N = 702)		
	PC	Mean.	SEM	PC	Mean	SEM	PC	Mean	SEM	PC	Mean	SEM
Raw Vegetables												
Carrots	10.4	27	2	17.8	32	2	9.2	35	6	11.9	32	4
Cucumbers	6.4	32	4	6.6	39	6	6.1	71[a]	22[a]	6.8	48	11
Lettuce	34.0	17	1	40.8	26	1	56.0	32	3	52.3	34	2
Onions	3.9	9	2	4.5	17	2	11.1	28	4	7.9	23	4
Tomatoes	14.8	31	2	14.0	42	4	25.7	49	5	23.9	44	3
Cooked Vegetables												
Beans (string)	16.8	50	2	12.1	71	6	8.3	85	9	7.6	78	5
Broccoli	7.2	61	3	5.6	102	16	3.9	127[a]	17[a]	5.7	109[a]	14[a]
Carrots	6.0	48	4	3.8	46	5	2.8	81[a]	16[a]	2.1	75[a]	17[a]
Corn	18.9	68	3	22.2	79	4	12.8	125	9	12.3	100	6
Peas	8.4	48	3	6.8	72	9	3.6	115[a]	15[a]	2.4	93[a]	17[a]
Potatoes (French-fried)	32.7	52	1	33.7	67	2	41.7	97	3	38.1	81	4
Potatoes (home-fried and hash-browned)	9.3	85	5	10.1	93	6	10.1	145	13	6.1	138	13
Potatoes (baked)	7.6	70	4	8.2	95	6	8.6	152	15	8.8	115	10
Potatoes (boiled)	4.8	81	9	2.7	103[a]	17[a]	2.0	250[a]	40[a]	3.2	144[a]	16[a]
Potatoes (mashed)	14.8	118	6	13.3	162	12	14.6	245	16	11.9	170	17
Fruits												
Apples (raw)	26.8	106	2	21.9	123	3	11.7	149	9	12.4	129	5
Apples (cooked and applesauce)	10.1	118	5	9.0	130	7	2.3	153[a]	19[a]	2.6	200[a]	47[a]
Apple juice	26.3	207	5	12.2	223	10	7.8	346	22	8.5	360	44
Bananas (raw)	25.0	95	2	16.5	105	3	10.3	122	6	8.4	119	5
Oranges (raw)	11.1	103	5	10.5	114	5	4.3	187[a]	38[a]	5.4	109[a]	8[a]
Orange juice	34.4	190	4	30.9	224	6	30.8	354	16	29.5	305	11

[a] Indicates a statistic that is potentially unreliable because of small sample size or large coefficient of variation
PC = Percent consuming at least once in 2 days.
SEM = Standard error of the mean.

Source: Smiciklas-Wright et al., 2002 (based on 1994-1996 CSFII data).

Table 9-12. Characteristics of the FITS Sample Population

	Sample Size	Percentage of Sample
Gender		
Male	1,549	51.3
Female	1,473	48.7
Age of Child		
4 to 6 months	862	28.5
7 to 8 months	483	16.0
9 to 11 months	679	22.5
12 to 14 months	374	12.4
15 to 18 months	308	10.2
19 to 24 months	316	10.4
Child's Ethnicity		
Hispanic or Latino	367	12.1
Non-Hispanic or Latino	2,641	87.4
Missing	14	0.5
Child's Race		
White	2,417	80.0
Black	225	7.4
Other	380	12.6
Urbanicity		
Urban	1,389	46.0
Suburban	1,014	33.6
Rural	577	19.1
Missing	42	1.3
Household Income		
Under $10,000	48	1.6
$10,000 to $14,999	48	1.6
$15,000 to $24,999	221	7.3
$25,000 to $34,999	359	11.9
$35,000 to $49,999	723	23.9
$50,000 to $74,999	588	19.5
$75,000 to $99,999	311	10.3
$100,000 and Over	272	9.0
Missing	452	14.9
Receives WIC		
Yes	821	27.2
No	2,196	72.6
Missing	5	0.2
Sample Size (Unweighted)	3,022	100.0

WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Devaney et al., 2004.

Table 9-13. Percentage of Infants and Toddlers Consuming Different Types of Vegetables

Food Group/Food	Percentage of Infants and Toddlers Consuming at Least Once in a Day					
	4 to 6 months	7 to 8 months	9 to 11 months	12 to 14 months	15 to 18 months	19 to 24 months
Any Vegetable	39.9	66.5	72.6	76.5	79.2	81.6
Baby Food Vegetables	35.7	54.5	34.4	12.7	3.0	1.6
Cooked Vegetables	5.2	17.4	45.9	66.3	72.9	75.6
Raw Vegetables	0.5	1.6	5.5	7.9	14.3	18.6
Types of Vegetables[a]						
Dark Green Vegetables[b]	0.1	2.9	4.2	5.0	10.4	7.8
Deep Yellow Vegetables[c]	26.5	39.3	29.0	24.0	13.6	13.4
White Potatoes	3.6	12.4	24.1	33.2	42.0	40.6
French Fries and Other Fried Potatoes	0.7	2.9	8.6	12.9	19.8	25.5
Other Starchy Vegetables[d]	6.5	10.9	16.9	17.3	20.8	24.2
Other Vegetables	11.2	25.9	35.1	39.1	45.6	43.3

[a] Totals include commercial baby food, cooked vegetables, and raw vegetables.
[b] Reported dark green vegetables include broccoli, spinach and other greens, and romaine lettuce.
[c] Reported deep yellow vegetables include carrots, pumpkin, sweet potatoes, and winter squash.
[d] Reported starchy vegetables include corn, green peas, immature lima beans, black-eyed peas (not dried), cassava, and rutabaga.

Source: Fox et al., 2004.

Table 9-14. Top Five Vegetables Consumed by Infants and Toddlers

Top Vegetables by Age Group[a]	Percentage Consuming at Least Once in a Day
4 to 6 months	
Baby Food Carrots	9.6
Baby Food Sweet Potatoes	9.1
Baby Food Squash	8.1
Baby Food Green Beans	7.2
Baby Food Peas	5.0
7 to 8 months	
Baby Food Carrots	14.2
Baby Food Sweet Potatoes	12.9
Baby Food Squash	12.9
Baby Food Green Beans	11.2
Baby Food Mixed/Garden Vegetables	10.1
9 to 11 months	
Cooked Green Beans	9.7
Mashed/Whipped Potatoes	9.0
French Fries/Other Fried Potatoes	8.6
Baby Food Mixed/Garden Vegetables	8.4
Cooked Carrots	8.0
12 to 14 months	
Cooked Green Beans	18.2
French Fries/Other Fried Potatoes	12.9
Cooked Carrots	11.5
Mashed/Whipped Potatoes	10.3
Cooked Peas	8.4
15 to 18 months	
French Fries/Other Fried Potatoes	19.8
Cooked Green Beans	16.7
Cooked Peas	13.9
Cooked Tomatoes/Tomato Sauce	13.7
Mashed/Whipped Potatoes	12.4
19 to 24 months	
French Fries/Other Fried Potatoes	25.5
Cooked Green Beans	16.8
Cooked Corn	15.2
Cooked Peas	11.4
Cooked Tomatoes/Tomato Sauce	9.4

[a] Baby food vegetables include single vegetables (majority of vegetables reported) as well as mixtures with the named vegetables the predominant vegetable, e.g., broccoli and cauliflower or broccoli and carrots.

Source: Fox et al., 2004.

Table 9-15. Percentage of Infants and Toddlers Consuming Different Types of Fruits

Food Group/Food	Percentage of Infants and Toddlers Consuming at Least Once in a Day					
	4 to 6 months	7 to 8 months	9 to 11 months	12 to 14 months	15 to 18 months	19 to 24 months
Any Fruit	41.9	75.5	75.8	77.2	71.8	67.3
Baby Food Fruit	39.1	67.9	44.8	16.2	4.2	1.8
Non-baby Food Fruit	5.3	14.3	44.2	67.1	69.4	66.8
Types of Non-baby Food Fruit						
Canned Fruit	1.4	5.8	21.6	31.9	25.1	20.2
Packed in Syrup	0.7	0.7	8.1	14.9	12.7	8.1
Packed in Juice or Water	0.7	4.5	13.5	18.5	11.3	11.4
Unknown Pack	0.0	0.7	1.5	1.2	3.1	1.2
Fresh Fruit	4.4	9.5	29.5	52.1	55.0	54.6
Dried Fruit	0.0	0.4	2.1	3.5	7.1	9.4
Types of Fruit[a]						
Apples	18.6	33.1	31.6	27.5	19.8	22.4
Bananas	16.0	30.6	34.5	37.8	32.4	30.0
Berries	0.1	0.6	5.3	6.6	11.3	7.7
Citrus Fruits	0.2	0.4	1.6	4.9	7.3	5.1
Melons	0.6	1.0	4.4	7.3	7.2	9.6

[a] Totals include all baby food and non-baby food fruits.

Source: Fox et al., 2004.

Table 9-16. Top Five Fruits Consumed by Infants and Toddlers

Top Fruits by Age Group[a]	Percentage Consuming at Least Once in a Day
4 to 6 months	
Baby Food Applesauce	17.5
Baby Food Bananas	13.0
Baby Food Pears	7.5
Baby Food Peaches	7.4
Fresh Banana	0.3
7 to 8 months	
Baby Food Applesauce	29.0
Baby Food Bananas	25.2
Baby Food Pears	18.2
Baby Food Peaches	13.1
Fresh Banana	6.6
9 to 11 months	
Fresh Banana	19.0
Baby Food Applesauce	17.7
Baby Food Bananas	16.8
Baby Food Pears	12.4
Canned Applesauce	11.1
12 to 14 months	
Fresh Banana	33.0
Canned Applesauce	15.2
Fresh Grapes	9.0
Fresh Apple	8.8
Canned Peaches	7.2
Canned Fruit Cocktail	7.2
15 to 18 Months	
Fresh Banana	30.5
Fresh Grapes	13.2
Fresh Apple	11.2
Fresh Strawberries	10.6
Canned peaches	8.9
19 to 24 months	
Fresh Banana	29.6
Fresh Apple	15.0
Fresh Grapes	11.2
Raisins	9.0
Fresh Strawberries	7.6

[a] Baby food fruits include single fruits (majority of fruits reported) as well as mixtures with the named fruit as the predominant fruit, e.g., pears and raspberries or prunes with pears. Baby food fruits with tapioca and other baby food dessert fruits were counted as desserts.

Source: Fox et al., 2004.

Table 9-17. Characteristics of WIC Participants and Non-participants[a] (Percentages)

	Infants 4 to 6 months		Infants 7 to 11 months		Toddlers 12 to 24 months	
	WIC Participant	Non-participant	WIC Participant	Non-participant	WIC Participant	Non-participant
Gender						
Male	55	54	55	51	57	52
Female	45	46	45	49	43	48
Child's Ethnicity		**		**		**
Hispanic or Latino	20	11	24	8	22	10
Non-Hispanic or Latino	80	89	76	92	78	89
Child's Race		**		**		**
White	63	84	63	86	67	84
Black	15	4	17	5	13	5
Other	22	11	20	9	20	11
Child In Day Care				**		*
Yes	39	38	34	46	43	53
No	61	62	66	54	57	47
Age of Mother		**		**		**
14 to 19	18	1	13	1	9	1
20 to 24	33	13	38	11	33	14
25 to 29	29	29	23	30	29	26
30 to 34	9	33	15	36	18	34
35 or Older	9	23	11	21	11	26
Missing	2	2	1	1	0	1
Mother's Education		**		**		**
11th Grade or Less	23	2	15	2	17	3
Completed High School	35	19	42	20	42	19
Some Postsecondary	33	26	32	27	31	28
Completed College	7	53	9	51	9	48
Missing	2	1	2	0	1	2
Parent's Marital Status		**		**		**
Married	49	93	57	93	58	88
Not Married	50	7	42	7	41	11
Missing	1	1	1	0	1	1

Table 9-17. Characteristics of WIC Participants and Non-participants[a] (Percentages) (continued)

	Infants 4 to 6 months		Infants 7 to 11 months		Toddlers 12 to 24 months	
	WIC Participant	Non-participant	WIC Participant	Non-participant	WIC Participant	Non-participant
Mother or Female Guardian Works				**		*
Yes	46	51	45	60	55	61
No	53	48	54	40	45	38
Missing	1	1	1	0	0	1
Urbanicity		**		**		**
Urban	34	55	37	50	35	48
Suburban	36	31	31	34	35	35
Rural	28	13	30	15	28	16
Missing	2	1	2	1	2	2
Sample Size (Unweighted)	265	597	351	808	205	791

[a] X^2 test were conducted to test for statistical significance in the differences between WIC participants and non-participants within each age group for each variable. The results of X^2 test are listed next to the variable under the column labeled non-participants for each of the three age groups. * P<0.05; ** P>0.01; non-participants significantly different from WIC participants on the variable.

WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Ponza et al., 2004.

Table 9-18. Food Choices for Infants and Toddlers by WIC Participation Status

	Infants 4 to 6 months		Infants 7 to 11 months		Toddlers 12 to 24 months	
	WIC Participant	Non-participant	WIC Participant	Non-participant	WIC Participant	Non-participant
Vegetables						
Any Vegetable	40.2	39.8	68.2	70.7	77.5	80.2
Baby Food Vegetables	32.9	37.0	38.2	45.0	4.8	4.7
Cooked Vegetables	8.0	3.9*	33.8	33.8	73.1	72.3
Raw Vegetables	1.4	0.1**	3.6	4.1	11.8	15.4
Dark Green Vegetables	0.4	0.0	2.9	4.0	6.3	8.4
Deep Yellow Vegetables	23.2	28.1	30.1	34.8	12.5	16.9
Other Starchy Vegetables	6.5	6.4	12.9	15.2	21.1	21.5
Potatoes	6.0	2.4*	20.7	18.2	43.1	38.3
Fruits						
Any Fruit	47.8	39.2*	64.7	81.0**	58.5	74.6**
Baby Food Fruits	43.8	36.9	48.4	57.4*	3.8	6.5
Non-Baby Food Fruit	8.1	4.0	22.9	35.9**	56.4	70.9**
Fresh Fruit	5.4	3.8	14.3	24.3**	43.6	57.0**
Canned Fruit	3.4	0.5**	10.3	17.3**	22.3	25.3
Sample Size (unweighted)	265	597	351	808	205	791

* = P<0.05 non-participants significantly different from WIC participants.
** = P<0.01 non-participants significantly different from WIC participants.
WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Ponza et al. 2004.

Table 9-19. Percentage of Hispanic and Non-Hispanic Infants and Toddlers Consuming Different Types of Fruits and Vegetables on A Given Day

	Age 4 to 5 months		Age 6 to 11 months		Age 12 to 24 months	
	Hispanic (n=84)	Non-Hispanic (n=538)	Hispanic (n=163)	Non-Hispanic (n=1,228)	Hispanic (n=124)	Non-Hispanic (n=871)
Fruits						
Any Fruit or 100% Fruit Juice	45.0	35.9	86.2	86.8	84.6	87.2
Any Fruit[a]	39.4	28.8	68.1	76.0	67.6	71.5
100% Fruit Juice	19.3	15.3	57.8	47.7	64.1	58.9
Fruit Preparation						
Baby Food Fruit	32.6	28.4	42.9*	58.1	5.6†	6.3
Non-Baby Food Fruit	9.1†	1.3†	35.8	27.4	64.2	68.0
Canned Fruit	2.3†	-	8.8	13.7	12.1**	26.2
Fresh Fruit	9.1*†	-	30.0**	17.7	59.3	53.1
Vegetables						
Any Vegetable or 100% Vegetable Juice[b]	30.0	27.3	66.2	70.3	76.0	80.5
Type of Preparation	25.7	25.4	34.4*	47.6	4.1†	4.9
Baby Food Vegetables	4.2†	2.4†	33.2	29.4	71.4	72.9
Cooked Vegetables	2.3†	-	8.3†	2.6	25.0	13.1
Raw Vegetables						
Types of Vegetables[b]	-	-	3.3†	3.1	11.4†	7.5
Dark Green Vegetables[c]	21.0	18.2	32.2	25.9	20.0	15.4
Deep Yellow Vegetables[d]						
Starchy Vegetable:	1.4†	2.3†	20.7	17.4	43.5	39.0
White Potatoes	-	-	5.7†	5.3	23.4	20.3
French Fries/Fried Potatoes	-	-	14.4†	10.7	19.8	17.7
Baked/Mashed	5.0†	4.0	6.7**	15.1	16.6	22.2
Other Starchy Vegetables[e]	8.1†	8.0	28.5	29.0	42.0	43.4
Other Non-starchy Vegetables[f]						

[a] Total includes all baby food and non-baby food fruits and excludes 100% fruit juices and juice drinks.
[b] Total includes commercial baby food, cooked vegetables, raw vegetables, and 100% vegetable juices.
[c] Reported dark green vegetables include broccoli, spinach, romaine lettuce and other greens such as kale.
[d] Reported yellow vegetables include carrots, pumpkin, sweet potatoes, and winter squash.
[e] Reported starchy vegetables include corn, green peas, immature lima beans, black-eyed peas (not dried), cassava, and rutabaga. Corn is also shown as a subcategory of other starchy vegetables.
[f] Reported non-starchy vegetables include asparagus, cauliflower, cabbage, onions, green beans, mixed vegetables, peppers, and tomatoes.
- = Less than 1 percent of the group consumed this food on a given day.
* = Significantly different from non-Hispanic at the $P<0.05$.
** = Significantly different from non-Hispanic at the $P>0.01$.
† = Statistic is potentially unreliable because of a high coefficient of variation.

Source: Mennella et al., 2006.

Table 9-20. Top Five Fruits and Vegetables Consumed by Hispanic and Non-Hispanic Infants and Toddlers Per Age Group [a]

	Ethnicity	
	Hispanic	Non-Hispanic
	Top Fruits By Age Group	
4 to 5 months	Bananas (16.3%) Apples (14.7%) Peaches (10.9%) Melons (3.5%) Pears (2.5%)	Apples (12.5%) Bananas (10.0%) Pears (5.9%) Peaches (5.8%) Prunes (1.6%)
6 to 11 months	Bananas (35.9%) Apples (29.7%) Pears (15.2%) Peaches (11.7%) Melons (4.7%)	Apples (32.9%) Bananas (31.5%) Pears (17.5%) Peaches (13.9%) Apricots (3.7%)
12 to 24 months	Bananas (41.5%) Apples (25.7%) Berries (8.5%) Melons (7.6%) Pears (7.3%)	Bananas (30.9%) Apples (22.0%) Grapes (12.3%) Peaches (9.6%) Berries (8.7%)
	Top Vegetables By Age Group	
4 to 5 months	Carrots (9.9%) Sweet Potatoes (6.8%) Green Beans (5.8%) Peas (5.0%) Squash (4.3%)	Sweet Potatoes (7.5%) Carrots (6.6%) Green Beans (5.9%) Squash (5.4%) Peas (3.8%)
6 to 11 months	Potatoes (20.7%) Carrots (19.0%) Mixed Vegetables (11.1%) Green Beans (11.0%) Sweet Potatoes (8.7%)	Carrots (17.5%) Potatoes (16.4%) Green Beans (15.9%) Squash (11.8%) Sweet Potatoes (11.4%)
12 to 24 months	Potatoes (43.5%) Tomatoes (23.1%) Carrots (18.6%) Onions (11.8%) Corn (10.2%)	Potatoes (39.0%) Green Beans (19.6%) Peas (12.8%) Carrots (12.3%) Tomatoes (11.9%)

[a] Percentage consuming at least one in a day is in parentheses.

Source: Mennella, et al., 2006.

Table 9-21. Average Portion Sizes per Eating Occasion of Fruits and Vegetables Commonly Consumed by Infants from the 2002 Feeding Infants and Toddlers Study

Food group	Reference unit	4 to 5 months (N=624)	6 to 8 months (N=708)	9 to 11 months (N=687)
			Mean± SEM	
Fruits and Juices				
All fruits	tablespoon	3.6±0.19	4.7±0.11	5.8±0.17
Baby food fruit	tablespoon	3.3±0.16	4.6±0.11	5.6±0.17
Baby food peaches	tablespoon	3.6±0.37	4.4±0.26	5.3±0.36
Baby food pears	tablespoon	3.5±0.46	4.5±0.21	6.0±0.40
Baby food bananas	tablespoon	3.4±0.23	5.0±0.21	5.9±0.35
Baby food applesauce	tablespoon	3.7±0.29	4.6±0.17	5.6±0.25
Canned fruit	tablespoon	-	4.5±0.59	4.8±0.25
Fresh fruit	tablespoon	-	5.3±0.52	6.4±0.37
100% juice	fluid ounce	2.5±0.17	2.8±0.11	3.1±0.09
Apple/apple blends	fluid ounce	2.7±0.22	2.9±0.13	3.2±0.11
Grape	fluid ounce	-	2.6±0.19	3.1±0.21
Pear	fluid ounce	-	2.6±0.29	3.1±0.28
Vegetables				
All vegetables	tablespoon	3.8±0.20	5.8±0.16	5.6±0.20
Baby food vegetables	tablespoon	4.0±0.20	5.9±0.16	6.6±0.21
Baby food green beans	tablespoon	3.5±0.33	5.1±0.28	6.1±0.50
Baby food squash	tablespoon	4.3±0.47	5.6±0.30	6.9±0.41
Baby food sweet	tablespoon	4.3±0.31	6.1±0.34	7.2±0.69
Baby food carrots	tablespoon	3.5±0.33	5.6±0.27	6.7±0.48
Cooked vegetables, excluding french fries	tablespoon	-	4.2±0.47	3.8±0.31
Deep yellow vegetables	tablespoon	-	3.2±0.59	3.2±0.39
Mashed potatoes	tablespoon	-	4.1±0.67	2.8±0.37
Green beans	tablespoon	-	3.2±0.62	5.0±0.61

\- = Cell size was too small to generate a reliable estimate.
N = Number of respondents.
SEM = Standard error.

Source: Fox et al., 2006.

Table 9-22. Average Portion Sizes per Eating Occasion of Fruits and Vegetables Commonly Consumed by Toddlers from the 2002 Feeding Infants and Toddlers Study

Food group	Reference unit	12 to 14 months (N=371)	15 to 18 months (N=312)	19 to 24 months (N=320)
		Mean± SEM		
Fruits and Juices				
All fruits	cup	0.4±0.02	0.5±0.03	0.6±0.03
Canned fruit	cup	0.3±0.02	0.4±0.03	0.4±0.04
Fresh fruit	cup	0.4±0.02	0.5±0.03	0.6±0.03
Fresh apple	cup, slice	0.4±0.05	0.6±0.07	0.8+0.14
	1 medium	0.3±0.04	0.5±0.06	0.6±0.11
Fresh banana	cup, slice	0.4+0.02	0.5±0.03	0.5±0.03
	1 medium	0.6±0.03	0.7±0.03	0.7±0.04
Fresh grapes	cup	0.2±0.01	0.3±0.03	0.3±0.02
100% juice	fluid ounce	3.7±0.15	5.0±0.20	5.1±0.18
Orange/orange blends	fluid ounce	3.3+0.38	4.5±0.33	5.2±0.35
Apple/apple blends	fluid ounce	3.6±0.21	4.5±0.29	4.9±0.27
Grape	fluid ounce	3.6±0.38	5.6±0.43	4.7±0.31
Vegetables				
All vegetables	cup	0.4±0.02	0.4±0.03	0.4±0.02
Cooked vegetables, excluding french fries	cup	0.3±0.03	0.3±0.03	0.3±0.02
Deep yellow vegetables	cup	0.2±0.03	0.3±0.05	0.3±0.05
Corn	cup	0.2±0.03	0.2±0.03	0.2±0.03
Peas	cup	0.2±0.02	0.2±0.02	0.2±0.02
Green beans	cup	0.4±0.05	0.4±0.05	0.3±0.03
Mashed potatoes	cup	0.3±0.05	0.4±0.05	0.3±0.05
Baked, boiled potatoes	cup	0.3±0.05	0.4±0.06	-
French fries	cup	0.4±0.05	0.6±0.05	0.6±0.05

- Cell size too small to generate reliable estimate.
N = Number of respondents.
SEM = Standard error of the mean.

Source: Fox et al., 2006.

Table 9-23. Mean Moisture Content of Selected Food Groups Expressed as Percentages of Edible Portions

Food	Moisture Content		Comments
	Raw	Cooked	
Fruits			
Apples - dried	31.76	84.13*	sulfured; * without added sugar
Apples	85.56* 86.67**		*with skin **without skin
Apples - juice		87.93	canned or bottled
Applesauce		88.35*	*unsweetened
Apricots	86.35	86.62*	*canned juice pack with skin
Apricots - dried	30.09	75.56*	sulfured; *without added sugar
Bananas	74.91		
Blackberries	88.15		
Blueberries	84.21	86.59*	*frozen unsweetened
Boysenberries	85.90		frozen unsweetened
Cantaloupes	90.15		
Casabas	91.85		
Cherries - sweet	82.25	84.95*	*canned, juice pack
Crabapples	78.94		
Cranberries	87.13		
Cranberries - juice cocktail	85.00		bottled
Currants (red and white)	83.95		
Elderberries	79.80		
Grapefruit (pink, red and white)	90.89		
Grapefruit - juice	90.00	90.10*	*canned unsweetened
Grapefruit - unspecified	90.89		pink, red, white
Grapes - fresh	81.30		American type (slip skin)
Grapes - juice	84.12		canned or bottled
Grapes - raisins	15.43		seedless
Honeydew melons	89.82		
Kiwi fruit	83.07		
Kumquats	80.85		
Lemons - juice	90.73	92.46*	*canned or bottled
Lemons - peel	81.60		
Lemons - pulp	88.98		
Limes	88.26		
Limes - juice	90.79	92.52*	*canned or bottled
Loganberries	84.61*		*frozen
Mulberries	87.68		
Nectarines	87.59		
Oranges - unspecified	86.75		all varieties
Peaches	88.87	87.49*	*canned juice pack
Pears - dried	26.69	64.44*	sulfured; *without added sugar
Pears - fresh	83.71	86.47*	*canned juice pack
Pineapple	86.00	83.51*	*canned juice pack
Pineapple - juice		86.37	canned

Table 9-23. Mean Moisture Content of Selected Food Groups Expressed as Percentages of Edible Portions (continued)

Food	Moisture Content		Comments
	Raw	Cooked	
Plums - dried (prunes)	30.92		
Plums	87.23	84.02*	*canned juice pack
Quinces	83.80		
Raspberries	85.75		
Strawberries	90.95	89.97*	*frozen unsweetened
Tangerine - juice	88.90	87.00*	*canned sweetened
Tangerines	85.17	89.51*	*canned juice pack
Watermelon	91.45		
Vegetables			
Alfalfa seeds - sprouted	92.82		
Artichokes - globe & French	84.94	84.08	boiled, drained
Artichokes - Jerusalem	78.01		
Asparagus	93.22	92.63	boiled, drained
Bamboo shoots	91.00	95.92	boiled, drained
Beans - dry - blackeye peas (cowpeas)	77.20	75.48	boiled, drained
Beans - dry - hyacinth (mature seeds)	87.87	86.90	boiled, drained
Beans - dry - navy (mature seeds)	79.15	76.02	boiled, drained
Beans - dry - pinto (mature seeds)	81.30	93.39	boiled, drained
Beans - lima	70.24	67.17	boiled, drained
Beans - snap - green - yellow	90.27	89.22	boiled, drained
Beets	87.58	87.06	boiled, drained
Beets - tops (greens)	91.02	89.13	boiled, drained
Broccoli	90.69	89.25	boiled, drained
Brussel sprouts	86.00	88.90	boiled, drained
Cabbage - Chinese (pak-choi)	95.32	95.55	boiled, drained
Cabbage - red	90.39	90.84	boiled, drained
Cabbage - savoy	91.00	92.00	boiled, drained
Carrots	88.29	90.17	boiled, drained
Cassava (yucca blanca)	59.68		
Cauliflower	91.91	93.00	boiled, drained
Celeriac	88.00	92.30	boiled, drained
Celery	95.43	94.11	boiled, drained
Chives	90.65		
Cole slaw	81.50		
Collards	90.55	91.86	boiled, drained
Corn - sweet	75.96	69.57	boiled, drained
Cress - garden	89.40	92.50	boiled, drained
Cucumbers - peeled	96.73		
Dandelion - greens	85.60	89.80	boiled, drained
Eggplant	92.41	89.67	boiled, drained
Endive	93.79		
Garlic	58.58		
Kale	84.46	91.20	boiled, drained
Kohlrabi	91.00	90.30	boiled, drained

Table 9-23. Mean Moisture Content of Selected Food Groups Expressed as Percentages of Edible Portions (continued)

Food	Moisture Content		Comments
	Raw	Cooked	
Lambsquarter	84.30	88.90	boiled, drained
Leeks - bulb and lower leaf-portion	83.00	90.80	boiled, drained
Lentils - sprouted	67.34	68.70	stir-fried
Lettuce - iceberg	95.64		
Lettuce - cos or romaine	94.61		
Mung beans - mature seeds (sprouted)	90.40	93.39	boiled, drained
Mushrooms - unspecified		91.08	boiled, drained
Mushrooms - oyster	88.80		
Mushrooms - Maitake	90.53		
Mushrooms - portabella	91.20		
Mustard greens	90.80	94.46	boiled, drained
Okra	90.17	92.57	boiled, drained
Onions	89.11	87.86	boiled, drained
Onions - dehydrated or dried	3.93		
Parsley	87.71		
Parsnips	79.53	80.24	boiled, drained
Peas - edible-podded	88.89	88.91	boiled, drained
Peppers - sweet - green	93.89	91.87	boiled, drained
Peppers - hot chili-green	87.74	92.50*	*canned solids & liquid
Potatoes (white)	81.58	75.43	baked
Pumpkin	91.60	93.69	boiled, drained
Radishes	95.27		
Rutabagas - unspecified	89.66	88.88	boiled, drained
Salsify (vegetable oyster)	77.00	81.00	boiled, drained
Shallots	79.80		
Soybeans - mature seeds - sprouted	69.05	79.45	steamed
Spinach	91.40	91.21	boiled, drained
Squash - summer	94.64	93.70	all varieties; boiled, drained
Squash - winter	89.76	89.02	all varieties; baked
Sweet Potatoes	77.28	75.78	baked in skin
Swiss chard	92.66	92.65	boiled, drained
Taro - leaves	85.66	92.15	steamed
Taro	70.64	63.80	
Tomatoes - juice		93.90	canned
Tomatoes - paste		73.50	canned
Tomatoes - puree		87.88	canned
Tomatoes	93.95		
Towelgourd	93.85	84.29	boiled, drained
Turnips	91.87	93.60	boiled, drained
Turnips - greens	89.67	93.20	boiled, drained
Water chestnuts - Chinese	73.46	86.42*	*canned solids and liquids
Yambean - tuber	90.07	90.07	boiled, drained

Source: USDA, 2007.

APPENDIX 9A

CODES AND DEFINITIONS USED TO DETERMINE THE VARIOUS FRUITS AND VEGETABLES USED IN THE U.S. EPA ANALYSIS OF CSFII DATA IN FCID

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data

Food Category	**EPA Food Commodity Codes**	
TOTAL FRUITS AND VEGETABLES		
Total Fruits	95000010 Acerola	95001930 Jackfruit
	11000090 Apple, dried	95001950 Kiwifruit
	11000091 Apple, dried-babyfood	10001970 Kumquat
	11000070 Apple, fruit with peel	10001990 Lemon
	11000080 Apple, peeled fruit	10002010 Lemon, peel
	11000081 Apple, peeled fruit-babyfood	10002060 Lime
	11000110 Apple, sauce	13012080 Loganberry
	11000111 Apple, sauce-babyfood	95002090 Longan
	12000120 Apricot	11002100 Loquat
	12000130 Apricot, dried	95002110 Lychee
	12000121 Apricot-babyfood	95002120 Lychee, dried
	95000200 Avocado	95002140 Mamey apple
	95000230 Banana	95002150 Mango
	95000240 Banana, dried	95002160 Mango, dried
	95000241 Banana, dried-babyfood	95002151 Mango-babyfood
	95000231 Banana-babyfood	95002270 Mulberry
	13010550 Blackberry	12002300 Nectarine
	13020570 Blueberry	10002400 Orange
	13020571 Blueberry-babyfood	10002420 Orange, peel
	13010580 Boysenberry	95002450 Papaya
	95000600 Breadfruit	95002460 Papaya, dried
	95000740 Canistel	95002451 Papaya-babyfood
	95000890 Cherimoya	95002520 Passionfruit
	12000900 Cherry	95002521 Passionfruit-babyfood
	12000901 Cherry-babyfood	95002540 Pawpaw
	10001060 Citrus citron	12002600 Peach
	10001070 Citrus hybrids	12002610 Peach, dried
	95001120 Coconut, dried	12002611 Peach, dried-babyfood
	95001110 Coconut, meat	12002601 Peach-babyfood
	95001111 Coconut, meat-babyfood	11002660 Pear
	95001130 Coconut, milk	11002670 Pear, dried
	11001290 Crabapple	11002661 Pear-babyfood
	95001300 Cranberry	95002770 Persimmon
	95001310 Cranberry, dried	95002790 Pineapple
	95001301 Cranberry-babyfood	95002800 Pineapple, dried
	13021360 Currant	95002791 Pineapple-babyfood
	13021370 Currant, dried	95002830 Plantain
	95001410 Date	95002840 Plantain, dried
	13011420 Dewberry	12002850 Plum
	08001480 Eggplant	12002870 Plum, prune, dried
	13021490 Elderberry	12002871 Plum, prune, dried-babyfood
	95001510 Feijoa	12002860 Plum, prune, fresh
	95001530 Fig	12002861 Plum, prune, fresh-babyfood
	95001540 Fig, dried	12002851 Plum-babyfood
	13021740 Gooseberry	95002890 Pomegranate
	95001750 Grape	10003070 Pummelo
	95001780 Grape, raisin	11003100 Quince
	10001800 Grapefruit	13013200 Raspberry
	95001830 Guava	13013201 Raspberry-babyfood
	95001831 Guava-babyfood	95003330 Sapote, Mamey
	13021910 Huckleberry	95003460 Soursop
	95001920 Jaboticaba	95003510 Spanish lime

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	**EPA Food Commodity Codes**			
Total Fruits (continued)	95003580	Starfruit	95003610	Sugar apple
	95003590	Strawberry	95003680	Tamarind
	95003591	Strawberry-babyfood	10003690	Tangerine
Total Vegetables	18000020	Alfalfa, seed	09020880	Chayote, fruit
	04010050	Amaranth, leafy	06030990	Chickpea, flour
	01030150	Arrowroot, flour	06030980	Chickpea, seed
	01030151	Arrowroot, flour-babyfood	06030981	Chickpea, seed-babyfood
	95000160	Artichoke, globe	01011000	Chicory, roots
	01030170	Artichoke, Jerusalem	02001010	Chicory, tops
	04010180	Arugula	09021020	Chinese waxgourd
	95000190	Asparagus	19011030	Chive
	09020210	Balsam pear	04011040	Chrysanthemum, garland
	95000220	Bamboo, shoots	19021050	Cinnamon
	19010290	Basil, dried leaves	19021051	Cinnamon-babyfood
	19010291	Basil, dried leaves-babyfood	19011180	Coriander, leaves
	19010280	Basil, fresh leaves	19011181	Coriander, leaves-babyfood
	19010281	Basil, fresh leaves-babyfood	19021190	Coriander, seed
	06020330	Bean, cowpea, succulent	19021191	Coriander, seed-babyfood
	06030360	Bean, kidney, seed	04011380	Dandelion, leaves
	06030380	Bean, lima, seed	01031390	Dasheen, corm
	06020370	Bean, lima, succulent	02001400	Dasheen, leaves
	06030390	Bean, mung, seed	19011440	Dill
	06030400	Bean, navy, seed	19021430	Dill, seed
	06030410	Bean, pink, seed	04021520	Fennel, Florence
	06030420	Bean, pinto, seed	03001640	Garlic
	06010430	Bean, snap, succulent	03001650	Garlic, dried
	06010431	Bean, snap, succulent-babyfood	03001651	Garlic, dried-babyfood
	01010500	Beet, garden, roots	01031660	Ginger
	01010501	Beet, garden, roots-babyfood	01031670	Ginger, dried
	02000510	Beet, garden, tops	01031661	Ginger-babyfood
	95000540	Belgium endive	01011680	Ginseng, dried
	05010610	Broccoli	95001770	Grape, leaves
	05020630	Broccoli raab	06031820	Guar, seed
	05010620	Broccoli, Chinese	06031821	Guar, seed-babyfood
	05010611	Broccoli-babyfood	19011840	Herbs, other
	05010640	Brussels sprouts	19011841	Herbs, other-babyfood
	05010690	Cabbage	05021940	Kale
	05020700	Cabbage, Chinese, bok choy	05011960	Kohlrabi
	05010720	Cabbage, Chinese, mustard	03001980	Leek
	05010710	Cabbage, Chinese, napa	19012020	Lemongrass
	95000730	Cactus	04012040	Lettuce, head
	09010750	Cantaloupe	04012050	Lettuce, leaf
	04020760	Cardoon	19012200	Marjoram
	01010780	Carrot	19012201	Marjoram-babyfood
	01010781	Carrot-babyfood	08002340	Okra
	09010800	Casaba	03002370	Onion, dry bulb
	01030820	Cassava	03002380	Onion, dry bulb, dried
	01030821	Cassava-babyfood	03002381	Onion, dry bulb, dried-babyfood
	05010830	Cauliflower	03002371	Onion, dry bulb-babyfood
	01010840	Celeriac	03002390	Onion, green
	04020850	Celery	95002430	Palm heart, leaves
	04020851	Celery-babyfood	19012490	Parsley, dried leaves
	04020870	Celtuce	19012491	Parsley, dried leaves-babyfood

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	**EPA Food Commodity Codes**			
Total Vegetables (continued)	04012480	Parsley, leaves	01013270	Rutabaga
	01012500	Parsley, turnip rooted	01013310	Salsify, roots
	01012510	Parsnip	02003320	Salsify, tops
	01012511	Parsnip-babyfood	19013340	Savory 95003350 Seaweed
	06032560	Pea, dry	95003351	Seaweed-babyfood
	06032561	Pea, dry-babyfood	03003380	Shallot
	06012570	Pea, edible podded, succulent	06003480	Soybean, flour
	06032580	Pea, pigeon, seed	06003481	Soybean, flour-babyfood
	06022590	Pea, pigeon, succulent	06003470	Soybean, seed
	06022550	Pea, succulent	19023540	Spices, other
	06022551	Pea, succulent-babyfood	19023541	Spices, other-babyfood
	08002700	Pepper, bell	09023560	Squash, summer
	08002710	Pepper, bell, dried	09023561	Squash, summer-babyfood
	08002711	Pepper, bell, dried-babyfood	09023570	Squash, winter
	08002701	Pepper, bell-babyfood	09023571	Squash, winter-babyfood
	19022740	Pepper, black and white	01033660	Sweet potato
	19022741	Pepper, black and white-babyfood	01033661	Sweet potato-babyfood
	08002720	Pepper, nonbell	04023670	Swiss chard
	08002730	Pepper, nonbell, dried	01033710	Tanier, corm
	08002721	Pepper, nonbell-babyfood	08003740	Tomatillo
	95002750	Peppermint	08003750	Tomato
	01032960	Potato, chips	08003780	Tomato, dried
	01032970	Potato, dry (granules/ flakes)	08003781	Tomato, dried-babyfood
	01032971	Potato, dry (granules/ flakes)-babyfood	08003760	Tomato, paste
	01032980	Potato, flour	08003761	Tomato, paste-babyfood
	01032981	Potato, flour-babyfood	08003770	Tomato, puree
	01033000	Potato, tuber, w/o peel	08003771	Tomato, puree-babyfood
	01033001	Potato, tuber, w/o peel-babyfood	95003800	Tomato, Tree
	01032990	Potato, tuber, w/peel	08003751	Tomato-babyfood
	01032991	Potato, tuber, w/peel-babyfood	01033870	Turmeric
	09023080	Pumpkin	05023890	Turnip, greens
	04013130	Radicchio	01013880	Turnip, roots
	01013160	Radish, Oriental, roots	95003970	Water chestnut
	02003170	Radish, Oriental, tops	95003980	Watercress
	01013140	Radish, roots	09013990	Watermelon
	02003150	Radish, tops	01034070	Yam bean
	05023180	Rape greens	01034060	Yam, true
	04023220	Rhubarb		
INDIVIDUAL FRUIT CATEGORIES				
Apples	11000090	Apple, dried	11000080	Apple, peeled fruit
	11000091	Apple, dried-babyfood	11000081	Apple, peeled fruit-babyfood
	11000070	Apple, fruit with peel	11000110	Apple, sauce
	11000100	Apple, juice	11000111	Apple, sauce-babyfood
	11000101	Apple, juice-babyfood		
Bananas	95000230	Banana	95002830	Plantain
	95000240	Banana, dried	95002840	Plantain, dried
	95000241	Banana, dried-babyfood		
	95000231	Banana-babyfood		

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	**EPA Food Commodity Codes**			
Berries and Small Fruits	13010550	Blackberry	13021910	Huckleberry
	13010580	Boysenberry	95001300	Cranberry
	13011420	Dewberry	95001301	Cranberry-babyfood
	13012080	Loganberry	95001310	Cranberry, dried
	13013200	Raspberry	95001750	Grape
	13013201	Raspberry-babyfood	95001770	Grape, leaves
	13020570	Blueberry	95001780	Grape, raisin
	13020571	Blueberry-babyfood	95001950	Kiwifruit
	13021360	Currant	95002270	Mulberry
	13021370	Currant, dried	95003590	Strawberry
	13021490	Elderberry	95003591	Strawberry-babyfood
	13021740	Gooseberry		
Citrus Fruits	10001060	Citrus citron	10002060	Lime
	10001070	Citrus hybrids	10002400	Orange
	10001800	Grapefruit	10002420	Orange, peel
	10001970	Kumquat	10003070	Pummelo
	10001990	Lemon	10003690	Tangerine
	10002010	Lemon, peel		
Peaches	12002600	Peach		
	12002610	Peach, dried		
	12002611	Peach, dried-babyfood		
	12002601	Peach-babyfood		
Pears	11002660	Pear		
	11002670	Pear, dried		
	11002680	Pear, juice		
	11002681	Pear, juice-babyfood		
	11002661	Pear-babyfood		
Pome Fruits	11000070	Apple, fruit with peel	11001290	Crabapple
	11000080	Apple, peeled fruit	11002100	Loquat
	11000081	Apple, peeled fruit-babyfood	11002660	Pear
	11000090	Apple, dried	11002661	Pear-babyfood
	11000091	Apple, dried-babyfood	11002670	Pear, dried
	11000110	Apple, sauce	11003100	Quince
	11000111	Apple, sauce-babyfood		
Strawberries	95003590	Strawberry		
	95003591	Strawberry-babyfood		
Stone Fruits	12000120	Apricot	12002611	Peach, dried-babyfood
	12000121	Apricot-babyfood	12002850	Plum
	12000130	Apricot, dried	12002851	Plum-babyfood
	12000900	Cherry	12002860	Plum, prune, fresh
	12000901	Cherry-babyfood	12002861	Plum, prune, fresh-babyfood
	12002300	Nectarine	12002870	Plum, prune, dried
	12002600	Peach	12002871	Plum, prune, dried-babyfood
	12002601	Peach-babyfood		
	12002610	Peach, dried		

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	**EPA Food Commodity Codes**			
Tropical Fruits	95000010	Acerola	95002140	Mamey apple
	95000220	Avocado	95002150	Mango
	95000230	Banana	95002151	Mango-babyfood
	95000231	Banana-babyfood	95002160	Mango, dried
	95000240	Banana, dried	95002450	Papaya
	95000241	Banana, dried-babyfood	95002451	Papaya-babyfood
	95000600	Breadfruit	95002460	Papaya, dried
	95000740	Canistel	95002520	Passionfruit
	95000890	Cherimoya	95002521	Passionfruit-babyfood
	95001110	Coconut, meat	95002540	Pawpaw
	95001111	Coconut, meat-babyfood	95002790	Pineapple
	95001120	Coconut, dried	95002791	Pineapple-babyfood
	95001130	Coconut, milk	95002800	Pineapple, dried
	95001410	Date	95002830	Plantain
	95001510	Feijoa	95002840	Plantain, dried
	95001530	Fig	95002890	Pomegranate
	95001540	Fig, dried	95003330	Sapote, Mamey
	95001830	Guava	95003460	Soursop
	95001831	Guava-babyfood	95003510	Spanish lime
	95001930	Jackfruit	95003580	Starfruit
	95002090	Longan	95003610	Sugar apple
	95002110	Lychee	95003680	Tamarind
	95002120	Lychee, dried		
INDIVIDUAL VEGETABLE CATEGORIES				
Asparagus	95000190	Asparagus		
Beans	06030350	Bean, great northern, seed	06020370	Bean, lima, succulent
	06030300	Bean, black, seed	06030390	Bean, mung, seed
	06030320	Bean, broad, seed	06030400	Bean, navy, seed
	06020310	Bean, broad, succulent	06030410	Bean, pink, seed
	06030340	Bean, cowpea, seed	06030420	Bean, pinto, seed
	06020330	Bean, cowpea, succulent	06010430	Bean, snap, succulent
	06030360	Bean, kidney, seed	06010431	Bean, snap, succulent-babyfood
	06030380	Bean, lima, seed		
Beets	01010500	Beet, garden, roots		
	01010501	Beet, garden, roots-babyfood		
	02000510	Beet, garden, tops		
Broccoli	05010610	Broccoli		
	05010611	Broccoli-babyfood		
Bulb Vegetables	03001640	Garlic	03002371	Onion, dry bulb-babyfood
	03001650	Garlic, dried	03002380	Onion, dry bulb, dried
	03001651	Garlic, dried-babyfood	03002381	Onion, dry bulb, dried-babyfood
	03001980	Leek	03002390	Onion, green
	03002370	Onion, dry bulb	03003380	Shallot
Cabbage	05010690	Cabbage		
	05010720	Cabbage, Chinese, mustard		
	05010710	Cabbage, Chinese, napa		

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	**EPA Food Commodity Codes**			
Carrots	01010780	Carrot		
Corn	15001220	Corn, field, bran	15001231	Corn, field, starch-babyfood
	15001200	Corn, field, flour	15001260	Corn, pop
	15001201	Corn, field, flour-babyfood	15001270	Corn, sweet
	15001210	Corn, field, meal	15001271	Corn, sweet-babyfood
	15001211	Corn, field, meal-babyfood		
	15001230	Corn, field, starch		
Cucumbers	09021350	Cucumber		
Cucurbit Vegetables	09010750	Cantaloupe	09021350	Cucumber
	09010800	Casaba	09023080	Pumpkin
	09011870	Honeydew melon	09023090	Pumpkin, seed
	09013990	Watermelon	09023560	Squash, summer
	09020210	Balsam pear	09023561	Squash, summer-babyfood
	09020880	Chayote, fruit	09023570	Squash, winter
	09021020	Chinese waxgourd	09023571	Squash, winter-babyfood
Fruiting Vegetables	08001480	Eggplant	08003750	Tomato
	08002340	Okra	08003751	Tomato-babyfood
	08002700	Pepper, bell	08003760	Tomato, paste
	08002701	Pepper, bell-babyfood	08003761	Tomato, paste-babyfood
	08002710	Pepper, bell, dried	08003770	Tomato, puree
	08002711	Pepper, bell, dried-babyfood	08003771	Tomato, puree-babyfood
	08002720	Pepper, nonbell	08003780	Tomato, dried
	08002721	Pepper, nonbell-babyfood	08003781	Tomato, dried-babyfood
	08002730	Pepper, nonbell, dried		
	08003740	Tomatillo		
Leafy Vegetables (Brassica and Nonbrassica)	02000510	Beet, garden, tops	04021520	Fennel, Florence
	02001010	Chicory, tops	04023220	Rhubarb
	02001400	Dasheen, leaves	04023670	Swiss chard
	02003150	Radish, tops	05010610	Broccoli
	02003170	Radish, Oriental, tops	05010611	Broccoli-babyfood
	02003320	Salsify, tops	05010620	Broccoli, Chinese
	04010050	Amaranth, leafy	05010640	Brussels sprouts
	04010180	Arugula	05010690	Cabbage
	04011040	Chrysanthemum, garland	05010710	Cabbage, Chinese, napa
	04011330	Cress, garden	05010720	Cabbage, Chinese, mustard
	04011340	Cress, upland	05010830	Cauliflower
	04011380	Dandelion, leaves	05011960	Kohlrabi
	04011500	Endive	05020630	Broccoli raab
	04012040	Lettuce, head	05020700	Cabbage, Chinese, bok choy
	04012050	Lettuce, leaf	05021170	Collards
	04012480	Parsley, leaves	05021940	Kale
	04013130	Radicchio	05022290	Mustard greens
	04013550	Spinach	05023180	Rape greens
	04013551	Spinach-babyfood	05023890	Turnip, greens
	04020760	Cardoon	95000540	Belgium endive
	04020850	Celery	95003350	Seaweed
	04020851	Celery-babyfood	95003351	Seaweed - babyfood
	04020870	Celtuce	95003980	Watercress

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	EPA Food Commodity Codes			
Legume Vegetables	06003470	Soybean, seed	06030340	Bean, cowpea, seed
	06003480	Soybean, flour	06030350	Bean, great northern, seed
	06003481	Soybean, flour-babyfood	06030360	Bean, kidney, seed
	06003490	Soybean, soy milk	06030380	Bean, lima, seed
	06003491	Soybean, soy milk-babyfood or infant formula	06030390	Bean, mung, seed
			06030400	Bean, navy, seed
	06010430	Bean, snap, succulent	06030410	Bean, pink, seed
	06010431	Bean, snap, succulent-babyfood	06030420	Bean, pinto, seed
	06012570	Pea, edible podded, succulent	06030980	Chickpea, seed
	06020310	Bean, broad, succulent	06030981	Chickpea, seed-babyfood
	06020330	Bean, cowpea, succulent	06030990	Chickpea, flour
	06020370	Bean, lima, succulent	06031820	Guar, seed
	06022550	Pea, succulent	06031821	Guar, seed-babyfood
	06022551	Pea, succulent-babyfood	06032030	Lentil, seed
	06022590	Pea, pigeon, succulent	06032560	Pea, dry
	06030300	Bean, black, seed	06032561	Pea, dry-babyfood
	06030320	Bean, broad, seed	06032580	Pea, pigeon, seed
Lettuce	04012040	Lettuce, head		
	04012050	Lettuce, leaf		
Okra	08002340	Okra		
Onions	03002370	Onion, dry bulb		
	03002380	Onion, dry bulb, dried		
	03002381	Onion, dry bulb, dried-babyfood		
	03002371	Onion, dry bulb-babyfood		
	03002390	Onion, green		
Peas	06032560	Pea, dry	06022550	Pea, succulent
	06032561	Pea, dry-babyfood	06022551	Pea, succulent-babyfood
	06012570	Pea, edible podded, succulent		
	06032580	Pea, pigeon, seed		
	06022590	Pea, pigeon, succulent		
Peppers	08002700	Pepper, bell	08002730	Pepper, nonbell, dried
	08002710	Pepper, bell, dried	08002721	Pepper, nonbell-babyfood
	08002711	Pepper, bell, dried-babyfood		
	08002701	Pepper, bell-babyfood		
	08002720	Pepper, nonbell		
Pumpkin	09023080	Pumpkin		
	09023090	Pumpkin, seed		

Table 9A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	EPA Food Commodity Codes			
Root and Tuber Vegetables	01030150	Arrowroot, flour	01012510	Parsnip
	01030151	Arrowroot, flour-babyfood	01012511	Parsnip-babyfood
	01030170	Artichoke, Jerusalem	01032960	Potato, chips
	01010500	Beet, garden, roots	01032970	Potato, dry (granules/ flakes)
	01010501	Beet, garden, roots-babyfood	01032971	Potato, dry (granules/ flakes)-babyfood
	02000510	Beet, garden, tops	01032980	Potato, flour
	01010520	Beet, sugar	01032981	Potato, flour-babyfood
	01010521	Beet, sugar-babyfood	01033000	Potato, tuber, w/o peel
	01010670	Burdock	01033001	Potato, tuber, w/o peel-babyfood
	01010780	Carrot	01032990	Potato, tuber, w/peel
	01010781	Carrot-babyfood	01032991	Potato, tuber, w/peel-babyfood
	01030820	Cassava	01013160	Radish, Oriental, roots
	01030821	Cassava-babyfood	01013140	Radish, roots
	01010840	Celeriac	01013270	Rutabaga
	01011000	Chicory, roots	01033660	Sweet potato
	01031390	Dasheen, corm	01033661	Sweet potato-babyfood
	01031660	Ginger	01033710	Tanier, corm
	01031670	Ginger, dried	01033870	Turmeric
	01031661	Ginger-babyfood	01013880	Turnip, roots
	01011680	Ginseng, dried	95003970	Water chestnut
	01011900	Horseradish	01034070	Yam bean
	01012500	Parsley, turnip rooted	01034060	Yam, true
Stalk and Stem Vegetable and Edible Fungi	95000160	Artichoke, globe		
	95000190	Asparagus		
	95000220	Bamboo, shoots		
	95002280	Mushroom		
	95002430	Palm heart, leaves		
Tomatoes	08003750	Tomato	08003770	Tomato, puree
	08003780	Tomato, dried	08003771	Tomato, puree-babyfood
	08003781	Tomato, dried-babyfood	08003751	Tomato-babyfood
	08003760	Tomato, paste		
	08003761	Tomato, paste-babyfood		
White Potatoes	01032960	Potato, chips	01033000	Potato, tuber, w/o peel
	01032970	Potato, dry (granules/ flakes)	01033001	Potato, tuber, w/o peel-babyfood
	01032971	Potato, dry (granules/ flakes)-babyfood	01032990	Potato, tuber, w/peel
	01032980	Potato, flour	01032991	Potato, tuber, w/peel-babyfood
	01032981	Potato, flour-babyfood		

10 INTAKE OF FISH AND SHELLFISH

10.1 INTRODUCTION

Contaminated finfish and shellfish are potential sources of human exposure to toxic chemicals. Pollutants are carried in the surface waters, but also may be stored and accumulated in the sediments as a result of complex physical and chemical processes. Consequently, finfish and shellfish are exposed to these pollutants and may become sources of contaminated food. Exposure to some contaminants may be of concern for children because they may be less able to metabolize, detoxify, and excrete these substances (Moya, 2004).

Accurately estimating exposure to a toxic chemical among a population that consumes fish from a polluted water body requires an estimation of intake rates of the caught fish by both fishermen and their families. Commercially caught fish are marketed widely, making the prediction of an individual's consumption from a particular water body or contaminant source difficult. Since the catch of recreational and subsistence fishermen is not "diluted" by fish from other water bodies, these individuals and their families represent the population that is most vulnerable to exposure by intake of contaminated fish from a specific location. This chapter focuses on intake rates of fish. Note that in this section the term fish refers to both finfish and shellfish. Intake rates for the general population, and recreational and Native American fishing populations are addressed, and data are presented for intake rates for both marine and freshwater fish, when available.

Survey data on fish consumption have been collected using a number of different approaches which need to be considered when interpreting the results. Typical surveys seek to draw inferences about a larger population from a smaller sample of that population. This larger population, from which the survey sample is taken and to which the results of the survey are generalized, is denoted the target population of the survey. In order to generalize from the sample to the target population, the probability of being sampled must be known for each member of the target population. This probability is reflected in weights assigned to survey respondents, with weights being inversely proportional to sampling probability. When all members of the target population have the same probability of being sampled, all weights can be set to one and essentially ignored. For example, in a mail or phone study of licensed anglers, the target population is generally all licensed anglers in a particular area, and in the studies presented, the sampling probability is essentially equal for all target population members. In a creel study (i.e., a study in which fishermen are interviewed while fishing), the target population is anyone who fishes at the locations being studied; generally, in a creel study, the probability of being sampled is not the same for all members of the target population. For instance, if the survey is conducted for one day at a site, then it will include all persons who fish there daily, but only about 1/7 of the people who fish there weekly, 1/30th of the people who fish there monthly, etc. In this example, the probability of being sampled (or inverse weight) is seen to be proportional to the frequency of fishing. However, if the survey involves interviewers revisiting the same site on multiple days, and persons are only interviewed once for the survey, then the probability of being in the survey is not proportional to frequency; in fact, it increases less than proportionally with frequency. At the extreme of surveying the same site every day over the survey period with no re-interviewing, all members of the target population would have the same probability of being sampled regardless of fishing frequency, implying that the survey weights should all equal one. On the other hand, if the survey protocol calls for individuals to be interviewed each time an interviewer encounters them (i.e., without regard to whether they were previously interviewed), then the inverse weights will again be proportional to fishing frequency, no matter how many times interviewers revisit the same site. Note that when individuals can be interviewed multiple times, the results of each interview are included as separate records in the data base and the survey weights should be inversely proportional to the expected number of times that an individual's interviews are included in the data base.

The U.S. EPA has prepared a review of and an evaluation of five different survey methods used for obtaining fish consumption data. They are:

- Recall-Telephone Survey;
- Recall-Mail Survey;
- Recall-Personal Interview;
- Diary; and
- Creel Census.

The reader is referred to U.S. EPA (1998) *Guidance for Conducting Fish and Wildlife Consumption Surveys* for more detail on these survey methods and their advantages and limitations. The type of survey used, its design, and any weighting factors used in estimating consumption should be considered when interpreting survey data for exposure assessment purposes. For surveys used in this handbook, respondents are typically adults who have reported on fish intake for children living in their households.

The recommendations for fish and shellfish ingestion rates are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on the key study identified by U.S. EPA for this factor. Following the recommendations, the studies on fish ingestion among the general population (Section 10.3), marine recreational angler households (Section 10.4), freshwater recreational households (Section 10.5), and Native American populations (Section 10.6) are summarized. Information is provided on the key study that forms the basis for the fish and shellfish intake rate recommendations. Relevant data on ingestion of fish and shellfish are also provided. These studies are presented to provide the reader with added perspective on the current state-of-knowledge pertaining to ingestion of fish and shellfish among children. Information on serving size (Section 10.7), and other factors (Section 10.8) are also presented.

10.2 RECOMMENDATIONS

Considerable variation exists in the mean and upper percentile fish consumption rates obtained from the studies presented in this chapter. This can be attributed largely to the type of water body (i.e., marine, estuarine, freshwater) and the characteristics of the survey population (i.e., general population, recreational, Native American), but other factors such as study design, method of data collection, and geographic location also play a role. Based on these study variations, fish consumption studies were classified into the following categories:

- General Population (total, marine, freshwater/estuarine);
- ? Recreational Marine Intake;
- Recreational Freshwater Intake; and
- Native American Populations

For exposure assessment purposes, the selection of intake rates for the appropriate category (or categories) will depend on the exposure scenario being evaluated.

Fish consumption rates are recommended for various ages of children in the general population, based on the key study presented in Section 10.3.1. The key study for estimating mean fish intake among the general population is the U.S. EPA (2002) analysis of data from the U.S. Department of Agriculture (USDA) Continuing Survey of Food Intake by Individuals (CSFII) 1994-1996, 1998. Per capita and consumer-only values for children ages 3 to < 6, 6 to <11, 11 to < 16, and 16 to < 18 years, by habitat (i.e., marine, freshwater/estuarine, or total fish), are shown in Table 10-1. It should be noted, however, that the key general population study presented in this chapter pre-dated the age groups recommended by U.S. EPA in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). Thus, recommended values were not available for children less than 3 years old or 18 to < 21. The confidence ratings for the fish intake recommendations for the general population are presented in Table 10-2. Note that the fish intake values presented in Table 10-1 are reported as uncooked fish weights. The CSFII 1994-1996, 1998 recipe files were used to convert, for each fish-containing food, the as-eaten fish weight consumed into an uncooked equivalent weight of fish. This is important because the concentrations of the contaminants in fish are generally measured in the uncooked samples. Assuming that cooking results in some reductions in weight (e.g., loss of moisture), and the mass of the contaminant in the fish tissue remains constant, then the contaminant concentration in the cooked fish tissue will increase. In terms of calculating the dose, actual consumption may be overestimated when intake is expressed on an uncooked basis, but the actual concentration may be underestimated when it is based on the uncooked sample. The net effect on the dose would depend on the magnitude of the opposing effects on these two exposure factors. On the other hand, if the "as-prepared" (i.e., as-consumed) intake rate and the uncooked concentration are used in the dose equation, dose may be underestimated since the concentration in the cooked fish is likely to be higher, if the mass of the contaminant remains constant after cooking. Therefore, it is more conservative and appropriate to use uncooked fish intake rates. If concentration data can be adjusted to account for changes after cooking, then the "as-prepared" (i.e., as-consumed) intake rates are appropriate. However, data on the effects of cooking on contaminant concentrations are limited and assessors generally make the conservative assumption that cooking has no effect on the contaminant mass. Both "as-prepared" (i.e., as-consumed) and uncooked general population fish intake values are presented in this handbook so that the assessor can choose the intake data that best matches the concentration data that are being used.

The CSFII data on which the general population recommendations are based, are short-term survey data and should not be used to estimate the distribution over the long term. Also, it is important to note that a limitation associated with these data is that the total amount of fish reported by respondents included fish from all sources (e.g., fresh, frozen, canned, domestic, international origin). The CSFII surveys did not identify the source of the fish consumed. This type of information may be relevant for some assessments. It should also be noted that because these recommendations are based on 1994-1996, 1998 CSFII data, they may not reflect any recent changes that may have occurred in consumption patterns.

Recommended values should be selected that are relevant to the assessment, choosing the appropriate age groups and source of fish (i.e., freshwater/estuarine, marine, and total fish). In some cases a different study or studies may be particularly relevant to the needs of an assessment, in which case results from that specific study or studies may be used instead of the recommended values provided here. For example, it may be advantageous to use available regional or site-specific estimates if the assessment targets a particular region or site. In addition, seasonal, gender, and fish species variations should be considered when appropriate, if data are available.

Recommendations are not provided for recreational marine fish intake, recreational freshwater fish intake, or intake among Native American children because the available data are limited to certain geographic areas and/or tribes and cannot be readily generalized to the U.S. population as a whole. However, data from two relevant recreational marine studies (KCA, 1994 and Alcoa, 1998); two relevant recreational freshwater studies (West et al., 1989 and Benson et al., 2001); and four Native American studies (CRITFC, 1994; Toy et al., 1996; Duncan, 2000; and Polissar et al., 2006) are provided in this chapter. Assessors may use these data, if appropriate to the scenarios being assessed. These studies were performed at various study locations using various age groups of children.

For recreational marine fish intake, the KCA (1994) study was conducted in Delaware using the age groups 0 to 9 years and 10 to 19 years and the Alcoa (1998) study was conducted in Texas using the age groups <6 years and 6 to 19 years. Mean recreational marine fish intake values in the KCA (1994) study were 6 grams/day and 11.4 grams/day for the 0 to 9 years (N = 73) and 10 to 19 years (N = 102), respectively. The Alcoa (1998) study provided mean recreational marine intake values for finfish at 11.4 grams/day for the children <6 years old (N = 320) and 15.6 grams/day for children 6 to 19 years old (N = 749). Mean shellfish values were 0.4 grams/day and 0.7 grams/day for the same age groups, respectively. Readers are referred to the studies provided in Section 10.4 of this chapter to determine if the values presented are applicable to their specific assessment.

For recreational freshwater fish intake, the West et al. (1989) study was conducted in Michigan to estimate intake based on 7-day recall and the frequency of fish meals over each of the four seasons. Based on a U.S. EPA analysis of the data, mean recreational freshwater fish intake rates were 5.6, 7.9, and 7.3 grams/day for children ages 1 to 5 years (N = 121), 6 to 10 years (N = 151), and 11 to 20 years (N = 349), respectively. Benson et al. (2001) reported median freshwater sports-caught fish intake rates of 1.2 and 1.7 grams/day for children, ages 0 to 14 years, in Minnesota (N = 582) and North Dakota (N = 343), respectively. Readers are referred to the studies provided in Section 10.5 of this chapter to determine if the values presented are applicable to their specific assessment.

Fish consumption data for Native American children are very limited, and fish consumption rates, habits, and patterns can vary among tribes and other sub-populations. Therefore, fish intake data for a particular tribe may not be representative of other tribes. Available data on fish consumption among this population is presented in Section 10.6. These data should be used, as appropriate.

Table 10-1. Recommended Values for General Population Fish Intake [a]

Age Group	Per Capita				Consumer Only				Multiple Percentiles	Source
	Mean		95th Percentile		Mean		95th Percentile			
	g/day	g/kg-day	g/day	g/kg-day	g/day	g/kg-day	g/day	g/kg-day		
Total Fish									See Tables 10-7 through 10-10	U.S. EPA Analysis of CSFII, 1994-96 and 1998. (Rates are for uncooked weight)
3 to < 6 years	7.7	0.43	51	3.0	74	4.2	184	10		
6 to < 11 years	8.5	0.28	56	1.9	95	3.2	313*	8.7*		
11 to < 16 years	12	0.23	87	1.5	113	2.2	308*	6.2*		
16 to < 18 years	11	0.16	84	1.3	136*	2.1*	357*	6.6*		
Marine Fish										
3 to < 6 years	5.5	0.31	39	2.3	66	3.7	165	9.3*		
6 to < 11 years	5.6	0.20	38	1.5	78	2.8	202*	8.0*		
11 to < 16 years	7.6	0.15	56	1.3	102	2.0	262*	5.2*		
16 to < 18 years	6.1	0.10	29	0.46	126*	2.0*	353*	6.5*		
Freshwater/Estuarine Fish										
3 to < 6 years	2.2	0.12	12	0.71	40	2.3	129	7.2*		
6 to < 11 years	3.0	0.08	13	0.35	61	1.8	248*	6.2*		
11 to < 16 years	4.3	0.08	26	0.48	71	1.3	199*	4.4*		
16 to < 18 years	4.6	0.07	19	0.29	100*	1.4*	242*	3.3*		

* The sample size does not meet the minimum reporting requirements, as described in the Third Report on Nutrition Monitoring in the United States (LSRO, 1995).

[a] Analysis was conducted prior to Agency' s issuance of *Guidance on Selecting Age groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA 2005). Thus, data were not presented for children less than 3 years old or for 18 to < 21 years.

Table 10-2. Confidence in Recommendations for General Population Fish Intake

General Assessment Factors	Rationale	Rating
Soundness		High
Adequacy of Approach	The survey methodology and the analysis of the survey data were adequate. Primary data were collected and used in a secondary analysis of the data. The sample size was large.	
Minimal (Or Defined) Bias	The survey data were based on recent recall. Data were collected over a short-duration (i.e., 2 days).	
Applicability and Utility		High
Exposure Factor of Interest	The key study focused the exposure factor of interest.	
Representativeness	The survey was conducted nationwide and was representative of the general U.S. population.	
Currency	The most current CSFII 1994-96; 98 data were used.	
Data Collection Period	Data were collected for two non-consecutive days.	
Clarity and Completeness		High
Accessibility	The primary data are accessible through USDA.	
Reproducibility	The methodology was clearly presented; enough information was available to allow for reproduction of the results.	
Quality Assurance	Quality assurance of CSFII data was good; quality control of secondary analysis was good.	
Variability and Uncertainty		Medium
Variability in Population	Full distributions were provided by the key study.	
Uncertainty	The survey was not designed to capture long-term intake and was based on recall. Otherwise, the sources of uncertainty were minimal.	
Evaluation and Review		Medium
Peer Review	The primary data were reviewed by USDA; U.S. EPA review conducted a review of the secondary data analysis for fish intake.	
Number and Agreement of Studies	The number of studies is 1.	
Overall Rating		**High** (mean) **Medium** (upper percentile)

10.3 GENERAL POPULATION STUDIES

10.3.1 Key General Population Study

10.3.1.1 *U.S. EPA 2002 - Estimated Per Capita Fish Consumption in the United States*

U.S. EPA's Office of Water used data from the 1994-96 CSFII and its 1998 Children's Supplement (referred to collectively as CSFII 1994-96, 1998) to generate fish intake estimates. Participants in the CSFII 1994-96, 98 provided two non-consecutive days of dietary data. Respondents estimated the weight of each food that they consumed. Information on the consumption of food was classified using 11,345 different food codes, and stored in a database in units of grams consumed per day. A total of 831 of these food codes related to fish or shellfish; survey respondents reported consumption across 665 of these codes. The fish component (by weight) of the various foods was calculated using data from the recipe file for release 7 of USDA's Nutrient Data Base for Individual Food Intake Surveys. The amount of fish consumed by each individual was then calculated by summing, over all fish containing foods, the product of the weight of food consumed and the fish component (i.e., the percentage fish by weight) of the food. The recipe file also contains cooking loss factors associated with each food. These were used to convert, for each fish-containing food, the as-eaten fish weight consumed into an uncooked equivalent weight of fish. Analyses of fish intake were performed on both an "as-prepared" (i.e., as-consumed) and uncooked basis.

Each fish-related food code was assigned, by U.S. EPA, to a habitat category. The habitat categories included freshwater/estuarine, or marine. Food codes were also designated as finfish or shellfish. Average daily individual consumption (g/day) was calculated, for a given fish type-by-habitat category (e.g., marine finfish), by summing the amount of fish consumed by the individual across the two reporting days for all fish-related food codes in the given fish-by-habitat category and then dividing by 2. Individual daily fish consumption (g/day) was calculated similarly except that total fish consumption was divided by the specific number of survey days the individual reported consuming fish; this was calculated for fish consumers only (i.e., those consuming fish on at least one of the two survey days). The reported body weight of the individual was used to convert consumption in g/day to consumption in g/kg-day.

There were a total of 20,607 respondents in the combined data set who had two-day dietary intake data. A total of 7,429 of these individuals were children between the ages of 3 and 17 years. Data for these children were used in estimating fish intake in g/day. Slightly fewer children were used in the fish intake rates estimated in units of g/kg-day because body weights were not reported for some individuals. Survey weights were assigned to this data set to make it representative of the U.S. population with respect to various demographic characteristics related to food intake. These weights were used to project the estimates for the 7,429 children in the data set to 58,923,560 children in the U.S. population.

U.S. EPA (2002) reported means and estimates of the 90th, 95th, and 99th percentiles of fish intake. Tables 10-3 through 10-10 present these statistics for daily average fish consumption. These data are presented for selected age groups: 3 to 5, 6 to 10, 11 to 15, and 16 to 17 years of age. Tables 10-3 and 10-4 present per capita fish consumption, on an as-consumed basis, in g/day and in mg/kg-day, respectively. Tables 10-5 and 10-6 provide consumer-only fish intake data, on an as-consumed basis, in units of g/day and mg/kg-day, respectively. Tables 10-7 through 10-10 provide per capita and consumer only fish intake data (g/day and mg/kg-day) on an uncooked equivalent basis.

The advantages of this study are that the data used were from the CSFII survey, which had a large sample size and was representative of the U.S. population. The CSFII survey was also designed to give unbiased estimates of food consumption (U.S. EPA, 2002). In addition, through use of the USDA recipe files, the analysis included all fish eaten (i.e., both fish eaten alone and in mixtures).

10.3.2 Relevant General Population Studies

10.3.2.1 *U.S. EPA, 1996 - National Human Activity Pattern Survey (NHAPS)*

The U.S. EPA (1996) collected information for the general population on the duration and frequency of time spent in selected activities and time spent in selected microenvironments via 24-hour diaries as part of the National Human Activity Pattern Survey (NHAPS). Over 9,000 individuals from 48 contiguous states participated in NHAPS. Approximately 4,700 participants also provided information on seafood consumption, with 2,980 responding that they ate seafood (including shellfish, eel, or squid) in the last month. Over 900 of these participants were children between the ages of 1 and 17 years. The survey was conducted between October 1992 and September 1994. Data were collected on the (1) number of people that ate seafood in the last month, (2) the number of servings of seafood consumed, and (3) whether the seafood consumed was caught or purchased. The participant responses were weighted according to selected demographics such as age, gender, and race to ensure that results were representative of the U.S. population. In order to conform to the standardized age categories used in this handbook, U.S. EPA subsequently accessed the source data from U.S. EPA (1996) and recalculated the relevant statistics using the age categories recommended in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). The results of U.S. EPA's analysis are shown in Table 10-11.

Intake data were not provided in the survey. However, intake of fish can be estimated using the information on the number of servings of fish eaten from this study and serving size data for each age group from other studies (see Section 10.7.1). Using the mean value for serving size and the number of servings per month from Table 10-11, the age-specific amount of seafood eaten per month can be estimated.

The advantages of NHAPS is that the data were collected for a large number of individuals and are representative of the U.S. general population. However, evaluation of seafood intake was not the primary purpose of the study and the data do not reflect the actual amount of seafood that was eaten. However, using the assumption described above, the estimated seafood intakes from this study are comparable to those observed in the U.S. EPA CSFII analysis. It should be noted that an all inclusive description for seafood was not presented in U.S. EPA (1996) or in the NHAPS data. It is not known if processed or canned seafood and seafood mixtures are included in the seafood category.

10.3.2.2 *Moya et al., 2008 - Estimates of Fish Consumption Rates for Consumers of Bought and Sel-caught fish in Connecticut, Florida, Minnesota, and North Dakota*

Moya et al. (2008) analyzed the raw data from three fish consumption studies to derive fish consumption rates for various age, gender, and ethnic groups, and according to the source of fish consumed (i.e., bought or caught) and habitat (i.e., freshwater, estuarine, or marine). The studies represented data from four states: Connecticut, Florida, Minnesota and North Dakota.

The Connecticut data were collected in 1996/1997 by the University of Connecticut to obtain estimates of fish consumption for the general population, sports fishing households, commercial fishing households, minority and limited income households, women of child-bearing years, and children. Data were obtained from 810 households, representing 2,080 individuals, using a combination of a mail questionnaire that included a 10-day diary, and personal interviews. The response rate for this survey was low (i.e., 6 percent for the general population and 10 percent for anglers), but was considered to be adequate by the study authors (Balcom et al., 1999). Data from this survey were available for 54 children, ages 0 to 15 years.

The Florida data were collected by telephone and in-person interviews by the University of Florida, and represented a random sample of 8,000 households (telephone interviews), and 500 food stamp recipients (in-person interviews). Data from this survey were available for 1,160 children, ages 0 to 15 years. The purpose of the survey was to obtain information on the quantity of fish and shellfish eaten, as well as the cooking method used. Additional information of the Florida survey can be found in Degner et al. (1994).

The Minnesota and North Dakota data were collected by the University of North Dakota in 2000 and represented 1,572 households and 4,273 individuals. Data from this survey were available for 273 children, ages 0 to 15 years (151 in Minnesota and 122 in North Dakota). Data on purchased and caught fish were collected for the general population, anglers, new mothers, and Native American tribes. The survey also collected information of the species of fish eaten. Additional information on this study can be found in Benson et al. (2001).

Moya et al. (2008) utilized the data from these three studies to generate intake rates for three age groups of children (i.e., 1 to <6 years, 6 to <11 years, and 11 to <16 years). These data represented the general population of children in the four states. Recreational fish intake rates were not provided for children, and data were not provided for children according to the source of intake (i.e., bought or caught) or habitat (i.e., freshwater, estuarine, or marine). Table 10-12 presents the intake rates for the general population of children who consumed fish and shellfish in g/kg-day, as-consumed. Table 10-13 provides information on the fish intake among the sample populations from the four states, based on the source of the fish (i.e., caught or bought). Table 10-14 provides estimated fish intake rates among the general populations and angler populations from Connecticut, Minnesota, and North Dakota. While the data in Tables 10-13 and 10-14 do not pertain specifically to children, they provide an indication of the proportion of fish consumption that is either caught or bought among the sample population, and similarities and/or differences between fish intake among the general population and anglers.

10.4 MARINE RECREATIONAL STUDIES

10.4.1 Relevant Marine Recreational Studies

10.4.1.1 *KCA Research Division, 1994 - Fish Consumption of Delaware Recreational Fishermen and Their Households*

In support of the Delaware Estuary Program, the State of Delaware's Department of Natural Resources and Environmental Control conducted a survey of marine recreational fishermen along the coastal areas of Delaware between July 1992 and June 1993 (KCA Research Division, 1994). There were two components of the study. One was a field survey of fishermen as they returned from their fishing trips and the second part was a telephone follow-up call. The purpose of the first component was to obtain information on their fishing trips and on their household composition. This information included the method and location of fishing, number of fish caught and kept by species, and weight of each fish kept. Household information included race, age, gender, and number of persons in the household. Information was also recorded as to the location of the angler intercept (i.e., where the angler was interviewed) and the location of the household. The purpose of the second component was to obtain information on the amount of fish caught and kept from the fishing trip and then eaten by the household. The methods used for preparing and cooking the fish were also documented.

The field portion of the study was designed to interview 2,000 anglers. Data were obtained from 1,901 anglers, representing 6,204 household members (KCA Research Division, 1994). A total of 1,717 of these were children between the ages of 0 and 19 years of age. While the primary goal of the study was to collect data on marine recreational fishing practices, the survey included some freshwater fishing and crabbing sites. Followup phone interviews typically occurred two weeks after the field interview and were used to gather information about consumption. Interviewers aided respondents in their estimation of fish intake by describing the weight of ordinary products, for the purpose of comparison to the quantity of fish eaten. Information on the number of fishing trips a respondent had taken during the month was used to estimate average annual consumption rates.

Table 10-15 presents the results of the study for children who consumed fish (i.e., consumers only). Children, ages 0 to 9 years old, had a mean fish consumption rate of 6.0 g/day (N = 73), while children, ages 10 to 19 years old, had a mean fish consumption rate of 11.4 g/day (N = 102). More than half of the study respondents reported that they skinned the fish that they ate (i.e., 450 out of 807 who reported whether they skinned their catch); the majority ate filleted fish (i.e., 617 out of 794 who reported the preparation method used), and over half fried their fish (i.e., 506 out of 875 who reported the cooking method).

One limitation of this study is that information on fish consumption by children is based on anglers' recall of amount of fish eaten. Also, the study was limited to one geographic area and may not be representative of the U.S. population.

10.4.1.2 *Alcoa, 1998 - Draft Report for the Finfish/Shellfish Consumption Study Alcoa (Point Comfort)/Lavaca Bay Superfund Site*

The Texas Saltwater Angler Survey was conducted in 1996/97 to evaluate the quantity and species of finfish and shellfish consumed by individuals who fish at Lavaca Bay. The target population for this study was residents of three Texas counties: Calhoun, Victoria, and Jackson (over 70 percent of the anglers who fish Lavaca Bay are from these three counties). The random sample design specified that the population percentages for the counties should be as follows: 50 percent from Calhoun, 30 percent from Victoria, and 20 percent from Jackson.

Each individual in the sample population was sent an introductory note describing the study and then was contacted by telephone. People who agreed to participate and had taken fewer than six fishing trips to Lavaca Bay were interviewed by telephone. Persons who agreed to participate and had taken more than five fishing trips to Lavaca Bay were sent a mail survey with the same questions. A total of 1,979 anglers participated in this survey, representing a response rate greater than 68 percent. Data were collected from the households for men, women, and children. There were 4,489 records with valid information and of those records, 320 were for small children (less than 6 years old) and 749 records for youths (6 to 19 years old).

The information collected as part of the survey included recreational fishing trip information for November 1996 (i.e., fishing site, site facilities, distance traveled, number and species caught), self-caught fish consumption (by the respondent, spouse and child, if applicable), opinions on different types of fishing experiences, and socio-demographics. Portion size for shellfish was determined by utilizing the number of shrimp, crabs, oysters, etc. that an individual consumed during a meal and the assumed tissue weight of the particular species of shellfish. Red drum was the most commonly consumed self-caught fish, followed by speckled sea trout, flounder, all other finfish and black drum. For shellfish, the order from highest to lowest amount consumed was oysters, blue crab, and shrimp.

Table 10-16 presents the mean and upper-percentile consumption rates of self-caught fish, expressed as grams per day, for small children (<6 years of age) and youths (ages 6 to 19 years of age). Small children consumed an average of 11.4 grams of finfish per day while youths consumed an average of 15.6 grams daily. Small children consumed an average of 0.4 g/day of shellfish, while youths consumed an average of 0.7 g/day. Note that these data represent the amount of self-caught fish that is consumed from all locations (i.e., not just from Lavaca Bay). Table 10-17 shows the average number of meals consumed by each age group of children and the average portion size in grams (converted from ounces) for these meals. Small children and youths consumed slightly less than three meals per month of finfish and less than one meal per month of shellfish. For finfish, youths consumed an average, per meal, portion size of 187 grams, and small children consumed less than 128 grams per meal. Youths consumed an average shellfish portion size of 71 grams per meal, while small children consumed 57 grams per meal.

The study authors noted that since the survey relied on the anglers' recall of meal frequency and portion, fish consumption may have been overestimated. Also, the study was conducted at one geographic location and may not be representative of the U.S. population.

10.5 FRESHWATER RECREATIONAL STUDIES

10.5.1 Relevant Freshwater Recreational Studies

10.5.1.1 *West et al., 1989 - Michigan Sport Anglers Fish Consumption Survey*

The Michigan Sport Anglers Fish Consumption Survey (West et al., 1989) surveyed a stratified random sample of Michigan residents with fishing licences. The sample was divided into 18 cohorts, with one cohort receiving a mail questionnaire each week between January and May 1989. The survey included both a short-term recall component, and a usual frequency component. For the short-term recall component, respondents were asked to identify all household members and list all fish meals consumed by each household member during the past seven days. Information on the source of the fish for each meal was also requested (self-caught, gift, market, or restaurant). Respondents were asked to categorize serving size by comparison with pictures of 8 ounce fish portions; serving sizes could be designated as either "about the same size", "less", or "more" than the size pictured. Data on fish species, locations of self-caught fish and methods of preparation and cooking were also obtained.

The usual frequency component of the survey asked about the frequency of fish meals during each of the four seasons and requested respondents to give the overall percentage of household fish meals that came from recreational sources. A sample of 2,600 individuals were selected from state records to receive survey questionnaires. A total of 2,334 survey questionnaires were deliverable and 1,104 were completed and returned, giving a response rate of 47.3 percent.. The responses represented a total of 621 children between the ages of 1 and 20 years.

U.S. EPA obtained the raw data from the West et al. (1989) survey and analyzed it to estimate mean fish intake rates for children. Only respondents with information on both short term and usual intake were included in this analysis. For the analysis, U.S. EPA modified the serving size weights used by West et al. (1989), which were 5, 8 and 10 ounces, respectively, for portions that were described as less, about the same, and more than the 8 ounce picture. U.S. EPA examined the percentiles of the distributions of fish meal sizes reported in Pao et al. (1982), derived from the 1977-1978 USDA National Food Consumption Survey (NCFS), and observed that a lognormal distribution provided a good visual fit to the percentile data. Using this lognormal distribution, the mean values for serving sizes greater than 8 ounces and for serving sizes at least 10 percent greater than 8 ounces were determined. In both cases, a serving size of 12 ounces was consistent with the Pao et al. (1982) distribution. The weights used in the U.S. EPA analysis then were therefore 5, 8, and 12 ounces for fish meals described as less, about the same, and more than the 8 ounce picture, respectively. It should be noted that the mean serving size from Pao et al. (1982) was about 5 ounces, well below the value of 8 ounces most commonly reported by respondents in the West et al. (1989) survey.

Table 10-18 displays the mean number of total and recreational fish meals for each household member between age 1 and 20 years based on the seven day recall data. Also shown are mean fish intake rates derived by applying the weights described above to each fish meal. Intake was calculated in units of both grams/day and grams/kg body weight/day. This analysis was restricted to individuals who eat fish and who reside in households reporting some recreational fish consumption during the previous year. About 75 percent of the survey respondents (i.e., licensed anglers) and about 84 percent of the respondents who fished in the prior year reported some household recreational fish consumption.

The advantages of this data set and analysis are that the survey was relatively large and contained both short-term and usual intake data. The response rate of this survey, 47 percent, was relatively low and it was conducted in one geographic location. This study was conducted in the winter and spring months of 1989. This period does not include the summer months when peak fishing activity can be anticipated, leading to the possibility that intake results based on the 7 day recall data may understate individuals' usual (annual average) fish consumption.

10.5.1.2 *Benson et al., 2001 - Fish Consumption Survey: Minnesota and North Dakota*

Benson et al (2001) conducted a fish consumption survey among Minnesota and North Dakota residents. The target population included the general population, licensed anglers, and members of Native American tribes. The survey focused on obtaining the most recent year's fish intake from all sources, including locally caught fish. Survey questionnaires were mailed to potential respondent households. For the entire population, approximately 1,570 surveys were returned completed (out of 7,835 that were mailed out). Information on fish consumption by children was collected if they were a part of a respondent household. Data were collected for a total of 604 children (ages 0 to 14 years) in Minnesota and a total of 375 children (ages 0 to 14 years) in North Dakota. Among these respondents, data on sport-caught fish intake were available for 582 Minnesota children and 343 North Dakota children. Table 10-19 presents the recreational freshwater intake rates for children (ages 0 to 14 years). Rates for both purchased and sports-caught fish are provided. For Minnesota, the 50th percentile sports-caught fish consumption rate was 1.2 grams/day and the 95th percentile rate was 14.6 grams/day. For North Dakota, the 50th percentile sports-caught fish consumption rate was 1.7 grams/day, and the 95th percentile rate was 23.3 grams/day. Intake rates of purchased fish were higher for both Minnesota (3.6 grams/day 50th percentile; 30.9 grams/day 95th percentile) and North Dakota (4.7 grams/day 50th percentile; 42.8 grasm/day 95th percentile).

An advantage of this study is its large overall sample size. A limitation of the study is the broad age range of children used (i.e., 0 to 14 years). Also, the study was limited to two states. Therefore, the results may not be representative of the U.S. population as a whole..

10.6 NATIVE AMERICAN STUDIES

10.6.1 Relevant Native American Studies

10.6.1.1 *Columbia River Inter-Tribal Fish Commission (CRITFC), 1994 - A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin*

The Columbia River Inter-Tribal Fish Commission (CRITFC) (1994) conducted a fish consumption survey among four Columbia River Basin Native American tribes during the fall and winter of 1991-1992. The target population included all adult tribal members who lived on or near the Yakama, Warm Springs, Umatilla or Nez Perce reservations. The survey was based on a stratified random sampling design where respondents were selected from patient registration files at the Indian Health Service. The overall response rate was 69 percent yielding a sample size of 513 tribal members, 18 years old and above. Interviews were performed in person at a central location on the member's reservation. Each participating adult was asked if there were any children 5 years old or younger in his or her household. Those responding affirmatively were asked a set of survey questions about the fish consumption patterns of the youngest child in the household (CRITFC, 1994). Information for 204 children, 5 years old and younger, was provided by participating adult respondents. Consumption data were available for 194 of these children.

Participants were asked to describe and quantify all food and drink consumed during the previous day. They were then asked to identify the months in which they ate the most and the least fish, and the number of fish meals consumed per week during each of those periods and an average value for the whole year. The typical portion size (in ounces) was determined with the aid of food models provided by the questioner. The next set of questions identified specific species of fish and addressed the number of times per month each was eaten, as well as what parts (e.g., fillet, skin, head, eggs, bones, other) were eaten. Respondents were then asked to identify the frequency with which they used various preparation methods, expressed as a percentage. Respondents sharing a household with a child, aged 5 years or less, were asked to repeat the serving size, eating frequency, and species questions for the child's consumption behavior. All respondents were asked about the geographic origin of any fish they personally caught and consumed, and to identify the major sources of fish in their diet (e.g., self-caught, grocery store, tribe, etc.). Fish intake rates were calculated by multiplying the annual frequency of fish meals by the average serving size per fish meal.

The population sizes of the four tribes were highly unequal, ranging from 818 to 3,872 individuals (CRITFC, 1994). In order to ensure an adequate sample size from each tribe, the study was designed to give nearly equal sample sizes for each tribe. Weighting factors were applied to the pooled data (in proportion to tribal population size) so that the survey results would be representative of the overall population of the four tribes for adults only. Because the sample size for children was considered small, only an unweighted analysis was performed for this population. Based on a desired sample size of approximately 500 and an expected response rate of 70 percent, 744 individuals were selected at random from lists of eligible patients; the numbers from each tribe were approximately equal.

Intake rates were calculated for children for which both the number of fish meals per week and serving size information were available. A total of 49 percent of respondents of the total survey population reported that they caught fish from the Columbia River basin and its tributaries for personal use or for tribal ceremonies and distributions to other tribe members and 88 percent reported that they obtained fish from either self-harvesting, family or friends, at tribal ceremonies or from tribal distributions. Of all fish consumed, 41 percent came from self or family harvesting, 11 percent from the harvest of friends, 35 percent from tribal ceremonies or distribution, 9 percent from stores and 4 percent from other sources (CRITFC, 1994).

Of the 204 children, the total number of respondents used in the analysis varied from 167 to 202, depending on the topic (amount and species consumed, fish meals consumed /week, age consumption began, serving size, consumption of fish parts) of the analysis. The unweighted mean for the age when children begin eating fish was 13.1 months of age (N = 167). The unweighted mean number of fish meals consumed per week by children was 1.2 meals per week (N = 195) and the unweighted mean serving size of fish for children aged five years old and less was 95 grams (i.e., 3.36 ounces) (N = 201). The unweighted percent of fish consumed by children by species was 82.7 percent for salmon, followed by 46.5 percent (N = 202) for trout. The analysis of seasonal intake showed that May and June tended to be high-consumption months and December and January low consumption months. Table 10-20 presents the fish intake distribution for children under 5 years of age (N = 194). The mean intake rate was 19.6 g/day (N = 194) and the 95^{th} percentile was approximately 70 g/day. These mean intake rates include both consumers and non-consumers. These values are based on survey questions involving estimated behavior throughout the year, which survey participants answered in terms of meals per week or per month and typical serving size per meal. Table 10-21 presents consumption rates for children who were reported to consume particular species of fish.

The authors noted that some non-response bias may have occurred in the survey since respondents were more likely to be female and live near the reservation than non-respondents. In addition, they hypothesized that non-consumers may have been more likely to be non-respondents than fish consumers since non-consumers may have thought their contribution to the survey would be meaningless; if such were the case, this study would overestimate the mean intake rate. It was also noted that the timing of the survey, which was conducted during low fish consumption months, may have led to underestimation of actual fish consumption; the authors conjectured that an individual may have reported higher annual consumption if interviewed during a relatively high consumption month and lower annual consumption if interviewed during a relatively low consumption month. Finally, with respect to children's intake, it was observed that some of the respondents provided the same information for their children as for themselves; thereby, the reliability of some of these data is questioned (CRITFC, 1994). The combination of four different tribes' survey responses into a single pooled data set is somewhat problematic. The data presented in Table 10-20 are unweighted and therefore contain a bias toward the smaller tribes, who were oversampled compared to the larger tribes.

The limitations of this study, particularly with regard to the estimates of children's consumption, result in a high degree of uncertainty in the estimated rates of consumption. However, it is one of a relative few studies aimed at the fish consumption patterns of Native Americans. It should be noted that the selection process for children may be biased because the 204 children included in the study were not selected independently, but were identified through a parent's patient registration file. This indicates that children from larger households would be less likely to be chosen to participate in the study than would be the case if the children themselves, rather than the parents, were randomly selected.

10.6.1.2 *Toy et al., 1996 - A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region*

Toy et al. (1996) conducted a study to determine fish and shellfish consumption rates of the Tulalip and Squaxin Island tribes living in the Puget Sound region. These two Indian tribes were selected on the basis of judgment that they would be representative of the expected range of fishing and fish consumption activities of the fourteen tribes in the region. Commercial fishing is a major source of income for members of both tribes; some members the Squaxin Island tribe also participate in commercial shellfishing. Both tribes participate in subsistence fishing and shellfishing.

Fish consumption patterns for the two tribes were estimated using a survey in which sample sizes were calculated separately for each tribe. This allowed separate analyses to be conducted for each tribe. The appropriate sample size was calculated based on the enrolled population of each tribe and a desired confidence interval of ±20 percent from the mean, with an additional 25 percent added to the total to allow for non-response or unusable data. The target population, derived from lists of enrolled tribal members provided by the tribes, consisted of enrolled tribal members aged 18 years and older and children aged five years and younger living in the same household as an enrolled member. Only members living on or within 50 miles of the reservation were considered for the survey. Each eligible enrolled tribal member was assigned a number, and computer-generated random numbers were used to identify the survey participants. Children were not sampled directly, but through adult members of their household; if one adult had more than one eligible child in his or her household, one of the children was selected at random. This indirect sampling method was necessitated by the available tribal records, but may have introduced sampling bias to the process of selecting children for the study. A total of 190 adult tribal members (ages 18 years old and older) and 69 children between ages birth and 5 years old (i.e., 0 to <6 years) were surveyed about their consumption of 52 fish species in six categories: anadromous, pelagic, bottom, shellfish, canned tuna, and miscellaneous.

Respondents described their consumption behavior for the past year in terms of frequency of fish meals eaten per week or per month, including seasonal variations in consumption rates. Portion sizes (in ounces) were estimated with the aid of model portions provided by the questioner. Data were also collected on fish parts consumed, preparation methods, patterns of acquisition for all fish and shellfish consumption, and children's consumption rates. Interviews were conducted between February and May 1994. The response rate for adults was 77 percent for the Squaxin Island tribe and 76 percent for the Tulalip tribes.

The mean and median consumption rates for children 5 years and younger for both tribes combined were 0.53 and 0.17 g/kg-day, respectively (Table 10-22). Squaxin Island children tended to consume more fish than Tulalip children (mean 0.83 g/kg-day vs. 0.24 g/kg-day). The data were insufficient to allow re-analysis to fit the data to the standard U.S. EPA age categories used elsewhere in this handbook.

One limitation associated with this study is that although data from the Tulalip and Squaxin Island tribes may be representative of consumption rates of children in these specific tribes, fish consumption rates, habits, and patterns can vary among tribes and other sub-populations; as a result, the consumption rates of these two tribes may not be useful as a surrogate for consumption rates of other Native American tribes. Furthermore, there were differences in consumption patterns between the two tribes included in this study; the study provided data for each tribe and for the pooled data from both tribes, but the latter may not be a statistically valid measure for tribes in the region. There might also be a possible bias due to the time the survey was conducted; many species in the survey are seasonal. For example, because of the timing of the survey, respondents may have overestimated annual consumption.

10.6.1.3 *Duncan, 2000 - Fish Consumption Survey of the Squamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region*

The Squamish Tribal Council conducted a study of the Squamish tribal members living on and near the Port Madison Indian Reservation in the Puget Sound region (Duncan, 2000). The study was funded by the Agency for Toxic Substances and Disease Registry (ATSDR) through a grant to the Washington State Department of Health. The purpose of the study was to determine seafood consumption rates, patterns, and habits of the members of the Squamish Tribe. The second objective was to identify cultural practices and attributes that affect consumption rates, patterns and habits of members of the Squamish Tribe.

A systematic random sample of adults, defined as individuals age 16 years and older, were selected from a sorted Tribal enrollment roster. The study had a participation rate of 64.8 percent, which was calculated on the basis of 92 respondents out of a total of 142 potentially eligible adults on the list of those selected into the sample. Consumption data for children under six years of age were gathered through adult respondents who had children in this age group living in the household at the time of the survey. Data were collected for 31 children under six years old.

A survey questionnaire was administered by personal interview. The survey included four parts: (1) 24-hour dietary recall; (2) identification, portions, frequency of consumption, preparation, harvest location of fish; (3) shellfish consumption, preparation, harvest location; and (4) changes in consumption over time, cultural information, physical information, and socioeconomic information. A display booklet was used to assist respondents in providing consumption data and identifying harvest locations of seafood consumed. Physical models of finfish and shellfish were constructed to assist respondents in determining typical food portions. Finfish and shellfish were grouped into categories based on similarities in life history as well as practices of Tribal members who fish for subsistence, ceremonial, and commercial purposes.

Interviewers collected data for 31 children under six years of age. Table 10-23 provides the consumption rates for children in units of g/kg-day for all respondents. Table 10-24 provides consumption rates for consumers only. Because all of the children involved in the study consumed some form of fish, the consumption distribution of all fish is the same in both tables. The mean, median, and 95th percentile consumption rates of all fish were 1.5 g/kg-day, 0.72 g/kg-day, and 7.3 g/kg-day, respectively. These values are significantly greater than those presented for the Tulalip and Squaxin Island tribes (Toy et al., 1996; see Section 10.6.1.2). This disparity illustrates the high degree of variability found between tribes even within a small geographic region (Puget Sound) and indicates that exposure and risk assessors should exercise care when imputing fish consumption rates to a population of interest using data from tribal studies.

A limitation of this study is that the sample size for children was fairly small (31 children). An important attribute of this survey is that it provided consumption rates by individual type of fish and shellfish.

10.6.1.4 *Polissar et al., 2006 - A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region–Consumption Rates for Fish-consumers Only*

Using fish consumption data from the Toy et al. (1996) survey of the Tulalip and Squaxin Island tribes of Puget Sound, Polissar et al. (2006) calculated consumption rates for various fish species groups, considering only the consumers of fish within each group. Weight-adjusted consumption rates were calculated by tribe, age, gender, and species groups. Species groups (anadromous, bottom, pelagic, and shellfish) were defined by life history and distribution in the water column. Data were available for 69 children, birth to <6 years of age; 18 of these children had no reported fish consumption and were excluded from the analysis. Thus, estimated fish consumption rates are based on data for 51 children; 15 from the Tulalip tribe and 36 from the Squaxin Island tribe. Both median and mean fish consumption rates for children within each tribe were calculated in terms of grams per kilogram of body weight per day (g/kg-day). Anadromous fish and shellfish were the groups of fish most frequently consumed by both tribes and genders. The consumption rates for groups of fish differed between the tribes. The distribution of consumption rates was skewed toward large values. The estimated mean consumption rate of all fish was 0.45 g/kg-day for the Tulalip children and 2.9 g/kg-day for the Squaxin Island children (Table 10-25). Table 10-26 presents consumption rates for children by species and gender.

Because this study used the data originally generated by Toy et al. (1996) the advantages and limitations associated with the Toy et al. (1996) study, as described in Section 10.6.1.2, also apply to this study. However, an advantage of this study is that the consumption rates are based only on individuals who consumed fish within the selected categories.

10.7 SERVING SIZE STUDY

10.7.1 Smiciklas-Wright et al., 2002 - Foods Commonly Eaten in the United States: Quantities Consumed per Eating Occasion and in a Day,1994-1996

Using data gathered in the 1994-96 USDA CSFII, Smiciklas-Wright et al. (2002) calculated distributions for the quantities of canned tuna and other finfish consumed per eating occasion by members of the U.S. population (i.e., serving sizes), over a 2-day period. The estimates of serving size are based on data obtained from 14,262 respondents, ages 2 years and above, who provided 2 days of dietary intake information. A total of 4,939 of these respondents were children, ages 2 to 19 years of age. Only dietary intake data from users of the specified food were used in the analysis (i.e., consumers only data).

Table 10-27 and Table 10-28 present serving size data for canned tuna and other finfish, respectively. These data are presented on an as-consumed basis (grams), and represent the quantity of fish consumed per eating occasion. These estimates may be useful for assessing acute exposures to contaminants in specific foods, or other assessments where the amount consumed per eating occasion is necessary.

The advantages of using these data are that they were derived from the USDA CSFII and are representative of the U.S. population. The analysis conducted by Smiciklas-Wright et al. (2002) accounted for individual foods consumed as ingredients of mixed foods. Mixed foods were disaggregated via recipe files so that the individual ingredients could be grouped together with similar foods that were reported separately. Thus, weights of foods consumed as ingredients were combined with weights of foods reported separately to provide a more thorough representation of consumption. However, it should be noted that since the recipes for the mixed foods consumed by respondents were not provided by the respondents, standard recipes were used. As a result, the estimates of the quantity of some food types are based on assumptions about the types and quantities of ingredients consumed as part of mixed foods.

10.8 OTHER FACTORS TO CONSIDER FOR FISH CONSUMPTION

Other factors to consider when using the available survey data include location, climate, season, and ethnicity of the angler or consumer population, as well as the parts of fish consumed and the methods of preparation. Some contaminants (for example, persistent, bioaccumulative, aand toxic contaminants such as dioxins and polychlorinated biphenyls) have the affinity to accumulate more in certain tissues, such as the fatty tissue, as well as in certain internal organs. The effects of cooking methods for various food products on the levels of dioxin-like compounds have been addressed by evaluating a number of studies in U.S. EPA (2003). These studies showed various results for contamination losses based on the methodology of the study and the method of food preparation. The reader is referred to U.S. EPA (2003) for a detailed review of these studies. Additionally, users of the data presented in this chapter should ensure that consistent units are used for intake rate and concentration of contaminants in fish. The following sections provide information on converting between wet weight and dry weight, and between wet weight and lipid weight.

10.8.1 Conversion Between Wet and Dry Weight

The intake data presented in this chapter are reported in units of wet weight (i.e., as-consumed or uncooked weight of fish consumed per day or per eating occasion). However, data on the concentration of contaminants in fish may be reported in units of either wet or dry weight (e.g., mg contaminant per gram-dry-weight of fish). It is essential that exposure assessors be aware of this difference so that they may ensure consistency between the units used for intake rates and those used for concentration data (i.e., if the contaminant concentration is measured in dry weight of fish, then the dry weight units should be used for fish intake values).

If necessary, wet weight (e.g., as-consumed) intake rates may be converted to dry weight intake rates using the moisture content percentages presented in Table 10-29 and the following equation:

$$IR_{dw} = IR_{ww}\left[\frac{100-W}{100}\right] \qquad \text{(Eqn. 10-1)}$$

where:

IR_{dw} = dry weight intake rate;

IR_{ww} = wet weight intake rate; and

W = percent water content.

Alternately, dry weight residue levels in fish may be converted to wet weight residue levels for use with wet weight (e.g., as-consumed) intake rates, as follows:

$$C_{ww} = C_{dw}\left[\frac{100-W}{100}\right] \quad \text{(Eqn. 10-2)}$$

where:

C_{ww} = wet weight intake rate;

C_{dw} = dry weight intake rate; and

W = percent water content.

The moisture content data presented in Table 10-29 are for selected fish taken from USDA, 2007.

10.8.2 Conversion Between Wet Weight and Lipid Weight Intake Rates

In some cases, the residue levels of contaminants in fish are reported as the concentration of contaminant per gram of fat. This may be particularly true for lipophilic compounds. When using these residue levels, the assessor should ensure consistency in the exposure assessment calculations by using consumption rates that are based on the amount of fat consumed for the fish product of interest.

If necessary, wet weight (e.g., as-consumed) intake rates may be converted to lipid weight intake rates using the fat content percentages presented in Table 10-29 and the following equation:

$$IR_{lw} = IR_{ww}\left[\frac{L}{100}\right] \quad \text{(Eqn. 10-3)}$$

where:

IR_{lw} = lipid weight intake rate;

IR_{ww} = wet weight intake rate; and

L = percent lipid (fat) content.

Alternately, wet weight residue levels in fish may be estimated by multiplying the levels based on fat by the fraction of fat per product as follows:

$$C_{ww} = C_{lw}\left[\frac{L}{100}\right] \quad \text{(Eqn. 10-4)}$$

where:

C_{ww} = wet weight intake rate;

C_{lw} = lipid weight intake rate; and

L = percent lipid (fat) content.

The resulting residue levels may then be used in conjunction with wet weight (e.g., as-consumed) consumption rates. The total fat content data presented in Table 10-29 are for selected fish taken from USDA, 2007.

10.9 REFERENCES FOR CHAPTER 10

Alcoa (1998) Draft report for the finfish/shellfish consumption study Alcoa (Point Comfort)/Lavaca Bay Superfund Site, Volume B7b: Bay System Investigation Phase 2. Point Comfort, TX: Aluminum Company of America.

Balcom, N.; Capacchione, C.; Hirsch D.W. (1999) Quantification of seafood consumption rates for Connecticut. Report prepared for the Connecticut Department of Environmental Protection, Office of Long Island Sound Programs, Hartford, CT. Contract No. CWF-332-R.

Benson, S.; Crocker, C.; Erjavec, J.; Jensen, R.R.; Nyberg, C.M.; Wixo, C.Y.; Zola, J.M. (2001) Fish consumption survey: Minnesota and North Dakota. Report prepared for the U.S. Department of Energy by the Energy and Environmental Research Center, University of North Dakota, Grand Forks, ND. DOE Cooperative Agreement No, DE-FC26-98FT40321.

Columbia River Inter-Tribal Fish Commission (CRITFC) (1994) A fish consumption survey of the Umatilla, Nez Perce, Yakama and Warm Springs tribes of the Columbia River Basin. Technical Report 94-3. Portland, OR: CRITFC.

Degner, R.L.; Adams, C.M.; Moss, S.D.; Mack, S.K. (1994) Per capita fish and shellfish consumption in Florida. Gainesville, FL: University of Florida.

Duncan, M. (2000) Fish consumption survey of the Squamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region. Squamish, WA: The Squamish Tribe, Port Madison Indian Reservation.

KCA Research Division (1994) Fish consumption of Delaware recreational fishermen and their households. Prepared for the State of Delaware, Department of Natural Resources and Environmental Control in support of the Delaware Estuary Program, Dover, DE.

LSRO (1995) Life Sciences Research Office, Federation of American Societies for Experimental Biology Prepared for the Interagency Board for Nutrition Monitoring and Related Research. Third Report on Nutrition Monitoring in the United States: Volume 1. U.S. Government Printing Office, Washington, DC.

Moya, J. (2004) Overview of fish consumption rates in the United States. Hum Eco Risk Assess 10:1195-1211.

Moya, J.; Itkin, C.; Selevan, S.G.; Rogers, J.W.; Clickner, R.P. (2008) Estimates of fish consumption rates for consumers of bought and self-caught fish in Connecticut, Florida, Minnesota, and North Dakota. Sci Tot Environ (in press).

Pao, E.M.; Fleming, K.H.; Guenther, P.M.; Mickle, S.J. (1982) Foods commonly eaten by individuals: amount per day and per eating occasion. U.S. Department of Agriculture. Home Economic Report No. 44.

Polissar, N.L.; Neradilek, B.; Liao, S.; Toy, K.A.; Mittelstaedt, G.D. (2006) A fish consumption survey of the Tulalip and Squaxin Island tribes of the Puget Sound region – Consumption rates for fish-consumers only. Report prepared by Mountain-Whisper-Light Statistical Consulting, Seattle, WA.

Smiciklas-Wright, H.; Mitchell, D.C.; Mickle, S.J.; Cook, A.J.; Goldman, J.D. (2002) Foods commonly eaten in the United States 1994-1996: Quantities consumed per eating occasion and in a day. U.S. Department of Agriculture. Agricultural Research Center NFS Report No. 96-5, 264 pp.

Toy, K.A.; Polissar, N.L.; Liao, S.; Mittelstaedt, G.D. (1996) A fish consumption survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region. Marysville, WA: Tulalip Tribes, Department of Environment.

USDA, Agricultural Research Service. (2007) USDA National Nutrient Database for Standard Reference, Release 20. Nutrient Data Laboratory Home Page: http://www.ars.usda.gov/ba/bhnrc/ndl.

U.S. EPA (1996) Descriptive statistics tables from a detailed analysis of the National Human Activity Pattern Survey (NHAPS) data. Washington, DC: Office of Research and Development. EPA/600/R-96/148.

U.S. EPA (1998) Guidance for conducting fish and wildlife consumption surveys. Washington, DC: Office of Water. EPA-823-B-98-007.

U.S. EPA (2002) Estimated Per Capita Fish Consumption in the United States. Washington, DC: Office of Water. EPA/821/C-02/003.

U.S. EPA (2003) Exposure and human health reassessment of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and related compounds, Part 1: Estimating exposure to dioxin-like compounds, Volume 2: Properties, environmental levels, and background exposures. (National Academy of Sciences Review Draft). Washington, DC: Office of Research and Development, National Center for Environmental Assessment. www.epa.gov/NCEA/dioxin.

U.S. EPA (2005) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants. Washington, DC: U.S. Environmental Protection Agency. EPA/630/P-03/003F.

West, P.C.; Fly, M.J.; Marans, R.; Larkin, F. (1989) Michigan sport anglers fish consumption survey. A report to the Michigan Toxic Substance Control Commission. Michigan Department of Management and Budget Contract No. 87-20141.

Table 10-3. Per Capita Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - g/day, As-Consumed

Age (years)	Sample Size	Mean (90% CI)	90th % (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
			Freshwater/Estuarine		
Ages 3 to 5	4,391	1.5 (1.2-1.8)	0.1 (0.0-1.0)	5.1 (4.1-6.2)	39 (33-44)
Ages 6 to 10	1,670	2.1 (1.4-2.9)	0.0 (0.0-0.6)	5.9 (3.2-13)	61* (51-86)
Ages 11 to 15	1,005	3.0 (2.2-3.8)	1.4 (0.5-5.5)	18 (15-21)	70* (56-75)
Ages 16 to 17	363	3.4 (1.6-5.3)	0.0 (0.0-1.5)	13* (5.2-29)	81* (42-117)
			Marine		
Ages 3 to 5	4,391	3.7 (3.2-4.3)	11 (10-13)	28 (24-29)	60 (52-71)
Ages 6 to 10	1,670	4.2 (3.5-4.9)	13 (9.7-17)	29 (28-34)	79* (49-84)
Ages 11 to 15	1,005	5.5 (4.2-6.7)	14 (9.8-21)	39 (31-50)	102* (84-114)
Ages 16 to 17	363	4.7 (2.9-6.4)	0.0 (0.0-6.9)	24* (7.8-71)	108* (68-119)
			All Fish		
Ages 3 to 5	4,391	5.2 (4.6-5.8)	19 (15-21)	35 (31-40)	72 (67-81)
Ages 6 to 10	1,670	6.3 (5.3-7.3)	24 (21-27)	40 (34-51)	108* (92-131)
Ages 11 to 15	1,005	8.5 (6.9-10)	28 (25-31)	60 (53-74)	122* (107-132)
Ages 16 to 17	363	8.1 (5.4-11)	19 (7.0-41)	74* (29-90)	142* (108-200)

a Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-4. Per Capita Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - mg/kg-day, As-Consumed

Age (years)	Sample Size	Mean (90% CI)	90th % (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
			Freshwater/Estuarine		
Ages 3 to 5	4,112	83 (67-99)	0 (0-55)	284 (240-353)	2,317 (1,736-2,463)
Ages 6 to 10	1,553	59 (39-79)	0 (0-5)	178 (88-402)	1,662* (1,433-2,335)
Ages 11 to 15	975	53 (42-64)	27 (0-78)	312 (253-390)	1,237* (950-1,521)
Ages 16 to 17	360	49 (23-76)	0 (0-33)	213* (106-390)	1,186* (600-2,096)
			Marine		
Ages 3 to 5	4,112	209 (182-237)	614 (525-696)	1,537 (1,340-1,670)	3,447 (3,274-3,716)
Ages 6 to 10	1,553	150 (123-177)	416 (326-546)	1,055 (969-1,275)	2,800* (2,021-3,298)
Ages 11 to 15	975	109 (84-133)	338 (179-413)	821 (629-1,034)	1,902* (1,537-2,366)
Ages 16 to 17	360	75 (46-103)	0 (0-124)	381* (132-951)	1,785* (1,226-2,342)
			All Fish		
Ages 3 to 5	4,112	292 (259-326)	1,057 (931-1,232)	1,988 (1,813-2,147)	4,089 (3,733-4,508)
Ages 6 to 10	1,553	209 (176-242)	780 (644-842)	1,357 (1,173-1,452)	3,350* (2,725-4,408)
Ages 11 to 15	975	162 (133-191)	570 (476-664)	1,051 (991-1,313)	2,305* (1,908-2,767)
Ages 16 to 17	360	124 (83-165)	261 (110-600)	1,029* (390-1,239)	2,359* (2,096-2,676)

a Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-5. Consumer Only Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - g/day, As-Consumed

Age (years)	Sample Size	Mean (90% CI)	90th % (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
Freshwater/Estuarine					
Ages 3 to 5	442	27 (23-31)	73 (65-79)	96 (87-110)	159* (136-260)
Ages 6 to 10	147	43 (32-55)	122* (83-187)	187* (115-260)	260* (172-261)
Ages 11 to 15	107	49 (39-59)	127* (104-148)	150* (135-193)	307* (193-384)
Ages 16 to 17	28	76* (59-93)	159* (151-171)	168* (159-484)	372* (171-484)
Marine					
Ages 3 to 5	682	45 (41-48)	91 (84-105)	119 (102-143)	228* (169-293)
Ages 6 to 10	217	59 (53-66)	129 (112-158)	159* (135-219)	243* (219-292)
Ages 11 to 15	122	72 (60-85)	165* (158-203)	204* (169-227)	246* (214-269)
Ages 16 to 17	37	97* (65-129)	219* (180-238)	238* (180-293)	365* (230-428)
All Fish					
Ages 3 to 5	834	50 (46-54)	103 (94.5-125)	134 (121-152)	260* (195-293)
Ages 6 to 10	270	71 (64-77)	155 (130-183)	218* (198-261)	281* (260-292)
Ages 11 to 15	172	80 (70-89)	167* (154-193)	209* (206-257)	285* (264-327)
Ages 16 to 17	52	104* (75-133)	201* (167-243)	242* (216-484)	451* (293-484)

[a] Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-6. Consumer Only Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - mg/kg-day, As-Consumed

Age (years)	Sample Size	Mean (90% CI)	90th % (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
Freshwater/Estuarine					
Ages 3 to 5	416	1,532 (1,320-1,743)	4,307 (3,472-4,624)	5,257 (4,926-5,746)	10,644* (9,083-12,735)
Ages 6 to 10	132	1,296 (1,004-1,588)	3,453* (2,626-4,671)	4,675* (3,459-8,816)	8,314* (4,684-9,172)
Ages 11 to 15	101	869 (725-1,013)	2,030* (1,628-2,104)	3,162* (2,104-3,601)	4,665* (3,597-7,361)
Ages 16 to 17	28	1,063* (781-1,346)	2,293* (2,096-2,577)	2,505* (2,096-6,466)	5,067* (2,295-6,466)
Marine					
Ages 3 to 5	640	2,492 (2,275-2,709)	5,303 (4,873-5,930)	6,762 (6,097-7,168)	11,457* (7,432-14,391)
Ages 6 to 10	203	2,120 (1,880-2,361)	4,950 (4,043-5,384)	5,817* (5,333-6,596)	8,092* (6,146-9,184)
Ages 11 to 15	120	1,427 (1,203-1,651)	2,971* (2,858-3,741)	4,278* (3,026-4,766)	5,214* (4,647-5,646)
Ages 16 to 17	37	1,534* (1,063-2,004)	3,602* (2,974-4,685)	4,475* (3,068-4,685)	4,982* (3,467-5,238)
All Fish					
Ages 3 to 5	779	2,828 (2,608-3,049)	5,734 (5,268-6,706)	7,422 (6,907-8,393)	13,829* (11,349-14,391)
Ages 6 to 10	250	2,375 (2,199-2,551)	5,135 (4,684-5,816)	6,561* (5,404-8,816)	9,179* (8,130-10,485)
Ages 11 to 15	164	1,533 (1,384-1,682)	3,207* (2,945-3,485)	3,925* (3,485-4,764)	5,624* (4,764-6,929)
Ages 16 to 17	52	1,578* (1,187-1,969)	3,468* (2,676-4,752)	4,504* (3,709-6,466)	5,738* (4,752-6,466)

[a] Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-7. Per Capita Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - g/day, Uncooked Fish Weight

Age (years)	Sample Size	Mean (90% CI)	90th (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
			Freshwater/Estuarine		
Ages 3 to 5	4,391	2.2 (1.8-2.6)	0.1 (0.0-1.5)	12 (10-14)	52 (46-62)
Ages 6 to 10	1,670	3.0 (1.9-4.1)	0.0 (0.0-0.5)	13 (4.8-20)	78* (64-111)
Ages 11 to 15	1,005	4.3 (3.2-5.4)	2.3 (0.1-7.7)	26 (21-29)	95* (83-110)
Ages 16 to 17	363	4.6 (2.2-6.9)	0.0 (0.0-1.9)	19* (13-37)	109* (58-155)
			Marine		
Ages 3 to 5	4,391	5.5 (4.8-6.2)	20 (17-23)	39 (38-41)	82 (73-95)
Ages 6 to 10	1,670	5.6 (4.6-6.5)	19 (14-24)	38 (38-42)	100* (63-111)
Ages 11 to 15	1,005	7.6 (5.9-9.4)	25 (16-35)	56 (45-67)	132* (110-149)
Ages 16 to 17	363	6.1 (3.7-8.4)	0.0 (0.0-9.3)	29* (12-91)	136* (92.0-177)
			All Fish		
Ages 3 to 5	4,391	7.7 (6.9-8.6)	33 (28-34)	51 (46-57)	101 (89.1-111)
Ages 6 to 10	1,670	8.5 (7.1-10)	33 (27-38)	56 (50-70)	144* (117-183)
Ages 11 to 15	1,005	12 (9.7-14)	43 (37-51)	87 (70-103)	171* (148-176.8)
Ages 16 to 17	363	11 (7.0-14)	29 (9.4-49)	84* (42-114)	193* (121-266)

a Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-8. Per Capita Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - mg/kg-day, Uncooked Fish Weight

Age (years)	Sample Size	Mean (90% CI)	90th % (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
			Freshwater/Estuarine		
Ages 3 to 5	4,112	124 (103-146)	0 (0-83)	712 (599-784)	3,091 (2,495-3,475)
Ages 6 to 10	1,553	84 (55-112)	0 (0-1)	354 (116-685)	2,322* (1,856-2,994)
Ages 11 to 15	975	77 (60-94)	20 (0-116)	477 (411-618)	1,610* (1,358-2,203)
Ages 16 to 17	360	65 (30-100)	0 (0-23)	285* (167-491)	1,542* (760-2,767)
			Marine		
Ages 3 to 5	4,112	309 (270-348)	1,108 (984-1,332)	2,314 (2,096-2,481)	4,608 (4,301-5,354)
Ages 6 to 10	1,553	198 (161-235)	600 (474-733)	1,481 (1,310-1,549)	3,684* (2,458-4,353)
Ages 11 to 15	975	153 (117-189)	481 (361-609)	1,251 (808-1,390)	2,381* (2,162-3,207)
Ages 16 to 17	360	98 (58-137)	0 (0-177)	460* (197-1,079)	2,148* (1,648-3,901)
			All Fish		
Ages 3 to 5	4,112	433 (385-482)	1,841 (1,555-1,957)	2,964 (2,790-3,194)	5,604 (5,231-6,135)
Ages 6 to 10	1,553	282 (235-328)	1,045 (745-1,219)	1,854 (1,638-2,175)	4,371* (3,433-5,814)
Ages 11 to 15	975	231 (186-275)	824 (657-952)	1,531 (1,362-1,850)	3,651* (2,745-3,795)
Ages 16 to 17	360	163 (108-219)	406 (145-756)	1,272* (558-1,500)	3,544* (2,767-3,946)

a Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-9. Consumer Only Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - g/day, Uncooked Fish Weight

Age (years)	Sample Size	Mean (90% CI)	90th % (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
Freshwater/Estuarine					
Ages 3 to 5	442	40 (35-46)	95 (86-102)	129 (120-142)	205* (200-381)
Ages 6 to 10	147	61 (44-79)	157* (117-250)	248* (150-381)	386* (221-401)
Ages 11 to 15	107	71 (58-83)	173* (166-196)	199* (173-296)	392* (296-514)
Ages 16 to 17	28	100* (80-121)	203* (197-248)	242* (206-643)	501* (241-643)
Marine					
Ages 3 to 5	682	66 (60-71)	125 (114-150)	165 (139-190)	316* (227-390)
Ages 6 to 10	217	78 (67-89)	150 (129-201)	202* (165-317)	350* (223-392)
Ages 11 to 15	122	102 (86-118)	220* (205-265)	262. (227-307)	320* (277-379)
Ages 16 to 17	37	126* (80-171)	281* (241-354)	353* (241-390)	530* (291-650)
All Fish					
Ages 3 to 5	834	74 (69-79)	149 (136-165)	184 (172-223)	363* (310-391)
Ages 6 to 10	270	95 (85-106)	200 (177-235)	313* (254-381)	387* (381-401)
Ages 11 to 15	172	113.(99-127)	227* (205-296)	308* (271-348)	380* (353-409)
Ages 16 to 17	52	136* (97-174)	242* (206-358)	357* (266-643)	645* (390-650)

[a] Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-10. Consumer Only Distribution of Fish (Finfish and Shellfish) Intake
General Population Children Ages 3 to 17 Years - mg/kg-day, Uncooked Fish Weight

Age (years)	Sample Size	Mean (90% CI)	90th % (90% BI)[a]	95th % (90% BI)[a]	99th % (90% BI)[a]
Freshwater/Estuarine					
Ages 3 to 5	416	2,292 (2,012-2,572)	5,852 (4,703-6,068)	7,160 (6,950-7,442)	15,600* (11,877-18,670)
Ages 6 to 10	132	1,830 (1,416-2,245)	4,688* (3,673-5,987)	6,207* (4,767-12,926)	12,365* (6,763-12,926)
Ages 11 to 15	101	1,273 (1,082-1,464)	2,777* (2,091-3,026)	4,419* (3,026-5,522)	5,717* (5,457-9,852)
Ages 16 to 17	28	1,401* (1,058-1,744)	2,971* (2,743-3,692)	3,279* (2,767-8,577)	6,819* (3,221-8,577)
Marine					
Ages 3 to 5	640	3,689 (3,395-3,982)	7,253 (6,777-8,504)	9,270 (8,415-9,991)	16,100* (11,980-17,989)
Ages 6 to 10	203	2,787 (2,417-3,157)	5,910 (4,813-7,365)	8,001* (6,375-8,707)	10,754* (8,707-12,055)
Ages 11 to 15	120	2,020 (1,741-2,327)	4,224* (3,744-4,781)	5,195* (3,859-6,448)	6,839* (6,076-8,970)
Ages 16 to 17	37	2,007* (1,302-2,712)	4,468* (3,880-7,802)	6,537* (3,991-7,802)	7,886* (4,661-7,958)
All Fish					
Ages 3 to 5	779	4,198 (3,894-4,502)	8,061 (7,366-9,223)	10,444 (9,475-12,261)	17,874* (15,290-18,670)
Ages 6 to 10	250	3,188 (2,923-3,452)	6,544 (6,013-8,707)	8,654* (7,086-11,756)	12,785* (10,930-13,979)
Ages 11 to 15	164	2,199 (1,950-2,449)	4,387* (3,785-5,522)	6,234* (4,420-7,589)	8,345* (6,076-8,970)
Ages 16 to 17	52	2,066* (1,529-2,603)	3,902* (3,536-7,892)	6,594* (4,661-8,577)	8,210* (7,892-8,577)

[a] Percentile intervals were estimated using the percentile bootstrap method with 1,000 bootstrap replications.
* The sample size does not meet minimum reporting requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).
CI = Confidence interval.
BI = Bootstrap interval.

Source: U.S. EPA, 2002.

Table 10-11. Number of General Population Respondents Reporting Consumption of a Specified Number of Servings of Seafood in 1 Month, and Source of Seafood Eaten

Age Group (years)	N	Number of Servings in a Month							Source of Seafood		
		0	1-2	3-5	6-10	11-19	20+	DK	Mostly Purchased	Mostly Caught	DK
0 to <1	34	27	5	2	0	0	0	0	7	0	0
1 to <2	49	30	12	4	2	0	0	1	15	3	1
2 to <3	59	34	12	7	4	1	0	1	24	1	0
3 to <6	169	80	42	26	13	1	1	6	78	8	3
6 to <11	224	117	45	36	12	4	3	7	98	4	5
11 to <16	236	128	50	42	6	1	1	8	98	3	7
16 to <21	220	110	41	37	18	4	2	8	96	5	9

DK = Don't know.
N = Sample size.

Source: U.S. EPA re-analysis of data in U.S. EPA, 1996.

Table 10-12. Fish Consumption Among General Population Children in Four States, Consumers Only, g/kg-day As-Consumed

Age Group (years)	N	Mean	CI	Percentiles						Maximum
				10th	25th	50th	75th	90th	95th	
Connecticut										
1 to <6	14	0.61	0.42-0.81	0.16	0.26	0.55	0.83	1.4	1.6	1.6
6 to <11	22	0.59	0.040-0.77	0.14	0.23	0.47	0.96	1.2	1.3	1.5
11 to <16	18	0.32	0.17-0.46	0.07	0.14	0.19	0.38	0.52	0.84	1.3
Florida										
1 to <6	420	2.3	2.05-2.63	0.5	1.0	1.7	2.8	4.7	6.8	14.6
6 to <11	375	1.1	0.98-1.22	0.28	0.52	0.81	1.4	2.2	3.0	9.4
11 to <16	365	0.85	0.73-0.98	0.20	0.36	0.63	0.99	1.6	2.2	11.0
Minnesota										
1 to <6	46	0.58	0.32-0.85	0.07	0.15	0.46	0.73	1.1	1.8	8.0
6 to <11	42	0.38	0.21-0.54	0.05	0.07	0.25	0.47	1.0	1.4	5.3
11 to <16	63	0.24	0.16-0.31	0.03	0.06	0.21	0.32	0.55	0.59	1.4
North Dakota										
1 to <6	28	0.70	0.24-1.17	0.05	0.12	0.23	0.68	1.6	3.8	6.8
6 to <11	41	0.56	0.31-0.81	0.11	0.21	0.30	0.66	1.2	1.5	4.3
11 to <16	53	0.41	0.23-0.59	0.06	0.12	0.22	0.54	1.0	1.3	2.3

N = Sample size.
CI = Confidence interval.

Source: Moya et al, 2008.

Table 10-13. Fish Consumption Among General Population in Four States According to Caught or Bought Status, g/kg-day As-Consumed

Category	N	Mean	CI	Percentiles						Maximum
				10th	25th	50th	75th	90th	95th	
Connecticut										
Eats Caught Only	1	0.01	-	-	-	-	-	-	-	0.01
Eats Caught and Bought	70	0.49	0.36-0.61	0.10	0.17	0.34	0.75	1.1	1.3	2.2
Eats Bought Only	291	0.48	0.40-0.57	0.06	0.16	0.32	0.61	1.1	1.4	7.0
Florida										
Eats Caught Only	511	0.76	0.66-0.86	0.15	0.30	0.50	0.90	1.7	2.3	7.4
Eats Caught and Bought	701	1.8	1.6-2.1	0.50	0.76	1.2	2.0	3.4	5.1	34
Eats Bought Only	6545	0.85	0.81-0.89	0.18	0.30	0.54	0.98	1.8	2.5	24
Minnesota										
Eats Caught Only	38	0.16	0.05-0.26	0.02	0.03	0.08	0.25	0.37	0.51	0.57
Eats Caught and Bought	555	0.40	0.27-0.52	0.08	0.11	0.23	0.49	0.70	1.3	9.2
Eats Bought Only	200	0.23	0.18-0.28	0.02	0.05	0.14	0.26	0.56	0.91	8.0
North Dakota										
Eats Caught Only	30	0.21	0.09-0.32	0.05	0.09	0.14	0.22	0.33	0.51	1.8
Eats Caught and Bought	359	0.39	0.29-0.49	0.07	0.13	0.23	0.43	0.82	1.3	4.3
Eats Bought Only	157	0.25	0.13-0.36	0.03	0.05	0.10	0.24	0.53	0.97	6.8

N = Sample size.
CI = Confidence interval.

Source: Moya et al., 2008.

Table 10-14. Fish Consumption Among General Population and Anglers in Three States, g/kg-day As-Consumed

Category	N	Mean	Percentiles						
			10th	25th	50th	75th	90th	95th	99th
Connecticut									
Anglers	244	0.66	0.10	0.20	0.40	0.80	1.6	2.1	3.5
General Population	362	0.48	0.07	0.16	0.32	0.63	1.1	1.4	2.4
Minnesota									
Anglers	1,109	0.32	0.05	0.10	0.18	0.34	0.67	0.99	2.2
General Population	793	0.33	0.04	0.10	0.20	0.34	0.65	1.1	1.8
North Dakota									
Anglers	808	0.34	0.05	0.10	0.20	0.39	0.81	1.2	2.0
General Population	546	0.34	0.05	0.09	0.19	0.35	0.74	1.2	2.2

N = Sample size.

Source: Moya et al., 2008.

Table 10-15. Recreational Fish Consumption in Delaware Consumers Only

Age Group	N	Mean consumption (g/day)[a]	Standard Error (%)
0 to 9 years	73	6.0	13.4
10 to 19 years	102	11.4	16.8

[a] Converted from ounces/day; 1 ounce = 28.35 grams.

Source: KCA Research Division, 1994.

Table 10-16. Consumption of Self-Caught Fish by Recreational Anglers
Lavaca Bay, Texas, g/day

Age Group	N	Mean	95% Upper Confidence Limit on Mean	90th or 95th Percentile of Distribution[a]
Finfish				
Small children (<6 years)	320	11.4	14.2	30.3
Youths (6 to 19 years)	749	15.6	17.8	45.4
Shellfish				
Small children (<6 years)	320	0.4	0.6	2.0
Youths (6 to 19 years)	749	0.7	1.0	4.5

[a] The 90th percentile values are presented for finfish. For shellfish, the 95th percentile value is provided because less than 90 percent of the individuals consumed shellfish, resulting in a 90th percentile of zero.

Source: Alcoa, 1998.

Table 10-17. Number of Meals and Portion Sizes of Self-Caught Fish Consumed by Recreational Anglers
Lavaca Bay, Texas

Age Group	Number of Meals		Portion Size (grams)[a]	
	Mean	95% Upper Confidence Limit on Mean	Mean	95% Upper Confidence Limit on Mean
Finfish				
Small children (<6 years)	2.6	3.1	128	133
Youths (6 to 19 years)	2.4	2.7	187	196
Shellfish				
Small children (<6 years)	0.3	0.5	57	68
Youths (6 to 19 years)	0.3	0.4	71	82

[a] Converted from ounces; 1 ounce = 28.35 grams.

Source: Alcoa, 1998.

Table 10-18. Mean Fish Intake Among Individuals Who Eat Fish and Reside in Households With Recreational Fish Consumption - Michigan

Age Group	N	Meals/Week		Intake g/day		Intake g/kg-day	
		All Fish	Recreational Fish	Total Fish	Recreational Fish	Total Fish	Recreational Fish
1 to 5 years	121	0.46	0.22	11.4	5.6	0.74	0.37
6 to 10 years	151	0.49	0.28	13.6	7.9	0.48	0.28
11 to 20 years	349	0.41	0.23	12.3	7.3	0.22	0.12

N = Sample size.

Source: U.S. EPA analysis, using data from West et al., 1989.

Table 10-19. Consumption of Sports-caught and Purchased Fish by Minnesota and North Dakota Children, Ages 0 to 14 Years (g/day)

	N	Percentile 50th	75th	90th	95th
Minnesota					
Sports-caught	582	1.2	3.3	8.3	14.6
Purchased		3.6	8.7	19.2	30.9
North Dakota					
Sports-caught	343	1.7	5.1	13.1	23.3
Purchased		4.7	11.6	26.3	42.8

Source: Benson et al., 2001.

Table 10-20. Fish Consumption Rates among Native American Children (age 5 years and under)[a]

Grams/Day	Unweighted Cumulative Percent
0.0	21.1
0.4	21.6
0.8	22.2
1.6	24.7
2.4	25.3
3.2	28.4
4.1	32.0
4.9	33.5
6.5	35.6
8.1	47.4
9.7	48.5
12.2	51.0
13.0	51.5
16.2	72.7
19.4	73.2
20.3	74.2
24.3	76.3
32.4	87.1
48.6	91.2
64.8	94.3
72.9	96.4
81.0	97.4
97.2	98.5
162.0	100

[a] Sample size = 194; unweighted mean = 19.6 grams/day; unweighted standard error = 1.94.
Note: Data are compiled from the Umatilla, Nez Perce, Yakama, and Warm Springs tribes of the Columbia River Basin.

Source: CRITFC, 1994.

Table 10-21. Number of Fish Meal Eaten per Month and Fish Intake Among Native American Children who Consume Particular Species

Species	N	Fish Meals/Month		Intake (g/day)	
		Unweighted Mean	Unweighted SE	Unweighted Mean	Unweighted SE
Salmon	164	2.3	0.16	19	1.5
Lamprey	37	0.89	0.27	8.1	2.8
Trout	89	0.96	0.12	8.8	1.4
Smelt	39	0.40	0.09	3.8	0.99
Whitefish	21	3.5	2.83	21	16
Sturgeon	21	0.43	0.12	4.0	1.3
Walleye	5	0.22	0.20	2.0	1.5
Squawfish	2	0.00	-	0.0	-
Sucker	4	0.35	0.22	2.6	1.7
Shad	3	0.10	0.06	1.1	0.57

SE = Standard error.

Source: CRITFC, 1994.

Table 10-22. Consumption Rates for Native American Children, Age Birth to Five Years (g/kg-day)

Fish Category	Mean (SE)	95% CI	50th percentile	90th percentile
Tulalip Tribes (N = 21)				
Shellfish	0.13 (0.056)	(0.014, 0.24)	0.0	0.60
Total finfish	0.11 (0.030)	(0.056, 0.17)	0.060	0.29
Total, all fish	0.24 (0.077)	(0.088, 0.39)	0.078	0.74
Squaxin Island Tribe (N = 48)				
Shellfish	0.23 (0.053)	(0.13, 0.37)	0.045	0.57
Total finfish	0.25 (0.063)	(0.13, 0.37)	0.061	0.83
Total, all fish	0.83 (0.14)	(0.55, 1.1)	0.51	2.1
Both Tribes Combined (weighted)				
Shellfish	0.18 (0.039)	(0.10, 0.25)	0.012	0.57
Total finfish	0.18 (0.035)	(0.10, 0.25)	0.064	0.32
Total, all fish	0.53 (0.081)	(0.37, 0.69)	0.17	1.4

SE = Standard error.
CI = Confidence interval.
N = Sample size.

Source: Toy et al., 1996.

Table 10-23. Consumption Rates for Native American Children (g/kg-day), All Children (including non-consumers): Individual Finfish and Shellfish and Fish Groups

Group	Species	N	Mean	SE	95% LCL	95% UCL	P5	Median	P75	P90	P95	Maximum
Group E												
	Manila/Littleneck clams	31	0.095	0.051	0.0	0.20	0.0	0.031	0.063	0.18	0.76	1.6
	Horse clams	31	0.022	0.013	0.0	0.048	0.0	0.0	0.006	0.048	0.27	0.35
	Butter clams	31	0.021	0.014	0.0	0.048	0.0	0.0	0.0	0.041	0.25	0.42
	Geoduck	31	0.11	0.041	0.033	0.19	0.0	0.027	0.12	0.25	0.84	1.1
	Cockles	31	0.12	0.079	0.0	0.27	0.0	0.0	0.054	0.24	1.2	2.4
	Oysters	31	0.019	0.012	0.0	0.043	0.0	0.0	0.056	0.058	0.21	0.36
	Mussels	31	0.001	0.001	0.0	0.002	0.0	0.0	0.0	0.0	0.011	0.026
	Moon snails	31	0.000	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0
	Shrimp	31	0.093	0.038	0.019	0.17	0.0	0.004	0.059	0.39	0.71	0.98
	Dungeness crab	31	0.30	0.13	0.053	0.55	0.0	0.047	0.17	1.3	2.7	2.8
	Red rock crab	31	0.007	0.003	0.001	0.014	0.0	0.0	0.0	0.046	0.064	0.082
	Scallops	31	0.011	0.006	0.0	0.022	0.0	0.0	0.005	0.031	0.089	0.17
	Squid	31	0.002	0.002	0.0	0.005	0.0	0.0	0.0	0.0	0.0	0.41
	Sea urchin	31	0.0	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0
	Sea cucumber	31	0.0	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0
Group A[a]		31	0.27	0.12	0.043	0.50	0.0	0.063	0.22	0.53	2.1	3.6
Group B[b]		31	0.004	0.002	0.0	0.008	0.0	0.0	0.0	0.015	0.038	0.069
Group C[c]		31	0.13	0.040	0.052	0.21	0.0	0.036	0.21	0.34	0.84	1.0
Group D[d]		31	0.03	0.011	0.008	0.053	0.0	0.010	0.037	0.081	0.19	0.34
Group F[e]		31	0.24	0.075	0.094	0.39	0.0	0.092	0.25	0.68	1.6	1.9
All Finfish		31	0.68	0.17	0.35	1.0	0.026	0.31	0.74	2.1	3.5	4.1
All Shellfish		31	0.80	0.27	0.26	1.3	0.0	0.29	0.80	2.3	5.0	7.9
All Seafood		31	1.5	0.35	0.80	2.2	0.042	0.72	2.0	3.3	7.3	9.1

[a] Group A is salmon, including king, sockeye, coho, chum, pink, and steelhead.
[b] Group B is finfish, including smelt and herring.
[c] Group C is finfish, including cod, perch, pollock, sturgeon, sablefish, spiny dogfish and greenling.
[d] Group D is finfish, including halibut, sole, flounder and rockfish.
[e] Group F includes tuna, other finfish, and all others not included in Groups A, B, C, and D.
N = Sample size.
SE = Standard error
LCL = Lower confidence limit
UCL = Upper confidence limit
P5...P95 = Percentile value.
Note: The minimum consumption for all species and groups was zero, except for "all finfish" and "all seafood." The minimum rate for "all finfish" was 0.023, and for "all seafood" was 0.035.

Source: Duncan, 2000.

Table 10-24. Consumption Rates for Native American Children (g/kg-day), Consumers Only: Individual Finfish and Shellfish and Fish Groups

Group	Species	N	Mean	SE	Median	Percentiles	
						75th	90th
Group E	Manila/Littleneck clams	23	0.13	0.068	0.043	0.066	0.20
	Horse clams	12	0.058	0.032	0.009	0.046	0.31
	Butter clams	6	0.11	0.066	0.032	0.20	-
	Geoduck	22	0.16	0.054	0.053	0.23	0.55
	Cockles	10	0.36	0.23	0.078	0.29	2.2
	Oysters	10	0.060	0.035	0.015	0.074	0.34
	Mussels	1	0.026	-	-	-	-
	Moon snails	0	-	-	-	-	-
	Shrimp	17	0.17	0.064	0.035	0.30	0.62
	Dungeness crab	21	0.44	0.18	0.082	0.305	2.3
	Red rock crab	5	0.046	0.011	0.051	0.067	-
	Scallops	8	0.042	0.019	0.027	0.032	-
	Squid	2	0.033	0.008	0.033	-	-
	Sea urchin	0	-	-	-	-	-
	Sea cucumber	0	-	-	-	-	-
Group A[a]		28	0.300	0.13	0.11	0.25	0.60
Group B[b]		5	0.023	0.012	0.017	0.043	-
Group C[c]		25	0.16	0.048	0.048	0.24	0.49
Group D[d]		17	0.055	0.019	0.033	0.064	0.14
Group F[e] (tuna/other finfish)		24	0.31	0.092	0.18	0.34	1.0
All finfish		31	0.68	0.17	0.31	0.74	2.1
All shellfish		28	0.89	0.30	0.36	0.85	2.5
All seafood		31	1.5	0.35	0.72	2.0	3.4

[a] Group A is salmon, including king, sockeye, coho, chum, pink, and steelhead.
[b] Group B is finfish, including smelt and herring.
[c] Group C is finfish, including cod, perch, pollock, sturgeon, sablefish, spiny dogfish and greenling.
[d] Group D is finfish, including halibut, sole, flounder and rockfish.
[e] Group F includes tuna, other finfish, and all others not included in Groups A, B, C, and D.
N = Sample size.
SE = Standard error.
\- = No data.

Source: Duncan, 2000.

Table 10-25. Fish Consumption Rates for Tulalip and Squaxin Island Children
Consumers Only (g/kg-day)

Species[a]	N	Mean	SD	Percentiles[b] 5th	10th	25th	50th	75th	90th	95th
Squaxin Island Tribe										
Anadromous fish	33	0.39	1.3	0.005	0.006	0.030	0.049	0.13	0.69	0.79
Pelagic fish	21	0.16	0.25	0.010	0.014	0.019	0.044	0.11	0.55	0.71
Bottom fish	18	0.17	0.36	-	0.006	0.014	0.026	0.050	0.48	-
Shellfish	31	2.3	8.6	0.006	0.025	0.050	0.26	0.40	0.77	4.5
Other fish	30	0.58	0.58	0.012	0.051	0.11	0.40	0.57	1.6	1.6
All finfish	35	0.54	1.3	0.005	0.007	0.046	0.062	0.22	1.7	2.3
All fish	36	2.9	8.4	0.012	0.019	0.24	0.70	1.5	2.8	7.7
Tulalip Tribe										
Anadromous fish	14	0.15	0.23	-	0.012	0.026	0.045	0.14	0.33	-
Pelagic fish	7	0.15	0.18	-	-	0.027	0.053	0.17	-	-
Bottom fish	2	0.044	0.005	-	-	-	0.041	-	-	-
Shellfish	11	0.31	0.39	-	0.012	0.034	0.036	0.52	0.80	-
Other fish	1	0.12	0.12	-	-	-	-	-	-	-
All finfish	15	0.31	0.33	-	0.027	0.082	0.133	0.43	0.73	-
All fish	15	0.45	0.53	-	0.066	0.088	0.22	0.60	0.88	-

[a] Anadromous included: salmon, steelhead,and smelt. Pelagic included: cod, pollock, sablefish, rockfish, greenling, herring, spiny dogfish, perch, mackarel, and shark. Bottom included: halibut, sole/flounder, sturgeon, skate, eel, and grunters. Shellfish included: clams, cockles, mussels, oysters, shrimp, crabs, snails, scallops, squid, sea urchins, geoduck, limpets, lobster, bullhead, manta ray, razor clam, chitons, octopus, abalone, barnacles, and crayfish. Other included canned tuna and trout,

[b] Due to the small sample size for some fish groups, some percentiles could not be computed. A percentile was only calculated if it was between 100%*1/(N+1) and 100%*N/(N+1), where N is the number of consumers of a species group.

N = Sample size.
SD = Standard deviation.
\- = No data.

Source: Polissar et al., 2006.

Table 10-26. Fish Consumption Rates by Gender for Tulalip and Squaxin Island Children Consumers Only (g/kg-day)

Species[a]	Gender	N	Mean	SD	Percentiles[b]						
					5th	10th	25th	50th	75th	90th	95th
Squaxin Island Tribe											
Anadromous fish	Male	15	0.70	1.9	-	0.009	0.026	0.062	0.33	1.1	-
	Female	18	0.16	0.25	-	0.005	0.025	0.046	0.090	0.60	-
Pelagic fish	Male	8	0.10	0.14	-	-	0.015	0.058	0.099	-	-
	Female	13	0.18	0.28	-	0.015	0.020	0.040	0.11	0.68	-
Bottom fish	Male	6	0.038	0.057	-	-	0.016	0.020	0.026	-	-
	Female	12	0.24	0.44	-	0.005	0.010	0.028	0.11	0.74	-
Shellfish	Male	13	0.28	0.24	-	0.036	0.047	0.24	0.35	0.46	-
	Female	18	3.8	11.2	-	0.008	0.050	0.23	0.49	1.3	-
Other fish	Male	13	0.84	0.66	-	0.11	0.23	0.45	1.5	1.6	-
	Female	17	0.40	0.46	-	0.013	0.096	0.31	0.49	0.61	-
All finfish	Male	15	0.79	1.9	-	0.009	0.038	0.062	0.52	1.5	-
	Female	20	0.37	0.72	0.005	0.005	0.037	0.071	0.18	1.4	2.1
All fish	Male	15	1.7	2.0	-	0.061	0.48	1.2	1.9	2.4	-
	Female	21	3.7	10.7	0.008	0.014	0.16	0.60	0.92	2.8	16.4
Tulalip Tribe											
Anadromous fish	Male	7	0.061	0.052	-	-	0.023	0.034	0.067	-	-
	Female	7	0.24	0.31	-	-	0.032	0.080	0.20	-	-
Pelagic fish	Male	5	0.11	0.081	-	-	0.044	0.053	0.13	-	-
	Female	2	0.27	0.35	-	-	-	0.017	-	-	-
Bottom fish	Male	0	-	-	-	-	-	-	-	-	-
	Female	2	0.044	0.005	-	-	-	0.041	-	-	-
Shellfish	Male	5	0.14	0.22	-	-	0.012	0.027	0.11	-	-
	Female	6	0.43	0.46	-	-	0.034	0.22	0.65	-	-
Other fish	Male	0	-	-	-	-	-	-	-	-	-
	Female	1	0.12	0.12	-	-	-	-	-	-	-
All finfish	Male	8	0.21	0.18	-	-	0.087	0.13	0.32	-	-
	Female	7	0.43	0.44	-	-	0.045	0.17	0.65	-	-
All fish	Male	8	0.20	0.17	-	-	0.071	0.12	0.23	-	-
	Female	7	0.75	0.67	-	-	0.16	0.49	0.84	-	-

[a] Anadromous included: salmon, steelhead,and smelt. Pelagic included: cod, pollock, sablefish, rockfish, greenling, herring, spiny dogfish, perch, mackarel, and shark. Bottom included: halibut, sole/flounder, sturgeon, skate, eel, and grunters. Shellfish included: clams, cockles, mussels, oysters, shrimp, crabs, snails, scallops, squid, sea urchins, geoduck, limpets, lobster, bullhead, manta ray, razor clam, chitons, octopus, abalone, barnacles, and crayfish. Other included canned tuna and trout,

[b] Due to the small sample size for some fish groups, some percentiles could not be computed. A percentile was only calculated if it was between 100%*1/(N+1) and 100%*N/(N+1), where N is the number of consumers of a species group.

N = Sample size.

SD = Standard deviation.

\- = No data.

Source: Polissar et al., 2006.

Table 10-27. Distribution of Quantity of Canned Tuna Consumed (grams) Per Eating Occasion, by Age and Sex									
Age (years)-Sex Group	Mean	SE	Percentiles						
			5th	10th	25th	50th	75th	90th	95th
2 to 5									
Male-Female	38	3	7*	8	15	29	55	73	85*
6 to 11									
Male-Female	57	8	14*	20*	26	49	59	99*	157*
12 to 19									
Male	84*	12*	-	18*	49*	74	97*	162*	-
Female	64	6	14*	18*	28*	56	77*	105*	156*

SE = Standard error.
* Indicates a statistic that is potentially unreliable because of small sample size or large coefficient of variation.
\- Indicates a percentage that could not be estimated.

Source: Smiciklas-Wright et al., 2002 (based on 1994-1996 CSFII data).

Table 10-28. Distribution of Quantity of Other Finfish Consumed (grams) Per Eating Occasion, by Age and Sex									
Age (years)-Sex Group	Mean	SE	Percentiles						
			5th	10th	25th	50th	75th	90th	95th
2 to 5									
Male-Female	64	4	8*	16	33	58	77	124	128*
6 to 11									
Male-Female	93	8	17*	31*	50	77	119	171*	232*
12 to 19									
Male	119*	11*	40*	50*	64*	89	170*	185*	249*
Female	89*	13*	20*	26*	47*	67	124*	164*	199*

SE = Standard error.
* Indicates a statistic that is potentially unreliable because of small sample size or large coefficient of variation.

Source: Smiciklas-Wright et al., 2002 (based on 1994-1996 CSFII data).

Table 10-29. Mean Percent Moisture and Total Fat Content for Selected Species			
Species	Moisture Content (%)	Total Fat Content (%)	Comments
FINFISH			
Anchovy, European	73.37	4.84	Raw
	50.30	9.71	Canned in oil, drained solids
Bass, Freshwater	75.66	3.69	Raw
	68.79	4,73	Cooked, dry heat
Bass, Striped	79.22	2.33	Raw
	73.36	2.99	Cooked, dry heat
Bluefish	70.86	4.24	Raw
	62.64	5.44	Cooked, dry heat
Burbot	79.26	0.81	Raw
	73.41	1.04	Cooked, dry heat
Butterfish	74.13	8.02	Raw
	66.83	10.28	Cooked, dry heat
Carp	76.31	5.60	Raw
	69.63	7.17	Cooked, dry heat
Catfish, Channel, Farmed	75.38	7.59	Raw
	71.58	8.02	Cooked, dry heat
Catfish, Channel, Wild	80.36	2.82	Raw
	77.67	2.85	Cooked, dry heat
Cavier, Black and Red	47.50	17.90	--
Cisco	78.93	69.80	Raw
	1.91	11.90	Smoked
Cod, Atlantic	81.22	0.67	Raw
	75.61	0.86	Canned, solids and liquids
	75.92	0.86	Cooked, dry heat
	16.14	2.37	Dried and salted
Cod, Pacific	81.28	0.63	Raw
	76.00	0.81	Cooked, dry heat
Croaker, Atlantic	78.03	3.17	Raw
	59.76	12.67	Cooked, breaded and fried
Cusk	76.35	0.69	Raw
	69,68	0.88	Cooked, dry heat
Dolphinfish	77.55	0.70	Raw
	71.22	0.90	Cooked, dry heat
Drum, Freshwater	77.33	4.93	Raw
	70.94	6.32	Cooked, dry heat
Eel	69.26	11.66	Raw
	59.31	14.95	Cooked, dry heat
Flatfish, Flounder, and Sole	79.06	1.19	Raw
	73.16	1.53	Cooked, dry heat
Grouper	79.22	1.02	Raw, mixed species
	73.36	1.30	Cooked, dry heat
Haddock	79.92	0.72	Raw
	74.25	0.93	Cooked, dry heat
	71.48	0.96	Smoked
Halibut, Atlantic and Pacific	77.92	2.29	Raw
	71.69	2.94	Cooked, dry heat
Halibut, Greenland	70.27	13.84	Raw
	61.88	17.74	Cooked, dry heat
Herring, Atlantic	72.05	9.04	Raw
	64.16	11.59	Cooked, dry heat
	59.70	12.37	Kippered
	55.22	18.00	Pickled
Herring, Pacific	71.52	13.88	Raw
	63.49	17.79	Cooked, dry heat
Ling	79.63	0.64	Raw
	73.88	0.82	Cooked, dry heat

Table 10-29. Mean Percent Moisture and Total Fat Content for Selected Species (continued)

Species	Moisture Content (%)	Total Fat Content (%)	Comments
Lingcod	81.03	1.06	Raw
	75.68	1.36	Cooked, dry heat
Mackerel, Atlantic	63.55	13.89	Raw
	53.27	17.81	Cooked, dry heat
Mackerel, Jack	69.17	6.30	Canned, drained solids
Mackerel, King	75.85	2.00	Raw
	69.04	2.56	Cooked, dry heat
Mackerel, Pacific and Jack	70.15	7.89	Raw
	61.73	10.12	Cooked, dry heat
Mackerel, Spanish	71.67	6.30	Raw
	68.46	6.32	Cooked, dry heat
Milkfish	70.85	6.73	Raw
	62.63	8.63	Cooked, dry heat
Monkfish	83.24	1.52	Raw
	78.51	1.95	Cooked, dry heat
Mullet, Striped	77.01	3.79	Raw
	70.52	4.86	Cooked, dry heat
Ocean Perch, Atlantic	78.70	1.63	Raw
	72.69	2.09	Cooked, dry heat
Perch	79.13	0.92	Raw
	73.25	1.18	Cooked, dry heat
Pike, Northern	78.92	0.69	Raw
	72.97	0.88	Cooked, dry heat
Pike, Walleye	79.31	1.22	Raw
	73.47	1.56	Cooked, dry heat
Pollock, Atlantic	78.18	0.98	Raw
	72.03	1.26	Cooked, dry heat
Pollock, Walleye	81.56	0.80	Raw
	74.06	1.12	Cooked, dry heat
Pompano, Florida	71.12	9.47	Raw
	62.97	12.14	Cooked, dry heat
Pout, Ocean	81.36	0.91	Raw
	76.10	1.17	Cooked, dry heat
Rockfish, Pacific	79.26	1.57	Raw
	73.41	2.01	Cooked, dry heat
Roe	67.73	6.42	Raw
	58.63	8.23	Cooked, dry heat
Roughy, Orange	75.67	0.70	Raw
	66.97	0.90	Cooked, dry heat
Sablefish	71.02	15.30	Raw
	62.85	19.62	Cooked, dry heat
	60.14	20.14	Smoked
Salmon, Atlantic, Farmed	68.90	10.85	Raw
	64.75	12.35	Cooked, dry heat
Salmon, Atlantic, WIld	68.50	6.34	Raw
	59.62	8.13	Cooked, dry heat
Salmon, Chinook	71.64	10.43	Raw
	65.60	13.38	Cooked, dry heat
	72.00	4.32	Smoked
Salmon, Chum	75.38	3.77	Raw
	68.44	4.83	Cooked, dry heat
	70.77	5.50	Drained solids with bone
Salmon, Coho, Farmed	70.47	7.67	Raw
	67.00	8.23	Cooked, dry heat
Salmon, Coho, Wild	72.66	5.93	Raw
	71.50	4.30	Cooked, dry heat
	65.39	7.50	Cooked, moist heat

Table 10-29. Mean Percent Moisture and Total Fat Content for Selected Species (Continued)			
Species	Moisture Content (%)	Total Fat Content (%)	Comments
Salmon, Pink	76.35	3.45	Raw
	69.68	4.42	Cooked, dry heat
	68.81	6.05	Canned, solids with bone and liquid
Salmon, Sockeye	70.24	8.56	Raw
	61.84	10.97	Cooked, dry heat
	67.51	7.31	Canned, drained solids with bone
Sardine, Atlantic	59.61	11.45	Canned in oil, drained solids with bone
Sardine, Pacific	66.65	10.46	Canned in tomato sauce, drained solids with bone
Scup	75.37	2.73	Raw
	68.42	3.50	Cooked, dry heat
Sea Bass	78.27	2.00	Raw
	72.14	2.56	Cooked, dry heat
Seatrout	78.09	3.61	Raw
	71.91	4.63	Cooked, dry heat
Shad, American	68.19	13.77	Raw
	59.22	17.65	Cooked, dry heat
Shark, mixed species	73.58	4.51	Raw
	60.09	13.82	Cooked, batter-dipped and fried
Sheepshead	77.97	2.41	Raw
	69.04	1.63	Cooked, dry heat
Smelt, Rainbow	78.77	2.42	Raw
	72.79	3.10	Cooked, dry heat
Snapper	76.87	1.34	Raw
	70.35	1.72	Cooked, dry heat
Spot	75.95	4.90	Raw
	69.17	6.28	Cooked, dry heat
Sturgeon	76.55	4.04	Raw
	69.94	5.18	Cooked, dry heat
	62.50	4.40	Smoked
Sucker, white	79.71	2.32	Raw
	73.99	2.97	Cooked, dry heat
Sunfish, Pumpkinseed	79.50	0.70	Raw
	73.72	0.90	Cooked, dry heat
Surimi	76.34	0.90	-
Swordfish	75.62	4.01	Raw
	68.75	5.14	Cooked, dry heat
Tilapia	78.08	1.70	Raw
	71.59	2.65	Cooked, dry heat
Tilefish	78.90	2.31	Raw
	70.24	4.69	Cooked, dry heat
Trout, Mixed Species	71.42	6.61	Raw
	63.36	8.47	Cooked, dry heat
Trout, Rainbow, Farmed	72.73	5.40	Raw
	67.53	7.20	Cooked, dry heat
Trout, Rainbow, Wild	71.87	3.46	Raw
	70.50	5.82	Cooked, dry heat
Tuna, Fresh, Bluefin	68.09	4.90	Raw
	59.09	6.28	Cooked, dry heat
Tuna, Fresh, Skipjack	70.58	1.01	Raw
	62.28	1.29	Cooked, dry heat
Tuna, Fresh, Yellowfin	70.99	0.95	Raw
	62.81	1.22	Cooked, dry heat
Tuna, Light	59.83	8.21	Canned in oil, drained solids
	74.51	0.82	Canned in water, drained solids
Tuna, White	64.02	8.08	Canned in oil, drained solids
	73.19	2.97	Canned in water, drained solids

Table 10-29. Mean Percent Moisture and Total Fat Content for Selected Species (Continued)

Species	Moisture Content (%)	Total Fat Content (%)	Comments
Turbot, European	76.95	2.95	Raw
	70.45	3.78	Cooked, dry heat
Whitefish, mixed species	72.77	5.86	Raw
	65.09	7.51	Cooked, dry heat
	70.83	0.93	Smoked
Whiting, mixed species	80.27	1.31	Raw
	74.71	1.69	Cooked, dry heat
Wolffish, Atlantic	79.90	2.39	Raw
	74.23	3.06	Cooked, dry heat
Yellowtail, mixed species	74.52	5.24	Raw
	67.33	6.72	Cooked, dry heat
SHELLFISH			
Abalone	74.56	0.76	Raw
	60.10	6.78	Coofed, fried
Clam	81.82	0.97	Raw
	63.64	1.95	Canned, drained solids
	97.70	0.02	Canned, liquid
	61.55	11.15	Cooked, breaded and fried
	63.64	1.95	Cooked, moist heat
Crab, Alaska King	79.57	0.60	Raw
	77.55	1.54	Cooked, moist heat
	74.66	0.46	Imitation, made from surimi
Crab, Blue	79.02	1.08	Raw
	79.16	1.23	Canned
	77.43	1.77	Cooked, moist heat
	71.00	7.52	Crab cakes
Crab, Dungeness	79.18	0.97	Raw
	73.31	1.24	Cooked, moist heat
Crab, Queen	80.58	1.18	Raw
	75.10	1.51	Cooked, moist heat
Crayfish, Farmed	84.05	0.97	Raw
	80.80	1.30	Cooked, moist heat
Crayfish, Wild	82.24	0.95	Raw
	79.37	1.20	Cooked, moist heat
Cuttlefish	80.56	0.70	Raw
	61.12	1.40	Cooked, moist heat
Lobster, Northern	76.76	0.90	Raw
	76.03	0.59	Cooked, moist heat
Lobster, Spiny	74.07	1.51	Raw
	66.76	1.94	Cooked, moist heat
Mussel, Blue	80.58	2.24	Raw
	61.15	4.48	Cooked, moist heat
Octopus	80.25	1.04	Raw
	60.50	2.08	Cooked, moist heat
Oyster, Eastern	86.20	1.55	Raw, farmed
	85.16	2.46	Raw, wild
	85.14	2.47	Canned
	64.72	12.58	Cooked, breaded and fried
	81.95	2.12	Cooked, farmed, dry heat
	83.30	1.90	Cooked, wild, dry heat
	70.32	4.91	Cooked, wild, moist heat

Table 10-29. Mean Percent Moisture and Total Fat Content for Selected Species (Continued)			
Species	Moisture Content (%)	Total Fat Content (%)	Comments
Oyster, Pacific	82.06	2.30	Raw
	64.12	4.60	Cooked, moist heat
Scallop, mixed species	78.57	0.76	Raw
	58.44	10.94	Cooked, breaded and fried
	73.10	1.40	Steamed
Shrimp	75.86	1.73	Raw
	75.85	1.36	Canned
	52.86	12.28	Cooked, breaded and fried
	77.28	1.08	Cooked, moist heat
Squid	78.55	1.38	Raw
	64.54	7.48	Cooked, fried
Source: USDA, 2007.			

11 INTAKE OF MEATS, DAIRY PRODUCTS AND FATS

11.1 INTRODUCTION

The American food supply is generally considered to be one of the safest in the world. Nevertheless, meats, dairy products, and fats may become contaminated with toxic chemicals by several pathways. These foods sources can become contaminated if animals are exposed to contaminated media (i.e., soil, water, or feed crops). To assess exposure through this pathway, information on meat, dairy, and fat ingestion rates are needed.

Children's exposure from contaminated meats, dairy products, and fats may differ from that of adults because of differences in the type and amounts of food eaten. Also, for many foods, the intake per unit body weight is greater for children than for adults. Common meats, dairy products, and fats eaten by children include non-fat milk solids, milk fat and solids, lean beef, and milk sugar (lactose) (Goldman, 1995).

A variety of terms may be used to define intake of meats, dairy products, and fats (e.g., consumer-only intake, per capita intake, total meat, dairy product, or fat intake, as-consumed intake, dry weight intake). As described in Chapter 9, Intake of Fruits and Vegetables, consumer-only intake is defined as the quantity of meats, dairy products, or fats consumed by children during the survey period averaged across only the children who consumed these food items during the survey period. Per capita intake rates are generated by averaging consumer-only intakes over the entire population of children. In general, per capita intake rates are appropriate for use in exposure assessment for which average dose estimates for children are of interest because they represent both children who ate the foods during the survey period and children who may eat the food items at some time, but did not consume them during the survey period. Per capita intake, therefore, represents an average across the entire population of interest, but does so at the expense of underestimating consumption for the subset of the population that consume the food in question. Total intake refers to the sum of all meats, diary products, or fats consumed in a day.

Intake rates may be expressed on the basis of the as-consumed weight (e.g., cooked or prepared) or on the uncooked or unprepared weight. As-consumed intake rates are based on the weight of the food in the form that it is consumed and should be used in assessments where the basis for the contaminant concentrations in foods is also indexed to the as-consumed weight. The food ingestion values provided in this chapter are expressed as as-consumed intake rates because this is the fashion in which data were reported by survey respondents. This is of importance because concentration data to be used in the dose equation are often measured in uncooked food samples. It should be recognized that cooking can either increase or decrease food weight. Similarly, cooking can increase the mass of contaminant in food (due to formation reactions, or absorption from cooking oils or water) or decrease the mass of contaminant in food (due to vaporization, fat loss or leaching). The combined effects of changes in weight and changes in contaminant mass can result in either an increase or decrease in contaminant concentration in cooked food. Therefore, if the as-consumed ingestion rate and the uncooked concentration are used in the dose equation, dose may be under-estimated or over-estimated. Ideally, after-cooking food concentrations should be combined with the as-consumed intake rates. In the absence of data, it is reasonable to assume that no change in contaminant concentration occurs after cooking. It is important for the assessor to be aware of these issues and choose intake rate data that best match the concentration data that are being used. For more information on cooking losses and conversions necessary to account for such losses, the reader is referred to Chapter 13 of this handbook.

Sometimes contaminant concentrations in food are reported on a dry weight basis. When these data are used in an exposure assessment, it is recommended that dry-weight intake rates also be used. Dry-weight food concentrations and intake rates are based on the weight of the food consumed after the moisture content has been removed. Similarly, when contaminant concentrations in food are reported on a lipid weight basis, lipid weight intake rates should be used. For information on converting the intake rates presented in this chapter to dry weight or lipid weight intake rates, the reader is referred to Sections 11.5 and 11.6 of this chapter.

The purpose of this chapter is to provide intake data for meats, diary products, and fats among children. The recommendations for ingestion rates of meats, dairy products, and fats are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on the key studies identified by U.S. EPA for this factor. Following the recommendations, the key studies on ingestion of meats, dairy products, and fats are summarized. Relevant data on ingestion of meats, dairy products, and fats are also provided. These studies are presented to provide the reader with added perspective on the current state-of-knowledge pertaining to ingestion of meats, dairy products, and fats among children.

11.2 RECOMMENDATIONS

Table 11-1 presents a summary of the recommended values for per capita and consumers-only intake of meats, diary products, and fats, on an as-consumed basis. Confidence ratings for the meats, dairy products, and fat intake recommendations for general population children are provided in Table 11-2.

U.S. EPA analyses of data from the 1994-96 and 1998 Continuing Survey of Food Intake among Individuals (CSFII) were used in selecting recommended intake rates for general population children. The U.S. EPA analysis of meat and dairy products was conducted using age groups that differed slightly from U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). However, for the purposes of the recommendations presented here, data were placed in the standardized age categories closest to those used in the analysis. The U.S. EPA analysis of fat intake data from the CSFII used the age groups recommended by U.S. EPA (2005). The CSFII data on which the recommendations for meats, dairy products, and fats are based are short-term survey data and may not necessarily reflect the long-term distribution of average daily intake rates. However, for these broad categories of food (i.e., total meats and diary products), because they are eaten on a daily basis throughout the year with minimal seasonality, the short term distribution may be a reasonable approximation of the long-term distribution, although it will display somewhat increased variability. This implies that the upper percentiles shown here will tend to overestimate the corresponding percentiles of the true long-term distribution. It should be noted that because these recommendations are based on 1994-96 and 1998 CSFII data, they may not reflect the most recent changes that may have occurred in consumption patterns.

Table 11-1. Recommended Values for Intake of Meats, Dairy Products, and Fats, As Consumed

Age Group	Per Capita Mean	Per Capita 95th Percentile	Consumers Only Mean	Consumers Only 95th Percentile	Multiple Percentiles	Source
	g/kg-day	g/kg-day	g/kg-day	g/kg-day		
Total Meats[a]						
Birth to 1 year	1.2	6.7	3.0	9.2	See Tables 11-3 and 11-4	U.S. EPA Analysis of CSFII, 1994-96 and 1998.
1 to <2 years	4.1	9.8	4.2	9.8		
2 to <3 years	4.1	9.8	4.2	9.8		
3 to <6 years	4.1	9.4	4.2	9.4		
6 to <11 years	2.9	6.5	2.9	6.5		
11 to <16 years	2.1	4.8	2.1	4.8		
16 to <21 years	2.1	4.8	2.1	4.8		
Total Dairy Products[a]						
Birth to 1 year	13	49	16	58	See Tables 11-3 and 11-4	U.S. EPA Analysis of CSFII, 1994-96 and 1998.
1 to <2 years	37	88	37	88		
2 to <3 years	37	88	37	88		
3 to <6 years	23	49	23	49		
6 to <11 years	14	32	14	32		
11 to <16 years	5.6	16	5.6	16		
16 to <21 years	5.6	16	5.6	16		
Individual Meat and Dairy Products - See Tables 11-5 and 11-6						
Total Fats						
Birth to <1 month	5.2	16	7.8	16	See Tables 11-20 and 11-24	U.S. EPA Analysis of CSFII, 1994-96 and 1998.
1 to <3 months	4.5	11	6.0	12		
3 to <6 months	4.1	8.2	4.4	8.3		
6 to <12 months	3.7	7.0	3.7	7.0		
1 to <2 years	4.0	7.1	4.0	7.1		
2 to <3 years	3.6	6.4	3.6	6.4		
3 to <6 years	3.4	5.8	3.4	5.8		
6 to <11 years	2.6	4.2	2.6	4.2		
11 to <16 years	1.6	3.0	1.6	3.0		
16 to <21 years	1.3	2.7	1.3	2.7		

[a] Analysis was conducted using slightly different age groups than those recommended in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005). Data were placed in the standardized age categories closest to those used in the analysis.

Table 11-2. Confidence in Recommendations for Intake of Meats, Diary Products, and Fats

General Assessment Factors	Rationale	Rating
Soundness		High
Adequacy of Approach	The survey methodology and data analysis was adequate. The survey sampled approximately 11,000 children. An analysis of primary data was conducted.	
Minimal (or Defined) Bias	No physical measurements were taken. The method relied on recent recall of meats and diary products eaten.	
Applicability and Utility		Medium
Exposure Factor of Interest	The key studies were directly relevant to meat, dairy, and fat intake.	
Representativeness	The data were demographically representative of the U.S. population (based on stratified random sample).	
Currency	Data were collected between 1994 and 1998.	
Data Collection Period	Data were collected for two non-consecutive days.	
Clarity and Completeness		High
Accessibility	The CSFII data are publicly available.	
Reproducibility	The methodology used was clearly described; enough information was included to reproduce the results.	
Quality Assurance	Quality assurance of the CSFII data was good; quality control of the secondary data analysis was not well described.	
Variability and Uncertainty		Medium
Variability in Population	Full distributions were provided for total meats, total diary products, and total fats. Means were provided for individual meats and diary products.	
Uncertainty	Data collection was based on recall of consumption for a 2-day period; the accuracy of using these data to estimate long-term intake (especially at the upper percentiles) is uncertain. However, use of short-term data to estimate chronic ingestion can be assumed for broad categories of foods such as total meats, total diary products, and total fats. Uncertainty is likely to be greater for individual meats and diary products.	

Table 11-2. Confidence in Recommendations for Intake of Meats, Diary Products, and Fats (continued)		
General Assessment Factors	Rationale	Rating
Evaluation and Review		Medium
Peer Review	The USDA CSFII survey received a high level of peer review. The U.S. EPA analysis of these data has not been peer reviewed outside the Agency.	
Number and Agreement of Studies	There was 1 key study for intake of meat and diary products and 1 key study for fat intake. Both were based on the 1994-96, 1998 CSFII.	
Overall Rating		**High** confidence in the averages; **Low** confidence in the long-term upper percentiles

11.3 INTAKE STUDIES

The primary source of recent information on consumption rates of meat and diary products among children is the U.S. Department of Agriculture's (USDA) CSFII. Data from the 1994-96 CSFII and the 1998 Children's supplement to the 1994-96 CSFII have been used in various studies to generate children's consumer-only and per capita intake rates for both individual meats and diary products and total meats and diary products. The CSFII is a series of surveys designed to measure the kinds and amounts of foods eaten by Americans. The CSFII 1994-96 was conducted between January 1994 and January 1997 with a target population of non-institutionalized individuals in all 50 states and Washington, D.C. In each of the 3 survey years, data were collected for a nationally representative sample of individuals of all ages. The CSFII 1998 was conducted between December 1997 and December 1998 and surveyed children 9 years of age and younger. It used the same sample design as the CSFII 1994-96 and was intended to be merged with CSFII 1994-96 to increase the sample size for children. The merged surveys are designated as CSFII 1994-96, 1998. Additional information on these surveys can be obtained at http://www.ars.usda.gov/Services/docs.htm?docid=14531.

The CSFII 1994-96, 1998 collected dietary intake data through in-person interviews on 2 non-consecutive days. The data were based on 24-hour recall. A total of 21,662 individuals provided data for the first day; of those individuals, 20,607 provided data for a second day. Over 11,000 of the sample persons represented children up to 18 years of age. The 2-day response rate for the 1994-1996 CSFII was approximately 76 percent. The 2-day response rate for CSFII 1998 was 82 percent.

The CSFII 1994-96, 98 surveys were based on a complex multistage area probability sample design. The sampling frame was organized using 1990 U.S. population census estimates, and the stratification plan took into account geographic location, degree of urbanization, and socioeconomic characteristics. Several sets of sampling weights are available for use with the intake data. By using appropriate weights data for all fours years of the surveys can be combined. USDA recommends that all 4 years be combined in order to provide an adequate sample size for children.

11.3.1 Key Meat and Diary Intake Study

11.3.1.1 *U.S. EPA Analysis of CSFII 1994-96, 1998*

For many years, the U.S. EPA's Office of Pesticide Programs (OPP) has used food consumption data collected by the U.S. Department of Agriculture (USDA) for its dietary risk assessments. Most recently, OPP, in cooperation with USDA's Agricultural Research Service (ARS), used data from the 1994-96, 1998 CSFII to develop the Food Commodity Intake Database (FCID). CSFII data on the foods people reported eating were converted to the quantities of agricultural commodities eaten. "Agricultural commodity" is a term used by U.S. EPA to mean animal (or plant) parts consumed by humans as food; when such items are raw or unprocessed, they are referred to as "raw agricultural commodities." For example, a beef stew may contain the commodities beef, carrots, and potatoes. FCID contains approximately 553 unique commodity names and 8-digit codes. The FCID commodity names and codes were selected and defined by U.S. EPA and were based on the U.S. EPA Food Commodity Vocabulary (http://www.epa.gov/pesticides/foodfeed/).

The meats and dairy items/groups selected for the U.S. EPA analysis included total meats and total dairy products, and individual meats and dairy such as beef, pork, poultry, and eggs. Appendix 11A presents the food codes and definitions used to determine the various meats and dairy products used in the analysis. Intake rates for these food items/groups represent intake of all forms of the product (e.g., both home produced and commercially produced). Children who provided data for two days of the survey were included in the intake estimates. Individuals who did not provide information on body weight or for whom identifying information was unavailable were excluded from the analysis. Two-day average intake rates were calculated for all individuals in the database for each of the food items/groups. These average daily intake rates were divided by each individual's reported body weight to generate intake rates in units of grams per kilogram of body weight per day (g/kg-day). The data were weighted according to the four-year, two-day sample weights provided in the 1994-96, 1998 CSFII to adjust the data for the sample population to reflect the national population.

Summary statistics were generated on both a per capita and a consumer only basis. For per capita intake, both users and non-users of the food item were included in the analysis. Consumer only intake rates were calculated using data for only those individuals who ate the food item of interest during the survey period. Intake data from the CSFII are based on as-consumed (i.e., cooked or prepared) forms of the food items/groups. Summary statistics, including: number of observations, percentage of the population consuming the meat or dairy products being analyzed, mean intake rate, and standard error of the mean intake rate were calculated for total meats, total dairy products, and selected individual meats and dairy products. Percentiles of the intake rate distribution (i.e., 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, 99th, and 100th percentile were also provided for total meats and dairy products. Data were provided for the following age groups of children: birth to <1 year, 1 to <2 years, 3 to <5 years, 6 to <12 years, and 13 to <19 years. Because these data were developed for use in U.S. EPA's pesticide registration program, the age groups used are slightly different than those recommended in U.S. EPA's Guid*ance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005).

Table 11-3 presents as-consumed per capita intake data for total meats and dairy products in g/kg-day; as-consumed consumer-only intake data for total meats and dairy products in g/kg-day are provided in Table 11-4. Table 11-5 provides per capita intake data for certain individual meats and dairy products and Table 11-6 provides consumer only intake data for these individual meats and dairy products.

It should be noted that the distribution of average daily intake rates generated using short-term data (e.g., 2-day) do not necessarily reflect the long-term distribution of average daily intake rates. The distributions generated from short-term and long-term data will differ to the extent that each individual's intake varies from day to day; the distributions will be similar to the extent that individuals' intakes are constant from day to day. However, for broad categories of foods (e.g., total meats and dairy products) that are eaten on a daily basis throughout the year, the short-term distribution may be a reasonable approximation of the true long-term distribution, although it will show somewhat more variability. In this chapter, distributions are provided only for broad categories of meats and dairy products (i.e., total meats and dairy products). Because of the increased variability of the short-term distribution, the short-term upper percentiles shown here may overestimate the corresponding percentiles of the long-term distribution. For individual foods, only the mean, standard error, and percent consuming are provided.

The strengths of U.S. EPA's analysis are that it provides distributions of intake rates for various age groups of children, normalized by body weight. The analysis uses the 1994-96, 1998 CSFII data set which was designed to be representative of the U.S. population. The data set includes four years of intake data combined, and is based on a two-day survey period. As discussed above, short-term dietary data may not accurately reflect long-term eating patterns and may under-represent infrequent consumers of a given food. This is particularly true for the tails (extremes) of the distribution of food intake. Also, the analysis was conducted using slightly different age groups that those recommended in U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). However, given the similarities in the age groups used, the data should provide suitable intake estimates for the age groups of interest**.**

11.3.2 Relevant Meat and Dairy Intake Studies

11.3.2.1 *USDA, 1999a - Food and Nutrient Intakes by Children 1994-96, 1998, Table Set 17*

USDA (1999a) calculated national probability estimates of food and nutrient intake by children based on all 4 years of the CSFII (1994-96 and 1998) for children age 9 years and under and on CSFII 1994-96 only for individuals age 10 years and over. Sample weights were used to adjust for non-response, to match the sample to the U.S. population in terms of demographic characteristics, and to equalize intakes over the 4 quarters of the year and the 7 days of the week. A total of 503 breast-fed children were excluded from the estimates, but both consumers and non-consumers were included in the analysis.

USDA (1999a) provided data on the mean per capita quantities (grams) of various food products/groups consumed per individual for one day, and the percent of individuals consuming those foods in one day of the survey. Tables 11-7 and 11-8 present data on the mean quantities (grams) of meat and eggs consumed per individual for one day, and the percentage of survey individuals consuming meats and eggs on that survey day. Tables 11-9 and 11-10 present similar data for dairy products. Data on mean intakes or mean percentages are based on respondents' day-1 intakes.

The advantage of the USDA (1999a) study is that it uses the 1994-96, 98 CSFII data set, which includes four years of intake data, combined, and includes the supplemental data on children. These data are expected to be generally representative of the U.S. population and they include data on a wide variety of meats and dairy products. The data set is one of a series of USDA data sets that are publicly available. One limitation of this data set is that it is based on one day, and short-term dietary data may not accurately reflect long-term eating patterns. Other limitations of this study are that it only provides mean values of food intake rates, consumption is not normalized by body weight, and presentation of results is not consistent with U.S. EPA's recommended age groups.

11.3.2.2 *Smiciklas-Wright et al., 2002 - Foods Commonly Eaten in the United States: Quantities Consumed per Eating Occasion and in a Day, 1994-1996*

Using data gathered in the 1994-96 USDA CSFII, Smiciklas-Wright et al. (2002) calculated distributions for the quantities of meat, poultry, and dairy products consumed per eating occasion by members of the U.S. population (i.e., serving sizes). The estimates of serving size are based on data obtained from 14,262 respondents, ages 2 and above, who provided 2 days of dietary intake information. A total of 4,939 of these respondents were children, ages 2 to 19 years of age. Only dietary intake data from users of the specified food were used in the analysis (i.e., consumers only data).

Table 11-11 presents serving size data for meats and dairy products. These data are presented on an as-consumed basis (grams) and represent the quantity of meats and dairy products consumed per eating occasion. These estimates may be useful for assessing acute exposures to contaminants in specific foods, or other assessments where the amount consumed per eating occasion is necessary. Only the mean and standard deviation serving size data and percent of the population consuming the food during the 2-day survey period are presented in this handbook. Percentiles of serving sizes of the foods consumed by these age groups of the U.S. population can be found in Smiciklas-Wright et al. (2002).

The advantages of using these data are that they were derived from the USDA CSFII and are representative of the U.S. population. The analysis conducted by Smiciklas-Wright et al. (2002) accounted for individual foods consumed as ingredients of mixed foods. Mixed foods were disaggregated via recipe files so that the individual ingredients could be grouped together with similar foods that were reported separately. Thus, weights of foods consumed as ingredients were combined with weights of foods reported separately to provide a more thorough representation of consumption. However, it should be noted that since the recipes for the mixed foods consumed were not provided by the respondents, standard recipes were used. As a result, the estimates of quantity consumed for some food types are based on assumptions about the types and quantities of ingredients consumed as part of mixed foods. This study used data from the 1994 to 1996 CSFII; data from the 1998 children's supplement were not included.

11.3.2.3 *Fox et al., 2004 - Feeding Infants and Toddlers Study: What Foods Are Infants and Toddlers Eating*

Fox et al. (2004) used data from the Feeding Infants and Toddlers study (FITS) to assess food consumption patterns in infants and toddlers. The FITS was sponsored by Gerber Products Company and was conducted to obtain current information on food and nutrient intakes of children, ages 4 to 24 months old, in the 50 states and the District of Columbia. The FITS is described in detail in Devaney et al. (2004). FITS was based on a random sample of 3,022 infants and toddlers for which dietary intake data were collected by telephone from their parents or caregivers between March and July 2002. An initial recruitment and household interview was conducted, followed by an interview to obtain information on intake based on 24-hour recall. The interview also addressed growth, development and feeding patterns. A second dietary recall interview was conducted for a subset of 703 randomly selected respondents. The study over-sampled children in the 4 to 6 and 9 to 11 months age groups; sample weights were adjusted for non-response, over-sampling, and under-coverage of some subgroups. The response rate for the FITS was 73 percent for the recruitment interview. Of the recruited households, there was a response rate of 94 percent for the dietary recall interviews (Devaney et al., 2004). The characteristics of the FITS study population is shown in Table 11-12.

Fox et al. (2004) analyzed the first set of 24-hour recall data collected from all study participants. For this analysis, children were grouped into six age categories: 4 to 6 months, 7 to 8 months, 9 to 11 months, 12 to 14 months, 15 to 18 months, and 19 to 24 months. Table 11-13 provides the percentage of infants and toddlers consuming milk, meats or other protein sources at least once in a day. The percentage of children consuming any type of meat or protein source ranged from 14.2 percent for 4 to 6 month olds to 97.2 percent for 19 to 24 month olds (Table 11-13).

The advantages of this study were that the study population represented the U.S. population and the sample size was large. One limitation of the analysis done by Fox et al. (2004) was that only frequency data were provided; no information on actual intake rates was included. In addition, Devaney et al. (2004) noted several limitations associated with the FITS data. For the FITS, a commercial list of infants and toddlers was used to obtain the sample used in the study. Since many of the households could not be located and did not have children in the target population, a lower response rate than would have occurred in a true national sample was obtained (Devaney et al., 2004). In addition, the sample was likely from a higher socioeconomic status when compared with all U.S. infants in this age group (4 to 24 months old) and the use of a telephone survey may have omitted lower-income households without telephones (Devaney et al., 2004).

11.3.2.4 *Ponza et al., 2004 - Nutrient Food Intakes and Food Choices of Infants and Toddlers Participating in WIC*

Ponza et al. (2004) conducted a study using selected data from FITS to assess feeding patterns, food choices and nutrient intake of infants and toddlers participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). Ponza et al. (2004) evaluated FITS data for the following age groups: 4 to 6 months (N = 862), 7 to 11 months(N = 1159) and 12 to 24 months (N= 996). The total sample size described by WIC participant and non-participant is shown in Table 11-14.

The foods consumed were analyzed by tabulating the percentage of infants who consumed specific foods/food groups per day (Ponza et al., 2004). Weighted data were used in all of the analyses used in the study (Ponza et al., 2004). Table 11-14 presents the demographic data for WIC participants and non-participants. Table 11-15 provides the food choices for infants and toddlers. In general, there was little difference in food choices among WIC participants and non-participants, except for consumption of yogurt by infants 7 to 11 months of age and toddlers 12 to 24 months of age (Table 11-15). Non-participants, 7 to 24 months of age, were more likely to eat yogurt than WIC participants (Ponza et al., 2004).

An advantage of this study is that it had a relatively the large sample size and was representative of the U.S. general population of infants and children. A limitation of the study is that intake values for foods were not provided. Other limitations are one associated with the FITS data and are described previously in Section 11.3.2.3.

11.3.2.5 *Mennella et al., 2006 - Feeding Infants and Toddlers Study: The Types of Foods Fed to Hispanic Infants and Toddlers*

Mennella et al. (2006) investigated the types of food and beverages consumed by Hispanic infants and toddlers in comparison to the non-Hispanic infants and toddlers in the United States. The FITS 2002 data for children between 4 and 24 months old were used for the study. The data represent a random sample of 371 Hispanic and 2,367 non-Hispanic infants and toddlers (Menella et al., 2006). Menella et al. (2006) grouped the infants as follows: 4 to 5 months (N = 84 Hispanic; 538 non-Hispanic), 6 to 11 months (N = 163 Hispanic and 1,228 non-Hispanic), and 12 to 24 months (N = 124 Hispanic and 871 non-Hispanic) of age.

Table 11-16 provides the percentages of Hispanic and non-Hispanic infants and toddlers consuming milk, meats or other protein sources on a given day. In most instances the percentages consuming the different types of meats and protein sources were similar (Mennella et al., 2006).

The advantage of the study is that it provides information on food preferences for Hispanic and non-Hispanic infants and toddlers. A limitation is that the study did not provide food intake data, but provided frequency of use data instead. Other limitations are those noted previously in Section 11.3.2.3 for the FITS data.

11.3.2.6 *Fox et al., 2006 - Average Portion of Foods Commonly Eaten by Infants and Toddlers in the United States*

Fox et al. (2006) estimated average portion sizes consumed per eating occasion by children 4 to 24 months of age who participated in the FITS. The FITS is a cross-sectional study designed to collect and analyze data on feeding practices, food consumption, and usual nutrient intake of U.S. infants and toddlers and is described in Section 11.3.2.3 of this chapter. It included a stratified random sample of 3,022 children between 4 and 24 months of age.

Using the 24-hour recall data, Fox et al. (2006) derived average portion sizes for six major food groups, including meats and other protein sources. Average portion sizes for select individual foods within these major groups were also estimated. For this analysis, children were grouped into six age categories: 4 to 5 months, 6 to 8 months, 9 to 11 months, 12 to 14 months, 15 to 18 months, and 19 to 24 months. Tables 11-17 and 11-18 present the average portion sizes of meats and dairy products for infants and toddlers, respectively.

11.4 FAT INTAKE

11.4.1 Key Fat Intake Study

11.4.1.1 *U.S. EPA, 2007 - Analysis of Fat Intake Based on the U.S. Department of Agriculture's 1994–96, 1998 Continuing Survey of Food Intakes by Individuals (CSFII)*

U.S. EPA conducted an analysis to evaluate the dietary intake of fats by individuals in the United States using data from the USDA's 1994–1996, 1998 CSFII (USDA, 2000). Intakes of CSFII foods were converted to U.S. EPA food commodity codes using data provided in U.S. EPA's FCID (U.S. EPA, 2000). The FCID contains a "translation file" that was used to break down the USDA CSFII food codes into 548 U.S. EPA commodity codes. The method used to translate USDA food codes into U.S. EPA commodity codes is discussed in detail in U.S. EPA (2000).

Each of the 548 U.S. EPA commodity codes was assigned a value between 0 and 1 that indicated the mass fraction of fat in that food item. For many sources of fat, a commodity code existed solely for the nutrient fat portion of the food. For example, beef is represented in the FCID database by ten different commodity codes; several of these codes specifically exclude fat, and one code is described as "nutrient fat only." In these cases, the fat fraction could be expressed as 0 or 1, as appropriate. Most animal food products and food oils were broken down in this way. The fat contents of other foods in the U.S. EPA commodity code list were determined using the USDA Nutrient Database for Standard Reference, Release 13 (USDA, 1999b). For each food item in the U.S. EPA code list, the best available match in the USDA Nutrient database was used. If multiple values were available for different varieties of the same food item (e.g., green, white and red grapes), a mean value was calculated. If multiple values were available for different cooking methods (i.e, fried vs. dry cooked), the method least likely to introduce other substances, such as oil or butter, was preferred. In some cases, not all of the items that fall under a given food commodity code could be assigned a fat content. For example, the food commodity code list identified "turkey, meat byproducts" as including gizzard, heart, neck and tail. Fat contents could be determined only for the gizzard and heart. Because the relative amounts of the different items in the food commodity code was unknown, the mean fat content of these two items was assumed to be the best approximation of the fat content for the food code as a whole.

The analysis was based on approximately 11,000 CSFII child respondents who had provided body weights and who had completed both days of the two-day survey process. These individuals were grouped according to various age categories. The mean, standard error, and a range of percentiles of fat intake were calculated for 12 food categories (i.e., all fats, animal fats, meat and meat products, beef, pork, poultry, organ meats, milk and dairy products, fish, oils, and nuts/seeds/beans/legumes/tubers) and 98 demographic cohorts. Fat intake was calculated as a two-day average consumption across both survey days in units of grams per day and grams per kilogram of body weight per day for the whole survey population and for consumers only. A secondary objective of the study was to evaluate fat consumption patterns of individuals who consume high levels of animal fats. The entire data analysis was repeated for a subset of individuals who were identified as high consumers of animal fats. The selection of the high-consumption group was done for each age category individually, rather than on the whole population, because fat intake on a per-body-weight basis is heavily skewed towards young children, and an analysis across the entire American population was desired. For infants, the "less than one year old" group was used instead of the smaller infant groups (<1 month, 1 to <3 months, etc.). Within each of the age categories, individuals that ranked at or above the 90^{th} percentile of consumption of all animal fats on a per-unit body weight basis were identified. Because of the sample weighting factors, the high consumer group was not necessarily 10 percent of each age group. The selected individuals made up a survey population of 1,175 children. Fat intake of individuals in this group was calculated in g/day and g/kg-day for the whole population (i.e., per capita) and for consumers only.

The analysis presented in U.S. EPA (2007) was conducted before U.S. EPA published the guidance entitled *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). Therefore, the age groups used for children in U.S. EPA (2007) were not entirely consistent with the age groups recommended in the 2005 guidance. A re-analysis of the some of the data was conducted for this chapter to conform with U.S. EPA's recommended age groups for children. The results of this re-analysis are presented in Tables 11-19 through 11-26 for individuals less than 21 years of age. Only intake rates of all fats are provided in these tables; the reader is referred to U.S. EPA (2007) for fat intake rates from individual food sources. Tables 11-19 and 11-20 present intake rates of all fats for the whole population (i.e., per capita) in g/day and g/kg-day, respectively. Table 11-21 and 11-22 present intake rates of all fats for consumers only in g/day and g/kg-day, respectively. Fat intake rates of all fats for the top decile of animal fat consumers from the consumers only group are presented in Table 11-23 in g/day and in Table 11-24 in g/kg-day (per capita total fat intake rates for the top decile of animal fat consumers are not provided because they are the same as those for consumers only).

11.4.2 Relevant Fat Intake Studies

11.4.2.1 *Cresanta et al., 1988; Nicklas et al., 1993; and Frank et al., 1986 - Bogalusa Heart Study*

Cresanta et al. (1988), Nicklas et al. (1993), and Frank et al. (1986) analyzed dietary fat intake data as part of the Bogalusa heart study. The Bogalusa study, an epidemiologic investigation of cardiovascular risk-factor variables and environmental determinants, collected dietary data on subjects residing in Bogalusa, LA, beginning in 1973. Among other research, the study collected fat intake data for children, adolescents, and young adults. Researchers examined various cohorts of subjects, including (1) six cohorts of 10-year olds, (2) two cohorts of 13-year olds, (3) one cohort of subjects from 6 months to 4 years of age, and (4) one cohort of subjects from 10 to 17 years of age (Nicklas, 1995). To collect the data, interviewers used the 24-hour dietary recall method. According to Nicklas (1995), "the diets of children in the Bogalusa study are similar to those reported in national studies of children." Thus, these data are useful in evaluating the variability of fat intake among the general population. Data for 6-month old to 17-year old individuals collected during 1973 to 1982 are presented in Tables 11-25 and 11-26 (Frank et al., 1986). Data are presented for total fats, animal fats, vegetable fats, and fish fats in units of g/day (Table 11-25) and g/kg/day (Table 11-26).

11.4.2.2 *CDC, 1994 - Dietary Fat and Total Food-energy Intake: Third National Health and Nutrition Examination Survey, Phase 1, 1988-91*

The Centers for Disease Control and Prevention (CDC, 1994) used data from NHANES III to calculate daily total food energy intake (TFEI), total dietary fat intake, and saturated fat intake for the U.S. population during 1988 to 1991. The sample population comprised 20,277 individuals ages 2 months and above, of which 14,801 respondents (73 percent response rate) provided dietary information based on a 24-hour recall. Of these, 6,870 were children between the ages of 2 months and 19 years. TFEI was defined as "all nutrients (i.e., protein, fat, carbohydrate, and alcohol) derived from consumption of foods and beverages (excluding plain drinking water) measured in kilocalories (kcal)." Total dietary fat intake was defined as "all fat (i.e., saturated and unsaturated) derived from consumption of foods and beverages measured in grams" (CDC, 1994).

The authors estimated and provided data on the mean daily TFEI and the mean percentages of TFEI from total dietary fat grouped by age and gender. The overall mean daily TFEI for the total population was 2,095 kcal, of which 34 percent (712 kcal or 82 g) was from total dietary fat. Based on this information, the mean daily fat intake was calculated for the various age groups and genders (see Appendix 11B for detailed calculation). Table 11-27 presents the grams of fat per day obtained from the daily consumption of foods and beverages grouped by age and gender for the U.S. population, based on this calculation.

11.5 CONVERSION BETWEEN WET AND DRY WEIGHT INTAKE RATES

The intake rates presented in this chapter are reported in units of wet weight (i.e., as-consumed or uncooked weight of meats and dairy products consumed per day or per eating occasion). However, data on the concentration of contaminants in meats and dairy products may be reported in units of either wet or dry weight (e.g., mg contaminant per gram-dry-weight of meats and dairy products.). It is essential that exposure assessors be aware of this difference so that they may ensure consistency between the units used for intake rates and those used for concentration data (i.e., if the contaminant concentration is measured in dry weight of meats and dairy products, then the dry weight units should be used for their intake values).

If necessary, wet weight (e.g., as consumed) intake rates may be converted to dry weight intake rates using the moisture content percentages presented in Table 11-28 and the following equation:

$$IR_{dw} = IR_{ww}\left[\frac{100-W}{100}\right] \qquad \text{(Eqn. 11-1)}$$

where:

IR_{dw}= dry weight intake rate;
IR_{ww}= wet weight intake rate; and
W = percent water content

Alternatively, dry weight residue levels in meat and dairy products may be converted to wet weight residue levels for use with wet weight (e.g., as-consumed) intake rates as follows:

$$C_{ww} = C_{dw}\left[\frac{100-W}{100}\right] \qquad \text{(Eqn. 11-2)}$$

where:

C_{ww} = wet weight intake rate;
C_{dw} = dry weight intake rate; and
W = percent water content.

The moisture content data presented in Table 11-28 are for selected meats and dairy products taken from USDA (2007).

11.6 CONVERSION BETWEEN WET WEIGHT AND LIPID WEIGHT INTAKE RATES

In some cases, the residue levels of contaminants in meat and dairy products may be reported as the concentration of contaminant per gram of fat. This may be particularly true for lipophilic compounds. When using these residue levels, the assessor should ensure consistency in the exposure assessment calculations by using consumption rates that are based on the amount of lipids consumed for the meat or dairy product of interest.

If necessary, wet weight (e.g., as-consumed) intake rates may be converted to lipid weight intake rates using the fat content percentages presented in Table 11-28 and the following equation:

$$IR_{lw} = IR_{ww}\left[\frac{L}{100}\right] \qquad \text{(Eqn. 11-3)}$$

where:

IR_{lw}= lipid weight intake rate;
$_{Irww}$ = wet weight intake rate; and
L = percent lipid (fat) content.

Alternately, wet weight residue levels in meat and dairy products may be estimated by multiplying the levels based on fat by the fraction of fat per product as follows:

$$C_{ww} = C_{lw}\left[\frac{L}{100}\right] \qquad \text{(Eqn. 11-4)}$$

where:

C_{ww}= wet weight intake rate;
C_{lw} = lipid weight intake rate; and
L = percent lipid (fat) content.

The resulting residue levels may then be used in conjunction with wet weight (e.g., as-consumed) consumption rates. The total fat content data presented in Table 11-28 are for selected meat and dairy products taken from USDA, 2007.

11.7 REFERENCES FOR CHAPTER 11

CDC. (1994) Dietary fat and total food-energy intake: Third National Health and Nutrition Examination Survey, Phase 1, 1988-91. Center for Disease Control. Morbidity and Mortality Weekly Report, February 25, 1994: 43(7)118-125.

Cresanta, J.L.; Farris, R.P.; Croft, J.B.; Frank, G.C.; Berenson, G.S. (1988) Trends in fatty acid intakes of 10-year-old children, 1973-1982. J Am Diet Assoc 88: 178-184.

Devaney, B.; Kalb, L.; Briefel, R.; Zavitsky-Novak, T.; Clusen, N.; Ziegler, P. (2004) Feeding Infants and Toddlers Study: overview of the study design. J Am Diet Assoc 104(Suppl 1): S8-S13.

Fox, M.K.; Pac, S.; Devaney, B.; Jankowski, L. (2004) Feeding Infants and Toddlers Study: what foods are infants and toddlers eating. J Am Diet Assoc 104 (Suppl): S22-S30.

Fox, M.K.; Reidy, K.; Karwe, V.; Ziegler, P. (2006) Average portions of foods commonly eaten by infants and toddlers in the United States. J Am Diet Assoc. 106 (Suppl 1): S66-S76.

Frank, G.C.; Webber, L.S.; Farris, R.P.; Berenson, G.S. (1986) Dietary databook: quantifying dietary intakes of infants, children, and adolescents, the Bogalusa heart study, 1973-1983. National Research and Demonstration Center - Arteriosclerosis, Louisiana State University Medical Center, New Orleans, Louisiana.

Goldman, L. (1995) Children - unique and vulnerable. Environmental risks facing children and recommendations for response. Environ Health Perspect 103(6):13-17.

Mennella, J.; Ziegler, P.; Briefel, R.; Novak, T. (2006) Feeding Infants and Toddlers Study: the types of foods fed to Hispanic infants and toddlers. J Am Diet Assoc 106 (Suppl 1): S96-S106.

Nicklas, T.A. (1995) Dietary studies of children: The Bogalusa Heart Study experience. J Am Diet Assoc 95:1127-1133.

Nicklas, T.A.; Webber, L.S.; Srinivasan, S.R.; Berenson, G.S. (1993) Secular trends in dietary intakes and cardiovascular risk factors in 10-y-old children: the Bogalusa heart study (1973-1988). Am J Clin Nutr 57:930-937.

Ponza, M.; Devaney, B.; Ziegler, P.; Reidy, K.; Squatrito, C. (2004) Nutrient intakes and food choices of infants and toddlers participating in WIC. J Am Diet Assoc 104 (Suppl): S71-S79.

Smiciklas-Wright, H.; Mitchell, D.C.; Mickle, S.J.; Cook, A.J.; Goldman, J.D. (2002) Foods commonly eaten in the United States: quantities consumed per eating occasion and in a day, 1994-1996. U.S. Department of Agriculture NFS Report No. 96-5, pre-publication version, 252 pp.

USDA. (1999a) Food and nutrient intakes by children 1994-96, 1998: Table Set 17. Beltsville, MD: Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture.

USDA. (1999b) USDA Nutrient Database for Standard Reference, Release 13. Agricultural Research Service, Nutrient Data Laboratory. http://www.nal.usda.gov/fnic/foodcomp

USDA. (2000) 1994–96, 1998 Continuing Survey of Food Intakes by Individuals (CSFII). CD-ROM. Agricultural Research Service, Beltsville Human Nutrition Research Center, Beltsville, MD. Available from the National Technical Information Service, Springfield, VA; PB-2000-500027.

USDA. (2007) USDA National Nutrient Database for Standard Reference, Release 20. Agricultural Research Service, Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl

U.S. EPA. (2000) Food commodity intake database [FCID raw data file]. Office of Pesticide Programs, Washington, DC. Available from the National Technical Information Service, Springfield, VA; PB2000-5000101.

U.S. EPA. (2005) Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants. U.S. Environmental Protection Agency, Washington, D.C., EPA/630/P-03/003F.

U.S. EPA. (2007) Analysis of fat intake based on the U.S. Department of Agriculture's 1994–96, 1998 Continuing Survey of Food Intakes by Individuals (CSFII). National Center for Environmental Assessment, Washington, DC; EPA/600/R-05/021F. Available from the National Technical Information Service, Springfield, VA, and online at http://www.epa.gov/ncea.

Table 11-3. Per Capita Intake of Total Meat and Dairy Products (g/kg-day as consumed)

Age Group	N	Percent Consuming	Mean	SE	Percentiles 1st	5th	10th	25th	50th	75th	90th	95th	99th	100th
Total Meat														
Birth to 1 year	1,486	40.0	1.2	0.1	0.0	0.0	0.0	0.0	0.0	1.6	4.2	6.7	10.7	29.6
1 to 2 years	2,096	97.3	4.1	0.1	0.0	0.2	0.8	1.9	3.6	5.7	8.0	9.8	14.1	20.6
3 to 5 years	4,391	98.8	4.1	0.05	0.0	0.6	1.2	2.2	3.6	5.4	7.7	9.4	12.7	23.4
6 to 12 years	2,089	98.7	2.9	0.05	0.0	0.4	0.8	1.5	2.5	3.8	5.4	6.5	9.6	18.0
13 to 19 years	1,222	98.8	2.1	0.05	0.0	0.2	0.5	1.0	1.9	2.7	3.8	4.8	7.1	30.3
Total Dairy														
Birth to 1 year	1,486	79.5	12.6	0.9	0.0	0.0	0.0	1.0	8.0	14.1	24.1	48.7	127	186
1 to 2 years	2,096	99.8	36.7	0.7	0.4	3.9	7.7	17.4	31.3	49.8	72.1	88.3	126	223
3 to 5 years	4,391	100.0	23.3	0.3	1.1	4.2	7.0	13.0	20.8	30.9	42.0	49.4	67.7	198
6 to 12 years	2,089	100.0	13.6	0.4	0.3	1.8	3.5	6.7	11.7	18.5	26.0	31.5	42.7	80.6
13 to 19 years	1,222	99.8	5.6	0.2	0.01	0.2	0.5	1.5	4.2	8.1	12.5	15.5	25.4	32.7

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Age Group	N	Mean	SE	Percentiles									
				1st	5th	10th	25th	50th	75th	90th	95th	99th	100th
Total Meat													
Birth to 1 year	575	3.0	0.2	0.01	0.1	0.3	1.0	2.2	4.2	7.4	9.2	12.9	29.6
1 to 2 years	2,044	4.2	0.1	0.04	0.6	1.0	2.1	3.6	5.7	8.1	9.8	14.1	20.6
3 to 5 years	4,334	4.2	0.1	0.04	0.8	1.2	2.2	3.6	5.5	7.7	9.4	12.7	23.4
6 to 12 years	2,065	2.9	0.1	0.1	0.5	0.9	1.5	2.5	3.9	5.4	6.5	9.6	18.0
13 to 19 years	1,208	2.1	0.1	0.02	0.3	0.6	1.1	1.9	2.8	3.8	4.8	7.1	30.3
Total Dairy													
Birth to 1 year	1,192	15.9	1.0	0.03	0.8	1.9	5.8	10.2	16.0	27.7	57.5	141.8	185.6
1 to 2 years	2,093	36.8	0.7	0.4	4.2	7.8	17.4	31.3	49.8	72.1	88.3	126.2	223.2
3 to 5 years	4,390	23.3	0.3	1.1	4.2	7.0	13.0	20.8	30.9	42.0	49.4	67.7	198.4
6 to 12 years	2,089	13.6	0.4	0.3	1.8	3.5	6.7	11.7	18.5	26.0	31.5	42.7	80.6
13 to 19 years	1,221	5.6	0.2	0.01	0.3	0.5	1.5	4.2	8.1	12.5	15.5	25.4	32.7

Table 11-4. Consumer Only Intake of Total Meat and Dairy Products (g/(kg-day as consumed)

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 11-5. Per Capita Intake of Individual Meats and Dairy Products (g/kg-day as consumed)

Age Group	N	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE	Percent Consuming	Mean	SE
		Beef			Pork			Poultry			Eggs		
Birth to 1 year	1,486	25.3	0.41	0.04	17.7	0.15	0.02	30.1	0.66	0.05	27.9	0.30	0.04
1 to 2 years	2,096	85.5	1.7	0.06	69.7	0.72	0.03	73.7	1.7	0.05	92.3	1.3	0.04
3 to 5 years	4,391	90.8	1.8	0.04	79.8	0.84	0.02	73.0	1.5	0.03	95.1	0.91	0.03
6 to 12 years	2,089	92.7	1.3	0.04	82.4	0.59	0.03	67.1	0.93	0.03	95.8	0.51	0.02
13 to 19 years	1,222	91.1	1.0	0.05	81.5	0.40	0.03	65.5	0.68	0.03	95.4	0.33	0.02

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 11-6. Consumer Only Intake of Individual Meats and Dairy Products (g/kg-day as consumed)

Age Group	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
	Beef			Pork			Poultry			Eggs		
Birth to 1 year	361	1.6	0.2	248	0.83	0.08	434	2.2	0.1	402	1.1	0.1
1 to 2 years	1,795	2.0	0.06	1,488	1.0	0.04	1,552	2.2	0.06	1,936	1.4	0.04
3 to 5 years	3,964	1.9	0.04	3,491	1.1	0.03	3,210	2.0	0.04	4,171	0.96	0.03
6 to 12 years	1,932	1.4	0.04	1,731	0.72	0.03	1,421	1.4	0.04	2,001	0.53	0.02
13 to 19 years	1,118	1.1	0.05	1,002	0.50	0.03	808	1.0	0.04	1,167	0.34	0.02

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 11-7. Mean Quantities of Meat and Eggs consumed Daily by Sex and Age, Per Capita (g/day)

Age Group	Sample Size	Total	Beef	Pork	Lamb, veal, game	Organ meats	Frankfurters, sausages, luncheon meats	Poultry		Eggs	Mixtures, mainly meat/ poultry/ fish
								Total	Chicken		
Males and Females											
Under 1 year	1,126	24	1[a]	-[a,b]	-[a,b]	-[a,b]	2	3	2	3	16
1 year	1,016	80	5	2	-[a,b]	-[a,b]	13	12	12	13	43
2 years	1,102	94	7	6	-[a,b]	-[a,b]	18	17	16	18	41
1 to 2 years	2,118	87	6	4	-[a,b]	-[a,b]	15	15	14	16	42
3 years	1,831	101	8	6	-[a,b]	-[a,b]	19	19	18	13	43
4 years	1,859	115	10	6	-[a,b]	-[a,b]	22	20	19	13	49
5 years	884	121	14	6	-[a,b]	-[a,b]	22	22	19	13	51
3 to 5 years	4,574	112	11	6	-[b]	-[a,b]	21	21	19	13	47
5 years and under	7,818	93	8	5	-[b]	-[a,b]	17	16	15	13	42
Males											
6 to 9 years	787	151	18	7	-[a,b]	-[a,b]	24	23	21	11	71
6 to 11 years	1,031	154	19	7	-[a,b]	-[a,b]	24	22	20	12	72
12 to 19 years	737	250	30	12	1[a]	0	28	31	26	22	134
Females											
6 to 9 years	704	121	17	4	-[a,b]	-[a,b]	18	19	16	10	55
6 to 11 years	969	130	18	5	-[a,b]	-[a,b]	19	20	17	11	60
12 to 19 years	732	158	21	5	-[a,b]	-[a,b]	15	21	19	13	85
Males and Females											
9 years and under	9,309	110	12	5	-[b]	-[a,b]	19	18	17	12	50
19 years and under	11,287	152	18	7	-[a,b]	-[a,b]	20	22	19	14	76

[a] Estimate is not statistically reliable due to small sample size reporting intake.
[b] Value less than 0.5, but greater than 0.
Note: Consumption amounts shown are representative of the first day of each participant's survey response.

Source: USDA, 1999a.

Table 11-8. Percentage of Individuals Consuming Meats and Eggs, by Sex and Age (%)

Age Group	Sample Size	Total	Beef	Pork	Lamb, veal, game	Organ meats	Frankfurters, sausages, luncheon meats	Poultry		Eggs	Mixtures, mainly meat/ poultry/ fish
								Total	Chicken		
Males and Females											
Under 1 year	1,126	26.0	2.1	1.1 [a]	0.2 [a]	0.2 [a]	6.1	6.3	5.0	6.7	13.7
1 year	1,016	77.4	11.9	7.3	0.8 [a]	0.2 [a]	26.3	24.0	23.1	22.8	32.2
2 years	1,102	85.2	16.2	14.9	0.8 [a]	0.2 [a]	33.2	27.6	25.6	27.3	31.4
1 to 2 years	2,118	81.4	14.1	11.2	0.8 [a]	0.2 [a]	29.9	25.8	24.4	25.1	31.8
3 years	1,831	86.2	13.8	13.3	0.5 [a]	[a,b]	36.4	28.3	26.0	19.8	29.2
4 years	1,859	86.2	16.1	13.8	0.5 [a]	0.2 [a]	37.0	27.4	25.1	16.9	30.5
5 years	884	87.1	18.2	13.2	0.6 [a]	0.2 [a]	35.1	27.7	24.8	16.4	30.8
3 to 5 years	4,574	86.5	16.0	13.4	0.5	0.2 [a]	36.1	27.8	25.3	17.7	30.2
5 years and under	7,818	77.5	13.7	11.2	0.6	0.2 [a]	30.4	24.5	22.6	18.9	28.8
Males											
6 to 9 years	787	87.4	20.1	11.9	0.4 [a]	0.1[a]	37.4	24.8	22.3	15.1	36.2
6 to 11 years	1,031	87.8	22.0	12.2	0.4 [a]	0.2[a]	36.2	22.9	20.5	15.6	35.7
12 to 19 years	737	86.8	24.2	15.8	0.6 [a]	0.0	31.8	20.6	17.6	17.0	38.3
Females											
6 to 9 years	704	84.6	19.4	9.2	0.4 [a]	0.2 [a]	33.5	23.1	20.2	13.4	32.4
6 to 11 years	969	86.5	20.2	10.0	0.4 [a]	0.1 [a]	33.1	22.9	19.8	13.3	32.8
12 to 19 years	732	80.1	22.0	11.2	0.1 [a]	0.1 [a]	24.6	21.6	18.9	15.0	34.0
Males and Females											
9 years and under	9,309	80.9	16.1	10.9	0.5	0.2 [a]	24.3	24.3	22.0	17.1	31.0
19 years and under	11,287	82.8	19.6	12.1	0.4	0.1 [a]	22.7	22.7	20.1	16.4	33.3

[a] Estimate is not statistically reliable due to small sample size reporting intake.
[b] Value less than 0.5, but greater than 0.
Note: Percentages shown are representative of the first day of each participant's survey response.

Source: USDA, 1999a.

Table 11-9. Mean Quantities of Dairy Products Consumed Daily by Sex and Age, Per Capita (g/day)

Age Group	Sample Size	Total Milk and Milk Products	Milk, Milk Drinks, Yogurt						Milk Desserts	Cheese
			Total	Fluid Milk				Yogurt		
				Total	Whole	Lowfat	Skim			
Males and Females										
Under 1 year	1,126	762	757	61	49	11	[a,b]	4	3	1
1 year	1,016	546	526	475	347	115	5[a]	14	11	9
2 years	1,102	405	377	344	181	141	17	10	16	11
1 to 2 years	2,118	474	450	408	262	128	11	12	14	10
3 years	1,831	419	384	347	166	150	26	10	22	12
4 years	1,859	407	369	328	147	149	27	10	23	14
5 years	884	417	376	330	137	159	25	9	25	14
3 to 5 years	4,574	414	376	335	150	153	26	10	23	13
5 years and under	7,818	477	447	327	177	127	18	10	18	11
Males										
6 to 9 years	787	450	405	343	127	176	29	6	31	13
6 to 11 years	1,031	450	402	335	121	172	33	6	35	12
12 to 19 years	737	409	358	303	99	158	40	3[a]	29	19
Females										
6 to 9 years	704	380	337	288	105	146	26	4	29	13
6 to 11 years	969	382	336	283	108	136	29	4	30	14
12 to 19 years	732	269	220	190	66	92	30	4[a]	29	14
Males and Females										
9 years and under	9,309	453	417	323	153	141	22	8	23	12
19 years and under	11,287	405	362	291	121	135	29	6	27	14

[a] Estimate is not statistically reliable due to small sample size reporting intake.

[b] Value less than 0.5, but greater than 0.

Note: Consumption amounts shown are representative of the first day of each participant's survey response.

Source: USDA, 1999a.

Table 11-10. Percentage of Individuals Consuming Dairy Products, by Sex and Age (%)

Age Group	Sample Size	Total Milk and Milk Products	Milk, milk drinks, yogurt						Milk Desserts	Cheese
			Total	Fluid Milk				Yogurt		
				Total	Whole	Lowfat	Skim			
Males and Females										
Under 1 year	1,126	85.4	84.6	11.1	8.3	2.4	0.2[a]	3.1	4.5	6.0
1 year	1,016	95.3	92.7	87.7	61.7	26.5	1.5[a]	10.0	13.9	29.7
2 years	1,102	91.6	87.3	84.3	44.8	36.3	5.2	6.8	17.5	32.6
1 to 2 years	2,118	93.4	90.0	86.0	53.0	31.5	3.4	8.4	15.8	31.2
3 years	1,831	94.3	88.3	84.6	42.5	39.5	6.8	7.3	21.4	37.0
4 years	1,859	93.2	87.8	85.0	41.3	40.4	7.7	5.8	21.7	36.9
5 years	884	93.1	86.4	81.2	38.1	41.7	6.5	5.5	21.4	34.9
3 to 5 years	4,574	93.5	87.5	83.6	40.6	40.6	7.0	6.2	21.5	36.3
5 years and under	7,818	92.5	88.0	75.7	41.0	32.9	4.9	6.6	17.5	30.9
Males										
6 to 9 years	787	93.2	85.5	80.7	32.4	44.3	8.6	3.8	24.0	34.6
6 to 11 years	1,031	92.3	84.6	79.0	30.8	43.1	9.5	3.7	25.0	32.3
12 to 19 years	737	81.3	65.8	59.6	22.6	30.7	7.0	1.7[a]	13.6	37.1
Females										
6 to 9 years	704	90.2	82.5	77.5	31.5	40.8	8.1	2.9	24.1	30.9
6 to 11 years	969	90.2	81.5	76.0	33.2	37.8	8.4	3.0	22.4	31.9
12 to 19 years	732	75.4	54.0	49.7	17.5	23.9	9.5	2.2[a]	17.1	36.1
Males and Females										
9 years and under	9,309	92.2	86.4	77.1	37.4	36.8	6.3	5.3	20.1	31.7
19 years and under	11,287	86.7	75.6	68.1	30.1	33.1	7.5	3.8	18.6	33.5

[a] Estimate is not statistically reliable due to small sample size reporting intake.

Note: Percentages shown are representative of the first day of each participant's survey response.

Source: USDA, 1999a.

Table 11-11. Quantity (as consumed) of Meat and Dairy Products Consumed Per Eating Occasion and Percentage of Individuals Using These Foods in Two Days

	Quantity consumed per eating occasion (grams)											
	2 to 5 years old			6 to 11 years old			12 to 19 years old					
	Male and Female (N = 2,109)			Male and Female (N = 1,432)			Male (N = 696)			Female (N = 702)		
Food category	PC	Mean	SEM	PC	Mean	SEM	PC	Mean	SEM	PC	Mean	SEM
Meats												
Beef steaks	11.1	58	4	11.3	87	9	9.5	168	14	9.4	112	10
Beef roasts	5.2	49	5	4.8	67	7	5.1	233[a]	149[a]	5.5	97[a]	16[a]
Ground beef	59.5	31	1	63.7	41	1	73.4	66	3	61.5	52	3
Ham	6.9	35	4	8.5	40	4	11.6	68	7	9.9	40	5
Pork chops	11.0	48	3	10.1	62	4	11.6	100	8	8.5	72	7
Bacon	10.4	15	1	9.7	19	2	14.9	25	2	11.1	18	1
Pork breakfast sausage	5.3	33	2	6.0	32	3	6.3	40[a]	4[a]	3.3	40[a]	5[a]
Frankfurters and luncheon meats	51.7	49	1	50.9	57	2	46.7	76	3	38.5	57	3
Total chicken and turkey	63.8	46	1	53.8	62	2	58.4	100	4	54.1	71	2
Chicken	44.6	52	1	36.0	70	3	34.3	117	5	36.1	80	3
Turkey	5.1	63	7	5.7	66	5	8.2	117	14	5.8	60[a]	9[a]
Dairy Products												
Fluid milk (all)	92.5	196	3	89.2	241	4	72.3	337	8	64.4	262	8
Fluid milk consumed with cereal	68.1	149	4	64.7	202	5	44.4	276	10	42.7	222	8
Whole milk	50.0	202	3	39.5	244	7	30.0	333	13	22.4	258	7
Whole milk consumed with cereal	33.8	161	5	26.2	212	11	14.8	265	18	14.1	235	13
Lowfat milk	47.5	189	3	52.8	238	4	39.6	326	8	32.4	262	13
Lowfat milk consumed with cereal	31.5	136	4	32.7	198	4	24.3	277	12	21.1	227	12
Skim milk	7.8	171	9	11.1	225	9	9.7	375	38	13.5	255	14
Skim milk consumed with cereal	4.9	131	11	7.5	188	14	6.5	285[a]	23[a]	8.3	181	13
Cheese, other than cream or cottage	53.2	24	1	50.4	29	1	61.1	38	2	53.9	27	1
Ice cream and ice milk	18.4	92	3	21.1	135	4	14.2	221	12	15.2	187	14
Boiled, poached, and baked eggs	8.0	36	3	8.2	34	3	5.0	44[a]	9[a]	7.7	45	7
Fried eggs	17.3	48	1	14.0	58	2	14.9	83	5	13.5	59	3
Scrambled eggs	10.4	59	4	7.1	72	5	7.1	72	5	8.9	103	9

[a] Indicates a statistic that is potentially unreliable because of small sample size or large coefficient of variation.
PC = Percent consuming at least once in 2 days.
SEM = Standard error of the mean.

Source: Smiciklas-Wright et al., 2002 (based on 1994-1996 CSFII data).

Table 11-12. Characteristics of the FITS Sample Population

	Sample Size	Percentage of Sample
Gender		
Male	1,549	51.3
Female	1,473	48.7
Age of Child		
4 to 6 months	862	28.5
7 to 8 months	483	16.0
9 to 11 months	679	22.5
12 to 14 months	374	12.4
15 to 18 months	308	10.2
19 to 24 months	316	10.4
Child's Ethnicity		
Hispanic or Latino	367	12.1
Non-Hispanic or Latino	2,641	87.4
Missing	14	0.5
Child's Race		
White	2,417	80.0
Black	225	7.4
Other	380	12.6
Urbanicity		
Urban	1,389	46.0
Suburban	1,014	33.6
Rural	577	19.1
Missing	42	1.3
Household Income		
Under $10,000	48	1.6
$10,000 to $14,999	48	1.6
$15,000 to $24,999	221	7.3
$25,000 to $34,999	359	11.9
$35,000 to $49,999	723	23.9
$50,000 to $74,999	588	19.5
$75,000 to $99,999	311	10.3
$100,000 and Over	272	9.0
Missing	452	14.9
Receives WIC		
Yes	821	27.2
No	2,196	72.6
Missing	5	0.2
Sample Size (Unweighted)	3,022	100.0

WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Devaney et al., 2004.

Table 11-13. Percentage of Infants and Toddlers Consuming Meat or Other Protein Sources

Food Group/Food	Percentage of Infants and Toddlers Consuming at Least Once in a Day					
	4 to 6 months	7 to 8 months	9 to 11 months	12 to14 months	15 to18 months	19 to 24 months
Cow's Milk	0.8	2.9	20.3	84.8	88.3	87.7
Whole	0.5	2.4	15.1	68.8	71.1	58.8
Reduce-fat or non-fat	0.3	0.5	5.3	17.7	20.7	38.1
Unflavored	0.8	2.9	19.5	84.0	87.0	86.5
Flavored	0.0	0.0	0.9	1.8	4.4	5.6
Soy Milk	0.0	0.5	1.7	1.5	3.9	3.8
Any Meat or Protein Source	14.2	54.9	79.2	91.3	92.7	97.2
Baby Food Meat	1.7	4.0	3.1	1.1	0.0	0.0
Non-baby Food Meat	1.5	8.4	33.7	60.3	76.3	83.7
Other Protein Soources	2.7	9.7	36.1	59.2	66.8	68.9
Dried Beans and Peas, Vegetarian Meat	0.6	1.3	3.3	7.0	6.6	9.9
Eggs	0.7	2.9	7.3	17.0	25.0	25.2
Peanut Butter, Nuts, and Seeds	0.0	0.5	1.9	8.8	11.6	10.4
Cheese	0.4	2.1	18.5	34.0	39.1	41.1
Yogurt	1.2	4.1	15.7	14.9	20.2	15.3
Protein Sources in Mixed Dishes	11.0	43.3	46.2	30.1	25.5	20.5
Baby Food Dinners	9.5	39.8	33.5	10.2	2.4	1.3
Beans and Rice, Chilli, Other Bean Mixtures	0.0	0.0	0.9	1.2	2.1	2.0
Mixtures with Vegetables and/or Rice/Pasta	0.9	1.2	4.7	8.2	9.0	7.8
Soup[a]	0.9	3.4	10.1	12.5	13.8	11.5
Types of Meat[b]						
Beef	0.9	2.6	7.7	16.1	16.3	19.3
Chicken or Turkey	2.0	7.3	22.4	33.0	46.9	47.3
Fish and Shellfish	0.0	0.5	1.9	5.5	8.7	7.1
Hotdogs, Sausages, and Cold cuts	0.0	2.1	7.1	16.4	20.1	27.0
Pork/Ham	0.3	1.7	4.0	9.7	11.2	13.9
Other	0.3	0.6	2.5	2.8	2.1	3.9

[a] The amount of protein actually provided by soups varies. Soups could not be sorted reliably into different food groups because all soups were assigned the same two-digit food code and many food descriptions lacked detail about major soup ingredients.

[b] Includes baby food and non-baby food sources.

Source: Fox et al., 2004.

Table 11-14. Characteristics of WIC Participants and Non-participants[a] (Percentages)

	Infants 4 to 6 months		Infants 7 to 11 months		Toddlers 12 to 24 months	
	WIC Participant	Non-participant	WIC Participant	Non-participant	WIC Participant	Non-participant
Gender						
Male	55	54	55	51	57	52
Female	45	46	45	49	43	48
Child's Ethnicity		**		**		**
Hispanic or Latino	20	11	24	8	22	10
Non-Hispanic or Latino	80	89	76	92	78	89
Child's Race		**		**		**
White	69	84	63	86	67	84
Black	15	4	17	5	13	5
Other	22	11	20	9	20	11
Child In Day Care				**		*
Yes	39	38	34	46	43	53
No	61	62	66	54	57	47
Age of Mother		**		**		**
14 to 19 years	18	1	13	1	9	1
20 to 24 years	33	13	38	11	33	14
25 to 29 years	29	29	23	30	29	26
30 to 34 years	9	33	15	36	18	34
35 years or Older	9	23	11	21	11	26
Missing	2	2	1	1	0	1
Mother's Education		**		**		**
11th Grade or Less	23	2	15	2	17	3
Completed High School	35	19	42	20	42	19
Some Postsecondary	33	26	32	27	31	28
Completed College	7	53	9	51	9	48
Missing	2	1	2	0	1	2
Parent's Marital Status		**		**		**
Married	49	93	57	93	58	88
Not Married	50	7	42	7	41	11
Missing	1	1	1	0	1	1
Mother or Female Guardian Works				**		*
Yes	46	51	45	60	55	61
No	53	48	54	40	45	38
Missing	1	1	1	0	0	1
Urbanicity		**		**		**
Urban	34	55	37	50	35	48
Suburban	36	31	31	34	35	35
Rural	28	13	30	15	28	16
Missing	2	1	2	1	2	2
Sample Size (Unweighted)	265	597	351	808	205	791

[a] X^2 test were conducted to test for statistical significance in the differences between WIC participants and non-participants within each age group for each variable. The results of X^2 test are listed next to the variable under the column labeled non-participants for each of the three age groups. * $P<0.05$; ** $P>0.01$; non-participants significantly different from WIC participants on the variable.

WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Ponza et al., 2004.

Table 11-15. Food Choices for Infants and Toddlers by WIC Participation Status

	Infants 4 to 6 months		Infants 7 to 11 months		Toddlers 12 to 24 months	
	WIC Participant	Non-participant	WIC Participant	Non-participant	WIC Participant	Non-participant
Cow's Milk	1.0	0.6	11.4	13.2	92.3	85.8*
Meat or Other Protein Sources						
Baby Food Meat	0.9	2.0	3.3	3.6	0.0	0.3
Non-Baby Meat	3.7	0.5**	25.0	22.0	77.7	75.1
Eggs	0.9	0.6	8.5	4.2**	24.1	23.0
Peanut Butter, Nuts, Seeds	0.0	0.0	1.4	1.3	12.9	9.8
Cheese	0.0	0.6	9.0	12.5	38.5	38.8
Yogurt	0.8	1.4	5.5	13.3**	9.3	18.9**
Sample Size (unweighted)	265	597	351	808	205	791

* = P<0.05; non-participants significantly different from WIC participants.
** = P<0.01; non-participants significantly different from WIC participants.
WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Ponza et al., 2004.

Table 11-16. Percentage of Hispanic and Non-Hispanic Infants and Toddlers Consuming Different Types of Milk, Meats or Other Protein Sources on A Given Day

	Age 4 to 5 months		Age 6 to 11months		Age 12 to 24 months	
	Hispanic (N=84)	Non-Hispanic (N=538)	Hispanic (N=163)	Non-Hispanic (N=1,228)	Hispanic (N=124)	Non-Hispanic (N=871)
Milk						
Fed Any Cow's or Goat Milk	-	-	7.5†	11.3	85.6	87.7
Fed Cow's Milk						
Whole	-	-	5.6†	8.3	61.7	66.3
Reduced Fat or Non-fat	-	-	2.2†	3.0	29.0	27.0
Meat or Other Protein Sources						
Any Meat or Protein Source[a]	9.7†	5.3	71.6	62.0	90.3	94.7
Non-Baby Food Meat	-	-	22.5	19.2	72.3	76.0
Other Protein Sources	1.4†	-	26.5	21.2	70.1	65.3
Beans and Peas	1.4†	-	5.8†	1.8	19.1*	6.5
Eggs	-	-	9.5	4.2	26.4	22.5
Cheese	-	-	11.2	9.4	29.3	40.2
Yogurt	-	-	7.7	9.8	15.7	17.0
Protein Sources in Mixed Dishes	7.5†	4.4	44.8	41.6	33.3	22.7
Baby Food dinners	6.9†	3.9	24.7*	35.3	3.5†	3.9
Soup[b]	-	-	16.3**	5.1	23.4*	10.7
Types of Meat[a]						
Beef	-	-	5.0†	4.6	25.2	16.0
Chicken and Turkey	-	-	11.2	11.9	46.5	43.6
Hotdogs, Sausages, and Cold Cuts	-	-	7.2†	3.4	14.8	23.3
Pork/Ham	-	-	3.8†	1.7	11.7	12.1

[a] Includes baby food and non-baby food sources.
[b] The amount of protein actually provided by soups varies. Soups could not be sorted reliably into different food groups because many food descriptions lacked detail about major soup ingredients.
- = Less than 1 percent of the group consumed this food on a given day.
* = Significantly different from non-Hispanic at the $P<0.05$.
** = Significantly different from non-Hispanic at the $P>0.01$.
† = Statistic is potentially unreliable because of a high coefficient of variation.
N = Sample size.

Source: Mennella et al., 2006.

Table 11-17. Average Portion Sizes Per Eating Occasion of Meats and Dairy Products Commonly Consumed by Infants from the 2002 Feeding Infants and Toddlers Study

Food group	Reference Unit	4 to 5 months (N=624)	6 to 8 months (N=708)	9 to 11 months (N=687)
		Mean± SEM		
Non-baby food meats	ounce	-	0.9±0.16	0.8±0.05
Cheese	ounce	-	-	0.7±0.05
Scrambled eggs	cup	-	-	0.2±0.02
Yogurt	ounce	-	-	3.1±0.20
Baby food dinners	ounce	2.9±0.24	3.3±0.09	3.8±0.11

- = Cell size was too small to generate a reliable estimate.
N = Number of respondents.
SEM = Standard error of the mean.

Source: Fox et al., 2006.

Table 11-18. Average Portion Sizes Per Eating Occasion of Meats and Dairy Products Commonly Consumed by Toddlers from the 2002 Feeding Infants and Toddlers Study

Food Group	Reference unit	12 to 14 months (N=371)	15 to 18 months (N=312)	19 to 24 months (N=320)
		Mean ± SEM		
Milk				
Milk	fluid ounce	5.6±0.14	5.9±0.14	6.2±0.17
Milk, as a beverage	fluid ounce	5.7±0.14	6.1±0.14	6.4±0.17
Milk, on cereal	fluid ounce	3.4±0.37	2.7±0.26	3.6±0.29
Meats and other protein sources				
All meats	ounce	1.2±0.06	1.3±0.08	1.3±0.07
Beef	ounce	0.8±0.08	1.2±0.15	1.2±0.14
Chicken or turkey, plain	ounce	1.3±0.10	1.3±0.16	1.3±0.10
Hot dogs, luncheon meats, sausages	ounce	1.3±0.13	1.5±0.13	1.5±0.12
Chicken, breaded[a]	ounce	1.5±0.14	1.5±0.13	1.8±0.12
	nugget	2.4±0.22	2.4±0.21	2.8±0.19
Scrambled eggs	cup	0.2±0.02	0.3±0.03	0.3±0.02
Peanut butter	tablespoon	0.7±0.08	0.7±0.09	0.9±0.13
Yogurt	ounce	3.4±0.19	3.8±0.26	3.8±0.28
Cheese	ounce	0.8±0.05	0.8±0.05	0.7±0.04

[a] Not included in total for all meats because weight includes breading.
N = Number of respondents.
SEM = Standard error of the mean.

Source: Fox et al., 2006.

Table 11-19. Total Fat Intake (Per capita; g/day)

Age Group[a]	N	Mean	SE	Percentiles					
				10th	25th	50th	75th	95th	100th
Birth to <1 year									
all	1,422	29	18	0.03	19	31	40	59	107
female	728	28	17	0.03	18	30	39	57	92
male	694	30	18	0.04	20	32	40	61	107
Birth to <1 month									
all	88	17	16	0	0	19	32	52	64
female	50	19	15	0	0	18	29	39	52
male	38	15	18	0	0	19	31	43	64
1 to <3 months									
all	245	22	18	0	0	27	34	47	75
female	110	20	16	0	0	24	33	45	50
male	135	23	19	0	0	28	34	55	75
3 to <6 months									
all	411	28	17	0.10	20	31	39	52	107
female	223	27	17	0.02	16	29	38	51	74
male	188	30	18	0.15	22	31	39	50	107
6 to <12 months									
all	678	33	17	8.5	25	34	43	62	100
female	345	32	17	5.1	24	33	43	62	92
male	333	34	16	11	25	34	44	62	100
1 to <2 years									
all	1,002	46	19	24	33	43	55	79	159
female	499	45	18	25	33	43	54	77	116
male	503	46	20	23	32	44	56	80	159
2 to <3 years									
all	994	51	21	27	37	48	60	87	197
female	494	49	20	24	35	46	59	83	127
male	500	52	21	29	39	50	61	89	197
3 to <6 years									
all	4,112	59	22	34	44	56	70	99	218
female	2,018	56	21	33	43	54	68	96	194
male	2,094	61	23	35	45	59	72	103	218
6 to <11 years									
all	1,553	68	24	41	50	66	81	111	179
female	742	64	22	38	48	61	77	101	156
male	811	72	25	43	55	70	86	115	179
11 to <16 years									
all	975	80	38	42	56	74	97	145	342
female	493	69	29	37	49	65	82	123	259
male	482	91	42	50	64	84	111	163	342
16 to <21 years									
all	743	85	47	37	54	76	108	168	463
female	372	79	39	35	49	75	96	154	317
male	371	92	53	41	57	77	114	186	463

[a] Age groups are based on U.S. EPA (2005) *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants*.
N = Sample size.
SE = Standard error.

Source: Based on U.S. EPA, 2007.

Table 11-20. Total Fat Intake (Per capita; g/kg-day)

Age Group[a]	N	Mean	SE	Percentiles 10th	25th	50th	75th	95th	100th
Birth to <1 year									
all	1,422	4.0	2.8	0.01	2.3	4.1	5.6	8.9	20
female	728	4.1	2.8	0.01	2.4	4.3	5.8	8.7	18
male	694	4.0	2.8	0.01	2.3	4.0	5.5	9.2	20
Birth to <1 month									
all	88	5.2	4.9	0	0	5.7	9.1	16	20
female	50	5.9	4.6	0	0	6.2	8.4	13	16
male	38	4.3	5.3	0	0	4.7	9.7	18	20
1 to <3 months									
all	245	4.5	3.8	0	0	4.9	6.8	11	18
female	110	4.3	3.6	0	0	4.8	6.5	11	14
male	135	4.7	3.9	0	0	4.9	7.0	10	18
3 to <6 months									
all	411	4.1	2.7	0.01	2.4	4.3	5.7	8.2	18
female	223	4.2	2.8	0.00	2.3	4.5	6.0	8.2	18
male	188	4.1	2.5	0.02	2.6	4.1	5.5	8.2	16
6 to <12 months									
all	678	3.7	1.8	1.0	2.7	3.8	4.8	7.0	11
female	345	3.7	1.9	0.66	2.8	3.8	5.0	7.0	9.8
male	333	3.6	1.7	1.3	2.6	3.7	4.6	6.8	11
1 to <2 years									
all	1,002	4.0	1.7	2.1	2.8	3.7	4.7	7.1	12
female	499	4.1	1.6	2.2	3.0	3.7	5.0	6.9	9.7
male	503	3.9	1.7	1.9	2.6	3.6	4.5	7.2	12
2 to <3 years									
all	994	3.6	1.5	1.9	2.6	3.4	4.4	6.4	12
female	494	3.7	1.6	1.8	2.4	3.4	4.4	6.6	10
male	500	3.6	1.5	2.0	2.6	3.4	4.3	6.1	12
3 to <6 years									
all	4,112	3.4	1.3	1.9	2.4	3.2	4.0	5.8	11
female	2,018	3.4	1.3	1.8	2.4	3.1	4.0	5.8	11
male	2,094	3.5	1.4	1.9	2.4	3.2	4.1	5.8	11
6 to <11 years									
all	1,553	2.6	1.1	1.3	1.7	2.3	3.0	4.2	9.9
female	742	2.4	1.0	1.3	1.6	2.2	2.8	4.0	7.7
male	811	2.7	1.1	1.4	1.8	2.4	3.1	4.4	9.9
11 to <16 years									
all	975	1.6	0.80	0.77	1.1	1.4	2.0	3.0	5.7
female	493	1.4	0.69	0.67	0.91	1.3	1.7	2.6	5.0
male	482	1.8	0.86	0.88	1.2	1.6	2.1	3.3	5.7
16 to <21 years									
all	743	1.3	0.66	0.54	0.81	1.2	1.6	2.7	6.0
female	372	1.1	0.56	0.48	0.75	1.1	1.4	2.1	4.4
male	371	1.4	0.73	0.63	0.85	1.2	1.7	2.9	6.0

[a] Age groups are based on U.S. EPA (2005) *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants*.
N = Sample size.
SE = Standard error.

Source: Based on U.S. EPA, 2007.

Table 11-21. Total Fat Intake (Consumers Only; g/day)

Age Group[a]	N	Mean	SE	Percentiles					
				10th	25th	50th	75th	95th	100th
Birth to <1 year									
all	1,301	31	16	7.0	24	32	41	61	107
female	664	30	16	5.1	24	32	40	58	92
male	637	32	16	9.0	25	33	41	62	107
Birth to <1 month									
all	59	26	13	6.7	17	27	32	52	64
female	37	26	11	7.8	17	25	32	39	52
male	22	25	17	-	-	-	-	-	64
1 to <3 months									
all	182	29	14	5.8	24	31	35	53	75
female	79	28	12	4.3	21	30	35	46	50
male	103	31	16	8.5	27	31	38	59	75
3 to <6 months									
all	384	30	16	2.5	24	32	40	54	107
female	205	29	16	1.2	24	31	39	52	72
male	179	31	17	4.6	25	33	39	53	107
6 to <12 months									
all	676	33	16	8.9	25	34	43	62	100
female	343	32	17	6.2	24	34	43	62	92
male	333	34	16	11	25	34	44	62	100
1 to <2 year									
all	1,002	46	19	24	33	43	55	79	159
female	499	45	18	25	33	43	54	77	116
male	503	46	20	23	32	44	56	80	159
2 to <3 years									
all	994	51	21	27	37	48	60	87	197
female	494	49	20	24	35	46	59	83	127
male	500	52	21	29	39	50	61	89	197
3 to <6 years									
all	4,112	59	22	34	44	56	70	99	218
female	2,018	56	21	33	43	54	68	96	194
male	2,094	61	23	35	45	59	72	103	218
6 to <11 years									
all	1,553	68	24	41	50	66	81	111	179
female	742	64	22	38	48	61	77	101	156
male	811	72	25	43	55	70	86	115	179
11 to <16 years									
all	975	80	38	42	56	74	97	145	342
female	493	69	29	37	49	65	82	123	259
male	482	91	42	50	64	84	111	163	342
16 to <21 years									
all	743	85	47	37	54	76	108	168	463
female	372	79	39	35	49	75	96	154	317
male	371	92	53	41	57	77	114	186	463

[a] Age groups are based on U.S. EPA (2005) *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants*.

\- = Percentiles were not calculated for sample sizes less than 30.

N = Sample size.

SE = Standard error.

Source: Based on U.S. EPA, 2007.

Table 11-22. Total Fat Intake (Consumers Only; g/kg-day)

Age Group[a]	N	Mean	SE	Percentiles					
				10th	25th	50th	75th	95th	100th
Birth to <1 year									
all	1,301	4.4	2.6	0.94	2.9	4.3	5.8	9.2	20
female	664	4.5	2.6	0.67	3.1	4.5	6.0	8.9	18
male	637	4.3	2.6	1.2	2.8	4.1	5.6	9.3	20
Birth to <1 month									
all	59	7.8	4.1	1.4	5.4	8.0	9.7	16	20
female	37	8.0	3.5	2.0	5.3	7.7	9.1	13	16
male	22	7.4	4.9	-	-	-	-	-	20
1 to <3 months									
all	182	6.0	3.1	1.0	4.1	6.0	7.8	12	18
female	79	5.9	2.9	0.80	4.3	6.0	7.7	12	14
male	103	6.1	3.3	1.8	4.1	6.0	7.8	12	18
3 to <6 months									
all	384	4.4	2.5	0.35	3.1	4.5	5.8	8.3	18
female	205	4.5	2.6	0.14	3.1	4.7	6.1	8.2	18
male	179	4.3	2.4	0.57	3.1	4.2	5.6	8.8	16
6 to <12 months									
all	676	3.7	1.8	1.0	2.7	3.8	4.8	7.0	11
female	343	3.7	1.9	0.75	2.8	3.8	5.0	7.0	9.8
male	333	3.6	1.7	1.3	2.6	3.7	4.6	6.8	11
1 to <2 years									
all	1,002	4.0	1.7	2.1	2.8	3.7	4.7	7.1	12
female	499	4.1	1.6	2.2	3.0	3.7	5.0	6.9	9.7
male	503	3.9	1.7	1.9	2.6	3.6	4.5	7.2	12
2 to <3 years									
all	994	3.6	1.5	1.9	2.6	3.4	4.4	6.4	12
female	494	3.7	1.6	1.8	2.4	3.4	4.4	6.6	10
male	500	3.6	1.5	2.0	2.6	3.4	4.3	6.1	12
3 to <6 years									
all	4,112	3.4	1.3	1.9	2.4	3.2	4.0	5.8	11
female	2,018	3.4	1.3	1.8	2.4	3.1	4.0	5.8	11
male	2,094	3.5	1.4	1.9	2.4	3.2	4.1	5.8	11
6 to <11 years									
all	1,553	2.6	1.1	1.3	1.7	2.3	3.0	4.2	9.9
female	742	2.4	1.0	1.3	1.6	2.2	2.8	4.0	7.7
male	811	2.7	1.1	1.4	1.8	2.4	3.1	4.4	9.9
11 to <16 years									
all	975	1.6	0.80	0.77	1.1	1.4	2.0	3.0	5.7
female	493	1.4	0.69	0.67	0.91	1.3	1.7	2.6	5.0
male	482	1.8	0.86	0.88	1.2	1.6	2.1	3.3	5.7
16 to <21 years									
all	743	1.3	0.66	0.54	0.81	1.2	1.6	2.7	6.0
female	372	1.1	0.56	0.48	0.75	1.1	1.4	2.1	4.4
male	371	1.4	0.73	0.63	0.85	1.2	1.7	2.9	6.0

[a] Age groups are based on U.S. EPA (2005) *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants*.

\- = Percentiles were not calculated for sample sizes less than 30.

N = Sample size.

SE = Standard error.

Source: Based on U.S. EPA, 2007.

Table 11-23. Total Fat Intake - Top 10% of Animal Fat Consumers (Consumers Only; g/day)

Age Group[a]	N	Mean	SE	Percentiles					
				10th	25th	50th	75th	95th	100th
Birth to <1 year									
all	140	45	16	28	35	45	54	77	100
female	70	45	15	26	35	45	54	69	92
male	70	45	17	28	34	44	53	79	100
1 to <2 years									
all	109	75	20	52	61	74	85	108	159
female	54	68	16	52	57	70	78	89	114
male	55	81	22	54	67	78	90	125	159
2 to <3 years									
all	103	79	20	55	64	74	85	116	133
female	58	77	16	55	65	74	79	109	116
male	45	81	24	52	61	73	90	121	133
3 to <6 years									
all	461	88	25	62	72	84	102	135	218
female	217	84	24	59	68	80	95	130	194
male	244	92	25	66	76	90	103	136	218
6 to <11 years									
all	198	94	25	66	77	88	105	140	178
female	71	88	21	58	70	86	100	123	156
male	127	97	27	69	78	91	112	168	178
11 to <16 years									
all	96	133	53	85	95	121	154	223	342
16 to <21 years									
all	68	167	64	98	122	154	189	278	463
11 to 20 years									
all	165	146	60	90	105	139	168	254	463
female	53	117	30	81	92	111	140	162	195
male	112	160	65	94	117	151	191	276	463

a Age groups are based on U.S. EPA (2005) *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants.*
N = Sample size.
SE = Standard error.

Source: Based on U.S. EPA, 2007.

Table 11-24. Total Fat Intake - Top 10% of Animal Fat Consumers (Consumers Only; g/kg-day)

Age Group[a]	N	Mean	SE	Percentiles					
				10th	25th	50th	75th	95th	100th
Birth to <1 year									
all	140	4.7	1.7	2.8	3.7	4.6	6.0	7.7	11
female	70	4.8	1.6	2.7	3.7	4.7	6.0	7.7	9.5
male	70	4.6	1.7	2.8	3.6	4.4	5.8	7.5	11
1 to <2 years									
all	109	6.9	1.5	5.1	5.7	6.8	7.7	9.5	12
female	54	6.6	1.2	5.1	5.7	6.7	7.4	9.3	9.7
male	55	7.1	1.6	5.1	5.8	6.9	8.0	9.4	12
2 to <3 years									
all	103	6.1	1.3	4.6	5.2	5.8	6.7	8.3	9.5
female	58	6.2	1.2	4.6	5.2	5.9	6.8	7.9	9.5
male	45	6.1	1.3	4.5	5.2	5.6	6.6	8.4	9.5
3 to <6 years									
all	461	5.6	1.3	4.2	4.7	5.3	6.2	8.3	11
female	217	5.5	1.3	4.2	4.5	5.3	6.0	7.8	11
male	244	5.7	1.3	4.2	4.8	5.3	6.2	8.4	11
6 to <11 years									
all	198	4.2	1.1	3.0	3.4	3.8	4.6	6.0	9.9
female	71	4.2	1.1	2.9	3.3	3.8	4.8	5.8	7.7
male	127	4.2	1.1	3.0	3.4	3.8	4.5	6.3	9.9
11 to <16 years									
all	96	3.0	0.85	2.0	2.4	2.8	3.3	4.6	5.7
16 to <21 years									
all	68	2.5	0.74	1.7	2.0	2.4	2.9	3.7	6.0
11 to 20 years									
all	165	2.8	0.84	1.9	2.1	2.7	3.1	4.4	6.0
female	53	2.6	0.65	1.7	2.0	2.3	2.7	3.4	4.6
male	112	2.9	0.90	1.9	2.3	2.8	3.1	4.5	6.0

[a] Age groups are based on U.S. EPA (2005) *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants.*

N = Sample size.

SE = Standard error.

Source: Based on U.S. EPA, 2007.

Table 11-25. Fat Intake Among Children Based on Data from the Bogalusa Heart Study, 1973-1982 (g/day)

Age	N	Mean	SD	Percentiles					Minimum	Maximum
				10th	25th	50th	75th	90th		
Total Fat Intake										
6 months	125	37.1	17.5	18.7	25.6	33.9	46.3	60.8	3.4	107.6
1 year	99	59.1	26.0	29.1	40.4	56.1	71.4	94.4	21.6	152.7
2 years	135	86.7	41.3	39.9	55.5	79.2	110.5	141.1	26.5	236.4
3 years	106	91.6	38.8	50.2	63.6	82.6	114.6	153.0	32.6	232.5
4 years	219	98.6	56.1	46.0	66.8	87.0	114.6	163.3	29.3	584.6
10 years	871	93.2	50.8	45.7	60.5	81.4	111.3	154.5	14.6	529.5
13 years	148	107.0	53.9	53.0	69.8	90.8	130.7	184.1	9.8	282.2
15 years	108	97.7	48.7	46.1	65.2	85.8	124.0	165.2	10.0	251.3
17 years	159	107.8	64.3	41.4	59.7	97.3	140.2	195.1	8.5	327.4
Total Animal Fat Intake										
6 months	125	18.4	16.0	0.7	4.2	13.9	28.4	42.5	0.0	61.1
1year	99	36.5	20.0	15.2	23.1	33.0	45.9	65.3	0.0	127.1
2 years	135	49.5	28.3	20.1	28.9	42.1	66.0	81.4	10.0	153.4
3 years	106	50.1	29.4	21.3	29.1	42.9	64.4	88.9	14.1	182.6
4 years	219	50.8	31.7	21.4	28.1	42.6	66.4	92.6	5.9	242.2
10 years	871	54.1	39.6	20.3	30.6	45.0	64.6	97.5	0.0	412.3
13 years	148	56.2	39.8	19.8	28.5	44.8	72.8	109.4	4.7	209.6
15 years	108	53.8	35.1	15.9	28.3	44.7	67.9	105.8	0.6	182.1
17 years	159	64.4	48.5	15.2	30.7	51.6	86.6	128.8	2.6	230.3
Total Vegetable Fat Intake										
6 months	125	9.2	12.8	0.6	1.2	2.8	11.6	29.4	0.0	53.2
1 year	99	15.4	14.3	3.7	6.1	11.3	18.1	38.0	0.2	70.2
2 years	135	19.3	16.3	3.8	7.9	14.8	26.6	42.9	0.7	96.6
3 years	106	21.1	15.5	3.9	8.6	18.7	26.6	45.2	1.0	70.4
4 years	219	24.5	18.6	5.7	10.4	21.8	33.3	48.5	0.9	109.0
10 years	871	23.7	21.6	4.3	9.5	18.3	30.6	49.0	0.6	203.7
13 years	148	34.3	27.4	8.4	17.9	31.2	44.6	57.5	0.0	238.3
15 years	108	27.3	22.8	5.1	11.9	22.6	38.1	54.4	0.7	132.2
17 years	159	25.7	21.3	4.2	11.7	20.8	32.9	47.6	0.0	141.5

Table 11-25. Fat Intake Among Children Based on Data from the Bogalusa Heart Study, 1973-1982 (g/day) (continued)

Age	N	Mean	SD	Percentiles					Minimum	Maximum
				10th	25th	50th	75th	90th		
Total Fish Fat Intake										
6 months	125	0.05	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.9
1 year	99	0.05	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.9
2 years	135	0.04	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.9
3 years	106	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	4.5
4 years	219	2.3	31.1	0.0	0.0	0.0	0.0	0.0	0.0	459.2
10 years	871	0.3	1.5	0.0	0.0	0.0	0.0	0.0	0.0	19.2
13 years	148	0.3	2.2	0.0	0.0	0.0	0.0	0.0	0.0	25.4
15 years	108	0.4	1.5	0.0	0.0	0.0	0.0	1.5	0.0	9.5
17 years	159	0.5	2.0	0.0	0.0	0.0	0.0	0.4	0.0	15.3

N = Sample size.
SD = Standard deviation.

Source: Frank et al., 1986.

Table 11-26. Fat Intake Among Children Based on Data from the Bogalusa Heart Study, 1973-1982 (g/kg-day)

Age	N	Mean	SD	Percentiles					Minimum	Maximum
				10th	25th	50th	75th	90th		
Total Fat Intake										
6 months	125	4.9	2.3	2.4	3.3	4.7	6.2	8.0	0.4	13.2
1 year	99	6.1	2.8	3.0	4.1	5.7	7.5	9.5	2.3	16.4
2 years	132	7.0	3.3	3.4	4.5	6.2	8.6	11.9	2.1	18.7
3 years	106	6.4	2.7	3.6	4.6	5.5	8.2	9.9	2.2	16.7
4 years	218	6.1	3.7	2.9	4.0	5.2	7.0	10.0	2.0	38.2
10 years	861	2.7	1.5	1.2	1.7	2.4	3.3	4.5	0.3	13.9
13 years	147	2.3	1.3	1.0	1.5	2.0	2.8	3.8	0.2	10.2
15 years	105	1.7	0.8	0.8	1.2	1.5	2.1	3.1	0.2	4.7
17 years	149	1.8	1.0	0.7	0.9	1.6	2.2	3.1	0.2	6.2
Total Animal Fat Intake										
6 months	125	2.4	2.1	0.08	0.6	2.0	3.7	5.5	0.0	9.0
1 year	99	3.8	2.1	1.7	2.4	3.4	4.9	6.5	0.0	13.6
2 years	132	4.0	2.3	1.7	2.3	3.4	5.2	6.7	0.7	13.4
3 years	106	3.5	2.0	1.6	2.1	3.1	4.2	6.1	0.9	13.1
4 years	218	3.1	2.1	1.3	1.7	2.6	4.0	5.4	0.4	15.4
10 years	861	16	1.2	0.6	0.8	1.3	1.9	2.8	0.00	10.8
13 years	147	1.2	0.9	0.4	0.6	0.9	1.6	2.3	0.08	5.2
15 years	105	1.0	0.6	0.3	0.5	0.8	1.3	1.9	0.01	3.1
17 years	149	1.0	0.8	0.3	0.5	0.8	1.4	2.0	0.05	4.2
Total Vegetable Fat Intake										
6 months	125	1.2	1.8	0.08	0.2	0.4	1.6	4.1	0.0	8.2
1year	99	1.6	1.6	0.4	0.6	1.2	1.9	3.8	0.02	7.6
2 years	132	1.6	1.4	0.3	0.7	1.1	2.0	3.5	0.06	8.5
3 years	106	1.5	1.1	0.3	0.6	1.4	2.0	3.0	0.08	5.1
4 years	218	1.5	1.2	0.4	0.6	1.2	2.1	2.8	0.06	7.3
10 years	861	0.7	0.6	0.1	0.3	0.5	0.9	1.4	0.02	4.2
13 years	147	0.8	0.8	0.2	0.4	0.6	0.9	1.3	0.0	8.6
15 years	105	0.5	0.4	0.09	0.2	0.4	0.7	0.9	0.01	2.2
17 years	149	0.4	0.4	0.07	0.2	0.4	0.6	0.9	0.0	2.1

Table 11-26. Fat Intake Among Children Based on Data from the Bogalusa Heart Study, 1973-1982 (g/kg-day) (continued)

Age	N	Mean	SD	Percentiles					Minimum	Maximum
				10th	25th	50th	75th	90th		
Total Fish Fat Intake										
6 months	125	0.01	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.1
1 year	99	0.01	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.2
2 years	132	0.003	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.2
3 years	106	0.01	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.3
4 years	218	0.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
10 years	861	0.01	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.6
13 years	147	0.01	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.4
15 years	105	0.01	0.03	0.0	0.0	0.0	0.0	0.04	0.0	0.2
17 years	149	0.01	0.03	0.0	0.0	0.0	0.0	0.008	0.0	0.2

N = Sample size.
SD = Standard deviation.

Source: Frank et al., 1986.

Table 11-27. Mean Total Daily Dietary Fat Intake (g/day) Grouped by Age and Gender[a]

Age Group	Total		Males		Females	
	N	Mean Fat Intake (g/day)	N	Mean Fat Intake (g/day)	N	Mean Fat Intake (g/day)
2 to 11months	871	37.5	439	38.3	432	36.8
1 to 2 years	1,231	50.0	601	51.6	630	48.4
3 to 5 year	1,647	60.4	744	62.3	803	57.7
6 to 11 years	1,745	74.2	868	79.4	877	69.0
12 to 16 years	711	85.2	338	98.1	373	71.3
16 to 19 years	785	100.5	308	123.2	397	77.5

[a] Total dietary fat intake includes all fat (i.e., saturated and unsaturated) derived from consumption of foods and beverages (excluding plain drinking water).

N = Sample size.

Source: Adapted from CDC, 1994.

Table 11-28. Mean Percent Moisture and Total Fat Content of Selected Meat and Dairy Products[a]			
Product	Moisture Content (%)	Total Fat Content (%)	Comment
	Meats		
Beef (composite of trimmed retail cuts; all grades)	70.62	6.16	Raw; lean only
	59.25	9.91	Cooked; lean only
	60.44	19.24	Raw; lean and fat, 1/4 in. fat trim
	51.43	21.54	Cooked; lean and fat, 1/4 in. fat trim
Pork (composite of trimmed retail cuts)	72.34	5.88	Raw; lean only
	60.31	9.66	Cooked; lean only
	65.11	14.95	Raw; lean and fat
	54.55	17.18	Cooked; lean and fat
Cured ham	63.46	12.90	Center slice, unheated; lean and fat
	55.93	8.32	Raw, center slice, country style; lean only
Cured bacon		45.04	Raw
		43.27	Cooked, baked
		41.78	Cooked, broiled
		40.30	Cooked, pan-fried
		37.27	Cooked, microwaved
Lamb (composite of trimmed retail cuts)	73.42	5.25	Raw; lean only
	61.96	9.52	Cooked; lean only
	60.70	21.59	Raw; lean and fat, 1/4 in. fat trim
	53.72	20.94	Cooked; lean and fat, 1/4 in. fat trim
Veal (composite of trimmed retail cuts)	75.91	2.87	Raw; lean only
	60.16	6.58	Cooked; lean only
	72.84	6.77	Raw; lean and fat, 1/4 in. fat trim
	57.08	11.39	Cooked; lean and fat, 1/4 in. fat trim
Rabbit (domesticated)	72.82	5.55	Raw
	60.61	8.05	Cooked, roasted
		8.41	Cooked, stewed
Chicken (broilers or fryers)	75.46	3.08	Raw; meat only
		6.71	Cooked, stewed; meat only
	63.79	7.41	Cooked, roasted; meat only
		9.12	Cooked, fried; meat only
	65.99	15.06	Raw; meat and skin
		12.56	Cooked, stewed; meat and skin
	59.45	13.60	Cooked, roasted; meat and skin
		14.92	Cooked, fried, flour; meat and skin
Duck (domesticated)	73.77	5.95	Raw; meat only
	64.22	11.20	Cooked, roasted; meat only
	48.50	39.34	Raw; meat and skin
	51.84	28.35	Cooked, roasted; meat and skin
Turkey (all classes)	74.16	2.86	Raw; meat only
	64.88	4.97	Cooked, roasted; meat only
	70.40	8.02	Raw; meat and skin
	61.70	9.73	Cooked, roasted; meat and skin
	71.97	8.26	Raw; ground
	59.42	13.15	Cooked; ground

Table 11-28. Mean Percent Moisture and Total Fat Content of Selected Meat and Dairy Products[a] (continued)

Product		Moisture Content (%)	Total Fat Content (%)	Comment
Dairy				
Milk				
	Whole	88.32	3.25	3.25% milkfat
	Human	87.50	4.38	Whole, mature, fluid
	Lowfat (1%)	89.81	0.97	Fluid, with added non-fat milk solids and vitamin A
	Reduced fat (2%)	88.86	1.92	Fluid, with added non-fat milk solids and vitamin A
	Skim or fat free	90.38	0.25	Fluid, with added non-fat milk solids and vitamin A
Cream				
	Half and half	80.57	11.50	Fluid
	Light (coffee cream or table cream)	73.75	19.31	Fluid
	Heavy-whipping	57.71	37.00	Fluid
	Sour	70.95	20.96	Cultured
	Sour, reduced fat	80.14	12.00	Cultured
Butter		15.87	81.11	Salted
Cheese				
	American	39.16	31.25	Pasteurized
	Cheddar	36.75	33.14	
	Swiss	37.12	27.80	
	Cream	53.75	34.87	
	Parmesan	29.16; 20.84	25.83; 28.61	Hard; grated
	Cottage, lowfat	82.48; 79.31	1.02; 1.93	1% fat; 2% fat
	Colby	38.20	32.11	
	Blue	42.41	28.74	
	Provolone	40.95	26.62	
	Mozzarella	50.01; 53.78	22.35; 15.92	Whole milk; Skim milk
Yogurt		85.07; 87.90	1.55; 3.25	Plain, lowfat; Plain, with fat
Eggs		75.84	9.94	Chicken, whole raw, fresh

[a] Based on the water and lipid content in 100 grams, edible portion. Total Fat Content = saturated, monosaturated and polyunsaturated. For additional information, consult the USDA nutrient database.

Source: USDA, 2007.

APPENDIX 11A

CODES AND DEFINITIONS USED TO DETERMINE THE VARIOUS MEATS AND DAIRY PRODUCTS USED IN THE U.S. EPA ANALYSIS OF CSFII DATA IN FCID

Table 11A-1 Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data

Food Category	**EPA Food Commodity Codes**			
Total Meats	21000440	Beef, meat	21000480	Beef, kidney
	21000441	Beef, meat-babyfood	21000490	Beef, liver
	21000450	Beef, meat, dried	21000491	Beef, liver-babyfood
	21000460	Beef, meat byproducts	23001690	Goat, meat
	21000461	Beef, meat byproducts-babyfood	23001700	Goat, meat byproducts
	21000470	Beef, fat	23001710	Goat, fat
	21000471	Beef, fat-babyfood	23001720	Goat, kidney
	23001730	Goat, liver	40000950	Chicken, meat byproducts
	24001890	Horse, meat	40000951	Chicken, meat byproducts-babyfood
	25002900	Pork, meat	40000960	Chicken, fat
	25002901	Pork, meat-babyfood	40000961	Chicken, fat-babyfood
	25002910	Pork, skin	40000970	Chicken, skin
	25002920	Pork, meat byproducts	40000971	Chicken, skin-babyfood
	25002921	Pork, meat byproducts-babyfood	50003820	Turkey, meat
	25002930	Pork, fat	50003821	Turkey, meat-babyfood
	25002931	Pork, fat-babyfood	50003830	Turkey, liver
	25002940	Pork, kidney	50003831	Turkey, liver-babyfood
	25002950	Pork, liver	50003840	Turkey, meat byproducts
	26003390	Sheep, meat	50003841	Turkey, meat byproducts-babyfood
	26003391	Sheep, meat-babyfood	50003850	Turkey, fat
	26003400	Sheep, meat byproducts	50003851	Turkey, fat-babyfood
	26003410	Sheep, fat	50003860	Turkey, skin
	26003411	Sheep, fat-babyfood	50003861	Turkey, skin-babyfood
	26003420	Sheep, kidney	60003010	Poultry, other, meat
	26003430	Sheep, liver	60003020	Poultry, other, liver
	28002210	Meat, game	60003030	Poultry, other, meat byproducts
	29003120	Rabbit, meat	60003040	Poultry, other, fat
	40000930	Chicken, meat	60003050	Poultry, other, skin
	40000931	Chicken, meat-babyfood		
	40000940	Chicken, liver		
Total Dairy	27002220	Milk, fat	27022241	Milk, water-babyfood/infant formula
	27002221	Milk, fat - baby food/infant formula	27032251	Milk, sugar (lactose)-baby food/infant formula
	27012230	Milk, non-fat solids		
	27012231	Milk, non-fat solids-baby food/infant formula		
	27022240	Milk, water		

Table 11A-1 Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data (continued)

Food Category	**EPA Food Commodity Codes**			
Beef	21000440	Beef, meat	21000470	Beef, fat
	21000441	Beef, meat-babyfood	21000471	Beef, fat-babyfood
	21000450	Beef, meat, dried	21000480	Beef, kidney
	21000460	Beef, meat byproducts	21000490	Beef, liver
	21000461	Beef, meat byproducts-babyfood	21000491	Beef, liver-babyfood
Eggs	70001450	Egg, whole	70001461	Egg, white (solids)-babyfood
	70001451	Egg, whole-babyfood	70001470	Egg, yolk
	70001460	Egg, white	70001471	Egg, yolk-babyfood
Pork	25002900	Pork, meat	25002930	Pork, fat
	25002901	Pork, meat-babyfood	25002931	Pork, fat-babyfood
	25002910	Pork, skin	25002940	Pork, kidney
	25002920	Pork, meat byproducts	25002950	Pork, liver
	25002921	Pork, meat byproducts-babyfood		
Poultry	40000930	Chicken, meat	50003831	Turkey, liver-babyfood
	40000931	Chicken, meat-babyfood	50003840	Turkey, meat byproducts
	40000940	Chicken, liver	50003841	Turkey, meat byproducts-babyfood
	40000950	Chicken, meat byproducts	50003850	Turkey, fat
	40000951	Chicken, meat byproducts-babyfood	50003851	Turkey, fat-babyfood
	40000960	Chicken, fat	50003860	Turkey, skin
	40000961	Chicken, fat-babyfood	50003861	Turkey, skin-babyfood
	40000970	Chicken, skin	60003010	Poultry, other, meat
	40000971	Chicken, skin-babyfood	60003020	Poultry, other, liver
	50003820	Turkey, meat	60003030	Poultry, other, meat byproducts
	50003821	Turkey, meat-babyfood	60003040	Poultry, other, fat
	50003830	Turkey, liver	60003050	Poultry, other, skin

APPENDIX 11B

SAMPLE CALCULATION OF MEAN DAILY FAT INTAKE BASED ON CDC (1994) DATA

Sample Calculation of Mean Daily Fat Intake Based on CDC (1994) Data

CDC (1994) provided data on the mean daily total food energy intake (TFEI) and the mean percentages of TFEI from total dietary fat grouped by age and gender. The overall mean daily TFEI was 2,095 kcal for the total population and 34 percent (or 82 g) of their TFEI was from total dietary fat (CDC, 1994). Based on this information, the amount of fat per kcal was calculated as shown in the following example.

$$0.34 \times 2{,}095\ \frac{\text{kcal}}{\text{day}} \times X\ \frac{\text{g} - \text{fat}}{\text{day}} = 82\ \frac{\text{g} - \text{fat}}{\text{day}}$$

$$\therefore\ X = 0.12\ \frac{\text{g} - \text{fat}}{\text{kcal}}$$

where 0.34 is the fraction of fat intake, 2,095 is the total food intake, and X is the conversion factor from kcal/day to g-fat/day.

Using the conversion factor shown above (i.e., 0.12 g-fat/kcal) and the information on the mean daily TFEI and percentage of TFEI for the various age/gender groups, the daily fat intake was calculated for these groups. An example of obtaining the grams of fat from the daily TFEI (1,591 kcal/day) for children ages 3-5 years and their percent TFEI from total dietary fat (33 percent) is as follows:

$$1{,}591\ \frac{\text{kcal}}{\text{day}} \times 0.33 \times 0.12\ \frac{\text{g} - \text{fat}}{\text{kcal}} = 63\ \frac{\text{g} - \text{fat}}{\text{day}}$$

12 INTAKE OF GRAIN PRODUCTS

12.1 INTRODUCTION

The American food supply is generally considered to be one of the safest in the world. Nevertheless, grain products may become contaminated with toxic chemicals by several different pathways. Ambient air pollutants may be deposited on or absorbed by the plants, or dissolved in rainfall or irrigation waters that contact the plants. Pollutants may also be absorbed through plant roots from contaminated soil and ground water. The addition of pesticides, soil additives, and fertilizers may also result in contamination of grain products. To assess exposure through this pathway, information on ingestion rates of grain products are needed.

Children's exposure from contaminated foods may differ from that of adults because of differences in the type and amounts of food eaten. Also, for many foods, the intake per unit body weight is greater for children than for adults. Common grain products eaten by children include milled rice, oats, and wheat flour (Goldman, 1995).

A variety of terms may be used to define intake of grain products (e.g., consumer-only intake, per capita intake, total grain intake, as-consumed intake, dry weight intake). As described in Chapter 9, Intake of Fruits and Vegetables, consumer-only intake is defined as the quantity of grain products consumed by children during the survey period. These data are generated by averaging intake across only the children in the survey who consumed these food items. Per capita intake rates are generated by averaging consumer-only intakes over the entire population of children (including those children that reported no intake). In general, per capita intake rates are appropriate for use in exposure assessments for which average dose estimates for children are of interest because they represent both children who ate the foods during the survey period and children who may eat the food items at some time, but did not consume them during the survey period. Per capita intake, therefore, represents an average across the entire population of interest, but does so at the expense of underestimating consumption for the subset of the population that consumed the food in question. Total grain intake refers to the sum of all grain products consumed in a day.

Intake rates may be expressed on the basis of the as-consumed weight (e.g., cooked or prepared) or on the uncooked or unprepared weight. As-consumed intake rates are based on the weight of the food in the form that it is consumed and should be used in assessments where the basis for the contaminant concentrations in foods is also indexed to the as-consumed weight. The food ingestion values provided in this chapter are expressed as as-consumed intake rates because this is the fashion in which data were reported by survey respondents. This is of importance because concentration data to be used in the dose equation are often measured in uncooked food samples. It should be recognized that cooking can either increase or decrease food weight. Similarly, cooking can increase the mass of contaminant in food (due to formation reactions, or absorption from cooking oils or water) or decrease the mass of contaminant in food (due to vaporization, fat loss or leaching). The combined effects of changes in weight and changes in contaminant mass can result in either an increase or decrease in contaminant concentration in cooked food. Therefore, if the as-consumed ingestion rate and the uncooked concentration are used in the dose equation, dose may be under-estimated or over-estimated. Ideally, after-cooking food concentrations should be combined with the as-consumed intake rates. In the absence of data, it is reasonable to assume that no change in contaminant concentration occurs after cooking. It is important for the assessor to be aware of these issues and choose intake rate data that best match the concentration data that are being used. For more information on cooking losses and conversions necessary to account for such losses, the reader is referred to Chapter 13 of this handbook.

Sometimes contaminant concentrations in food are reported on a dry weight basis. When these data are used in an exposure assessment, it is recommended that dry-weight intake rates also be used. Dry-weight food concentrations and intake rates are based on the weight of the food consumed after the moisture content has been removed. For information on converting the intake rates presented in this chapter to dry weight intake rates, the reader is referred to Section 12.4.

The purpose of this chapter is to provide intake data for grain products among children. The recommendations for ingestion rates of grain products are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on the key study identified by U.S. EPA for this factor. Following the recommendations, the key study on ingestion of grain products is summarized. Relevant data on ingestion of grain products are also provided. These data are presented to provide the reader with added perspective on the current state-of-knowledge pertaining to ingestion of grain products among children.

12.2 RECOMMENDATIONS

Table 12-1 presents a summary of the recommended values for per capita and consumer-only intake of grain products, on an as- consumed basis. Confidence ratings for the grain intake recommendations for general population children are provided in Table 12-2.

The U.S. EPA analysis of data from the 1994-96 and 1998 Continuing Survey of Food Intake among Individuals (CSFII) was used in selecting recommended intake rates for general population children. The U.S. EPA analysis was conducted using age groups that differed slightly from U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). However, for the purposes of the recommendations presented here, data were placed in the standardized age categories closest to those used in the analysis. Also, the CSFII data on which the recommendations are based are short-term survey data and may not necessarily reflect the long-term distribution of average daily intake rates. However, for broad categories of food (i.e., total grains), because they are eaten on a daily basis throughout the year with minimal seasonality, the short term distribution may be a reasonable approximation of the long-term distribution, although it will display somewhat increased variability. This implies that the upper percentiles shown here will tend to overestimate the corresponding percentiles of the true long-term distribution. It should also be noted that because these recommendations are based on 1994-96 and 1998 CSFII data, they may not reflect the most recent changes that may have occurred in consumption patterns. More current data from the National Health and Nutrition Survey (NHANES) will be incorporated as the data become available and are analyzed.

Table 12-1. Recommended Values for Intake of Grains, As Consumed[a]						
Age Group	Per Capita		Consumers Only		Multiple Percentiles	Source
	Mean	95th Percentile	Mean	95th Percentile		
	g/kg-day	g/kg-day	g/kg-day	g/kg-day		
Total Grains						
Birth to 1 year	2.5	8.6	3.6	9.2	See Tables 12-3 and 12-4	U.S. EPA Analysis of CSFII, 1994-96 and 1998.
1 to <2 years	6.4	12	6.4	12		
2 to <3 years	6.4	12	6.4	12		
3 to <6 years	6.3	12	6.3	12		
6 to <11 years	4.3	8.2	4.3	8.2		
11 to <16 years	2.5	5.1	2.5	5.1		
16 to <21 years	2.5	5.1	2.5	5.1		
Individual Grain Products - See Tables 12-5 and 12-6						

[a] Analysis was conducted using slightly different age groups than those recommended in *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA. 2005). Data were placed in the standardized age categories closest to those used in the analysis.

Table 12-2. Confidence in Recommendations for Intake of Grain Products

General Assessment Factors	Rationale	Rating
Soundness		High
Adequacy of Approach	The survey methodology and data analysis was adequate. The survey sampled more than 11,000 individuals up to age 18 years. An analysis of primary data was conducted.	
Minimal (or defined) Bias	No physical measurements were taken. The method relied on recent recall of grain products eaten.	
Applicability and Utility		Medium
Exposure Factor of Interest	The key study was directly relevant to grain intake.	
Representativeness	The data were demographically representative of the U.S. population (based on stratified random sample).	
Currency	Data were collected between 1994 and 1998.	
Data Collection Period	Data were collected for two non-consecutive days.	
Clarity and Completeness		High
Accessibility	The CSFII data are publicly available.	
Reproducibility	The methodology used was clearly described; enough information was included to reproduce the results.	
Quality Assurance	Quality assurance of the CSFII data was good; quality control of the secondary data analysis was not well described.	
Variability and Uncertainty		Medium
Variability in Population	Full distributions were provided for total grains. Means were provided for individual grain products.	
Minimal Uncertainty	Data collection was based on recall for a 2-day period; the accuracy of using these data to estimate long-term intake (especially at the upper percentiles) is uncertain. However, use of short-term data to estimate chronic ingestion can be assumed for broad categories of foods such as total grains. Uncertainty is likely to be greater for individual grain products.	

Table 12-2. Confidence in Recommendations for Intake of Grain Products (continued)

General Assessment Factors	Rationale	Rating
Evaluation and Review		Medium
Peer Review	The USDA CSFII survey received a high level of peer review. The U.S. EPA analysis of these data has not been peer reviewed outside the Agency.	
Number and Agreement of Studies	There was 1 key study.	
Overall Rating		**High** confidence in the averages; **Low** confidence in the long-term upper percentiles

12.3 INTAKE STUDIES

The primary source of recent information on consumption rates of grain products among children is the U.S. Department of Agriculture's (USDA) CSFII. Data from the 1994-96 CSFII and the 1998 children's supplement to the 1994-96 CSFII have been used in various studies to generate children's consumer-only and per capita intake rates for both individual grain products and total grains. The CSFII is a series of surveys designed to measure the kinds and amounts of foods eaten by Americans. The CSFII 1994-96 was conducted between January 1994 and January 1997 with a target population of non-institutionalized individuals in all 50 states and Washington, D.C. In each of the 3 survey years, data were collected for a nationally representative sample of individuals of all ages. The CSFII 1998 was conducted between December 1997 and December 1998 and surveyed children 9 years of age and younger. It used the same sample design as the CSFII 1994-96 and was intended to be merged with CSFII 1994-96 to increase the sample size for children. The merged surveys are designated as CSFII 1994-96, 1998. Additional information on these surveys can be obtained at http://www.ars.usda.gov/Services/docs.htm?docid=14531.

The CSFII 1994-96, 1998 collected dietary intake data through in-person interviews on 2 non-consecutive days. The data were based on 24-hour recall. A total of 21,662 individuals provided data for the first day; of those individuals, 20,607 provided data for a second day. Over 11,000 of the sample persons represented children up to 18 years of age. The 2-day response rate for the 1994-1996 CSFII was approximately 76 percent. The 2-day response rate for CSFII 1998 was 82 percent.

The CSFII 1994-96, 98 surveys were based on a complex multistage area probability sample design. The sampling frame was organized using 1990 U.S. population census estimates, and the stratification plan took into account geographic location, degree of urbanization, and socioeconomic characteristics. Several sets of sampling weights are available for use with the intake data. By using appropriate weights, data for all fours years of the surveys can be combined. USDA recommends that all 4 years be combined in order to provide an adequate sample size for children.

12.3.1 Key Grain Intake Study

12.3.1.1 *U.S. EPA Analysis of CSFII 1994-96, 1998*

For many years, the U.S. EPA's Office of Pesticide Programs (OPP) has used food consumption data collected by the U.S. Department of Agriculture (USDA) for its dietary risk assessments. Most recently, OPP, in cooperation with USDA's Agricultural Research Service (ARS), used data from the 1994-96, 1998 CSFII to develop the Food Commodity Intake Database (FCID). CSFII data on the foods people reported eating were converted to the quantities of agricultural commodities eaten. "Agricultural commodity" is a term used by U.S. EPA to mean plant (or animal) parts consumed by humans as food; when such items are raw or unprocessed, they are referred to as "raw agricultural commodities." For example, an apple pie may contain the commodities apples, flour, fat, sugar and spices. FCID contains approximately 553 unique commodity names and 8-digit codes. The FCID commodity names and codes were selected and defined by U.S. EPA and were based on the U.S. EPA Food Commodity Vocabulary (http://www.epa.gov/pesticides/foodfeed/).

The grain items/groups selected for the U.S. EPA analysis included total grains, and individual grain products such as cereal and rice. Appendix 12A presents the food codes and definitions used to determine the various grain products used in the analysis. Intake rates for these food items/groups represent intake of all forms of the product (e.g., both home produced and commercially produced). Children who provided data for two days of the survey were included in the intake estimates. Individuals who did not provide information on body weight or for whom identifying information was unavailable were excluded from the analysis. Two-day average intake rates were calculated for all individuals in the database for each of the food items/groups. These average daily intake rates were divided by each individual's reported body weight to generate intake rates in units of grams per kilogram of body weight per day (g/kg-day). The data were weighted according to the four-year, two-day sample weights provided in the 1994-96, 1998 CSFII to adjust the data for the sample population to reflect the national population.

Summary statistics were generated on both a per capita and a consumer only basis. For per capita intake, both users and non-users of the food item were included in the analysis. Consumer-only intake rates were calculated using data for only those individuals who ate the food item of interest during the survey period. Intake data from the CSFII are based on as-consumed (i.e., cooked or prepared) forms of the food items/groups. Summary statistics, including: number of observations, percentage of the population consuming the grain product being analyzed, mean intake rate, and standard error of the mean intake rate were calculated for total grains and selected individual grain products. Percentiles of the intake rate distribution (i.e., 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, 99th, and 100th percentile were also provided for total grains. Data were provided for the following age groups of children: birth to <1 year, 1 to <2 years, 3 to <5 years, 6 to <12 years, and 13 to <19 years. Because these data were developed for use in U.S. EPA's pesticide registration program, the age groups used are slightly different than those recommended in U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005).

Table 12-3 presents as-consumed per capita intake data for total grains in g/kg-day; as-consumed consumer only intake data for total grains in g/kg-day are provided in Table 12-4. Table 12-5 provides per capita intake data for individual grain products and Table 12-6 provides consumer only intake data for individual grain products.

It should be noted that the distribution of average daily intake rates generated using short-term data (e.g., 2-day) do not necessarily reflect the long-term distribution of average daily intake rates. The distributions generated from short-term and long-term data will differ to the extent that each individual's intake varies from day to day; the distributions will be similar to the extent that individuals' intakes are constant from day to day. However, for broad categories of foods (e.g., total grains) that are eaten on a daily basis throughout the year, the short-term distribution may be a reasonable approximation of the true long-term distribution, although it will show somewhat more variability. In this chapter, distributions are provided only for total grains. Because of the increased variability of the short-term distribution, the short-term upper percentiles shown here may overestimate the corresponding percentiles of the long-term distribution. For individual grains, only the mean, standard error, and percent consuming are provided.

The strengths of U.S. EPA's analysis are that it provides distributions of intake rates for various age groups of children, normalized by body weight. The analysis uses the 1994-96, 1998 CSFII data set which was designed to be representative of the U.S. population. The data set includes four years of intake data combined, and is based on a two-day survey period. As discussed above, short-term dietary data may not accurately reflect long-term eating patterns and may under-represent infrequent consumers of a given food. This is particularly true for the tails (extremes) of the distribution of food intake. Also, the analysis was conducted using slightly different age groups that those recommended in U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). However, given the similarities in the age groups used, the data should provide suitable intake estimates for the age groups of interest.

12.3.2 Relevant Grain Intake Studies

12.3.2.1 *USDA, 1999 - Food and Nutrient Intakes by Children 1994-96, 1998, Table Set 17*

USDA (1999) calculated national probability estimates of food and nutrient intake by children based on all 4 years of the CSFII (1994-96 and 1998) for children age 9 years and under, and on CSFII 1994-96 only for individuals age 10 years and over. Sample weights were used to adjust for non-response, to match the sample to the U.S. population in terms of demographic characteristics, and to equalize intakes over the 4 quarters of the year and the 7 days of the week. A total of 503 breast-fed children were excluded from the estimates, but both consumers and non-consumers were included in the analysis.

USDA (1999) provided data on the mean per capita quantities (grams) of various food products/groups consumed per individual for one day, and the percent of individuals consuming those foods in one day of the survey. Tables 12-7 and 12-8 present data on the mean quantities (grams) of grain products consumed per individual for one day, and the percentage of survey individuals consuming grain products that survey day. Data on mean intakes or mean percentages are based on respondents' day-1 intakes.

The advantages of USDA (1999) study is that it uses the 1994-96, 98 CSFII data set, which includes four years of intake data, combined, and includes the supplemental data on children. These data are expected to be generally representative of the U.S. population and they include data on a wide variety of grain products. The data set is one of a series of USDA data sets that are publicly available. One limitation of this data set is that it is based on one-day, and short-term dietary data may not accurately reflect long-term eating patterns. Other limitations of this study are that it only provides mean values of food intake rates, consumption is not normalized by body weight, and presentation of results is not consistent with U.S. EPA's recommended age groups.

12.3.2.2 *Smiciklas-Wright et al., 2002 - Foods Commonly Eaten in the United States: Quantities Consumed per Eating Occasion and in a Day, 1994-1996*

Using data gathered in the 1994-96 USDA CSFII, Smiciklas-Wright et al. (2002) calculated distributions for the quantities of grain products consumed per eating occasion by members of the U.S. population (i.e., serving sizes). The estimates of serving size are based on data obtained from 14,262 respondents, ages 2 and above, who provided 2 days of dietary intake information. A total of 4,939 of these respondents were children, ages 2 to 19 years of age. Only dietary intake data from users of the specified food were used in the analysis (i.e., consumers only data).

Table 12-9 presents serving size data for selected grain products. These data are presented on an as-consumed basis (grams) and represent the quantity of grain products consumed per eating occasion. These estimates may be useful for assessing acute exposures to contaminants in specific foods, or other assessments where the amount consumed per eating occasion is necessary. Only the mean and standard deviation serving size data and percent of the population consuming the food during the 2-day survey period are presented in this handbook. Percentiles of serving sizes of the foods consumed by these age groups of the U.S. population can be found in Smiciklas-Wright et al. (2002).

The advantages of using these data are that they were derived from the USDA CSFII and are representative of the U.S. population. The analysis conducted by Smiciklas-Wright et al. (2002) accounted for individual foods consumed as ingredients of mixed foods. Mixed foods were disaggregated via recipe files so that the individual ingredients could be grouped together with similar foods that were reported separately. Thus, weights of foods consumed as ingredients were combined with weights of foods reported separately to provide a more thorough representation of consumption. However, it should be noted that since the recipes for the mixed foods consumed were not provided by the respondents, standard recipes were used. As a result, the estimates of quantity consumed for some food types are based on assumptions about the types and quantities of ingredients consumed as part of mixed foods. This study used data from the 1994 to 1996 CSFII; data from the 1998 children's supplement were not included.

12.3.2.3 *Fox et al., 2004 - Feeding Infants and Toddlers study: What Foods Are Infants and Toddlers Eating*

Fox et al. (2004) used data from the Feeding Infants and Toddlers study (FITS) to assess food consumption patterns in infants and toddlers. The FITS was sponsored by Gerber Products Company and was conducted to obtain current information on food and nutrient intakes of children, ages 4 to 24 months old, in the 50 states and the District of Columbia. The FITS is described in detail in Devaney et al. (2004). FITS was based on a random sample of 3,022 infants and toddlers for which dietary intake data were collected by telephone from their parents or caregivers between March and July 2002. An initial recruitment and household interview was conducted, followed by an interview to obtain information on intake based on 24-hour recall. The interview also addressed growth, development and feeding patterns. A second dietary recall interview was conducted for a subset of 703 randomly selected respondents. The study over-sampled children in the 4 to 6 and 9 to11 months age groups; sample weights were adjusted for non-response, over sampling , and under coverage of some subgroups. The response rate for the FITS was 73 percent for the recruitment interview. Of the recruited households, there was a response rate of 94 percent for the dietary recall interviews (Devaney et al., 2004). The characteristics of the FITS study population is shown in Table 12-10.

Fox et al. (2004) analyzed the first set of 24-hour recall data collected from all study participants. For this analysis, children were grouped into six age categories: 4 to 6 months, 7 to 8 months, 9 to 11 months, 12 to 14 months, 15 to 18 months, and 19 to 24 months. Table 12-11 provides the percentage of infants and toddlers consuming different types of grains or grain products at least once in a day. The percentages of children eating any type of grain or grain product ranged from 65.8 percent for 4 to 6 month olds to 99.2 percent for 19 to 24 month olds.

The advantages of this study were that the study population represents the U.S. population and the sample size was large. One limitation of the analysis done by Fox et al. (2004) is that only frequency data were provided; no information on actual intake rates was included. In addition, Devaney et al (2004) noted several limitations associated with the FITS data. For the FITS, a commercial list of infants and toddlers was used to obtain the sample used in the study. Since many of the households could not be located and did not have children in the target population, a lower response rate than would have occurred in a true national sample was obtained (Devaney et al., 2004). In addition, the sample was likely from a higher socioeconomic status when compared with all U.S. infants in this age group (4 to 24 months old) and the use of a telephone survey may have omitted lower-income households without telephones (Devaney et al., 2004).

12.3.2.4 *Ponza et al., 2004 - Nutrient Food Intakes and Food Choices of Infants and Toddlers Participating in WIC*

Ponza et al. (2004) conducted a study using selected data from the FITS to assess feeding patterns, food choices and nutrient intake of infants and toddlers participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC). Ponza et al. (2004) evaluated FITS data for the following age groups: 4 to 6 months (N = 862), 7 to 11 months (N = 1,159) and 12 to 24 months (N= 996). The total sample size described by WIC participants and non-participants is shown in Table 12-12.

The foods consumed were analyzed by tabulating the percentage of infants who consumed specific foods/food groups per day (Ponza et al., 2004). Weighted data were used in all of the analyses used in the study (Ponza et al., 2004). Table 12-12 presents the demographic data for WIC participants and non-participants. Table 12-13 provides information on the food choices for the infants and toddlers studied. In general, there was little difference in grain product choices among WIC participants and non-participants, except for the 7 to 11 months age category (Table 12-13). Nonparticipants, ages 7 to 11 months, were more likely to eat non-infant cereals than WIC participants.

An advantage of this study is that it had a relatively large sample size and was representative of the U.S. general population of infants and children. A limitation of the study is that intake values for foods were not provided. Other limitations are those associated with the FITS data, as described previously in Section 12.3.2.3.

12.3.2.5 *Mennella et al., 2006 - Feeding Infants and Toddlers Study: The Types of Foods Fed to Hispanic Infants and Toddlers*

Menella et al. (2006) investigated the types of food and beverages consumed by Hispanic infants and toddlers in comparison to the non-Hispanic infants and toddlers in the United States. The FITS 2002 data for children between 4 and 24 months of age were used for the study. The data represent a random sample of 371 Hispanic and 2,367 non-Hispanic infants and toddlers (Menella et al., 2006). Menella et al. (2006) grouped the infants as follows: 4 to 5 months (N = 84 Hispanic; 538 non-Hispanic), 6 to 11 months (N = 163 Hispanic and 1,228 non-Hispanic), and 12 to 24 months (N = 124 Hispanic and 871 non-Hispanic) of age.

Table 12-14 provides the percentage of Hispanic and non-Hispanic infants and toddlers consuming grain products. In most instances the percentages consuming the different types are similar. However, 6 to 11 month old Hispanic children were more likely to eat rice and pasta than non-Hispanic children in this age groups.

The advantage of the study is that it

provides information on food preferences for Hispanic and non-Hispanic infants and toddlers. A limitation is that the study did not provide food intake data, but provided frequency of use data instead. Other limitations are those noted previously in Section 12.3.2.3 for the FITS data.

12.3.2.6 *Fox et al., 2006 - Average Portion of Foods Commonly Eaten by Infants and Toddlers in the United States*

Fox et al. (2006) estimated average portion sizes consumed per eating occasion by children 4 to 24 months of age who participated in the FITS. The FITS is a cross-sectional study designed to collect and analyze data on feeding practices, food consumption, and usual nutrient intake of U.S. infants and toddlers and is described in Section 12.3.2.3 of this chapter. It included a stratified random sample of 3,022 children between 4 and 24 months of age.

Using the 24-hour recall data, Fox et al. (2006) derived average portion sizes for six major food groups, including breads and grains. Average portion sizes for select individual foods within these major groups were also estimated. For this analysis, children were grouped into six age categories: 4 to 5 months, 6 to 8 months, 9 to 11 months, 12 to 14 months, 15 to 18 months, and 19 to 24 months. Tables 12-15 and 12-16 present the average portion sizes for grain products for infants and toddlers, respectively.

12.4 CONVERSION BETWEEN WET AND DRY WEIGHT INTAKE RATES

The intake data presented in this chapter are reported in units of wet weight (i.e., as-consumed or uncooked weight of grain products consumed per day or per eating occasion). However, data on the concentration of contaminants in grain products may be reported in units of either wet or dry weight (e.g., mg contaminant per gram dry-weight of grain products.). It is essential that exposure assessors be aware of this difference so that they may ensure consistency between the units used for intake rates and those used for concentration data (i.e., if the contaminant concentration is measured in dry weight of grain products, then the dry weight units should be used for their intake values).

If necessary, wet weight (e.g., as consumed) intake rates may be converted to dry weight intake rates using the moisture content percentages presented in Table 12-17 and the following equation:

$$IR_{dw} = IR_{ww}\left[\frac{100-W}{100}\right] \qquad \text{(Eqn. 12-1)}$$

where:

IR_{dw} = dry weight intake rate;
IR_{ww} = wet weight intake rate; and
W = percent water content

Alternatively, dry weight residue levels in grain products may be converted to wet weight residue levels for use with wet weight (e.g., as-consumed) intake rates as follows:

$$C_{ww} = C_{dw}\left[\frac{100-W}{100}\right] \qquad \text{(Eqn. 12-2)}$$

where:

C_{ww} = wet weight intake rate;
C_{dw} = dry weight intake rate; and
W = percent water content.

The moisture data presented in Table 12-17 are for selected grain products taken from USDA (2007).

12.5 REFERENCES FOR CHAPTER 12

Devaney, B.; Kalb, L.; Briefel, R.; Zavitsky-Novak, T.; Clusen, N.; Ziegler, P. (2004) Feeding infants and toddlers study: overview of the study design. J Am Diet Assoc 104(Suppl 1): S8-S13.

Fox, M.K.; Pac, S.; Devaney, B.; Jankowski, L. (2004) Feeding infants and toddlers study: what foods are infants and toddlers eating. J Am Diet Assoc 104 (Suppl): S22-S30.

Fox, M.K.; Reidy, K.; Karwe, V.; Ziegler, P. (2006) Average portions of foods commonly eaten by infants and toddlers in the United States. J Am Diet Assoc 106 (Suppl 1): S66-S76.

Goldman, L. (1995) Children - unique and vulnerable. Environmental risks facing children and recommendations for response. Environ Health Perspect 103(6):13-17.

Mennella, J.; Ziegler, P.; Briefel, R.; Novak, T. (2006) Feeding infants and toddlers study: the types of foods fed to Hispanic infants and toddlers. J Am Diet Assoc 106 (Suppl 1): S96.

Ponza, M.; Devaney, B.; Ziegler, P.; Reidy, K.; Squatrito, C. (2004) Nutrient intakes and food choices of infants and toddlers participating in WIC. J Am Diet Assoc 104 (Suppl): S71-S79.

Smiciklas-Wright, H.; Mitchell, D.C.; Mickle, S.J.; Cook, A.J.; Goldman, J.D. (2002) Foods commonly eaten in the United States: Quantities consumed per eating occasion and in a day, 1994-1996. U.S. Department of Agriculture NFS Report No. 96-5, pre-publication version, 252 pp.

USDA. (1999) Food and nutrient intakes by children 1994-96, 1998: Table Set 17. Beltsville, MD: Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture.

USDA. (2007) USDA National Nutrient Database for Standard Reference, Release 20. Agricultural Research Service, Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl

U.S. EPA. (2005) Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants. U.S. Environmental Protection Agency, Washington, D.C., EPA/630/P-03/003F.

Table 12-3. Per Capita Intake of Total Grains (g/kg-day as consumed)														
Age Group	N	Percent Consuming	Mean	SE	Percentiles									
					1st	5th	10th	25th	50th	75th	90th	95th	99th	100th
Birth to 1 year	1,486	70.5	2.5	0.1	0.0	0.0	0.0	0.0	1.6	3.8	6.2	8.6	12.7	26.3
1 to 2 years	2,096	99.8	6.4	0.1	1.1	2.1	2.8	4.2	5.9	7.9	10.4	12.1	16.8	31.6
3 to 5 years	4,391	100.0	6.3	0.1	1.8	2.6	3.2	4.3	5.9	7.8	9.9	11.5	15.6	27.0
6 to 12 years	2,089	100.0	4.3	0.1	0.9	1.7	2.0	2.8	4.0	5.4	7.0	8.2	11.1	17.2
13 to 19 years	1,222	100.0	2.5	0.05	0.4	0.8	1.1	1.5	2.3	3.1	4.4	5.1	7.9	12.4

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 12-4. Consumer Only Intake of Total Grains (g/kg-day as consumed)													
Age Group	N	Mean	SE	Percentiles									
				1st	5th	10th	25th	50th	75th	90th	95th	99th	100th
Birth to 1 year	1,048	3.6	0.1	0.1	0.3	0.6	1.4	2.8	4.8	7.4	9.2	13.4	26.3
1 to 2 years	2,092	6.4	0.1	1.2	2.1	2.8	4.2	5.9	7.9	10.4	12.1	16.8	31.6
3 to 5 years	4,389	6.3	0.1	1.8	2.6	3.2	4.3	5.9	7.8	9.9	11.5	15.6	27.0
6 to 12 years	2,089	4.3	0.1	0.9	1.7	2.0	2.8	4.0	5.4	7.0	8.2	11.1	17.2
13 to 19 years	1,222	2.5	0.05	0.4	0.8	1.1	1.5	2.3	3.1	4.4	5.1	7.9	12.4

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 12-5. Per Capita Intake of Individual Grain Products (g/kg-day as consumed)

Age Group	N	Cereal			Rice		
		Percent Consuming	Mean	SE	Percent Consuming	Mean	SE
Birth to 1 year	1,486	74.6	4.0	0.14	60.2	0.74	0.04
1 to 2 years	2,096	99.8	8.4	0.08	86.4	0.57	0.03
3 to 5 years	4,391	100.0	8.7	0.07	87.9	0.50	0.03
6 to 12 years	2,089	100.0	6.2	0.06	88.0	0.35	0.02
13 to 19 years	1,222	100.0	4.1	0.06	85.8	0.27	0.02

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII .

Table 12-6. Consumer Only Intake of Individual Grain Products (g/kg-day as consumed)

Age Group	Cereal			Rice		
	N	Mean	SE	N	Mean	SE
Birth to 1 year	1,116	5.4	0.16	900	1.23	0.07
1 to 2 years	2,092	8.4	0.08	1,819	0.67	0.04
3 to 5 years	4,389	8.7	0.07	3,869	0.57	0.03
6 to 12 years	2,089	6.2	0.06	1,847	0.40	0.02
13 to 19 years	1,222	4.1	0.06	1,038	0.31	0.03

N = Sample size.
SE = Standard error.

Source: Based on unpublished U.S. EPA analysis of 1994-96, 1998 CSFII .

Table 12-7. Mean Quantities of Grain Products Consumed Daily by Sex and Age, Per Capita (g/day)

Age Group	Sample Size	Total	Yeast, breads, and rolls	Cereals and Pasta				Quick breads, pancakes, French toast	Cakes, cookies, pastries, pies	Crackers, popcorn, pretzels, corn chips	Mixtures, mainly grain
				Total	Ready-to-eat cereals	Rice	Pasta				
Males and Females											
Under 1year	1,126	56	2	2	1	2	1[a]	1	3	1	20
1 year	1,016	192	16	16	11	9	9	9	16	7	87
2 years	1,102	219	26	26	16	15	12	12	22	9	87
1 to 2 years	2,118	206	21	21	13	12	11	11	19	8	87
3 years	1,831	242	30	30	19	13	12	16	23	11	98
4 years	1,859	264	36	36	22	15	11	17	30	13	102
5 years	884	284	41	41	24	17	11	15	33	13	107
3 to 5 years	4,574	264	36	36	22	15	11	16	29	12	102
5 years and under	7,818	219	27	27	16	13	10	12	22	9	87
Males											
6 to 9 years	787	310	45	77	28	18	15	23	39	16	109
6 to 11 years	1,031	318	46	80	31	16	18	23	40	15	115
2 to 19 years	737	406	54	82	29	27	17	26	49	19	175
Females											
6 to 9 years	704	284	43	61	21	12	15	18	42	13	107
6 to 11 years	969	280	43	62	20	14	15	19	42	14	101
12 to 19 years	732	306	40	67	17	19	22	15	37	15	132
Males and Females											
9 years and under	9,309	250	34	64	20	14	12	16	30	12	96
19 years and under	11,287	298	40	69	22	17	15	18	36	14	120

[a] Estimate is not statistically reliable due to small sample size reporting intake.

Note: Consumption amounts shown are representative of the first day of each participant's survey response.

Source: USDA, 1999.

Table 12-8. Percentage of Individuals Consuming Grain Products, by Sex and Age (%)

Age Group	Sample Size	Total	Yeast, breads, and rolls	Cereals and Pasta				Quick breads, pancakes, French toast	Cakes, cookies, pastries, pies	Crackers, popcorn, pretzels, corn chips	Mixtures, mainly grain
				Total	Ready-to-eat cereals	Rice	Pasta				
Males and Females											
Under 1 year	1,126	70.6	10.9	62.8	9.1	3.4	2.1	4.4	16.5	10.3	15.0
1 year	1,016	98.2[a]	48.4	70.6	45.3	11.3	9.4	23.0	47.0	39.0	47.8
2 years	1,102	99.0[a]	58.7	71.1	51.9	14.4	9.4	27.5	46.6	37.9	45.3
1 to 2 years	2,118	98.7	53.7	70.9	48.7	12.9	9.4	25.3	46.8	38.4	46.5
3 years	1,831	99.4[a]	64.1	69.7	53.3	11.1	8.6	28.8	46.1	38.5	49.0
4 years	1,859	99.5[a]	67.0	69.1	54.8	11.4	7.1	28.6	52.3	39.4	46.2
5 years	884	99.9[a]	69.2	70.4	54.9	11.4	6.8	25.2	52.4	32.1	47.4
3 to 5 years	4,574	99.6[a]	66.8	69.7	54.3	11.3	7.5	27.5	50.3	36.7	47.5
5 years and under	7,818	95.8	55.5	69.3	46.9	10.9	7.5	24.0	45.0	34.1	43.3
Males											
6 to 9 years	787	98.9[a]	69.8	62.6	50.8	10.5	7.4	28.1	52.5	36.0	44.5
6 to 11 years	1,031	99.0[a]	69.1	64.0	52.4	9.7	8.1	27.1	52.3	33.8	45.3
12 to 19 years	737	98.2[a]	62.7	44.6	33.2	10.0	5.9	24.4	41.3	27.2	46.2
Females											
6 to 9 years	704	99.7[a]	71.5	61.2	47.6	9.0	7.9	26.3	57.1	38.3	48.0
6 to 11 years	969	99.3[a]	71.0	59.3	45.6	9.4	7.1	27.1	55.0	37.1	45.7
12 to 19 years	732	97.6[a]	60.9	45.9	30.3	8.6	9.3	19.8	40.6	30.9	46.1
Males and Females											
9 years and under	9,309	97.2	61.6	66.4	47.9	10.5	7.6	25.3	48.9	35.3	44.4
19 years and under	11,287	97.6	62.4	57.6	41.7	9.9	7.6	24.2	46.1	32.5	45.1

[a] Estimate is not statistically reliable due to small sample size reporting intake.

Note: Percentages shown are representative of the first day of each participant's survey response.

Source: USDA, 1999.

Table 12-9. Quantity (as consumed) of Grain Products Consumed Per Eating Occasion and Percentage of Individuals Using These Foods in Two Days

Food category	Quantity consumed per eating occasion (grams)											
	2 to 5 years			6 to 11 years			12 to 19 years					
	Male and Female (N = 2,109)			Male and Female (N = 1,432)			Male (N = 696)			Female (N = 702)		
	PC	Mean	SEM	PC	Mean	SEM	PC	Mean	SEM	PC	Mean	SEM
White bread	66.9	34	[a]	67.1	42	1	61.3	56	1	57.9	47	1
Whole grain and wheat bread	24.3	37	1	20.5	44	1	14.5	60	2	17.6	53	2
Rolls	40.0	39	1	53.5	48	1	61.9	69	2	48.8	51	1
Biscuits	8.3	38	2	9.7	48	3	12.2	72	4	10.3	55	4
Tortillas	14.6	32	2	16.4	47	2	22.9	76	5	20.1	56	3
Quickbreads and muffins	9.6	55	4	9.6	67	5	11.0	125	12	11.0	79	10
Doughnuts and sweet rolls	11.3	59	2	13.4	69	2	17.3	102	12	13.8	78	5
Crackers	25.4	17	1	17.2	26	2	10.6	39	5	14.2	26	3
Cookies	51.0	28	1	46.7	37	2	29.0	53	3	31.8	42	2
Cake	14.6	70	3	19.7	79	4	15.1	99	9	15.5	85	8
Pie	2.9	76	8	5.6	116	8	6.6	188	15	4.8	138[b]	12[b]
Pancake and waffles	19.1	49	1	21.5	77	3	13.5	96	6	8.2	74	5
Cooked cereal	16.8	211	10	9.0	245	14	5.2	310[b]	29[b]	6.0	256[b]	31[b]
Oatmeal	10.4	221	9	5.7	256	19	2.4	348[b]	45[b]	2.3	321[b]	40[b]
Ready-to-eat cereal	72.9	33	1	67.3	47	1	45.6	72	3	46.3	52	2
Corn Flakes	11.2	33	2	13.1	42	2	10.4	62	4	8.7	49	4
Toasted Oat Rings	20.6	30	1	12.5	45	2	7.3	62	5	8.1	42	3
Rice	29.6	84	3	24.6	124	6	24.2	203	10	28.8	157	10
Pasta	49.4	90	3	41.4	130	5	33.4	203	9	37.8	155	9
Macaroni and cheese	17.8	159	8	13.2	217	13	7.5	408	46	10.7	260	30
Spaghetti with tomato sauce	16.8	242	11	11.5	322	18	10.1	583	46	8.5	479	51
Pizza	23.7	86	3	32.8	108	6	39.6	205	13	30.5	143	8
Corn chips	19.6	29	2	25.6	33	2	26.9	58	5	25.1	44	3
Popcorn	11.6	20	1	12.7	31	2	7.8	54	5	10.5	37	4

[a] Indicates a SEM value that is greater than 0 but less than 0.5.
[b] Indicates a statistic that is potentially unreliable because of small sample size or large coefficient of variation.
PC = Percent consuming at least once in 2 days.
SEM = Standard error of the mean.

Source: Smiciklas-Wright et al., 2002 (based on 1994-1996 CSFII data).

Table 12-10. Characteristics of the FITS Sample Population

	Sample Size	Percentage of Sample
Gender		
Male	1,549	51.3
Female	1,473	48.7
Age of Child		
4 to 6 months	862	28.5
7 to 8 months	483	16.0
9 to 11 months	679	22.5
12 to 14 months	374	12.4
15 to 18 months	308	10.2
19 to 24 months	316	10.4
Child's Ethnicity		
Hispanic or Latino	367	12.1
Non-Hispanic or Latino	2,641	87.4
Missing	14	0.5
Child's Race		
White	2,417	80.0
Black	225	7.4
Other	380	12.6
Urbanicity		
Urban	1,389	46.0
Suburban	1,014	33.6
Rural	577	19.1
Missing	42	1.3
Household Income		
Under $10,000	48	1.6
$10,000 to $14,999	48	1.6
$15,000 to $24,999	221	7.3
$25,000 to $34,999	359	11.9
$35,000 to $49,999	723	23.9
$50,000 to $74,999	588	19.5
$75,000 to $99,999	311	10.3
$100,000 and Over	272	9.0
Missing	452	14.9
Receives WIC		
Yes	821	27.2
No	2,196	72.6
Missing	5	0.2
Sample Size (Unweighted)	3,022	100.0

WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Devaney et al., 2004.

Table 12-11. Percentage of Infants and Toddlers Consuming Different Types of Grain Products

Food Group/Food	Percentage of Infants and Toddlers Consuming at Least Once in a Day					
	4 to 6 months	7 to 8 months	9 to 11 months	12 to 14 months	15 to 18 months	19 to 24 months
Any Grain or Grain Product	65.8	91.5	97.5	97.8	98.6	99.2
Infant Cereals	64.8	81.2	63.8	23.9	9.2	3.1
Noninfant Cereals[a]	0.6	18.3	44.3	58.9	60.5	51.9
Not Pre-sweetened	0.5	17.0	37.0	44.5	40.6	31.9
Pre-sweetened[b]	0.0	1.8	9.0	17.7	26.4	22.7
Breads and Rolls[c]	0.6	9.9	24.5	47.3	52.7	53.1
Crackers, Pretzels, Rice Cakes	3.0	16.2	33.4	45.2	46.4	44.7
Cereal or Granola Bars	0.0	1.1	3.4	9.8	10.0	9.7
Pancakes, Waffles, French Toast	0.1	0.8	7.5	15.1	16.1	15.4
Rice and Pasta[d]	2.3	4.5	18.2	26.2	39.0	35.9
Other	0.2	0.1	2.7	2.8	2.5	4.5
Grains in Mixed Dishes	0.4	5.3	24.1	48.3	52.0	55.1
Sandwiches	0.0	1.1	8.6	21.5	25.8	25.8
Burrito, Taco, Enchilada, Nachos	0.0	0.0	1.0	4.5	2.8	2.1
Macaroni and Cheese	0.2	1.6	4.9	14.6	15.0	15.0
Pizza	0.1	0.7	2.2	6.8	9.0	9.4
Pot Pie/Hot Pocket	0.0	0.9	0.5	2.0	1.0	1.8
Spaghetti, Ravioli, Lasagna	0.1	1.8	9.9	15.3	12.1	8.8

[a] Includes both ready-to-eat and cooked cereals.
[b] Defined as cereals with more than 21.1 g sugar per 100 g.
[c] Does not include bread in sandwiches. Sandwiches are included in mixed dishes.
[d] Does not include rice or pasta in mixed dishes.

Source: Fox et al., 2004.

Table 12-12. Characteristics of WIC Participants and Nonparticipants[a] (Percentages)

	Infants 4 to 6 months		Infants 7 to 11 months		Toddlers 12 to 24 months	
	WIC Participant	Non-participant	WIC Participant	Non-participant	WIC Participant	Non-participant
Gender						
Male	55	54	55	51	57	52
Female	45	46	45	49	43	48
Child's Ethnicity		**		**		**
Hispanic or Latino	20	11	24	8	22	10
Non-Hispanic or Latino	80	89	76	92	78	89
Child's Race		**		**		**
White	69	84	63	86	67	84
Black	15	4	17	5	13	5
Other	22	11	20	9	20	11
Child In Day Care				**		*
Yes	39	38	34	46	43	53
No	61	62	66	54	57	47
Age of Mother		**		**		**
14 to 19	18	1	13	1	9	1
20 to 24	33	13	38	11	33	14
25 to 29	29	29	23	30	29	26
30 to 34	9	33	15	36	18	34
35 or Older	9	23	11	21	11	26
Missing	2	2	1	1	0	1
Mother's Education		**		**		**
11th Grade or Less	23	2	15	2	17	3
Completed High School	35	19	42	20	42	19
Some Postsecondary	33	26	32	27	31	28
Completed College	7	53	9	51	9	48
Missing	2	1	2	0	1	2
Parent's Marital Status		**		**		**
Married	49	93	57	93	58	88
Not Married	50	7	42	7	41	11
Missing	1	1	1	0	1	1
Mother or Female Guardian Works				**		*
Yes	46	51	45	60	55	61
No	53	48	54	40	45	38
Missing	1	1	1	0	0	1
Urbanicity		**		**		**
Urban	34	55	37	50	35	48
Suburban	36	31	31	34	35	35
Rural	28	13	30	15	28	16
Missing	2	1	2	1	2	2
Sample Size (Unweighted)	265	597	351	808	205	791

[a] X^2 test were conducted to test for statistical significance in the differences between WIC participants and non-participants within each age group for each variable. The results of X^2 test are listed next to the variable under the column labeled non-participants for each of the three age groups. *P<0.05; **P>0.01; non-participants significantly different from WIC participants on the variable.

WIC =Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Ponza et al., 2004.

Table 12-13. Food Choices for Infants and Toddlers by WIC Participation Status.

	Infants 4 to 6 months		Infants 7 to 11 months		Toddlers 12 to 24 months	
	WIC Participant	Non-participant	WIC Participant	Non-participant	WIC Participant	Non-participant
Infant Cereals	69.7	62.5	74.7	69.7	13.5	9.2
Noninfant Cereals, Total	0.9	0.5	21.7	38.5*	58.1	56.0
Not Pre-sweetened	0.5	0.5	18.7	32.9*	43.7	36.3
Pre-sweetened	0.0	0.0	4.0	6.9	17.7	24.1
Grains in Combination Foods	0.9	0.1	18.8	14.7	50.3	52.9
Sample Size (unweighted)	265	597	351	808	205	791

* = P<0.01 non-participants significantly different from WIC participants.
WIC = Special Supplemental Nutrition Program for Women, Infants, and Children.

Source: Ponza et al., 2004.

Table 12-14. Percentage of Hispanic and Non-Hispanic Infants and Toddlers Consuming Different Types of Grain Products on A Given Day

	Age 4 to 5 months		Age 6 to11 months		Age 12 to 24 months	
	Hispanic (n=84)	Non-Hispanic (n=538)	Hispanic (n=163)	Non-Hispanic (n=1,228)	Hispanic (n=124)	Non-Hispanic (n=871)
Any Grain or Grain Product	56.5	56.9	95.0	93.5	97.1	98.9
Infant Cereal	55.2	56.5	74.1	73.6	15.9	9.3
Noninfant Cereal	-	-	18.5*	29.2	45.3	57.8
Breads[a]	1.4†	-	18.2	15.1	44.0	52.9
Tortillas	1.4†	-	4.0†	-	6.7†*	0.6†
Crackers, Pretzels, Rice Cakes	1.3†	-	27.8	22.5	35.6	46.9
Pancakes, Waffles, French Toast	-	-	1.4†	4.3	13.0	16.0
Rice and Pasta[b]	-	-	20.1*	10.3	44.3	32.9
Rice	-	-	15.9**	4.7	26.9†*	13.0
Grains in Mixed Dishes	-	-	15.9	13.0	38.8*	54.4
Sandwiches	-	-	4.0†	4.6	24.2	24.9
Burrito, Taco, Enchilada, Nachos	-	-	1.3†	-	2.1†	3.0
Macaroni and Cheese	-	-	3.0†	3.1	10.1	15.5
Pizza	-	-	-	1.4	1.0**†	9.7
Spaghetti, Ravioli, Lasagna	-	-	8.3†	4.6	9.3†	12.1

[a] Does not include bread in sandwiches. Sandwiches are included in mixed dishes. Includes tortillas, also shown separately.

[b] Does not include rice or pasta in mixed dishes. Includes rice (e.g. white, brown, wild, and Spanish rice without meat) and pasta (e.g. spaghetti, macaroni, and egg noodles). Rice is also shown separately.

- = Less than 1 percent of the group consumed this food on a given day.

* = Significantly different from non-Hispanic at the *P*<0.05.

** = Significantly different from non-Hispanic at the *P*>0.01.

† = Statistic is potentially unreliable because of a high coefficient of variation.

Source: Mennella et al., 2006.

Table 12-15. Average Portion Sizes Per Eating Occasion of Grain Products Commonly Consumed by Infants from the 2002 Feeding Infants and Toddlers Study

Food group	Reference unit	4 to 5 months (N=624)	6 to 8 months (N=708)	9 to 11 months (N=687)
		Mean± SEM		
Infant cereal, dry	tablespoon	3.1±0.14	4.5±0.14	5.2±0.18
Infant cereal, jarred	tablespoon	-	5.6±0.26	7.4±0.34
Ready-to-eat cereal	tablespoon	-	2.3±0.34	3.4±0.21
Crackers	ounce	-	0.2±0.02	0.3±0.01
	saltine	-	2.2±0.14	2.7±0.12
Bread	slice	-	0.5±0.10	0.8±0.06

- = Cell size was too small to generate a reliable estimate.
N = Number of respondents.
SEM = Standard error of the mean.

Source: Fox et al., 2006.

Table 12-16. Average Portion Sizes Per Eating Occasion of Grain Products Commonly Consumed by Toddlers from the 2002 Feeding Infants and Toddlers Study

Food Group	Reference Unit	12 to 14 months (N=371)	15 to 18 months (N=312)	19 to 24 months (N=320)
		Mean± SEM		
Bread	slice	0.8±0.04	0.9±0.05	0.9±0.05
Rolls	ounce	0.9±0.11	1.0±0.10	0.9±0.15
Ready-to-eat cereal	cup	0.3+0.02	0.5±0.03	0.6±0.04
Hot cereal, prepared	cup	0.6±0.05	0.6±0.05	0.7±0.05
Crackers	ounce	0.3+0.02	0.4±0.02	0.4±0.02
	saltine	3.3+0.22	3.5±0.22	3.7±0.22
Pasta	cup	0.4±0.04	0.4+0.04	0.5±0.05
Rice	cup	0.3+0.04	0.4±0.05	0.4±0.05
Pancakes and waffles	1 (4-inch diameter)	1.0+0.08	1.4±0.21	1.4±0.17

N = Number of respondents.
SEM = Standard error of the mean.

Source: Fox et al., 2006.

Table 12-17. Mean Moisture Content of Selected Grain Products Expressed as Percentages of Edible Portions

Food	Moisture Content		Comments
	Raw	Cooked	
Barley - pearled	10.09	68.80	
Corn - grain - endosperm	10.37		
Corn - grain - bran	4.71		crude
Millet	8.67	71.41	
Oats	8.22		
Rice - white - long-grained	11.62	68.44	
Rye	10.95		
Rye - flour - medium	9.85		
Sorghum	9.20		
Wheat - hard white	9.57		
Wheat - germ	11.12		crude
Wheat - bran	9.89		crude
Wheat - flour - whole grain	10.27		

Source: USDA, 2007.

APPENDIX 12A

CODES AND DEFINITIONS USED TO DETERMINE THE VARIOUS GRAIN PRODUCTS USED IN THE U.S. EPA ANALYSIS OF CSFII DATA IN FCID

Table 12A-1. Food Codes and Definitions Used in Analysis of the 1994-96, 1998 USDA CSFII Data

Total Grains	95000060	Amaranth, grain	15002331	Oat, groats/rolled oats-babyfood
	15000250	Barley, pearled barley	95003060	Psyllium, seed
	15000251	Barley, pearled barley-babyfood	95003110	Quinoa, grain
	15000260	Barley, flour	15003230	Rice, white
	15000261	Barley, flour-babyfood	15003231	Rice, white-babyfood
	15000270	Barley, bran	15003240	Rice, brown
	15000650	Buckwheat	15003241	Rice, brown-babyfood
	15000660	Buckwheat, flour	15003250	Rice, flour
	15001200	Corn, field, flour	15003251	Rice, flour-babyfood
	15001201	Corn, field, flour-babyfood	15003260	Rice, bran
	15001210	Corn, field, meal	15003261	Rice, bran-babyfood
	15001211	Corn, field, meal-babyfood	15003280	Rye, grain
	15001220	Corn, field, bran	15003290	Rye, flour
	15001230	Corn, field, starch	15003440	Sorghum, grain
	15001231	Corn, field, starch-babyfood	15003810	Triticale, flour
	15001260	Corn, pop	15003811	Triticale, flour-babyfood
	15001270	Corn, sweet	15004010	Wheat, grain
	15001271	Corn, sweet-babyfood	15004011	Wheat, grain-babyfood
	15002260	Millet, grain	15004020	Wheat, flour
	15002310	Oat, bran	15004021	Wheat, flour-babyfood
	15002320	Oat, flour	15004030	Wheat, germ
	15002321	Oat, flour-babyfood	15004040	Wheat, bran
	15002330	Oat, groats/rolled oats	15004050	Wild rice
Cereal Grains	15000250	Barley, pearled barley	15003230	Rice, white
	15000251	Barley, pearled barley-babyfood	15003231	Rice, white-babyfood
	15000260	Barley, flour	15003240	Rice, brown
	15000261	Barley, flour-babyfood	15003241	Rice, brown-babyfood
	15000270	Barley, bran	15003250	Rice, flour
	15000650	Buckwheat	15003251	Rice, flour-babyfood
	15000660	Buckwheat, flour	15003260	Rice, bran
	15001200	Corn, field, flour	15003261	Rice, bran-babyfood
	15001201	Corn, field, flour-babyfood	15003280	Rye, grain
	15001210	Corn, field, meal	15003290	Rye, flour
	15001211	Corn, field, meal-babyfood	15003440	Sorghum, grain
	15001220	Corn, field, bran	15003450	Sorghum, syrup
	15001230	Corn, field, starch	15003810	Triticale, flour
	15001231	Corn, field, starch-babyfood	15003811	Triticale, flour-babyfood
	15001240	Corn, field, syrup	15004010	Wheat, grain
	15001241	Corn, field, syrup-babyfood	15004011	Wheat, grain-babyfood
	15001260	Corn, pop	15004020	Wheat, flour
	15001270	Corn, sweet	15004021	Wheat, flour-babyfood
	15001271	Corn, sweet-babyfood	15004030	Wheat, germ
	15002260	Millet, grain	15004040	Wheat, bran
	15002310	Oat, bran	15004050	Wild rice
	15002320	Oat, flour	95000060	Amaranth, grain
	15002321	Oat, flour-babyfood	95003060	Psyllium, seed
	15002330	Oat, groats/rolled oats	95003110	Quinoa, grain
	15002331	Oat, groats/rolled oats-babyfood		

Rice	15003260	Rice, bran	15003250	Rice, flour
	15003261	Rice, bran-babyfood	15003251	Rice, flour-babyfood
	15003240	Rice, brown	15003230	Rice, white
	15003241	Rice, brown-babyfood	15003231	Rice, white-babyfood

13 INTAKE OF HOME-PRODUCED FOODS

13.1 INTRODUCTION

Ingestion of home-produced foods can be a pathway for exposure to environmental contaminants. Home-produced foods can become contaminated in a variety of ways. Ambient pollutants in the air may be deposited on plants, adsorbed onto or absorbed by the plants, or dissolved in rainfall or irrigation waters that contact the plants. Pollutants may also be adsorbed onto plant roots from contaminated soil and water. Finally, the addition of pesticides, soil additives, and fertilizers to crops or gardens may result in contamination of food products. Meat and dairy products can become contaminated if animals consume contaminated soil, water, or feed crops. Farmers, as well as rural and urban residents who consume home-produced foods, may be potentially exposed if these foods become contaminated. Exposure via the consumption of home-produced foods may be a significant route of exposure for these populations (U.S. EPA, 1989; U.S. EPA, 1996). For example, consumption of home-produced fruits, vegetables, game, and fish has been shown to have an impact on blood lead levels in areas where soil lead contamination exists (U.S. EPA, 1994). At Superfund sites where soil contamination is found, ingestion of home-produced foods has been considered a potential route of exposure (U.S. EPA, 1991; U.S. EPA, 1993). Assessing exposures to individuals who consume home-produced foods requires knowledge of intake rates of such foods.

Data from the 1987-1988 Nationwide Food Consumption Survey (NFCS) were used to generate intake rates for home-produced foods (U.S. EPA, 1997). Until 1988, USDA conducted the NFCS every 10 years to analyze the food consumption behavior and dietary status of Americans (USDA, 1992). While more recent food consumption surveys have been conducted to estimate food intake among the general population (e.g., USDA's Continuing Survey of Food Intake among Individuals [CSFII] and the National Health and Nutrition Examination Survey [NHANES]), these surveys have not collected data that can be used to estimate consumption of home-produced foods. Thus, the 1987-1988 NFCS data set is currently the best available source of information for this factor.

The 1987-1988 NFCS was conducted between April 1987 and August 1988. The survey used a statistical sampling technique designed to ensure that all seasons, geographic regions of the 48 conterminous states in the U.S., and socioeconomic and demographic groups were represented (USDA, 1994). There were two components of the NFCS. The household component collected information over a seven-day period on the socioeconomic and demographic characteristics of households, and the types, amount, value, and sources of foods consumed by the household (USDA, 1994). The individual intake component collected information on food intakes of individuals within each household over a three-day period (USDA, 1993). The sample size for the 1987-1988 survey was approximately 4,300 households (over 10,000 individuals; approximately 3,000 children). This was a decrease over the previous survey conducted in 1977-1978, which sampled approximately 15,000 households (over 36,000 individuals) (USDA, 1994). The sample size was lower in the 1987-1988 survey as a result of budgetary constraints and low response rate (38 percent for the household survey and 31percent for the individual survey) (USDA, 1993). The methods used to analyze the 1987-1988 NFCS data and the results of these analyses that pertain to children are presented in Section 13.3.

13.2 RECOMMENDATIONS

The data presented in this section may be used to assess exposure to contaminants in foods grown, raised, or caught at a specific site. The recommended values for mean and upper percentile (i.e., 95th percentile) intake rates among consumers of the various home-produced food groups are presented in Table 13-1; these rates can be converted to per capita rates by multiplying by the fraction of the population consuming these food groups during the survey period (See Section 13.3). Table 13-2 presents the confidence ratings for home-produced food intake. The data presented in this chapter for consumers of home-produced foods represent average daily intake rates of food items/groups over the seven-day survey period and do not account for variations in eating habits during the rest of the year; thus the recommended upper percentile values, as well as the percentiles of the distributions presented in Section 13.3 may not necessarily reflect the long-term distribution of average daily intake of home produced foods.

Because the home-produced food intake rates presented in this chapter are based on foods as brought into the household and not in the form in which they are consumed, preparation loss factors should be applied, as appropriate. These factors are necessary to convert to intake rates to those that are representative of foods "as consumed". Additional conversions may be necessary to ensure that the form of the food used to estimate intake (e.g., wet or dry weight) is consistent with the form used to measure contaminant concentration (see Section 13.3).

The NFCS data used to generate intake rates of home-produced foods are over 20 years old and may not be reflective of current eating patterns among consumers of home-produced foods. Although USDA and others have conducted other food consumption studies since the release of the 1987-1988 NFCS, these studies do not include information on home-produced foods.

Recommended home-produced food intake rates are not provided for children under 1 year of age because the methodology used is based on apportionment of home-produced foods used by a household among the members of that household that consume those foods. It was assumed that the diets of children under 1 year of age differ markedly from that of other household members; thus, they were not assumed to consume any portion of the home-produced food brought into the home. Also, recommended home-produced food intake rates are not provided for individual food items for children because, in general, the sample size was too small to provide reliable data for individual age groups. However, if intake rates are needed for age groups under 1 year of age or for food items other than the major food groups presented here, data in Section 13.3 on the fraction of household intake that is home-produced may be used in conjunction with age-specific intake rates presented elsewhere in this handbook to estimate intake of home produced foods (U.S. EPA, 1997).

Table 13-1. Summary of Recommended Values for Intake of Home-produced Foods (Consumers Only)

Age Group[a]	Mean (g/kg-day)	95th Percentile (g/kg-day)	Multiple Percentiles	Source
Home-produced Fruits				
1 to 2 years	8.7	60.6	See Table 13-4	U.S. EPA Analysis of 1987-1988 NFCS
3 to 5 years	4.1	8.9		
6 to 11 years	3.6	15.8		
12 to 19 years	1.9	8.3		
Home-produced Vegetables				
1 to 2 years	5.2	19.6	See Table 13-4	U.S. EPA Analysis of 1987-1988 NFCS
3 to 5 years	2.5	7.7		
6 to 11 years	2.0	6.2		
12 to 19 years	1.5	6.0		
Home-produced Meats				
1 to 2 years	3.7	10.0	See Table 13-4	U.S. EPA Analysis of 1987-1988 NFCS
3 to 5 years	3.6	9.1		
6 to 11 years	3.7	14.0		
12 to 19 years	1.7	4.3		
Home Caught Fish				
1 to 2 years	-[b]	-	See Table 13-4	U.S. EPA Analysis of 1987-1988 NFCS
3 to 5 years	-	-		
6 to 11 years	2.8	7.1		
12 to 19 years	1.5	4.7		

a Analysis was conducted prior to Agency's issuance of *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005).

b Data not presented for age groups/food groups where less than 20 observations were available.

Table 13-2. Confidence in Recommendations for Intake of Home-produced Foods		
General Assessment Factors	Rationale	Rating
Soundness		Medium (Means) Low (Distributions)
Adequacy of Approach	The survey methodology and the approach to data analysis were adequate, but individual intakes were inferred from household consumption data. The sample size was large (approximately 3,000 children).	
Minimal (or Defined) Bias	Non-response bias can not be ruled out due to low response rate. Also, some biases may have occurred from using household data to estimate individual intake.	
Applicability and Utility		Low (Means & Short-term distributions) Low (Long-term distributions)
Exposure Factor of Interest	The analysis specifically addressed home-produced intake.	
Representativeness	Data from a nationwide survey, representative of the general U.S. population was used.	
Currency	The data were collected in 1987-1988.	
Data Collection Period	Household data were collected over 1 week.	
Clarity and Completeness		High
Accessibility	The methods used described to analyze the data are described in detail in this handbook; the primary data are accessible through USDA.	
Reproducibility	Sufficient detail on the methods used to analyze the data are presented to allow for the results to be reproduced.	
Quality Assurance	Quality assurance of NFCS data was good; quality control of the secondary data was sufficient.	

Table 13-2. Confidence in Recommendations for Intake of Home-produced Food (continued)		
General Assessment Factors	Rationale	Rating
Variability and Uncertainty		Low to Medium
Variability in Population	Full distributions of home-produced intake rates were provided.	
Uncertainty	Sources of uncertainty include: individuals' estimates of food weights, allocation of household food to family members, and potential changes in eating patterns since these data were collected,	
Evaluation and Review		Medium
Peer Review	The study was reviewed by USDA and U.S. EPA.	
Number and Agreement of Studies	The number of studies is 1.	
Overall Rating		**Low-Medium** (means and short-term distributions) **Low** (long-term distributions)

13.3 KEY STUDY FOR INTAKE OF HOME-PRODUCED FOODS

13.3.1 U.S. EPA Analysis of NFCS 1987-1988

U.S. EPA's National Center for Environmental Assessment (NCEA) analyzed USDA's 1987-1988 NFCS data to generate intake rates for home-produced foods (U.S. EPA, 1997). For the purposes of this study, home-produced foods were defined as homegrown fruits and vegetables, meat and dairy products derived from consumer-raised livestock or game meat, and home caught fish. The food groups selected for analysis of children's home-produced food intake included major food groups such as total fruits, total vegetables, total meats, total dairy, total fish and shellfish. These food groups were identified in the NFCS data base according to NFCS-defined food codes. Appendix 13A presents the codes and definitions used to determine these major food groups. Foods with these codes, for which the source was identified as home-produced, were included in the analysis. This chapter presents the intake rate data for these major food groups, except total dairy, for various age ranges of children. An insufficient number of observations (i.e., less than 30 households) were available to allow for estimates of home-produced dairy products. Also, child-specific intake rates for individual food items (e.g., carrots, citrus fruit) were not estimated because, in general, the sample size was too small to provide reliable data for the individual age groups of interest.

The USDA data were adjusted by applying the sample weights calculated by USDA to the data set prior to analysis. The USDA sample weights were designed to "adjust for survey non-response and other vagaries of the sample selection process" (USDA, 1987-1988). Also, the USDA weights are calculated "so that the weighted sample total equals the known population total, in thousands, for several characteristics thought to be correlated with eating behavior" (USDA, 1987-1988). The unweighted sample included approximately 3,000 children (ages <1 to 19 years), which was weighted to reflect nearly 54 million children.

Although the individual intake component of the NFCS gives the best measure of the amount of each food group eaten by each individual in the household, it could not be used directly to measure consumption of home-produced food because the individual component does not identify the source of the food item (i.e., as home-produced or not). Therefore, an analytical method which incorporated data from both the household and individual survey components was developed to estimate individual home-produced food intake. The USDA household data were used to determine (1) the amount of each home-produced food item used during a week by household members and (2) the number of meals eaten in the household by each household member during a week. As measured by the NFCS, the amount of food "consumed" by the household is a measure of consumption in an economic sense, i.e., a measure of the weight of food brought into the household that has been consumed (used up) in some manner. In addition to food being consumed by persons, food may be used up by spoiling, by being discarded (e.g., inedible parts), through cooking processes, etc. Note that the household survey reports the total amount of each food item used in the household (whether by guests or household members); the amount used by household members was derived by multiplying the total amount used in the household by the proportion of all meals served in the household (during the survey week) that were consumed by household members.

The individual survey data were used to generate average sex- and age-specific serving sizes for each food item. These serving sizes were used during subsequent analyses to generate home-produced food intake rates for individual household members. Assuming that the proportion of the household quantity of each home-produced food item/group was a function of the number of meals and the mean sex- and age-specific serving size for each family member, individual intakes of home-produced food were calculated for all members of the survey population using the following general equation:

$$w_i = w_f \left[\frac{m_i q_i}{\sum_{i=1}^{n} m_i q_i} \right] \qquad \text{(Eqn. 13-1)}$$

where:

w_i = Home-produced amount of food item/group attributed to member *i* during the week (g/week);
w_f = Total quantity of home-produced food item/group used by the family members (g/week);
m_i = Number of meals of household food consumed by member *i* during the week (meals/week); and
q_i = Serving size for an individual within the age and sex category of the member (g/meal).

Daily intake of a home-produced food group was determined by dividing the weekly value (w_i) by seven. Intake rates were indexed to the self-reported body weight of the survey respondent and reported in units of g/kg-day. For the major food groups (fruits, vegetables, meats, and fish), distributions of home-produced intake among consumers were generated by age group. Consumers were defined as members of survey households who reported consumption of the food group of interest during the one week survey period.

The age categories used in the analysis were as follows: 1 to 2 years; 3 to 5 years; 6 to 11 years; and 12 to 19 years Because this analysis was conducted prior to issuance of U.S. EPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005), the age groups used are not entirely consistent with recent guidelines. Intake rates were not calculated for children under 1 year because their diet differs markedly from that of other household members, and thus, the assumption that all household members share all foods would be invalid for this age group.

The intake data presented here for consumers of home-produced foods and the total number of individuals surveyed may be used to calculate the mean and the percentiles of the distribution of home-produced food consumption in the overall population (consumers and non-consumers) as follows:

Assuming that IR_p is the home-produced intake rate of the food group at the p^{th} percentile and N_c is the weighted number of individuals consuming the home-produced food item, and N_T is the weighted total number of individuals surveyed, then N_T - N_c is the weighted number of individuals who reported zero consumption of the food item. In addition, there are (p/100 x N_c) individuals below the p^{th} percentile. Therefore, the percentile that corresponds to a particular intake rate (IR_p) for the overall distribution of home-produced food consumption (including consumers and non-consumers) can be obtained by:

$$P^{th}_{overall} = 100 \text{ x } \frac{\left(\frac{P}{100} \text{ x } N_c + \left(N_T - N_c\right)\right)}{N_T} \quad \text{(Eqn. 13-2)}$$

Table 13-3 displays the weighted numbers N_T, as well as the unweighted total survey sample sizes, for each age category. Table 13-4 presents home-produced intake rates for fruits, vegetables, meats, and fish. These intake rates are based on the amount of household food consumption as well as age-specific serving size data.

USDA estimated preparation losses for various foods (USDA, 1975). For meats, a net cooking loss, which includes dripping and volatile losses, and a net post-cooking loss, which involves losses from cutting, bones, excess fat, scraps and juices, were derived for a variety of cuts and cooking methods. For total meats, U.S. EPA has averaged these losses across all meat types, cuts and cooking methods to obtain a mean net cooking loss and a mean net post-cooking loss. Mean percentage values for all meats and fish are provided in Table 13-5. For individual fruits and vegetables, USDA (1975) also gave cooking and post-cooking losses. These data, averaged across all types of fruits and vegetables to give mean net cooking and post cooking losses, are also provided in Table 13-5.

The following formula can be used to convert the home-produced intake rates tabulated here to rates reflecting actual consumption:

$$I_A = I \times \left(1 - L_1\right) \times \left(1 - L_2\right) \quad \text{(Eqn. 13-3)}$$

where:

I_A = the adjusted intake rate;
I = the tabulated intake rate;
L_1 = the cooking or preparation loss; and

L_2 = the post-cooking loss.

For fruits, corrections based on post-cooking losses only apply to fruits that are eaten in cooked forms. For raw forms of the fruits, paring or preparation loss data should be used to correct for losses from removal of skin, peel, core, caps, pits, stems, and defects, or draining of liquids from canned or frozen forms.

In calculating ingestion exposure, assessors should use consistent forms (e.g., "as-consumed" or dry weight) in combining intake rates with contaminant concentrations, as discussed in Chapter 9 of this handbook.

The USDA 1987-1988 NFCS household data were also used to estimate the fraction of household intake that can be attributed to home-produced foods (Table 13-6). The analysis was conducted for the major food groups (i.e., total meat, dairy, fruits, vegetables, and fish), as well as for a variety of individual food items (e.g., apples, tomatoes, beef, etc.). The fraction of intake that was home-produced was calculated as the ratio of total intake of the home-produced food item/group by the survey population to the total intake of all forms of the food by the survey population. The food codes used in this analysis are presented in Appendix 13-B.

The USDA NFCS data set is the largest publicly available source of information on home-produced food consumption habits in the United States. The advantages of using this data set are that it is expected to be representative of the U.S. population and that it provides information on a wide variety of food groups. However, the data collected by the USDA NFCS are based on short-term dietary recall and the intake distributions generated from this data set may not accurately reflect long-term intake patterns, particularly with respect to the tails (extremes) of the distributions. Also, the two survey components (i.e., household and individual) do not define food items/groups in a consistent manner; as a result, some errors may be introduced into these analyses because the two survey components are linked. The results presented here may also be biased by assumptions that are inherent in the analytical method utilized. The analytical method may not capture all high-end consumers within households because average serving sizes are used in calculating the proportion of home-produced food consumed by each household member. Thus, for instance, in a two-person household where one member had high intake and one had low intake, the method used here would assume that both members had an equal and moderate level of intake. In addition, the analyses assume that all family members consume a portion of the home-produced food used within the household. However, not all family members may consume each home-produced food item and serving sizes allocated here may not be entirely representative of the portion of household foods consumed by each family member. As was mentioned earlier, no analyses were performed for children under 1 year age.

The preparation loss factors discussed above are intended to convert intake rates based on "household consumption" to rates reflective of what individuals actually consume. However, these factors do not include losses to spoilage, feeding to pets, food thrown away, etc. It should also be noted that because this analysis is based on the 1987-1988 NFCS, it may not reflect recent changes in food consumption patterns. The low response rate associated with the 1987-1988 NFCS also contributes to the uncertainty of the home-produced intake rates generated using these data.

13.4 REFERENCES FOR CHAPTER 13

USDA (1975) Food yields summarized by different stages of preparation. Agricultural Handbook No. 102. Washington, DC. U.S. Department of Agriculture, Agriculture Research Service.

USDA (1987-1988) Dataset: Nationwide Food Consumption Survey 1987/88 Household Food Use. Washington, DC. U.S. Department of Agriculture. 1987/88 NFCS Database.

USDA (1992) Changes in food consumption and expenditures in American households during the 1980's. Washington, DC. U.S. Department of Agriculture. Statistical Bulletin No. 849.

USDA (1993) Food and nutrient intakes by individuals in the United States, 1 Day, 1987-1988. Nationwide Food Consumption Survey 1987-1988, NFCS Report No. 87-I-1.

USDA (1994) Food consumption and dietary levels of households in the United States, 1987-1988. U.S. Department of Agriculture, Agricultural Research Service. Report No. 87-H-1.

U.S. EPA (1989) Risk Assessment Guidance for Superfund (RAGS): Volume I, Human Health Evaluation Manual, Part A. Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/1-89/002. Available online at http://www.epa.gov/oswer/riskassessment/ragsa/index.htm

U.S. EPA (1991) Record of Decision. ROD ID EPA/ROD/R10-91-029.

U.S. EPA (1993) Record of Decision. ROD ID EPA/ROD/R04-93-166.

U.S. EPA (1994) Validation strategy for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. Office of Solid Waste and Emergency Response, Washington DC. EPA/540/R-94-039. Available online at http://www.epa.gov/superfund/lead/products/valstrat.pdf

U.S. EPA (1996) Soil Screening Fact Sheet Guidance. EPA/540/F-95/041. Available online at http://www.epa.gov/superfund/health/conmedia/soil/index.htm

U.S. EPA (1997) Exposure Factors Handbook. Office of Research and Development, Washington, DC. EPA/600/P-95/002F. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=12464

Table 13-3. Weighted and Unweighted Number of Observations (Individuals) for NFCS Data Used in Child-specific Analysis of Food Intake

Age Group	Number of Observations	
	weighted	unweighted
<1 year	2,814,000	156
1 to 2 years	5,699,000	321
3 to 5 years	8,103,000	461
6 to 11 years	16,711,000	937
12 to 19 years	20,488,000	1,084
Total	53,815,000	2,959

weighted = Weighted number of observations.
unweighted = Unweighted number of observations.

Table 13-4. Consumer Only Intake of Home-produced Foods (g/kg-day)[a]

Age (years)	Nc wgtd	Nc unwgtd	% Consuming	Mean	SE	P1	P5	P10	P25	P50	P75	P90	P95	P99	P100
Home-produced Fruits															
1 to 2	360,000	23	6.3	8.7	3.1	1.0	1.1	1.3	1.6	3.5	8.0	19.3	60.6	60.6	60.6
3 to 5	550,000	34	6.8	4.1	1.5	0.0	0.0	0.4	1.0	1.9	2.7	6.0	8.91	48.3	48.3
6 to 11	1,044,000	75	6.3	3.6	0.7	0.0	0.2	0.4	0.7	1.3	3.1	11.8	15.8	32.2	32.2
12 to 19	1,189,000	67	5.8	1.9	0.4	0.1	0.1	0.3	0.4	0.7	2.4	6.8	8.3	18.5	18.5
Home-produced Vegetables															
1 to 2	951,000	53	16.7	5.2	0.9	0.0	0.2	0.4	1.2	3.3	5.8	13.1	19.6	27.0	27.0
3 to 5	1,235,000	76	15.2	2.5	0.3	0.0	0.1	0.4	0.7	1.3	3.9	6.4	7.7	10.6	12.8
6 to 11	3,024,000	171	18.1	2.0	0.3	0.0	0.1	0.2	0.4	0.9	2.2	4.6	6.2	17.6	23.6
12 to 19	3,293,000	183	16.1	1.5	0.1	0.0	0.1	0.1	0.3	0.8	1.8	3.7	6.0	7.7	9.0
Home-produced Meats															
1 to 2	276,000	22	4.8	3.7	0.6	0.4	1.0	1.0	1.2	2.7	4.7	8.7	10.0	11.5	11.5
3 to 5	396,000	26	4.9	3.6	0.5	0.8	0.8	1.5	2.2	2.8	3.7	7.8	9.1	13.0	13.0
6 to 11	1,064,000	65	6.4	3.7	0.5	0.4	0.7	0.7	1.3	2.1	4.7	8.0	14.0	15.3	15.3
12 to 19	1,272,000	78	6.2	1.7	0.2	0.2	0.3	0.5	0.6	1.2	2.4	3.7	4.3	6.8	7.5
Home-caught Fish															
1 to 2	82,000	6	1.4	*	*	*	*	*	*	*	*	*	*	*	*
3 to 5	142,000	11	1.8	*	*	*	*	*	*	*	*	*	*	*	*
6 to 11	382,000	29	2.3	2.8	0.8	0.2	0.2	0.2	0.2	0.6	1.0	3.7	7.1	7.9	25.3
12 to 19	346,000	21	1.7	1.5	0.4	0.2	0.2	0.2	0.2	0.3	1.0	1.8	4.7	6.7	8.4

[a] Analysis was conducted prior to Agency's issuance of *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005).

SE = Standard error.
P = Percentile of the distribution.
Nc wgtd = Weighted number of consumers.
Nc unwgtd = Unweighted number of consumers in survey.
* = Less than 20 observations.

Source: Based on U.S. EPA's analyses of the 1987-1988 NFCS.

Table 13-5. Percent Weight Losses from Food Preparation

Food Group	Mean Net Preparation/Cooking Loss (%)	Mean Net Post Cooking (%)
Meats[a]	29.7[b]	29.7[c]
Fish and shellfish[d]	31.5[b]	10.5[c]
Fruits	25.4[e]	30.5[f]
Vegetables[g]	12.4[h]	22[i]

[a] Averaged over various cuts and preparation methods for various meats including beef, pork, chicken, turkey, lamb, and veal.
[b] Includes dripping and volatile losses during cooking.
[c] Includes losses from cutting, shrinkage, excess fat, bones, scraps, and juices.
[d] Averaged over a variety of fish and shellfish, to include: bass, bluefish, butterfish, cod, flounder, haddock, halibut, lake trout, mackerel, perch, porgy, red snapper, rockfish, salmon, sea trout, shad, smelt, sole, spot, squid, swordfish steak, trout, whitefish, clams, crab, crayfish, lobster, oysters, and shrimp and shrimp dishes.
[e] Based on preparation losses. Averaged over apples, pears, peaches, strawberries, and oranges. Includes losses from removal of skin or peel, core or pit, stems or caps, seeds, and defects. Also, includes losses from removal of drained liquids from canned or frozen forms.
[f] Averaged over apples and peaches. Include losses from draining cooked forms.
[g] Averaged over various vegetables, to include: asparagus, beets, broccoli, cabbage, carrots, corn, cucumbers, lettuce, lima beans, okra, onions, green peas, peppers, pumpkins, snap beams, tomatoes, and potatoes.
[h] Includes losses due to paring, trimming, flowering the stalk, thawing, draining, scraping, shelling, slicing, husking, chopping, and dicing and gains from the addition of water, fat, or other ingredients. Averaged over various preparation methods.
[i] Includes losses from draining or removal of skin. Based on potatoes only.

Source: U.S. EPA, 1997 (Derived from USDA, 1975).

Table 13-6. Fraction of Food Intake that is Home-produced			
	All Households	Households who garden	Households who farm
Total Fruits	0.04	0.101	0.161
Apples	0.030	0.070	0.292
Peaches	0.147	0.316	0.461
Pears	0.067	0.169	0.606
Strawberries	0.111	0.232	0.057
Other Berries	0.217	0.306	0.548
Citrus	0.038	0.087	0.005
Other	0.042	0.107	0.227
	All Households	Households who garden	Households who farm
Total Vegetables	0.068	0.173	0.308
Asparagus	0.063	0.125	0.432
Beets	0.203	0.420	0.316
Broccoli	0.015	0.043	0.159
Cabbage	0.038	0.099	0.219
Carrots	0.043	0.103	0.185
Corn	0.078	0.220	0.524
Cucumbers	0.148	0.349	0.524
Lettuce	0.010	0.031	0.063
Lima Beans	0.121	0.258	0.103
Okra	0.270	0.618	0.821
Onions	0.056	0.148	0.361
Peas	0.069	0.193	0.308
Peppers	0.107	0.246	0.564
Pumpkin	0.155	0.230	0.824
Snap Beans	0.155	0.384	0.623
Tomatoes	0.184	0.398	0.616
White Potatoes	0.038	0.090	0.134
	All Households	Households who raise animals/hunt	Households who farm
Total Meats	0.024	0.306	0.319
Beef	0.038	0.485	0.478
Game	0.276	0.729	-
Pork	0.013	0.242	0.239
Poultry	0.011	0.156	0.151
	All Households	Households who raise animals	Households who farm
Total Dairy	0.012	0.207	0.254
Eggs	0.014	0.146	0.214
	All Households	Households who fish	--
Total fish	0.094	0.325	--

- = No data.

Source: U.S. EPA Analysis of 1987-1988 NFCS.

APPENDIX 13A

FOOD CODES AND DEFINITIONS USED IN CHILD-SPECIFIC ANALYSIS OF THE 1987-1988 USDA NFCS DATA TO ESTIMATE HOME-PRODUCED INTAKE RATES

Table 13A-1. Food Codes and Definitions Used in Child-specific Analysis of the 1987-1988 USDA NFCS Data to Estimate Intake of Home-produced Foods		
Food Product	**Household Code/Definition**[a]	**Individual Code**
	MAJOR FOOD GROUPS	
Total Fruits	50- Fresh Fruits citrus other vitamin-C rich other fruits 512- Commercially Canned Fruits 522- Commercially Frozen Fruits 533- Canned Fruit Juice 534- Frozen Fruit Juice 535- Aseptically Packed Fruit Juice 536- Fresh Fruit Juice 542- Dried Fruits (includes baby foods)	6- Fruits citrus fruits and juices dried fruits other fruits fruits/juices & nectar fruit/juices baby food (includes baby foods)
Total Vegetables	48- Potatoes, Sweet potatoes 49- Fresh Vegetables dark green deep yellow tomatoes light green other 511- Commercially Canned Vegetables 521- Commercially Frozen Vegetables 531- Canned Vegetable Juice 532- Frozen Vegetable Juice 537- Fresh Vegetable Juice 538- Aseptically Packed Vegetable Juice 541- Dried Vegetables (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures/dinners)	7- Vegetables (all forms) white potatoes & PR starchy dark green vegetables deep yellow vegetables tomatoes and tom. mixtures other vegetables veg. and mixtures/baby food veg. with meat mixtures (includes baby foods; mixtures, mostly vegetables)
Total Meats	44- Meat beef pork veal lamb mutton goat game lunch meat mixtures 451- Poultry (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)	20- Meat, type not specified 21- Beef 22- Pork 23- Lamb, veal, game, carcass meat 24- Poultry 25- Organ meats, sausages, lunchmeats, meat spreads (excludes meat, poultry, and fish with non-meat items; frozen plate meals; soups and gravies with meat, poultry and fish base; and gelatin-based drinks; includes baby foods)

Table 13A-1. Food Codes and Definitions Used in Child-specific Analysis of the 1987-1988 USDA NFCS Data to Estimate Intake of Home-produced Foods (continued)

Food Product	Household Code/Definition[1]	Individual Code
MAJOR FOOD GROUPS		
Total Dairy	40- Milk Equivalent fresh fluid milk processed milk cream and cream substitutes frozen desserts with milk cheese dairy-based dips (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners)	1- Milk and Milk Products milk and milk drinks cream and cream substitutes milk desserts, sauces, and gravies cheeses (includes regular fluid milk, human milk, imitation milk products, yogurt, milk-based meal replacements, and infant formulas)
Total Fish	452- Fish, Shellfish various species fresh, frozen, commercial, dried (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners)	26- Fish, Shellfish various species and forms (excludes meat, poultry, and fish with non-meat items; frozen plate meals; soups and gravies with meat, poultry and fish base; and gelatin-based drinks)

[a] Food items within these categories that were identified by the household as being home-produced or home-caught (i.e., source code pertaining to home produced foods) were included in the analysis.

APPENDIX 13B

1987-1988 NFCS FOOD CODES AND DEFINITIONS USED IN ESTIMATING FRACTION OF HOUSEHOLD FOOD INTAKE THAT IS HOME-PRODUCED

Table 13B-1. Food Codes and Definitions Used in Analysis of the 1987-1988 USDA NFCS Household Data to Estimate Fraction of Food Intake that is Home-produced

Food Product	**Household Code/Definition**
INDIVIDUAL FOODS	
White Potatoes	4811- White Potatoes, fresh 4821- White Potatoes, commercially canned 4831- White Potatoes, commercially frozen 4841- White Potatoes, dehydrated 4851- White Potatoes, chips, sticks, salad (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners)
Peppers	4913- Green/Red Peppers, fresh 5111201 Sweet Green Peppers, commercially canned 5111202 Hot Chili Peppers, commercially canned 5211301 Sweet Green Peppers, commercially frozen 5211302 Green Chili Peppers, commercially frozen 5211303 Red Chili Peppers, commercially frozen 5413112 Sweet Green Peppers, dry 5413113 Red Chili Peppers, dry (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners)
Onions	4953- Onions, Garlic, fresh onions chives garlic leeks 5114908 Garlic Pulp, raw 5114915 Onions, commercially canned 5213722 Onions, commercially frozen 5213723 Onions with Sauce, commercially frozen 5413103 Chives, dried 5413105 Garlic Flakes, dried 5413110 Onion Flakes, dried (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners)
Corn	4956- Corn, fresh 5114601 Yellow Corn, commercially canned 5114602 White Corn, commercially canned 5114603 Yellow Creamed Corn, commercially canned 5114604 White Creamed Corn, commercially canned 5114605 Corn on Cob, commercially canned 5114607 Hominy, canned 5115306 Low Sodium Corn, commercially canned 5115307 Low Sodium Cr. Corn, commercially canned 5213501 Yellow Corn on Cob, commercially frozen 5213502 Yellow Corn off Cob, commercially frozen 5213503 Yell. Corn with Sauce, commercially frozen 5213504 Corn with other Veg., commercially frozen 5213505 White Corn on Cob, commercially frozen 5213506 White Corn off Cob, commercially frozen 5213507 Wh. Corn with Sauce, commercially frozen 5413104 Corn, dried 5413106 Hominy, dry 5413603 Corn, instant baby food (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby food)e

Table 13B-1. Food Codes and Definitions Used in Analysis of the 1987-1988 USDA NFCS Household Data to Estimate Fraction of Food Intake that is Home-produced (continued)

Food Product	Household Code/Definition
Apples	5031- Apples, fresh 5122101 Applesauce with sugar, commercially canned 5122102 Applesauce without sugar, comm. canned 5122103 Apple Pie Filling, commercially canned 5122104 Apples, Applesauce, baby/jr., comm. canned 5122106 Apple Pie Filling, Low Cal., comm. canned 5223101 Apple Slices, commercially frozen 5332101 Apple Juice, canned 5332102 Apple Juice, baby, Comm. canned 5342201 Apple Juice, comm. frozen 5342202 Apple Juice, home frozen 5352101 Apple Juice, aseptically packed 5362101 Apple Juice, fresh 5423101 Apples, dried (includes baby food; except mixtures)
Tomatoes	4931- Tomatoes, fresh 5113- Tomatoes, commercially canned 5115201 Tomatoes, low sodium, commercially canned 5115202 Tomato Sauce, low sodium, comm. canned 5115203 Tomato Paste, low sodium, comm. canned 5115204 Tomato Puree, low sodium, comm. canned 5311- Canned Tomato Juice and Tomato Mixtures 5321- Frozen Tomato Juice 5371- Fresh Tomato Juice 5381102 Tomato Juice, aseptically packed 5413115 Tomatoes, dry 5614- Tomato Soup 5624- Condensed Tomato Soup 5654- Dry Tomato Soup (does not include mixtures, and ready-to-eat dinners)
Snap Beans	4943- Snap or Wax Beans, fresh 5114401 Green or Snap Beans, commercially canned 5114402 Wax or Yellow Beans, commercially canned 5114403 Beans, baby/jr., commercially canned 5115302 Green Beans, low sodium, comm. canned 5115303 Yell. or Wax Beans, low sod., comm. canned 5213301 Snap or Green Beans, comm. frozen 5213302 Snap or Green w/sauce, comm. frozen 5213303 Snap or Green Beans w/other veg., comm. fr. 5213304 Sp. or Gr. Beans w/other veg./sc., comm. fr. 5213305 Wax or Yell. Beans, comm. frozen (does not include soups, mixtures, and ready-to-eat dinners; includes baby foods)
Beef	441- Beef (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Pork	442- Pork (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)

Table 13B-1. Food Codes and Definitions Used in Analysis of the 1987-1988 USDA NFCS Household Data to Estimate Fraction of Food Intake that is Home-produced (continued)

Food Product	Household Code/Definition
Game	445- Variety Meat, Game (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Poultry	451- Poultry (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Eggs	46- Eggs (fresh equivalent) fresh processed eggs, substitutes (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Broccoli	4912- Fresh Broccoli (and home canned/froz.) 5111203 Broccoli, comm. canned 52112- Comm. Frozen Broccoli (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Carrots	4921- Fresh Carrots (and home canned/froz.) 51121- Comm. Canned Carrots 5115101 Carrots, Low Sodium, Comm. Canned 52121- Comm. Frozen Carrots 5312103 Comm. Canned Carrot Juice 5372102 Carrot Juice Fresh 5413502 Carrots, Dried Baby Food (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Pumpkin	4922- Fresh Pumpkin, Winter Squash (and home canned/froz.) 51122- Pumpkin/Squash, Baby or Junior, Comm. Canned 52122- Winter Squash, Comm. Frozen 5413504 Squash, Dried Baby Food (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Asparagus	4941- Fresh Asparagus (and home canned/froz.) 5114101 Comm. Canned Asparagus 5115301 Asparagus, Low Sodium, Comm. Canned 52131- Comm. Frozen Asparagus (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Lima Beans	4942- Fresh Lima and Fava Beans (and home canned/froz.) 5114204 Comm. Canned Mature Lima Beans 5114301 Comm. Canned Green Lima Beans 5115304 Comm. Canned Low Sodium Lima Beans 52132- Comm. Frozen Lima Beans 54111- Dried Lima Beans 5411306 Dried Fava Beans (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures; does not include succotash)

Table 13B-1. Food Codes and Definitions Used in Analysis of the 1987-1988 USDA NFCS Household Data to Estimate Fraction of Food Intake that is Home-produced (continued)

Food Product	**Household Code/Definition**
Cabbage	4944- Fresh Cabbage (and home canned/froz.) 4958601 Sauerkraut, home canned or pkgd 5114801 Sauerkraut, comm. canned 5114904 Comm. Canned Cabbage 5114905 Comm. Canned Cabbage (no sauce; incl. baby) 5115501 Sauerkraut, low sodium., comm. canned 5312102 Sauerkraut Juice, comm. canned (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Lettuce	4945- Fresh Lettuce, French Endive (and home canned/froz.) (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Okra	4946- Fresh Okra (and home canned/froz.) 5114914 Comm. Canned Okra 5213720 Comm. Frozen Okra 5213721 Comm. Frozen Okra with Oth. Veg. & Sauce (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Peas	4947- Fresh Peas (and home canned/froz.) 51147- Comm Canned Peas (incl. baby) 5115310 Low Sodium Green or English Peas (canned) 5115314 Low Sod. Blackeye, Gr. or Imm. Peas (canned) 5114205 Blackeyed Peas, comm. canned 52134- Comm. Frozen Peas 5412- Dried Peas and Lentils (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Cucumbers	4952- Fresh Cucumbers (and home canned/froz.) (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Beets	4954- Fresh Beets (and home canned/froz.) 51145- Comm. Canned Beets (incl. baby) 5115305 Low Sodium Beets (canned) 5213714 Comm. Frozen Beets 5312104 Beet Juice (does not include soups, sauces, gravies, mixtures, and ready-to-eat dinners; includes baby foods except mixtures)
Strawberries	5022- Fresh Strawberries 5122801 Comm. Canned Strawberries with sugar 5122802 Comm. Canned Strawberries without sugar 5122803 Canned Strawberry Pie Filling 5222- Comm. Frozen Strawberries (does not include ready-to-eat dinners; includes baby foods except mixtures)

Table 13B-1. Food Codes and Definitions Used in Analysis of the 1987-1988 USDA NFCS Household Data to Estimate Fraction of Food Intake that is Home-produced (continued)

Food Product	**Household Code/Definition**
Other Berries	5033- Fresh Berries Other than Strawberries 5122804 Comm. Canned Blackberries with sugar 5122805 Comm. Canned Blackberries without sugar 5122806 Comm. Canned Blueberries with sugar 5122807 Comm. Canned Blueberries without sugar 5122808 Canned Blueberry Pie Filling 5122809 Comm. Canned Gooseberries with sugar 5122810 Comm. Canned Gooseberries without sugar 5122811 Comm. Canned Raspberries with sugar 5122812 Comm. Canned Raspberries without sugar 5122813 Comm. Canned Cranberry Sauce 5122815 Comm. Canned Cranberry-Orange Relish 52233- Comm. Frozen Berries (not strawberries) 5332404 Blackberry Juice (home and comm. canned) 5423114 Dried Berries (not strawberries) (does not include ready-to-eat dinners; includes baby foods except mixtures)
Peaches	5036- Fresh Peaches 51224- Comm. Canned Peaches (incl. baby) 5223601 Comm. Frozen Peaches 5332405 Home Canned Peach Juice 5423105 Dried Peaches (baby) 5423106 Dried Peaches (does not include ready-to-eat dinners; includes baby foods except mixtures)
Pears	5037- Fresh Pears 51225- Comm. Canned Pears (incl. baby) 5332403 Comm. Canned Pear Juice, baby 5362204 Fresh Pear Juice 5423107 Dried Pears (does not include ready-to-eat dinners; includes baby foods except mixtures)
Citrus Fruits	501- Fresh Citrus Fruits 5121 Comm. Canned Citrus Fruits 5331 Canned Citrus and Citrus Blend Juice 5341 Frozen Citrus and Citrus Blend Juice 5351 Aseptically Packed Citrus and Citr. Blend Juice 5361 Fresh Citrus and Citrus Blend Juice (includes baby foods; excludes dried fruits)
Other Fruits	502- Fresh Other Vitamin C-Rich Fruits 503- Fresh Other Fruits 5122- Comm. Canned Fruits Other than Citrus 5222- Frozen Strawberries 5332- Frozen Other than Citr. or Vitamin C-Rich Fr. 5333- Canned Fruit Juice Other than Citrus 5352- Frozen Juices Other than Citrus 5362- Aseptically Packed Fruit Juice Other than Citr. 542- Fresh Fruit Juice Other than Citrus Dry Fruits (includes baby foods; excludes dried fruits)

14 TOTAL FOOD INTAKE

14.1 INTRODUCTION

The U.S. food supply is generally considered to be one of the safest in the world. Nevertheless, contamination of foods may occur as a result of environmental pollution of the air, water, or soil, or the intentional use of chemicals such as pesticides or other agrochemicals. Ingestion of contaminated foods is a potential pathway of exposure to such contaminants among children. To assess chemical exposure through this pathway, information on food ingestion rates is needed. Per capita and consumers only data on food consumption rates for various food items and food categories are reported in Chapters 9 through 13 of this handbook. These intake rates were estimated by U.S. EPA using databases developed by the U.S. Department of Agriculture (USDA). U.S. EPA (2007) expanded the analysis of food intake in order to examine individuals' food consumption habits in greater detail. Using data from the USDA's Continuing Survey of Food Intake by Individuals (CSFII) conducted in 1994-1996, 1998, U.S. EPA (2007) derived distributions to characterize (1) total food intake among various groups in the U.S. population, subdivided by age, race, geographic region, and urbanization; (2) the contribution of various food categories (e.g., meats, grains, vegetables, etc.) to total food intake among these populations; and (3) the contribution of various food categories to total food intake among individuals exhibiting low- or high-end consumption patterns of a specific food category (e.g., individuals below the 10^{th} percentile or above the 90^{th} percentile for fish consumption). These data may be useful for assessing exposure among populations exhibiting lower or higher than usual intake of certain types of foods (e.g., people who eat little or no meat, or people who eat large quantities of fish).

The recommendations for total food intake rates are provided in the next section, along with a summary of the confidence ratings for these recommendations. Following the recommendations, the key study on total food intake is summarized.

14.2 RECOMMENDATIONS

A summary of recommended values for total food intake, on an as-consumed basis, is presented in Table 14-1. The confidence ratings for these recommendations are presented in Table 14-2. The recommended intake rates for children are based on data from the U.S. EPA (2007) analysis of CSFII data. However, the analysis presented in U.S. EPA (2007) was conducted before U.S. EPA published the guidance entitled *Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). As a result, the age groups used for children in U.S. EPA (2007) were not entirely consistent with the age groups recommended in the 2005 guidance. Therefore, a re-analysis of the data was conducted to conform with U.S. EPA's recommended age groups for children.

Because these recommendations are based on 1994-96 and 1998 CSFII data, they may not reflect recent changes that may have occurred in consumption patterns. In addition, these distributions are based on data collected over a 2-day period and may not necessarily reflect the long-term distribution of average daily intake rates. However, for the broad categories of foods used in this analysis (e.g., total foods, total fruits, total vegetables, etc.), because they are typically eaten on a daily basis throughout the year with minimal seasonality, the short-term distribution may be a reasonable approximation of the long-term distribution, although it will display somewhat increased variability. This implies that the upper percentiles shown here will tend to overestimate the corresponding percentiles of the true long-term distribution.

Table 14-1. Recommended Values for Per Capita Total Food Intake, As Consumed

Age Group	Mean	95th Percentile	Multiple Percentiles	Source
	g/kg-day			
Birth to <1 month	20	61	See Table 14-3	U.S. EPA re-analysis of CSFII 1994-96, 98 data (Based on U.S. EPA, 2007)
1 to <3 months	16	40		
3 to <6 months	28	65		
6 to <12 months	56	134		
1 to <2 years	90	161		
2 to <3 years	74	126		
3 to <6 years	61	102		
6 to <11 years	40	70		
11 to <16 years	24	45		
16 to <21 years	18	35		

Note: Total food intake was defined as intake of the sum of all foods in the following major food categories: dairy, meats, fish, eggs, grains, vegetables, fruits, and fats. Beverages, sugar, candy, and sweets, and nuts and nut products were not included because they could not be categorized into the major food groups. Also, human milk intake was not included.

Table 14-2. Confidence in Recommendations for Total Food Intake		
General Assessment Factors	Rationale	Rating
Soundness		High
Adequacy of Approach	The survey methodology was adequate and the analytical approach was competently executed. The study size was very large; sample size varied with age. The response rate was good. The key study analyzed primary data on recall of ingestion.	
Minimal (or Defined) Bias	No direct measurements were taken. The study relied on survey data.	
Applicability and Utility		Medium
Exposure Factor of Interest	The analysis was specifically designed to address food intake.	
Representativeness	The population studied was representative of the U.S. population.	
Currency	The data used were the most current data publicly available at the time the analysis was conducted for the handbook.	
Data Collection Period	Ingestion rates were estimated based on short-term data collected in the CSFII 1994-96, 1998.	
Clarity and Completeness		Medium
Accessibility	The CSFII data are publicly available. The U.S. EPA (2007) report is available online.	
Reproducibility	The methodology was clearly presented; enough information was included to reproduce results.	
Quality Assurance	Quality assurance methods were not described in the study report.	
Variability and Uncertainty		Medium
Variability in Population	Short term distributions were provided. The survey was not designed to capture long term day-to-day variability.	
Uncertainty	The survey data were based on recall over a 2-day period. Other sources of uncertainty were minimal.	
Evaluation and Review		Medium
Peer Review	The USDA CSFII survey received a high level of peer review. U.S. EPA (2007) analysis was also peer-reviewed; however, the re-analysis of these data using the new age categories was not peer reviewed outside the Agency.	
Number and Agreement of Studies	Only one key study was available for this factor	
Overall Rating		**Medium**

14.3 KEY STUDY OF TOTAL FOOD INTAKE

14.3.1 U.S. EPA Re-analysis of 1994-96, 1998 CSFII, Based on U.S. EPA (2007) - Analysis of Total Food Intake and Composition of Individual's Diet Based on USDA's 1994–96, 1998 Continuing Survey of Food Intakes by Individuals (CSFII)

U.S. EPA's National Center for Environmental Assessment (NCEA) conducted an analysis to evaluate the total food intake of individuals in the United States using data from the USDA's 1994–1996, 1998 CSFII (USDA, 2000) and U.S. EPA's *Food Commodity Intake Database* (FCID) (U.S. EPA, 2000). The 1994–96 CSFII and its 1998 Supplemental Children's Survey were designed to obtain data from a statistically representative sample of noninstitutionalized persons living in the United States. Survey participants were selected using a multistage process. The respondents were interviewed twice to collect information on food consumption during two non-consecutive days. For both survey days, data were collected by an in-home interviewer. The day two interview was conducted 3 to10 days later and on a different day of the week. Of the more than 20,000 individuals surveyed, approximately 10,000 were under 21 years of age, and approximately 9,000 were under the age of 11. The 1994-96 survey and 1998 supplement are referred to collectively as CSFII 1994-96, 1998. Each individual in the survey was assigned a sample weight based on his or her demographic data; these weights were taken into account when calculating mean and percentile values of food consumption for the various demographic categories that were analyzed in the study. The sample weighting process used in the CSFII 1994-96, 1998 are discussed in detail in USDA (2000).

For the analysis of total food intake, food commodity codes provided in U.S. EPA's Food Commodity Intake Database (FCID) (U.S. EPA, 2000) were used to translate as-eaten foods (e.g., beef stew) identified by USDA food codes in the CSFII data set into food commodities (e.g., beef, potatoes, carrots, etc.). The method used to translate USDA food codes into U.S. EPA commodity codes is discussed in detail in USDA (2000). The U.S. EPA commodity codes were assigned to broad food categories (e.g., total meats, total vegetables, etc.) for use in the analysis. Total food intake was defined as intake of the sum of all foods in the following major food categories: dairy, meats, fish, eggs, grains, vegetables, fruits, and fats. Beverages, sugar, candy, and sweets, and nuts and nut products were not included because they could not be categorized into the major food groups. Also, human milk intake was not included. Total food intake was calculated for various age groups of children. Percent consuming, mean, standard error, and a range of percentile values were calculated on the basis of grams of food per kilogram of body weight per day (g/kg-day) and on the basis of grams per day (g/day). In addition to total food intake, intake of the various major food groups for the various age groups in units of g/day and g/kg-day were also estimated for comparison to total intake.

To evaluate variability in the contributions of the major food groups to total food intake, individuals were ranked from lowest to highest, based on total food intake. Three subsets of individuals were defined, as follows: a group at the low end of the distribution of total intake (i.e., below the 10th percentile of total intake), a central group (i.e., the 45th to 55th percentile of total intake), and a group at the high end of the distribution of total intake (i.e., above the 90th percentile of total intake). Mean total food intake (in g/day and g/kg-day), mean intake of each of the major food groups (in g/day and g/kg-day), and the percent of total food intake that each of these food groups represents was calculated for each of the three populations (i.e., individuals with low-end, central, and high-end total food intake). A similar analysis was conducted to estimate the contribution of the major food groups to total food intake for individuals at the low-end, central, and high-end of the distribution of total meat intake, total dairy intake, total meat and dairy intake, total fish intake, and total fruit and vegetable intake. For example, to evaluate the variability in the diets of individuals at the low-end, central range, and high-end of the distribution of total meat intake, survey individuals were ranked according to their reported total meat intake. Three subsets of individuals were formed as described above. Mean total food intake, intake of the major food groups, and the percent of total food intake represented by each of the major food groups were tabulated. U.S. EPA (2007) presented the results of the analysis for the following age groups: <1 year, 1 to 2 years, 3 to 5 years, 6 to 11 years, and 12 to 19 years. The data were tabulated in units of g/kg-day and g/day.

In order to conform to the standard age categories recommended in *Guidance on Selecting Age*

Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants (U.S. EPA, 2005) and used in this handbook, each of the tables from U.S. EPA (2007) was modified by re-analyzing the source data and applying the new age categories (i.e., <1 month, 1 to <3 months, 3 to <6 months, 6 to <12 months, 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 results of this re-analysis are presented in Tables 14-3 through 14-11. Distributions of total food intake are presented in Table 14-3 in units of g/day and g/kg-day. Tables 14-4 and 14-5 compare total food intake to intake of the various major food groups for the various age groups in units of g/day and g/kg-day, respectively. It should be noted that some U.S. EPA commodity codes are listed under more than one food category. For this reason, in the tables, the intake rates for the individual food categories do not necessarily add up to the figure given for total food intake (U.S. EPA, 2007). Also, data are not reported for food groups for which there were less than 20 consumers in a particular age group. Tables 14-6 through 14-11 present the contributions of the major food groups to total food intake for individuals (in the various age groups) at the low-end, central, and high-end of the distribution of total food intake (Table 14-6), total meat intake (Table 14-7), total meat and dairy intake (Table 14-8), total fish intake (Table 14-9), total fruit and vegetable intake (Table 14-10), and total dairy intake (Table 14-11) in units of g/day and g/kg-day. For each of the three classes of consumers, consumption of nine different food categories is presented (i.e., total foods, dairy, meats, fish, eggs, grains, vegetables, fruits, and fats). For example, in Table 14-9 one will find the mean consumption of meats, eggs, vegetables, etc. for individuals with an unusually high (or low or average) consumption of fish.

As discussed in previous chapters, the 1994-96, 98 CSFII data set have both advantages and limitations with regard to estimating food intake rates. The large sample size (more than 20,000 persons; approximately 10,000 children) is sufficient to allow categorization within narrowly defined age categories. In addition, the survey was designed to obtain a statistically valid sample of the entire United States population that included children and low income groups. However, the survey design is of limited utility for assessing small and potentially at-risk subpopulations based on ethnicity, medical status, geography, or other factors such as activity level. Another limitation is that data are based on a two-day survey period and, as such, may not accurately reflect long-term eating patterns. This is particularly true for the tails (extremes) of the distribution of food intake.

14.4 REFERENCES FOR CHAPTER 14

USDA (2000) 1994–96, 1998 Continuing survey of food intakes by individuals (CSFII). CD-ROM. Agricultural Research Service, Beltsville Human Nutrition Research Center, Beltsville, MD. Available from the National Technical Information Service, Springfield, VA; PB-2000-500027.

U.S. EPA (2000) Food commodity intake database [FCID raw data file]. Office of Pesticide Programs, Washington, DC. Available from the National Technical Information Service, Springfield, VA; PB2000-5000101.

U.S. EPA (2005) Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants. U.S. Environmental Protection Agency, Washington, D.C., EPA/630/P-03/003F. Available from the National Technical Information Service, Springfield, VA, and online at www.epa.gov/ncea.

U.S. EPA (2007) Analysis of total food intake and composition of individual's diet based on USDA's 1994–96, 1998 continuing survey of food intakes by individuals (CSFII). National Center for Environmental Assessment, Washington, DC; EPA/600/R-05/062F. Available from the National Technical Information Service, Springfield, VA, and online at www.epa.gov/ncea.

Table 14-3. Per Capita Total Food Intake

Age Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile 1	5	10	25	50	75	90	95	99	100
Total Food Intake (g/day, as consumed)															
Birth to <1 month	59	88	67.0%	67	59	0	0	0	0	67	108	142	221	222	222
1 to <3 month	183	245	74.7%	80	70	0	0	0	0	94	120	168	188	273	404
3 to <6 month	385	411	93.7%	197	150	0	0	12	100	167	286	385	476	705	1,151
6 to <12 month	676	678	99.7%	507	344	34	141	191	283	413	600	925	1,220	1,823	2,465
1 to <2 years	1,002	1,002	100%	1,039	407	216	414	570	770	998	1,244	1,556	1,756	2,215	3,605
2 to <3 years	994	994	100%	1,024	377	312	491	575	752	994	1,257	1,517	1,649	2,071	2,737
3 to <6 years	4,112	4,112	100%	1,066	380	416	548	629	805	1,020	1,276	1,548	1,746	2,168	4,886
6 to <11 years	1,553	1,553	100%	1,118	372	438	586	680	846	1,052	1,344	1,642	1,825	2,218	3,602
11 to <16 years	975	975	100%	1,209	499	343	536	657	851	1,124	1,491	1,860	2,179	2,668	4,548
16 to <21 years	743	743	100%	1,184	634	308	467	556	750	1,061	1,447	1,883	2,283	3,281	8,840
Total Food Intake (g/kg-day, as consumed)															
Birth to <1 month	59	88	67.0%	20	18	0	0	0	0	19	33	43	61	69	69
1 to <3 month	183	245	74.7%	16	14	0	0	0	0	18	25	36	40	55	76
3 to <6 month	385	411	93.7%	28	21	0	0	2	15	24	38	53	65	107	169
6 to <12 month	676	678	99.7%	56	36	3	17	22	33	47	66	99	134	211	233
1 to <2 years	1,002	1,002	100%	90	37	17	38	48	65	85	109	137	161	207	265
2 to <3 years	994	994	100%	74	29	23	34	39	52	72	92	113	126	146	194
3 to <6 years	4,112	4,112	100%	61	24	21	30	34	44	57	73	91	102	132	239
6 to <11 years	1,553	1,553	100%	40	17	10	17	21	28	38	49	61	70	88	122
11 to <16 years	975	975	100%	24	11	5	9	11	16	22	30	38	45	55	82
16 to <21 years	743	743	100%	18	9	5	6	8	12	16	22	30	35	47	115

[a] Number of consumers. The number of consumers of total food may be less than the number of individuals in the study sample for the youngest age groups, because human milk was not included in the total food intake estimates presented here.
[b] Sample size.
PC = Percent consuming.
SE = Standard error.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-4. Per Capita Intake of Total Food and Intake of Major Food Groups (g/day, As Consumed)

Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age Birth to <1month															
Total Food Intake	59	88	67.0%	67	59	0	0	0	0	67	108	142	221	222	222
Total Dairy Intake	51	88	58.0%	41	38	0	0	0	0	40	72	81	156	156	156
Total Meat Intake	0	88	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Egg Intake	0	88	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Fish Intake	0	88	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Grain Intake	5	88	5.7%	-	-	-	-	-	-	-	-	-	-	-	-
Total Vegetable Intake	27	88	30.7%	5	23	0	0	0	0	0	0.29	16	32	108	125
Total Fruit Intake	2	88	2.3%	-	-	-	-	-	-	-	-	-	-	-	-
Total Fat Intake	58	88	65.9%	19	16	0	0	0	0	20	32	38	64	64	64
Age 1 to <3 months															
Total Food Intake	183	245	74.7%	80	70	0	0	0	0	94	120	168	188	273	404
Total Dairy Intake	147	245	60.0%	37	40	0	0	0	0	19	72	89	103	129	155
Total Meat Intake	1	245	0.4%	-	-	-	-	-	-	-	-	-	-	-	-
Total Egg Intake	0	245	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Fish Intake	0	245	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Grain Intake	44	245	18.0%	1	5	0	0	0	0	0	0	3	9	20	45
Total Vegetable Intake	88	245	35.9%	15	33	0	0	0	0	0	0.92	74	94	119	211
Total Fruit Intake	23	245	9.4%	4	21	0	0	0	0	0	0	0	31	114	171
Total Fat Intake	176	245	71.8%	21	17	0	0	0	0	27	34	42	49	65	72
Age 3 to <6 months															
Total Food Intake	385	411	93.7%	197	150	0	0	12	100	167	286	385	476	705	1,151
Total Dairy Intake	308	411	74.9%	56	56	0	0	0	0	60	85	109	124	260	496
Total Meat Intake	44	411	10.7%	2	7	0	0	0	0	0	0	1	13	29	92
Total Egg Intake	28	411	6.8%	0.23	3	0	0	0	0	0	0	0	0.49	4	50
Total Fish Intake	1	411	0.2%	-	-	-	-	-	-	-	-	-	-	-	-
Total Grain Intake	284	411	69.1%	8	11	0	0	0	0	4	11	21	27	44	68
Total Vegetable Intake	263	411	64.0%	34	46	0	0	0	0	13	58	102	120	184	226
Total Fruit Intake	218	411	53.0%	68	102	0	0	0	0	15	99	196	282	522	750
Total Fat Intake	357	411	86.9%	28	17	0	0	0	20	30	38	45	53	81	106

Table 14-4. Per Capita Intake of Total Food and Intake of Major Food Groups (g/day, As Consumed) (continued)

Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age 6 to <12 months															
Total Food Intake	676	678	99.7%	507	344	34	141	191	283	413	600	925	1,220	1,823	2,465
Total Dairy Intake	628	678	92.6%	151	246	0	0	0.52	26	71	124	401	722	1,297	1,873
Total Meat Intake	500	678	73.7%	22	27	0	0	0	0.013	14	32	59	78	117	269
Total Egg Intake	352	678	51.9%	6	13	0	0	0	0	0.019	2	22	42	73	103
Total Fish Intake	34	678	5.0%	0.62	3	0	0	0	0	0	0	0	0	21	42
Total Grain Intake	653	678	96.3%	33	28	0	0.83	6	14	28	45	66	84	125	260
Total Vegetable Intake	662	678	97.6%	91	67	0	2	14	41	81	127	180	231	285	452
Total Fruit Intake	639	678	94.2%	169	142	0	0	17	70	147	232	335	425	670	1,254
Total Fat Intake	661	678	97.5%	31	16	0	2	7	23	31	40	51	58	81	90
Age 1 to <2 years															
Total Food Intake	1,002	1,002	100%	1,039	407	216	414	570	770	998	1,244	1,556	1,756	2,215	3,605
Total Dairy Intake	999	1,002	99.7%	489	332	1	38	94	241	451	681	917	1,090	1,474	2,935
Total Meat Intake	965	1,002	96.3%	47	37	0	0.27	6	20	39	66	100	120	181	221
Total Egg Intake	906	1,002	90.4%	14	21	0	0	0.0014	1	4	23	45	57	86	212
Total Fish Intake	188	1,002	18.8%	3	10	0	0	0	0	0	0	11	21	45	135
Total Grain Intake	997	1,002	99.5%	66	34	8	19	27	42	60	83	111	126	172	209
Total Vegetable Intake	1,000	1,002	99.8%	120	75	9	25	37	68	107	155	220	255	402	739
Total Fruit Intake	986	1,002	98.4%	254	204	0	4	30	99	209	349	532	664	828	1,762
Total Fat Intake	1,002	1,002	100%	39	17	8	15	20	28	37	48	62	69	87	146
Age 2 to <3 years															
Total Food Intake	994	994	100%	1,024	377	312	491	575	752	994	1,257	1,517	1,649	2,071	2,737
Total Dairy Intake	994	994	100%	383	243	6	54	104	201	346	510	709	838	1,079	1,378
Total Meat Intake	981	994	98.7%	60	41	0	8	14	31	51	80	115	139	199	280
Total Egg Intake	943	994	94.9%	18	24	0	0	0.070	1	7	27	50	60	93	169
Total Fish Intake	190	994	19.1%	4	12	0	0	0	0	0	0	13	26	53	127
Total Grain Intake	993	994	99.9%	81	35	16	32	41	58	78	99	126	147	195	263
Total Vegetable Intake	994	994	100%	145	89	18	45	57	86	128	178	249	302	431	846
Total Fruit Intake	970	994	97.6%	279	230	0	2	25	117	231	382	594	750	992	2,042
Total Fat Intake	994	994	100%	42	18	11	17	22	30	40	51	65	73	101	129

Table 14-4. Per Capita Intake of Total Food and Intake of Major Food Groups (g/day, As Consumed) (continued)

Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age 3 to <6 years															
Total Food Intake	4,112	4,112	100%	1066	380	416	548	629	805	1,020	1,276	1,548	1,746	2,168	4,886
Total Dairy Intake	4,112	4,112	100%	392	249	14	68	121	224	356	522	706	805	1,151	3,978
Total Meat Intake	4,062	4,112	98.8%	73	49	0	11	20	38	65	97	133	163	230	433
Total Egg Intake	3,910	4,112	95.1%	16	23	0	0.00032	0.065	1	6	24	47	59	99	290
Total Fish Intake	801	4,112	19.5%	5	16	0	0	0	0	0	0	19	36	71	192
Total Grain Intake	4,111	4,112	100%	101	41	29	44	54	72	95	122	155	175	230	410
Total Vegetable Intake	4,111	4,112	100%	170	89	30	56	75	109	156	213	280	329	454	915
Total Fruit Intake	4,021	4,112	97.8%	243	220	0	2	16	85	196	344	516	642	1,000	2,252
Total Fat Intake	4,112	4,112	100%	50	19	14	23	27	36	47	60	74	85	113	167
Age 6 to <11 years															
Total Food Intake	1,553	1,553	100%	1118	372	438	586	680	846	1,052	1,344	1,642	1,825	2,218	3,602
Total Dairy Intake	1,553	1,553	100%	408	243	10	63	126	229	371	557	741	837	1,130	2,680
Total Meat Intake	1,533	1,553	98.7%	87	56	0	12	24	48	79	116	156	195	268	435
Total Egg Intake	1,490	1,553	95.9%	16	22	0	0.0019	0.13	2	6	22	46	58	107	163
Total Fish Intake	258	1,553	16.6%	6	17	0	0	0	0	0	0	23	38	102	169
Total Grain Intake	1,553	1,553	100%	119	48	31	54	67	87	114	143	179	201	262	513
Total Vegetable Intake	1,553	1,553	100%	210	103	42	76	96	136	193	264	342	410	560	896
Total Fruit Intake	1,515	1,553	97.6%	193	184	0	1	8	60	141	280	440	545	880	1,406
Total Fat Intake	1,553	1,553	100%	58	22	16	27	33	42	56	70	86	95	121	168
Age 11 to <16 years															
Total Food Intake	975	975	100%	1209	499	343	536	657	851	1,124	1,491	1,860	2,179	2,668	4,548
Total Dairy Intake	975	975	100%	368	291	1	25	43	152	307	507	740	948	1,401	1,972
Total Meat Intake	970	975	99.5%	114	75	1	18	32	63	101	154	208	244	355	578
Total Egg Intake	930	975	95.4%	19	27	0	0.00087	0.12	2	7	25	53	72	123	244
Total Fish Intake	167	975	17.1%	9	24	0	0	0	0	0	0	30	62	125	227
Total Grain Intake	975	975	100%	136	63	33	56	70	93	127	168	212	249	333	645
Total Vegetable Intake	975	975	100%	280	146	65	105	124	176	246	352	472	552	713	1,333
Total Fruit Intake	923	975	94.7%	195	202	0	0.000073	0.68	31	135	273	483	635	930	1,535
Total Fat Intake	975	975	100%	69	33	18	28	34	47	64	83	110	131	176	321

Table 14-4. Per Capita Intake of Total Food and Intake of Major Food Groups (g/day, As Consumed) (continued)

Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age 16 to <21 years															
Total Food Intake	743	743	100%	1184	634	308	467	556	750	1,061	1,447	1,883	2,283	3,281	8,840
Total Dairy Intake	742	743	99.9%	283	279	0.24	8	19	63	196	410	649	934	1,235	1,866
Total Meat Intake	730	743	98.3%	139	127	0	12	28	64	116	185	266	310	458	2,343
Total Egg Intake	703	743	94.6%	21	30	0	0	0.078	1	7	29	59	89	126	223
Total Fish Intake	143	743	19.2%	10	33	0	0	0	0	0	0	34	76	146	399
Total Grain Intake	743	743	100%	150	93	13	48	58	88	132	190	256	307	543	730
Total Vegetable Intake	743	743	100%	325	204	43	86	128	194	280	400	562	683	1,160	2,495
Total Fruit Intake	671	743	90.3%	168	237	0	0	0.0022	3	74	242	432	665	1,023	2,270
Total Fat Intake	743	743	100%	74	42	13	22	30	46	67	94	129	148	213	391

[a] Number of consumers. The number of consumers of total food may be less than the number of individuals in the study sample for the youngest age groups, because human milk was not included in the total food intake estimates presented here.
[b] Sample size.
PC = Percent consuming.
SE = Standard error.
\- = Data not reported where the number of consumers was less than 20.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-5. Per Capita Intake of Total Food and Intake of Major Food Groups (g/kg-day, As Consumed)

Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age Birth to <1month															
Total Food Intake	59	88	67.0%	20	18	0	0	0	0	19	33	43	61	69	69
Total Dairy Intake	51	88	58.0%	12	12	0	0	0	0	13	21	25	43	49	49
Total Meat Intake	0	88	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Egg Intake	0	88	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Fish Intake	0	88	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Grain Intake	5	88	5.7%	-	-	-	-	-	-	-	-	-	-	-	-
Total Vegetable Intake	27	88	30.7%	2	6	0	0	0	0	0	0.11	4	12	30	35
Total Fruit Intake	2	88	2.3%	-	-	-	-	-	-	-	-	-	-	-	-
Total Fat Intake	58	88	65.9%	6	5	0	0	0	0	6	9	11	18	20	20
Age 1 to <3 months															
Total Food Intake	183	245	74.7%	16	14	0	0	0	0	18	25	36	40	55	76
Total Dairy Intake	147	245	60.0%	8	9	0	0	0	0	4	15	20	26	34	43
Total Meat Intake	1	245	0.4%	-	-	-	-	-	-	-	-	-	-	-	-
Total Egg Intake	0	245	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Fish Intake	0	245	0.0%	-	-	-	-	-	-	-	-	-	-	-	-
Total Grain Intake	44	245	18.0%	0.23	1	0	0	0	0	0	0	1	2	3	9
Total Vegetable Intake	88	245	35.9%	3	6	0	0	0	0	0	0.18	13	17	26	34
Total Fruit Intake	23	245	9.4%	1	5	0	0	0	0	0	0	0	7	19	43
Total Fat Intake	176	245	71.8%	4	4	0	0	0	0	5	7	9	11	14	18
Age 3 to <6 months															
Total Food Intake	385	411	93.7%	28	21	0	0	2	15	24	38	53	65	107	169
Total Dairy Intake	308	411	74.9%	8	8	0	0	0	0	8	12	16	20	38	73
Total Meat Intake	44	411	10.7%	0.21	0.97	0	0	0	0	0	0	0.12	1	4	13
Total Egg Intake	28	411	6.8%	0.024	0	0	0	0	0	0	0	0	0.055	1	4
Total Fish Intake	1	411	0.2%	-	-	-	-	-	-	-	-	-	-	-	-
Total Grain Intake	284	411	69.1%	1	2	0	0	0	0	1	1	3	4	6	10
Total Vegetable Intake	263	411	64.0%	5	7	0	0	0	0	2	8	14	18	25	52
Total Fruit Intake	218	411	53.0%	9	15	0	0	0	0	2	13	29	37	72	110
Total Fat Intake	357	411	86.9%	4	3	0	0	0	2	4	6	7	8	12	17

Table 14-5. Per Capita Intake of Total Food and Intake of Major Food Groups (g/kg-day, As Consumed) (continued)

Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age 6 to <12 months															
Total Food Intake	676	678	99.7%	56	36	3	17	22	33	47	66	99	134	211	233
Total Dairy Intake	628	678	92.6%	16	26	0	0	0.068	3	8	14	38	72	165	180
Total Meat Intake	500	678	73.7%	2	3	0	0	0	0.0017	1	4	6	8	12	30
Total Egg Intake	352	678	51.9%	0.58	1	0	0	0	0	0.0023	0.21	2	4	7	11
Total Fish Intake	34	678	5.0%	0.064	0.35	0	0	0	0	0	0	0	0	2	4
Total Grain Intake	653	678	96.3%	4	3	0	0.097	0.67	2	3	5	7	9	14	26
Total Vegetable Intake	662	678	97.6%	10	8	0	0.26	2	5	9	14	20	25	34	67
Total Fruit Intake	639	678	94.2%	19	16	0	0	2	8	16	26	36	46	84	138
Total Fat Intake	661	678	97.5%	3	2	0	0.20	0.77	2	3	4	6	7	8	10
Age 1 to <2 years															
Total Food Intake	1,002	1,002	100%	90	37	17	38	48	65	85	109	137	161	207	265
Total Dairy Intake	999	1,002	99.7%	43	30	0.10	3	8	20	38	59	83	100	137	216
Total Meat Intake	965	1,002	96.3%	4	3	0	0.023	0.59	2	3	6	8	10	14	21
Total Egg Intake	906	1,002	90.4%	1	2	0	0	0.000098	0.085	0.37	2	4	5	7	15
Total Fish Intake	188	1,002	18.8%	0.27	0.88	0	0	0	0	0	0	1	2	3	12
Total Grain Intake	997	1,002	99.5%	6	3	0.87	2	2	4	5	7	9	11	15	19
Total Vegetable Intake	1,000	1,002	99.8%	10	7	0.65	2	3	6	9	14	19	22	33	61
Total Fruit Intake	986	1,002	98.4%	22	18	0	0.41	3	9	18	31	44	58	81	144
Total Fat Intake	1,002	1,002	100%	3	2	0.73	1	2	2	3	4	5	6	8	11
Age 2 to <3 years															
Total Food Intake	994	994	100%	74	29	23	34	39	52	72	92	113	126	146	194
Total Dairy Intake	994	994	100%	28	18	0.42	4	7	14	24	37	52	63	84	108
Total Meat Intake	981	994	98.7%	4	3	0	0.55	1	2	4	6	8	9	14	20
Total Egg Intake	943	994	94.9%	1	2	0	0	0.0051	0.098	0.49	2	4	4	6	13
Total Fish Intake	190	994	19.1%	0.27	0.89	0	0	0	0	0	0	0.91	2	4	11
Total Grain Intake	993	994	99.9%	6	3	1	2	3	4	5	7	9	10	14	28
Total Vegetable Intake	994	994	100%	10	6	1	3	4	6	9	13	18	22	34	64
Total Fruit Intake	970	994	97.6%	20	17	0	0.14	2	8	16	27	44	56	71	114
Total Fat Intake	994	994	100%	3	1	0.72	1	1	2	3	4	5	5	7	9

Table 14-5. Per Capita Intake of Total Food and Intake of Major Food Groups (g/kg-day, As Consumed) (continued)

Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age 3 to <6 years															
Total Food Intake	4,112	4,112	100%	61	24	21	30	34	44	57	73	91	102	132	239
Total Dairy Intake	4,112	4,112	100%	22	15	0.83	4	7	12	20	30	41	48	66	195
Total Meat Intake	4,062	4,112	98.8%	4	3	0	0.61	1	2	4	5	8	9	13	23
Total Egg Intake	3,910	4,112	95.1%	0.89	1	0	0.000022	0.0035	0.081	0.32	1	3	3	5	13
Total Fish Intake	801	4,112	19.5%	0.29	0.88	0	0	0	0	0	0	1	2	4	12
Total Grain Intake	4,111	4,112	100%	6	3	2	2	3	4	5	7	9	10	14	27
Total Vegetable Intake	4,111	4,112	100%	10	5	2	3	4	6	9	12	16	19	26	60
Total Fruit Intake	4,021	4,112	97.8%	14	13	0	0.13	0.94	5	11	20	30	39	57	124
Total Fat Intake	4,112	4,112	100%	3	1	0.85	1	2	2	3	3	4	5	6	10
Age 6 to <11 years															
Total Food Intake	1,553	1,553	100%	40	17	10	17	21	28	38	49	61	70	88	122
Total Dairy Intake	1,553	1,553	100%	15	10	0.35	2	4	7	13	20	27	33	42	79
Total Meat Intake	1,533	1,553	98.7%	3	2	0	0.44	0.82	2	3	4	6	7	10	18
Total Egg Intake	1,490	1,553	95.9%	0.55	1	0	0.000084	0.0034	0.054	0.21	0.72	2	2	4	8
Total Fish Intake	258	1,553	16.6%	0.21	0.66	0	0	0	0	0	0	0.79	1	3	7
Total Grain Intake	1,553	1,553	100%	4	2	0.92	2	2	3	4	5	7	8	11	16
Total Vegetable Intake	1,553	1,553	100%	7	4	1	2	3	5	7	9	12	15	20	50
Total Fruit Intake	1,515	1,553	97.6%	7	7	0	0.049	0.24	2	5	10	16	21	32	55
Total Fat Intake	1,553	1,553	100%	2	1	0.60	0.91	1	1	2	3	3	4	5	9
Age 11 to <16 years															
Total Food Intake	975	975	100%	24	11	5	9	11	16	22	30	38	45	55	82
Total Dairy Intake	975	975	100%	7	6	0.021	0.38	0.82	3	6	10	15	20	29	38
Total Meat Intake	970	975	99.5%	2	1	0.022	0.35	0.63	1	2	3	4	5	7	10
Total Egg Intake	930	975	95.4%	0.36	1	0	0.000015	0.0021	0.033	0.14	0.45	1	1	3	7
Total Fish Intake	167	975	17.1%	0.16	0.48	0	0	0	0	0	0	0.57	1	2	7
Total Grain Intake	975	975	100%	3	1	0.62	0.94	1	2	2	3	5	5	7	9
Total Vegetable Intake	975	975	100%	5	3	1	2	2	3	5	7	9	11	14	31
Total Fruit Intake	923	975	94.7%	4	4	0	0.000001	0.13	0.64	3	6	10	14	18	32
Total Fat Intake	975	975	100%	1	1	0.35	0.48	0.61	1	1	2	2	3	4	5

Table 14-5. Per Capita Intake of Total Food and Intake of Major Food Groups (g/kg-day, As Consumed) (continued)															
Food Group	N cons.[a]	N total[b]	PC	Mean	SE	Percentile									
						1	5	10	25	50	75	90	95	99	100
Age 16 to <21 years															
Total Food Intake	743	743	100%	18	9	5	6	8	12	16	22	30	35	47	115
Total Dairy Intake	742	743	99.9%	4	4	0.0058	0.13	0.28	0.88	3	6	10	12	19	25
Total Meat Intake	730	743	98.3%	2	2	0	0.18	0.49	0.95	2	3	4	5	7	30
Total Egg Intake	703	743	94.6%	0.31	0.43	0	0	0.0012	0.018	0.11	0.44	0.96	1	2	3
Total Fish Intake	143	743	19.2%	0.15	0.51	0	0	0	0	0	0	0.51	1	2	7
Total Grain Intake	743	743	100%	2	1	0.17	0.65	0.85	1	2	3	4	5	7	12
Total Vegetable Intake	743	743	100%	5	3	0.61	1	2	3	4	6	8	10	15	32
Total Fruit Intake	671	743	90.3%	3	4	0	0	0.000030	0.049	1	4	7	10	16	29
Total Fat Intake	743	743	100%	1	1	0.21	0.33	0.47	1	1	1	2	2	3	5

[a] Number of consumers. The number of consumers of total food may be less than the number of individuals in the study sample for the youngest age groups, because human milk was not included in the total food intake estimates presented here.
[b] Sample size.
PC = Percent consuming.
SE = Standard error.
- = Data not reported where the number of consumers was less than 20.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-6. 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

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/day, as consumed)						
Total Foods	0	0.0%	64	100.0%	196	100.0%
Total Dairy	0	0.0%	39	61.2%	109	55.4%
Total Meats	0	0.0%	0	0.0%	0	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0	0.0%	0	0.0%	4	2.1%
Total Vegetables	0	0.0%	5	7.4%	24	12.1%
Total Fruits	0	0.0%	0	0.0%	8	4.1%
Total Fats [a]	0	0.0%	19	29.4%	52	26.2%
Age 1 to <3 months (g/day, as consumed)						
Total Foods	0	0.0%	94	100.0%	206	100.0%
Total Dairy	0	0.0%	53	56.9%	63	30.8%
Total Meats	0	0.0%	0	0.0%	0	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0	0.0%	1	1.1%	3	1.3%
Total Vegetables	0	0.0%	11	12.0%	58	28.4%
Total Fruits	0	0.0%	0.033	0.0%	27	13.0%
Total Fats [a]	0	0.0%	27	28.4%	49	23.6%
Age 3 to <6 months (g/day, as consumed)						
Total Foods	1	100.0%	166	100.0%	507	100.0%
Total Dairy	0.038	3.0%	69	41.9%	90	17.8%
Total Meats	0	0.0%	0.38	0.2%	4	0.8%
Total Fish	0	0.0%	0	0.0%	0.42	0.1%
Total Eggs	0	0.0%	0.50	0.3%	0.60	0.1%
Total Grains	0.93	74.5%	8	4.9%	14	2.8%
Total Vegetables	0.14	10.9%	27	16.3%	73	14.4%
Total Fruits	0.12	9.9%	24	14.6%	284	56.0%
Total Fats [a]	0.017	1.3%	34	20.4%	36	7.2%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/kg-day, as consumed)						
Total Foods	0	0.0%	20	100.0%	58	100.0%
Total Dairy	0	0.0%	14	70.5%	35	60.1%
Total Meats	0	0.0%	0	0.0%	0	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0	0.0%	0	0.0%	1	2.1%
Total Vegetables	0	0.0%	0.012	0.1%	6	10.0%
Total Fruits	0	0.0%	0	0.0%	0	0.0%
Total Fats [a]	0	0.0%	6	29.4%	16	27.8%
Age 1 to <3 months (g/kg-day, as consumed)						
Total Foods	0	0.0%	18	100.0%	44	100.0%
Total Dairy	0	0.0%	9	51.9%	20	45.4%
Total Meats	0	0.0%	0	0.0%	0.012	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0	0.0%	0.19	1.1%	0.23	0.5%
Total Vegetables	0	0.0%	3	18.9%	7	16.4%
Total Fruits	0	0.0%	0	0.0%	5	12.3%
Total Fats [a]	0	0.0%	5	27.7%	11	24.4%
Age 3 to <6 months (g/kg-day, as consumed)						
Total Foods	0.26	100.0%	24	100.0%	73	100.0%
Total Dairy	0	0.5%	9	37.3%	13	17.9%
Total Meats	0	0.0%	0.11	0.5%	0.62	0.8%
Total Fish	0	0.0%	0	0.0%	0.056	0.1%
Total Eggs	0	0.0%	0	0.0%	0.031	0.0%
Total Grains	0.22	85.0%	0.95	4.0%	2	3.4%
Total Vegetables	0.019	7.4%	5	20.8%	11	14.5%
Total Fruits	0.017	6.7%	4	15.0%	40	55.0%
Total Fats [a]	0.00059	0.2%	5	21.3%	5	7.5%

Table 14-6. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/day, as consumed)							Age 6 to <12 months (g/kg-day, as consumed)						
Total Foods	124	100.0%	414	100.0%	1,358	100.0%	Total Foods	15	100.0%	47	100.0%	144	100.0%
Total Dairy	33	26.4%	72	17.5%	770	56.7%	Total Dairy	4	25.4%	6	13.8%	77	53.1%
Total Meats	3	2.4%	19	4.6%	47	3.5%	Total Meats	0.34	2.3%	2	4.9%	5	3.4%
Total Fish	0.25	0.2%	1	0.3%	0.28	0.0%	Total Fish	0.033	0.2%	0.090	0.2%	0.029	0.0%
Total Eggs	0.62	0.5%	7	1.6%	8	0.6%	Total Eggs	0.13	0.9%	0.69	1.5%	1	0.8%
Total Grains	11	9.1%	37	8.9%	50	3.7%	Total Grains	2	10.7%	4	9.1%	5	3.6%
Total Vegetables	30	24.2%	90	21.9%	121	8.9%	Total Vegetables	3	21.9%	10	22.4%	14	9.8%
Total Fruits	30	24.4%	151	36.5%	314	23.1%	Total Fruits	4	25.9%	19	40.0%	37	25.8%
Total Fats [a]	14	11.6%	35	8.4%	44	3.2%	Total Fats [a]	2	11.4%	4	7.5%	5	3.2%
Age 1 to <2 years (g/day, as consumed)							Age 1 to <2 years (g/kg-day, as consumed)						
Total Foods	407	100.0%	998	100.0%	1,859	100.0%	Total Foods	35	100.0%	85	100.0%	167	100.0%
Total Dairy	113	27.8%	487	48.8%	1,008	54.2%	Total Dairy	10	29.5%	41	48.1%	94	56.1%
Total Meats	28	6.9%	46	4.6%	66	3.5%	Total Meats	3	7.5%	4	4.7%	5	3.2%
Total Fish	1	0.3%	3	0.3%	4	0.2%	Total Fish	0.14	0.4%	0.46	0.5%	0.25	0.2%
Total Eggs	9	2.2%	16	1.6%	22	1.2%	Total Eggs	0.74	2.1%	1	1.4%	2	0.9%
Total Grains	44	10.8%	63	6.3%	81	4.3%	Total Grains	4	10.9%	5	6.0%	7	4.3%
Total Vegetables	82	20.1%	101	10.2%	165	8.9%	Total Vegetables	7	18.6%	10	11.9%	13	7.8%
Total Fruits	100	24.6%	238	23.8%	446	24.0%	Total Fruits	8	23.0%	19	22.8%	40	24.0%
Total Fats [a]	24	5.8%	38	3.8%	61	3.3%	Total Fats [a]	2	6.4%	3	3.8%	5	3.2%
Age 2 to <3 years (g/day, as consumed)							Age 2 to <3 years(g/kg-day, as consumed)						
Total Foods	448	100.0%	989	100.0%	1,760	100.0%	Total Foods	32	100.0%	72	100.0%	129	100.0%
Total Dairy	118	26.3%	370	37.4%	698	39.7%	Total Dairy	8	24.8%	26	36.3%	54	42.2%
Total Meats	50	11.1%	60	6.1%	72	4.1%	Total Meats	4	11.2%	4	5.3%	5	3.8%
Total Fish	1	0.3%	4	0.4%	7	0.4%	Total Fish	0.11	0.4%	0.18	0.2%	0.36	0.3%
Total Eggs	12	2.7%	14	1.4%	24	1.4%	Total Eggs	1	3.6%	1	1.7%	2	1.3%
Total Grains	62	13.7%	86	8.7%	98	5.6%	Total Grains	4	13.8%	6	8.0%	7	5.6%
Total Vegetables	98	21.9%	145	14.6%	185	10.5%	Total Vegetables	7	22.0%	10	13.3%	13	10.0%
Total Fruits	70	15.6%	255	25.8%	609	34.6%	Total Fruits	5	16.2%	21	29.8%	42	32.9%
Total Fats [a]	31	6.8%	44	4.4%	56	3.2%	Total Fats [a]	2	7.1%	3	3.9%	4	3.2%

Table 14-6. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/day, as consumed)						
Total Foods	527	100.0%	1,020	100.0%	1,817	100.0%
Total Dairy	144	27.3%	378	37.0%	728	40.1%
Total Meats	53	10.0%	72	7.0%	94	5.2%
Total Fish	3	0.6%	5	0.5%	9	0.5%
Total Eggs	11	2.0%	15	1.5%	24	1.3%
Total Grains	76	14.4%	103	10.1%	132	7.3%
Total Vegetables	117	22.3%	163	16.0%	233	12.8%
Total Fruits	76	14.4%	216	21.2%	509	28.0%
Total Fats [a]	34	6.5%	50	4.9%	68	3.7%
Age 6 to <11 years (g/day, as consumed)						
Total Foods	565	100.0%	1,060	100.0%	1,886	100.0%
Total Dairy	147	26.1%	370	34.9%	766	40.6%
Total Meats	65	11.4%	95	9.0%	104	5.5%
Total Fish	2	0.3%	6	0.6%	10	0.5%
Total Eggs	10	1.7%	16	1.5%	22	1.2%
Total Grains	89	15.8%	116	10.9%	157	8.3%
Total Vegetables	136	24.1%	203	19.2%	294	15.6%
Total Fruits	66	11.6%	178	16.8%	426	22.6%
Total Fats [a]	39	6.8%	58	5.5%	76	4.0%
Age 11 to <16 years (g/day, as consumed)						
Total Foods	513	100.0%	1,127	100.0%	2,256	100.0%
Total Dairy	92	17.9%	308	27.3%	808	35.8%
Total Meats	71	13.9%	116	10.3%	172	7.6%
Total Fish	4	0.8%	7	0.6%	16	0.7%
Total Eggs	10	1.9%	20	1.8%	28	1.2%
Total Grains	84	16.3%	133	11.8%	207	9.2%
Total Vegetables	162	31.6%	258	22.9%	459	20.3%
Total Fruits	42	8.2%	203	18.0%	420	18.6%
Total Fats [a]	40	7.8%	64	5.7%	114	5.0%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/kg-day, as consumed)						
Total Foods	28	100.0%	57	100.0%	108	100.0%
Total Dairy	8	27.3%	21	36.6%	43	40.3%
Total Meats	3	10.4%	4	7.1%	5	4.8%
Total Fish	0.14	0.5%	0.27	0.5%	0.43	0.4%
Total Eggs	0.59	2.1%	0.92	1.6%	1	1.1%
Total Grains	4	14.0%	6	9.9%	8	7.1%
Total Vegetables	6	22.0%	9	16.0%	14	12.5%
Total Fruits	4	15.2%	13	22.1%	31	29.0%
Total Fats [a]	2	6.4%	3	4.8%	4	3.7%
Age 6 to <11 years (g/kg-day, as consumed)						
Total Foods	16	100.0%	38	100.0%	73	100.0%
Total Dairy	4	26.2%	15	38.6%	30	40.8%
Total Meats	2	11.9%	3	8.1%	4	5.9%
Total Fish	0.075	0.5%	0.20	0.5%	0.28	0.4%
Total Eggs	0.28	1.8%	0.62	1.6%	0.95	1.3%
Total Grains	2	14.7%	4	10.8%	7	9.0%
Total Vegetables	4	24.7%	7	18.0%	11	15.5%
Total Fruits	2	11.2%	6	14.9%	15	21.2%
Total Fats [a]	1	7.3%	2	5.3%	3	4.3%
Age 11 to <16 years (g/kg-day, as consumed)						
Total Foods	8	100.0%	22	100.0%	46	100.0%
Total Dairy	1	17.3%	6	26.9%	18	38.4%
Total Meats	1	14.7%	2	10.3%	3	7.0%
Total Fish	0.072	0.9%	0.19	0.8%	0.38	0.8%
Total Eggs	0.15	1.8%	0.49	2.2%	0.61	1.3%
Total Grains	1	16.6%	3	11.7%	4	9.3%
Total Vegetables	3	31.7%	5	23.4%	9	18.4%
Total Fruits	0.60	7.2%	4	17.4%	8	18.2%
Total Fats [a]	0.70	8.3%	1	5.9%	2	4.8%

Table 14-6. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/day, as consumed)						
Total Foods	438	100.0%	1,060	100.0%	2,590	100.0%
Total Dairy	56	12.8%	219	20.7%	759	29.3%
Total Meats	61	14.0%	141	13.3%	272	10.5%
Total Fish	7	1.5%	11	1.1%	14	0.5%
Total Eggs	8	1.9%	17	1.6%	29	1.1%
Total Grains	67	15.2%	138	13.0%	241	9.3%
Total Vegetables	148	33.8%	312	29.4%	620	23.9%
Total Fruits	48	11.0%	138	13.1%	487	18.8%
Total Fats [a]	33	7.6%	72	6.8%	136	5.3%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/kg-day, as consumed)						
Total Foods	6	100.0%	16	100.0%	38	100.0%
Total Dairy	0.76	12.2%	4	23.8%	10	27.4%
Total Meats	0.97	15.6%	2	11.5%	4	10.0%
Total Fish	0.10	1.7%	0.15	1.0%	0.19	0.5%
Total Eggs	0.11	1.8%	0.24	1.6%	0.41	1.1%
Total Grains	0.92	14.8%	2	13.1%	4	9.9%
Total Vegetables	2	34.0%	5	30.0%	10	25.3%
Total Fruits	0.64	10.2%	2	10.9%	8	19.7%
Total Fats [a]	0.50	8.1%	1	7.1%	2	5.0%

[a] Includes added fats such as butter, margarine, dressings and sauces, vegetable oil, etc.; does not include fats eaten as components of other foods such as meats.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-7. 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

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/day, as consumed) [b]						
Total Foods	67	100.0%	-	-	-	-
Total Dairy	41	61.5%	-	-	-	-
Total Meats	0	0.0%	-	-	-	-
Total Fish	0	0.0%	-	-	-	-
Total Eggs	0	0.0%	-	-	-	-
Total Grains	0.44	0.7%	-	-	-	-
Total Vegetables	5	7.7%	-	-	-	-
Total Fruits	0.88	1.3%	-	-	-	-
Total Fats [a]	19	28.3%	-	-	-	-
Age 1 to <3 months (g/day, as consumed) [c]						
Total Foods	79	100.0%	-	-	149	100.0%
Total Dairy	37	46.4%	-	-	103	68.9%
Total Meats	0	0.0%	-	-	1	0.7%
Total Fish	0	0.0%	-	-	0	0.0%
Total Eggs	0	0.0%	-	-	0	0.0%
Total Grains	1	1.5%	-	-	0.18	0.1%
Total Vegetables	15	18.6%	-	-	3	2.1%
Total Fruits	4	5.2%	-	-	0	0.0%
Total Fats [a]	21	26.4%	-	-	42	28.2%
Age 3 to <6 months (g/day, as consumed) [d]						
Total Foods	181	100.0%	-	-	316	100.0%
Total Dairy	55	30.1%	-	-	62	19.7%
Total Meats	0	0.0%	-	-	16	4.9%
Total Fish	0	0.0%	-	-	0.44	0.1%
Total Eggs	0.092	0.1%	-	-	1	0.5%
Total Grains	7	3.7%	-	-	16	5.0%
Total Vegetables	31	17.0%	-	-	56	17.9%
Total Fruits	59	32.9%	-	-	133	42.3%
Total Fats [a]	28	15.3%	-	-	28	8.9%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/kg-day, as consumed) [b]						
Total Foods	20	100.0%	-	-	-	-
Total Dairy	12	61.6%	-	-	-	-
Total Meats	0	0.0%	-	-	-	-
Total Fish	0	0.0%	-	-	-	-
Total Eggs	0	0.0%	-	-	-	-
Total Grains	0.14	0.7%	-	-	-	-
Total Vegetables	2	7.7%	-	-	-	-
Total Fruits	0.21	1.1%	-	-	-	-
Total Fats [a]	6	28.4%	-	-	-	-
Age 1 to <3 months (g/kg-day, as consumed) [c]						
Total Foods	16	100.0%	-	-	47	100.0%
Total Dairy	8	47.9%	-	-	32	68.9%
Total Meats	0	0.0%	-	-	0.33	0.7%
Total Fish	0	0.0%	-	-	0	0.0%
Total Eggs	0	0.0%	-	-	0	0.0%
Total Grains	0.23	1.4%	-	-	0.06	0.1%
Total Vegetables	3	16.8%	-	-	0.97	2.1%
Total Fruits	0.91	5.6%	-	-	0	0.0%
Total Fats [a]	4	26.5%	-	-	13	28.2%
Age 3 to <6 months (g/kg-day, as consumed) [d]						
Total Foods	26	100.0%	-	-	41	100.0%
Total Dairy	8	30.6%	-	-	8	20.5%
Total Meats	0	0.0%	-	-	2	4.9%
Total Fish	0	0.0%	-	-	0.055	0.1%
Total Eggs	0.012	0.0%	-	-	0.13	0.3%
Total Grains	0.97	3.7%	-	-	2	4.8%
Total Vegetables	4	16.9%	-	-	7	17.6%
Total Fruits	8	32.2%	-	-	17	41.7%
Total Fats [a]	4	15.6%	-	-	4	9.2%

Table 14-7. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/day, as consumed)						
Total Foods	347	100.0%	466	100.0%	922	100.0%
Total Dairy	80	23.0%	108	23.2%	384	41.6%
Total Meats	0	0.0%	14	2.9%	85	9.3%
Total Fish	0.13	0.0%	0.34	0.1%	0.19	0.0%
Total Eggs	2	0.5%	3	0.6%	11	1.2%
Total Grains	24	6.8%	29	6.2%	51	5.6%
Total Vegetables	69	19.8%	116	24.8%	135	14.7%
Total Fruits	143	41.3%	162	34.8%	216	23.4%
Total Fats [a]	27	7.7%	31	6.7%	43	4.6%
Age 1 to <2 years (g/day, as consumed)						
Total Foods	921	100.0%	992	100.0%	1,229	100.0%
Total Dairy	464	50.4%	483	48.7%	460	37.4%
Total Meats	2	0.2%	39	4.0%	128	10.4%
Total Fish	3	0.3%	2	0.2%	6	0.5%
Total Eggs	8	0.9%	14	1.5%	24	1.9%
Total Grains	56	6.1%	64	6.5%	78	6.4%
Total Vegetables	97	10.5%	113	11.3%	189	15.4%
Total Fruits	250	27.2%	228	23.0%	290	23.6%
Total Fats [a]	30	3.3%	38	3.8%	57	4.6%
Age 2 to <3 years (g/day, as consumed)						
Total Foods	950	100.0%	947	100.0%	1,131	100.0%
Total Dairy	426	44.9%	373	39.3%	374	33.0%
Total Meats	7	0.7%	52	5.4%	148	13.1%
Total Fish	4	0.5%	4	0.5%	2	0.2%
Total Eggs	12	1.3%	18	1.9%	21	1.9%
Total Grains	73	7.7%	76	8.1%	90	8.0%
Total Vegetables	104	10.9%	146	15.4%	202	17.9%
Total Fruits	279	29.4%	226	23.8%	232	20.5%
Total Fats [a]	29	3.0%	40	4.2%	62	5.5%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/kg-day, as consumed)						
Total Foods	40	100.0%	48	100.0%	99	100.0%
Total Dairy	9	22.6%	11	23.9%	41	41.1%
Total Meats	0	0.0%	1	3.0%	9	9.3%
Total Fish	0.016	0.0%	0.053	0.1%	0	0.0%
Total Eggs	0.19	0.5%	0.45	1.0%	0.91	0.9%
Total Grains	3	6.6%	3	6.0%	6	5.8%
Total Vegetables	8	19.7%	10	21.9%	15	15.4%
Total Fruits	17	41.9%	17	36.5%	23	23.1%
Total Fats [a]	3	7.8%	3	7.1%	5	4.6%
Age 1 to <2 years (g/kg-day, as consumed)						
Total Foods	82	100.0%	90	100.0%	108	100.0%
Total Dairy	41	49.9%	46	50.5%	43	40.1%
Total Meats	0.15	0.2%	3	3.8%	11	10.0%
Total Fish	0.24	0.3%	0.25	0.3%	0.49	0.5%
Total Eggs	0.65	0.8%	1	1.4%	2	1.9%
Total Grains	5	6.1%	6	6.1%	7	6.9%
Total Vegetables	9	11.1%	10	10.8%	16	15.1%
Total Fruits	22	27.3%	21	22.7%	22	20.8%
Total Fats [a]	3	3.3%	3	3.8%	5	4.7%
Age 2 to <3 years(g/kg-day, as consumed)						
Total Foods	71	100.0%	68	100.0%	83	100.0%
Total Dairy	31	44.2%	26	37.7%	27	32.3%
Total Meats	0.51	0.7%	4	5.5%	10	12.4%
Total Fish	0.34	0.5%	0.18	0.3%	0.20	0.2%
Total Eggs	0.94	1.3%	0.92	1.3%	2	1.8%
Total Grains	6	7.8%	6	8.3%	7	8.1%
Total Vegetables	8	11.1%	10	15.1%	14	16.8%
Total Fruits	21	29.6%	18	26.7%	19	23.1%
Total Fats [a]	2	3.1%	3	4.0%	4	5.2%

Table 14-7. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/day, as consumed)							Age 3 to <6 years (g/kg-day, as consumed)						
Total Foods	991	100.0%	1,037	100.0%	1,246	100.0%	Total Foods	57	100.0%	59	100.0%	74	100.0%
Total Dairy	419	42.3%	376	36.3%	389	31.2%	Total Dairy	24	42.1%	23	38.2%	23	31.3%
Total Meats	10	1.0%	65	6.3%	176	14.1%	Total Meats	0.56	1.0%	4	6.0%	10	13.4%
Total Fish	7	0.7%	6	0.5%	4	0.3%	Total Fish	0.35	0.6%	0.29	0.5%	0.21	0.3%
Total Eggs	10	1.0%	16	1.5%	24	1.9%	Total Eggs	0.56	1.0%	0.81	1.4%	1	2.0%
Total Grains	98	9.9%	101	9.8%	117	9.4%	Total Grains	6	9.9%	6	9.5%	7	9.4%
Total Vegetables	128	13.0%	170	16.4%	217	17.4%	Total Vegetables	7	13.0%	9	15.8%	13	17.5%
Total Fruits	257	25.9%	238	22.9%	243	19.5%	Total Fruits	15	26.1%	13	22.0%	15	20.1%
Total Fats [a]	35	3.6%	48	4.7%	73	5.9%	Total Fats [a]	2	3.6%	3	4.8%	4	5.7%
Age 6 to <11 years (g/day, as consumed)							Age 6 to <11 years (g/kg-day, as consumed)						
Total Foods	1028	100.0%	1,087	100.0%	1,300	100.0%	Total Foods	36	100.0%	39	100.0%	51	100.0%
Total Dairy	424	41.3%	386	35.5%	382	29.4%	Total Dairy	15	41.5%	15	38.7%	15	29.7%
Total Meats	11	1.1%	79	7.3%	206	15.8%	Total Meats	0.38	1.0%	3	7.0%	8	14.8%
Total Fish	6	0.6%	5	0.5%	4	0.3%	Total Fish	0.31	0.9%	0.32	0.8%	0.15	0.3%
Total Eggs	13	1.3%	15	1.4%	17	1.3%	Total Eggs	0.44	1.2%	0.42	1.1%	0.75	1.5%
Total Grains	121	11.8%	117	10.7%	136	10.4%	Total Grains	4	11.5%	4	10.7%	5	10.4%
Total Vegetables	164	16.0%	212	19.5%	270	20.7%	Total Vegetables	5	15.1%	7	19.1%	10	20.2%
Total Fruits	214	20.8%	191	17.6%	198	15.2%	Total Fruits	8	21.7%	6	15.6%	8	16.5%
Total Fats [a]	40	3.9%	59	5.4%	81	6.2%	Total Fats [a]	1	3.8%	2	5.1%	3	6.0%
Age 11 to <16 years (g/day, as consumed)							Age 11 to <16 years (g/kg-day, as consumed)						
Total Foods	1043	100.0%	1,194	100.0%	1,606	100.0%	Total Foods	19	100.0%	22	100.0%	33	100.0%
Total Dairy	342	32.8%	377	31.6%	435	27.1%	Total Dairy	6	31.5%	6	27.0%	10	29.7%
Total Meats	17	1.6%	101	8.5%	268	16.7%	Total Meats	0.31	1.6%	2	8.8%	5	16.3%
Total Fish	13	1.3%	7	0.6%	7	0.4%	Total Fish	0.28	1.5%	0.12	0.5%	0.16	0.5%
Total Eggs	17	1.6%	13	1.1%	21	1.3%	Total Eggs	0.28	1.5%	0.29	1.3%	0.45	1.4%
Total Grains	116	11.1%	144	12.1%	159	9.9%	Total Grains	2	11.6%	3	11.7%	3	10.0%
Total Vegetables	227	21.7%	260	21.8%	404	25.2%	Total Vegetables	4	22.2%	5	24.1%	8	23.3%
Total Fruits	238	22.8%	202	16.9%	204	12.7%	Total Fruits	4	23.1%	4	18.9%	4	11.7%
Total Fats [a]	44	4.2%	67	5.6%	106	6.6%	Total Fats [a]	0.83	4.4%	1	5.7%	2	6.7%

Table 14-7. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/day, as consumed)							Age 16 to <21 years (g/kg-day, as consumed)						
Total Foods	922	100.0%	1,084	100.0%	1,957	100.0%	Total Foods	15	100.0%	18	100.0%	28	100.0%
Total Dairy	307	33.3%	280	25.8%	403	20.6%	Total Dairy	4	30.3%	4	24.0%	5	18.1%
Total Meats	12	1.3%	115	10.6%	385	19.7%	Total Meats	0.19	1.3%	2	9.6%	5	19.8%
Total Fish	20	2.1%	9	0.9%	12	0.6%	Total Fish	0.32	2.2%	0.18	1.0%	0.12	0.4%
Total Eggs	14	1.5%	15	1.4%	31	1.6%	Total Eggs	0.21	1.4%	0.35	1.9%	0.46	1.6%
Total Grains	131	14.2%	147	13.6%	231	11.8%	Total Grains	2	14.5%	2	12.8%	3	12.3%
Total Vegetables	215	23.3%	287	26.5%	532	27.2%	Total Vegetables	4	24.6%	5	27.5%	8	28.9%
Total Fruits	151	16.4%	147	13.5%	226	11.6%	Total Fruits	3	17.8%	3	15.7%	3	12.4%
Total Fats [a]	42	4.5%	73	6.7%	139	7.1%	Total Fats [a]	0.67	4.6%	1	6.2%	2	6.5%

[a] Includes added fats such as butter, margarine, dressings and sauces, vegetable oil, etc.; does not include fats eaten as components of other foods such as meats.

[b] All individuals in this sample group consumed 0 grams/day of meat. Therefore, results are reported in the low-end decile.

[c] Only one individual in this sample group consumed more than 0 grams/day of meat. This result is reported in the high-end decile. All other samples are reported in the low-end decile.

[d] All individuals in this sample group below the 89th percentile consumed 0 grams/day of meat. Therefore, only high-end and low-end consumer groups are reported.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-8. 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

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/day, as consumed)						
Total Foods	12	100.0%	60	100.0%	185	100.0%
Total Dairy	0	0.0%	40	67.3%	127	69.0%
Total Meats	0	0.0%	0	0.0%	0	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.031	0.3%	0	0.0%	4	2.2%
Total Vegetables	8	66.1%	2	3.4%	0.78	0.4%
Total Fruits	0	0.0%	0	0.0%	0	0.0%
Total Fats [a]	3	27.1%	18	29.2%	52	28.4%
Age 1 to <3 months (g/day, as consumed)						
Total Foods	36	100.0%	84	100.0%	166	100.0%
Total Dairy	0	0.0%	19	22.4%	109	65.6%
Total Meats	0	0.0%	0	0.0%	0.037	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.32	0.9%	1	1.2%	1	0.8%
Total Vegetables	21	58.8%	42	50.7%	4	2.7%
Total Fruits	2	4.3%	0.034	0.0%	6	3.7%
Total Fats [a]	10	26.7%	21	25.4%	45	27.2%
Age 3 to <6 months (g/day, as consumed)						
Total Foods	121	100.0%	204	100.0%	334	100.0%
Total Dairy	0	0.0%	60	29.7%	159	47.7%
Total Meats	0	0.0%	0.55	0.3%	5	1.4%
Total Fish	0	0.0%	0	0.0%	0.43	0.1%
Total Eggs	0	0.0%	0.30	0.1%	0.64	0.2%
Total Grains	5	4.5%	7	3.2%	12	3.7%
Total Vegetables	44	36.4%	29	14.5%	27	8.0%
Total Fruits	52	42.9%	80	39.0%	74	22.3%
Total Fats [a]	15	12.3%	27	13.2%	54	16.3%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/kg-day, as consumed)						
Total Foods	4	100.0%	18	100.0%	56	100.0%
Total Dairy	0	0.0%	12	67.1%	39	69.0%
Total Meats	0	0.0%	0	0.0%	0	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.0086	0.2%	0	0.0%	1	2.1%
Total Vegetables	2	64.4%	0.65	3.7%	0.26	0.5%
Total Fruits	0	0.0%	0	0.0%	0	0.0%
Total Fats [a]	1	27.5%	5	29.2%	16	28.4%
Age 1 to <3 months (g/kg-day, as consumed)						
Total Foods	7	100.0%	14	100.0%	41	100.0%
Total Dairy	0	0.0%	3	24.0%	26	64.1%
Total Meats	0	0.0%	0	0.0%	0.012	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.054	0.8%	0.29	2.0%	0.26	0.6%
Total Vegetables	4	57.8%	7	48.7%	0.43	1.1%
Total Fruits	0.37	5.4%	0.0067	0.0%	3	7.7%
Total Fats [a]	2	26.4%	4	25.0%	11	26.5%
Age 3 to <6 months (g/kg-day, as consumed)						
Total Foods	17	100.0%	30	100.0%	45	100.0%
Total Dairy	0	0.0%	8	26.5%	24	53.4%
Total Meats	0	0.0%	0.19	0.6%	0.57	1.3%
Total Fish	0	0.0%	0	0.0%	0.056	0.1%
Total Eggs	0	0.0%	0.10	0.3%	0.057	0.1%
Total Grains	0.78	4.5%	1	3.7%	2	3.6%
Total Vegetables	6	37.1%	3	11.2%	2	5.3%
Total Fruits	7	41.7%	14	46.0%	8	17.3%
Total Fats [a]	2	12.6%	3	11.4%	8	18.7%

Table 14-8. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/day, as consumed)						
Total Foods	253	100.0%	403	100.0%	1,284	100.0%
Total Dairy	1	0.5%	71	17.6%	827	64.5%
Total Meats	0.68	0.3%	17	4.1%	45	3.5%
Total Fish	0	0.0%	1	0.4%	0.28	0.0%
Total Eggs	3	1.0%	3	0.7%	7	0.5%
Total Grains	22	8.5%	32	8.0%	45	3.5%
Total Vegetables	95	37.7%	82	20.3%	108	8.4%
Total Fruits	110	43.4%	166	41.1%	209	16.3%
Total Fats [a]	17	6.7%	32	8.0%	41	3.2%
Age 1 to <2 years (g/day, as consumed)						
Total Foods	569	100.0%	1,014	100.0%	1,687	100.0%
Total Dairy	46	8.0%	456	45.0%	1,165	69.0%
Total Meats	30	5.2%	43	4.2%	52	3.1%
Total Fish	2	0.4%	2	0.2%	3	0.2%
Total Eggs	12	2.0%	13	1.3%	19	1.1%
Total Grains	54	9.5%	64	6.3%	65	3.8%
Total Vegetables	128	22.5%	114	11.3%	111	6.6%
Total Fruits	264	46.4%	278	27.4%	209	12.4%
Total Fats [a]	25	4.5%	36	3.6%	59	3.5%
Age 2 to <3 years (g/day, as consumed)						
Total Foods	641	100.0%	981	100.0%	1,546	100.0%
Total Dairy	57	9.0%	348	35.5%	883	57.1%
Total Meats	45	6.9%	59	6.0%	60	3.9%
Total Fish	4	0.6%	3	0.3%	4	0.3%
Total Eggs	21	3.2%	18	1.9%	20	1.3%
Total Grains	75	11.8%	86	8.7%	86	5.6%
Total Vegetables	155	24.1%	148	15.1%	143	9.2%
Total Fruits	240	37.5%	264	26.9%	286	18.5%
Total Fats [a]	32	5.0%	42	4.3%	55	3.6%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/kg-day, as consumed)						
Total Foods	29	100.0%	43	100.0%	135	100.0%
Total Dairy	0.12	0.4%	8	18.0%	87	64.2%
Total Meats	0.083	0.3%	2	4.7%	5	3.3%
Total Fish	0	0.0%	0.14	0.3%	0.029	0.0%
Total Eggs	0.32	1.1%	0.39	0.9%	0.66	0.5%
Total Grains	2	8.0%	3	7.1%	5	3.5%
Total Vegetables	11	38.2%	9	20.0%	12	8.6%
Total Fruits	13	43.4%	17	40.4%	22	16.6%
Total Fats [a]	2	6.7%	4	8.3%	4	3.2%
Age 1 to <2 years (g/kg-day, as consumed)						
Total Foods	51	100.0%	82	100.0%	155	100.0%
Total Dairy	4	7.7%	38	45.6%	106	68.2%
Total Meats	3	5.5%	4	5.3%	4	2.8%
Total Fish	0.13	0.2%	0.22	0.3%	0.20	0.1%
Total Eggs	1	2.1%	1	1.6%	1	0.9%
Total Grains	5	9.5%	6	7.2%	6	3.7%
Total Vegetables	11	22.2%	11	13.0%	11	6.9%
Total Fruits	24	46.6%	19	22.7%	21	13.7%
Total Fats [a]	2	4.5%	3	3.8%	5	3.4%
Age 2 to <3 years(g/kg-day, as consumed)						
Total Foods	46	100.0%	73	100.0%	114	100.0%
Total Dairy	4	8.2%	24	32.6%	67	58.3%
Total Meats	3	7.4%	5	6.5%	4	3.8%
Total Fish	0.19	0.4%	0.25	0.3%	0.28	0.2%
Total Eggs	1	3.2%	1	1.6%	2	1.3%
Total Grains	5	11.6%	6	8.7%	7	5.7%
Total Vegetables	11	23.6%	11	14.9%	11	9.5%
Total Fruits	18	38.7%	22	29.9%	19	16.6%
Total Fats [a]	2	5.2%	3	4.3%	4	3.7%

Table 14-8. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/day, as consumed)							Age 3 to <6 years (g/kg-day, as consumed)						
Total Foods	702	100.0%	1,043	100.0%	1,646	100.0%	Total Foods	39	100.0%	59	100.0%	97	100.0%
Total Dairy	75	10.7%	352	33.8%	878	53.3%	Total Dairy	4	10.8%	20	33.6%	52	53.1%
Total Meats	52	7.5%	79	7.6%	88	5.4%	Total Meats	3	7.6%	4	7.1%	5	5.2%
Total Fish	5	0.7%	5	0.5%	5	0.3%	Total Fish	0.33	0.8%	0.22	0.4%	0.28	0.3%
Total Eggs	15	2.2%	16	1.5%	19	1.2%	Total Eggs	0.87	2.2%	0.93	1.6%	0.97	1.0%
Total Grains	85	12.0%	107	10.2%	121	7.3%	Total Grains	5	12.0%	6	10.0%	7	7.2%
Total Vegetables	159	22.6%	167	16.0%	191	11.6%	Total Vegetables	9	22.7%	10	16.1%	11	11.7%
Total Fruits	258	36.7%	251	24.1%	259	15.8%	Total Fruits	14	36.1%	15	25.0%	16	16.2%
Total Fats [a]	35	5.0%	51	4.9%	67	4.1%	Total Fats [a]	2	5.1%	3	4.7%	4	4.1%
Age 6 to <11 years (g/day, as consumed)							Age 6 to <11 years (g/kg-day, as consumed)						
Total Foods	725	100.0%	1,061	100.0%	1,727	100.0%	Total Foods	21	100.0%	38	100.0%	68	100.0%
Total Dairy	76	10.5%	366	34.5%	883	51.1%	Total Dairy	2	11.6%	13	34.8%	35	51.0%
Total Meats	66	9.2%	91	8.6%	105	6.1%	Total Meats	2	9.9%	3	8.2%	4	5.9%
Total Fish	6	0.8%	7	0.7%	6	0.3%	Total Fish	0.18	0.8%	0.22	0.6%	0.24	0.4%
Total Eggs	16	2.3%	17	1.6%	18	1.1%	Total Eggs	0.52	2.4%	0.52	1.4%	0.70	1.0%
Total Grains	101	13.9%	116	10.9%	151	8.7%	Total Grains	3	14.1%	4	10.9%	6	9.2%
Total Vegetables	202	27.9%	205	19.4%	245	14.2%	Total Vegetables	6	27.0%	7	18.7%	10	14.1%
Total Fruits	198	27.3%	178	16.7%	221	12.8%	Total Fruits	6	25.9%	7	17.8%	8	12.4%
Total Fats [a]	43	6.0%	56	5.3%	73	4.2%	Total Fats [a]	1	6.2%	2	5.4%	3	4.4%
Age 11 to <16 years (g/day, as consumed)							Age 11 to <16 years (g/kg-day, as consumed)						
Total Foods	727	100.0%	1,111	100.0%	2,045	100.0%	Total Foods	12	100.0%	23	100.0%	43	100.0%
Total Dairy	38	5.2%	299	26.9%	1,004	49.1%	Total Dairy	0.59	4.9%	6	26.0%	21	47.9%
Total Meats	58	8.0%	118	10.6%	161	7.9%	Total Meats	1	9.3%	2	10.9%	3	7.5%
Total Fish	10	1.4%	11	1.0%	12	0.6%	Total Fish	0.15	1.3%	0.14	0.6%	0.35	0.8%
Total Eggs	16	2.2%	22	2.0%	26	1.3%	Total Eggs	0.30	2.5%	0.34	1.5%	0.52	1.2%
Total Grains	103	14.2%	137	12.4%	181	8.9%	Total Grains	2	14.2%	3	11.5%	4	9.1%
Total Vegetables	234	32.2%	265	23.9%	332	16.2%	Total Vegetables	4	32.4%	6	24.5%	7	15.5%
Total Fruits	213	29.3%	176	15.8%	204	10.0%	Total Fruits	3	27.0%	4	17.1%	5	11.8%
Total Fats [a]	42	5.8%	66	6.0%	104	5.1%	Total Fats [a]	0.75	6.3%	1	6.1%	2	4.9%

Table 14-8. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/day, as consumed)							Age 16 to <21 years (g/kg-day, as consumed)						
Total Foods	610	100.0%	1,017	100.0%	2,379	100.0%	Total Foods	9	100.0%	15	100.0%	34	100.0%
Total Dairy	22	3.5%	204	20.1%	923	38.8%	Total Dairy	0.35	3.8%	3	19.1%	13	39.1%
Total Meats	42	6.8%	128	12.6%	256	10.8%	Total Meats	0.63	6.8%	2	13.4%	4	10.8%
Total Fish	12	1.9%	12	1.2%	8	0.3%	Total Fish	0.17	1.8%	0.14	0.9%	0.10	0.3%
Total Eggs	13	2.2%	19	1.8%	28	1.2%	Total Eggs	0.19	2.0%	0.28	1.8%	0.38	1.1%
Total Grains	87	14.3%	140	13.8%	233	9.8%	Total Grains	1	14.6%	2	14.3%	3	10.1%
Total Vegetables	202	33.1%	305	29.9%	492	20.7%	Total Vegetables	3	34.0%	5	30.4%	7	20.8%
Total Fruits	177	29.1%	133	13.1%	282	11.9%	Total Fruits	3	28.1%	2	12.2%	4	11.2%
Total Fats [a]	34	5.6%	68	6.6%	127	5.3%	Total Fats [a]	0.51	5.5%	1	6.8%	2	5.4%

[a] Includes added fats such as butter, margarine, dressings and sauces, vegetable oil, etc.; does not include fats eaten as components of other foods such as meats.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-9. 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

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/day, as consumed)[b]						
Total Foods	67	100.0%	-	-	-	-
Total Dairy	41	61.5%	-	-	-	-
Total Meats	0	0.0%	-	-	-	-
Total Fish	0	0.0%	-	-	-	-
Total Eggs	0	0.0%	-	-	-	-
Total Grains	0.44	0.7%	-	-	-	-
Total Vegetables	5	7.7%	-	-	-	-
Total Fruits	0.88	1.3%	-	-	-	-
Total Fats [a]	19	28.3%	-	-	-	-
Age 1 to <3 months (g/day, as consumed)[b]						
Total Foods	80	100.0%	-	-	-	-
Total Dairy	37	46.5%	-	-	-	-
Total Meats	0	0.0%	-	-	-	-
Total Fish	0	0.0%	-	-	-	-
Total Eggs	0	0.0%	-	-	-	-
Total Grains	1	1.5%	-	-	-	-
Total Vegetables	15	18.5%	-	-	-	-
Total Fruits	4	5.2%	-	-	-	-
Total Fats [a]	21	26.4%	-	-	-	-
Age 3 to <6 months (g/day, as consumed) [c]						
Total Foods	196	100.0%	-	-	410	100.0%
Total Dairy	55	28.3%	-	-	159	38.8%
Total Meats	2	0.8%	-	-	28	6.8%
Total Fish	0	0.0%	-	-	17	4.1%
Total Eggs	0.22	0.1%	-	-	4	1.0%
Total Grains	8	3.9%	-	-	47	11.5%
Total Vegetables	34	17.2%	-	-	34	8.3%
Total Fruits	68	34.7%	-	-	30	7.2%
Total Fats [a]	28	14.1%	-	-	81	19.8%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/kg-day, as consumed)[b]						
Total Foods	20	100.0%	-	-	-	-
Total Dairy	12	61.6%	-	-	-	-
Total Meats	0	0.0%	-	-	-	-
Total Fish	0	0.0%	-	-	-	-
Total Eggs	0	0.0%	-	-	-	-
Total Grains	0.14	0.7%	-	-	-	-
Total Vegetables	2	7.7%	-	-	-	-
Total Fruits	0.21	1.1%	-	-	-	-
Total Fats [a]	6	28.4%	-	-	-	-
Age 1 to <3 months (g/kg-day, as consumed)[b]						
Total Foods	16	100.0%	-	-	-	-
Total Dairy	8	48.2%	-	-	-	-
Total Meats	0	0.0%	-	-	-	-
Total Fish	0	0.0%	-	-	-	-
Total Eggs	0	0.0%	-	-	-	-
Total Grains	0.23	1.4%	-	-	-	-
Total Vegetables	3	16.6%	-	-	-	-
Total Fruits	0.90	5.5%	-	-	-	-
Total Fats [a]	4	26.5%	-	-	-	-
Age 3 to <6 months (g/kg-day, as consumed) [c]						
Total Foods	28	100.0%	-	-	53	100.0%
Total Dairy	8	28.9%	-	-	21	38.8%
Total Meats	0.20	0.7%	-	-	4	6.8%
Total Fish	0	0.0%	-	-	2	4.1%
Total Eggs	0.022	0.1%	-	-	0.52	1.0%
Total Grains	1	3.8%	-	-	6	11.5%
Total Vegetables	5	17.1%	-	-	4	8.3%
Total Fruits	9	33.9%	-	-	4	7.2%
Total Fats [a]	4	14.5%	-	-	11	19.8%

Table 14-9. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/day, as consumed)[d]							Age 6 to <12 months (g/kg-day, as consumed)[d]						
Total Foods	799	100.0%	-	-	770	100.0%	Total Foods	81	100.0%	-	-	74	100.0%
Total Dairy	334	41.8%	-	-	287	37.3%	Total Dairy	34	41.8%	-	-	27	37.1%
Total Meats	38	4.7%	-	-	46	6.0%	Total Meats	4	4.7%	-	-	4	6.0%
Total Fish	0	0.0%	-	-	7	0.9%	Total Fish	0	0.0%	-	-	0.63	0.9%
Total Eggs	11	1.4%	-	-	14	1.9%	Total Eggs	1	1.4%	-	-	1	2.0%
Total Grains	47	5.9%	-	-	66	8.6%	Total Grains	5	5.9%	-	-	6	8.4%
Total Vegetables	101	12.6%	-	-	117	15.3%	Total Vegetables	10	12.6%	-	-	12	15.6%
Total Fruits	227	28.4%	-	-	194	25.2%	Total Fruits	23	28.4%	-	-	19	25.2%
Total Fats [a]	37	4.7%	-	-	36	4.7%	Total Fats [a]	4	4.7%	-	-	3	4.7%
Age 1 to <2 years (g/day, as consumed) [d]							Age 1 to <2 years (g/kg-day, as consumed) [d]						
Total Foods	1032	100.0%	-	-	1,139	100.0%	Total Foods	90	100.0%	-	-	98	100.0%
Total Dairy	496	48.1%	-	-	461	40.5%	Total Dairy	43	48.2%	-	-	41	42.4%
Total Meats	46	4.5%	-	-	56	4.9%	Total Meats	4	4.4%	-	-	5	4.8%
Total Fish	0	0.0%	-	-	26	2.3%	Total Fish	0	0.0%	-	-	2	2.2%
Total Eggs	14	1.4%	-	-	19	1.7%	Total Eggs	1	1.3%	-	-	2	1.6%
Total Grains	65	6.3%	-	-	76	6.7%	Total Grains	6	6.2%	-	-	7	6.7%
Total Vegetables	118	11.4%	-	-	151	13.2%	Total Vegetables	10	11.4%	-	-	12	12.3%
Total Fruits	247	24.0%	-	-	300	26.3%	Total Fruits	22	24.0%	-	-	25	25.5%
Total Fats [a]	39	3.8%	-	-	43	3.8%	Total Fats [a]	3	3.8%	-	-	4	3.8%
Age 2 to <3 years (g/day, as consumed) [d]							Age 2 to <3 years(g/kg-day, as consumed) [d]						
Total Foods	1015	100.0%	-	-	1,107	100.0%	Total Foods	73	100.0%	-	-	82	100.0%
Total Dairy	381	37.6%	-	-	424	38.3%	Total Dairy	28	37.9%	-	-	31	37.6%
Total Meats	62	6.1%	-	-	53	4.8%	Total Meats	4	6.0%	-	-	4	4.6%
Total Fish	0	0.0%	-	-	31	2.8%	Total Fish	0	0.0%	-	-	2	2.9%
Total Eggs	18	1.8%	-	-	17	1.6%	Total Eggs	1	1.7%	-	-	1	1.5%
Total Grains	81	7.9%	-	-	84	7.6%	Total Grains	6	7.9%	-	-	6	7.5%
Total Vegetables	144	14.2%	-	-	142	12.8%	Total Vegetables	10	14.1%	-	-	10	12.7%
Total Fruits	276	27.2%	-	-	304	27.4%	Total Fruits	20	27.0%	-	-	23	28.5%
Total Fats [a]	42	4.2%	-	-	43	3.9%	Total Fats [a]	3	4.2%	-	-	3	3.9%

Table 14-9. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/day, as consumed)[d]						
Total Foods	1,053	100.0%	-	-	1,156	100.0%
Total Dairy	390	37.1%	-	-	399	34.5%
Total Meats	76	7.2%	-	-	62	5.3%
Total Fish	0	0.0%	-	-	43	3.7%
Total Eggs	16	1.5%	-	-	17	1.4%
Total Grains	101	9.6%	-	-	103	8.9%
Total Vegetables	168	15.9%	-	-	193	16.7%
Total Fruits	237	22.5%	-	-	273	23.6%
Total Fats [a]	50	4.8%	-	-	50	4.3%
Age 6 to <11 years (g/day, as consumed) [d]						
Total Foods	1,109	100.0%	-	-	1,234	100.0%
Total Dairy	408	36.8%	-	-	430	34.8%
Total Meats	89	8.0%	-	-	76	6.2%
Total Fish	0	0.0%	-	-	51	4.1%
Total Eggs	15	1.3%	-	-	22	1.8%
Total Grains	119	10.7%	-	-	126	10.2%
Total Vegetables	208	18.8%	-	-	233	18.9%
Total Fruits	190	17.1%	-	-	218	17.7%
Total Fats [a]	58	5.2%	-	-	61	4.9%
Age 11 to <16 years (g/day, as consumed) [d]						
Total Foods	1,197	100.0%	-	-	1,378	100.0%
Total Dairy	372	31.1%	-	-	397	28.8%
Total Meats	117	9.8%	-	-	104	7.5%
Total Fish	0	0.0%	-	-	72	5.2%
Total Eggs	17	1.4%	-	-	28	2.0%
Total Grains	135	11.3%	-	-	146	10.6%
Total Vegetables	277	23.1%	-	-	310	22.5%
Total Fruits	190	15.8%	-	-	226	16.4%
Total Fats [a]	69	5.8%	-	-	76	5.5%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/kg-day, as consumed)[d]						
Total Foods	60	100.0%	-	-	66	100.0%
Total Dairy	22	37.1%	-	-	22	33.9%
Total Meats	4	7.1%	-	-	3	5.3%
Total Fish	0	0.0%	-	-	2	3.7%
Total Eggs	0.88	1.5%	-	-	1	1.6%
Total Grains	6	9.5%	-	-	6	9.0%
Total Vegetables	9	15.8%	-	-	11	16.9%
Total Fruits	14	22.7%	-	-	16	23.8%
Total Fats [a]	3	4.7%	-	-	3	4.3%
Age 6 to <11 years (g/kg-day, as consumed) [d]						
Total Foods	40	100.0%	-	-	44	100.0%
Total Dairy	15	37.0%	-	-	16	35.6%
Total Meats	3	7.9%	-	-	3	6.1%
Total Fish	0	0.0%	-	-	2	4.1%
Total Eggs	0.53	1.3%	-	-	0.73	1.6%
Total Grains	4	10.7%	-	-	4	10.1%
Total Vegetables	7	18.5%	-	-	8	18.4%
Total Fruits	7	17.3%	-	-	8	17.5%
Total Fats [a]	2	5.2%	-	-	2	4.9%
Age 11 to <16 years (g/kg-day, as consumed) [d]						
Total Foods	24	100.0%	-	-	28	100.0%
Total Dairy	7	31.1%	-	-	9	30.9%
Total Meats	2	9.7%	-	-	2	6.9%
Total Fish	0	0.0%	-	-	1	4.9%
Total Eggs	0.34	1.4%	-	-	0.52	1.9%
Total Grains	3	11.3%	-	-	3	10.5%
Total Vegetables	5	22.9%	-	-	6	21.1%
Total Fruits	4	16.2%	-	-	5	17.1%
Total Fats [a]	1	5.7%	-	-	1	5.2%

Table 14-9. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/day, as consumed)[d]							Age 16 to <21 years (g/kg-day, as consumed)[d]						
Total Foods	1,171	100.0%	-	-	1,339	100.0%	Total Foods	18	100.0%	-	-	19	100.0%
Total Dairy	288	24.6%	-	-	261	19.5%	Total Dairy	4	24.5%	-	-	4	20.3%
Total Meats	143	12.2%	-	-	139	10.4%	Total Meats	2	11.9%	-	-	2	9.4%
Total Fish	0	0.0%	-	-	86	6.5%	Total Fish	0	0.0%	-	-	1	6.7%
Total Eggs	20	1.7%	-	-	21	1.6%	Total Eggs	0.30	1.7%	-	-	0.30	1.6%
Total Grains	146	12.5%	-	-	162	12.1%	Total Grains	2	12.5%	-	-	2	12.0%
Total Vegetables	325	27.8%	-	-	357	26.6%	Total Vegetables	5	27.9%	-	-	5	26.0%
Total Fruits	160	13.7%	-	-	219	16.3%	Total Fruits	2	13.9%	-	-	3	16.9%
Total Fats [a]	75	6.4%	-	-	80	6.0%	Total Fats [a]	1	6.4%	-	-	1	5.9%

[a] Includes added fats such as butter, margarine, dressings and sauces, vegetable oil, etc.; does not include fats eaten as components of other foods such as meats.

[b] All individuals in this sample group consumed 0 grams/day of fish. Therefore, only low-end consumers are reported.

[c] Only one individual in this sample group consumed more than 0 grams/day of fish. Therefore, this sample is reported in the high-end consumer group and all other samples are placed in the low-end consumer group.

[d] All individuals in this sample group below the 80th percentile consumed 0 grams/day of fish. Therefore, only high-end and low-end consumer groups are reported.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-10. 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

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/day, as consumed)[b]						
Total Foods	49	100.0%	-	-	101	100.0%
Total Dairy	34	69.7%	-	-	21	21.1%
Total Meats	0	0.0%	-	-	0	0.0%
Total Fish	0	0.0%	-	-	0	0.0%
Total Eggs	0	0.0%	-	-	0	0.0%
Total Grains	0.58	1.2%	-	-	0.21	0.2%
Total Vegetables	0	0.0%	-	-	44	43.3%
Total Fruits	0	0.0%	-	-	8	7.6%
Total Fats [a]	14	29.1%	-	-	25	24.8%
Age 1 to <3 months (g/day, as consumed) [b]						
Total Foods	49	100.0%	-	-	171	100.0%
Total Dairy	34	69.2%	-	-	16	9.5%
Total Meats	0	0.0%	-	-	0	0.0%
Total Fish	0	0.0%	-	-	0	0.0%
Total Eggs	0	0.0%	-	-	0	0.0%
Total Grains	0.91	1.9%	-	-	2	1.0%
Total Vegetables	0	0.0%	-	-	89	52.0%
Total Fruits	0	0.0%	-	-	18	10.2%
Total Fats [a]	14	28.9%	-	-	40	23.4%
Age 3 to <6 months (g/day, as consumed)						
Total Foods	69	100.0%	144	100.0%	495	100.0%
Total Dairy	47	68.0%	51	35.6%	49	9.9%
Total Meats	0	0.0%	2	1.3%	4	0.8%
Total Fish	0	0.0%	0.43	0.3%	0	0.0%
Total Eggs	0	0.0%	0.58	0.4%	0.094	0.0%
Total Grains	2	3.3%	10	6.7%	12	2.4%
Total Vegetables	0	0.0%	24	16.6%	88	17.7%
Total Fruits	0	0.0%	29	19.9%	311	62.8%
Total Fats [a]	20	28.4%	25	17.7%	27	5.4%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/kg-day, as consumed)[b]						
Total Foods	14	100.0%	-	-	29	100.0%
Total Dairy	10	69.6%	-	-	6	19.4%
Total Meats	0	0.0%	-	-	0	0.0%
Total Fish	0	0.0%	-	-	0	0.0%
Total Eggs	0	0.0%	-	-	0	0.0%
Total Grains	0.18	1.3%	-	-	0.057	0.2%
Total Vegetables	0	0.0%	-	-	13	44.8%
Total Fruits	0	0.0%	-	-	2	6.4%
Total Fats [a]	4	29.1%	-	-	7	25.4%
Age 1 to <3 months (g/kg-day, as consumed) [b]						
Total Foods	11	100.0%	-	-	35	100.0%
Total Dairy	7	69.4%	-	-	4	11.5%
Total Meats	0	0.0%	-	-	0	0.0%
Total Fish	0	0.0%	-	-	0	0.0%
Total Eggs	0	0.0%	-	-	0	0.0%
Total Grains	0.17	1.7%	-	-	0.38	1.1%
Total Vegetables	0	0.0%	-	-	16	46.8%
Total Fruits	0	0.0%	-	-	5	13.9%
Total Fats [a]	3	29.0%	-	-	8	22.7%
Age 3 to <6 months (g/kg-day, as consumed)						
Total Foods	11	100.0%	21	100.0%	70	100.0%
Total Dairy	7	68.1%	8	37.2%	7	10.1%
Total Meats	0	0.0%	0.32	1.5%	0.52	0.7%
Total Fish	0	0.0%	0.057	0.3%	0	0.0%
Total Eggs	0	0.0%	0.10	0.5%	0.021	0.0%
Total Grains	0.35	3.2%	1	6.6%	2	2.6%
Total Vegetables	0	0.0%	3	15.1%	12	17.7%
Total Fruits	0	0.0%	4	20.8%	44	62.4%
Total Fats [a]	3	28.5%	4	16.9%	4	5.5%

Table 14-10. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/day, as consumed)						
Total Foods	189	100.0%	461	100.0%	951	100.0%
Total Dairy	91	48.3%	129	28.0%	207	21.8%
Total Meats	8	4.0%	17	3.6%	37	3.9%
Total Fish	0.80	0.4%	0.80	0.2%	0.16	0.0%
Total Eggs	4	1.9%	9	1.9%	8	0.8%
Total Grains	23	12.1%	31	6.8%	41	4.3%
Total Vegetables	18	9.4%	83	18.1%	160	16.8%
Total Fruits	15	7.7%	158	34.3%	459	48.2%
Total Fats [a]	31	16.3%	31	6.8%	35	3.6%
Age 1 to <2 years (g/day, as consumed)						
Total Foods	796	100.0%	1,048	100.0%	1,499	100.0%
Total Dairy	578	72.7%	535	51.0%	425	28.4%
Total Meats	35	4.5%	46	4.4%	62	4.2%
Total Fish	0.93	0.1%	3	0.3%	5	0.4%
Total Eggs	8	1.0%	16	1.5%	17	1.1%
Total Grains	49	6.2%	65	6.2%	77	5.1%
Total Vegetables	56	7.1%	123	11.7%	179	11.9%
Total Fruits	26	3.2%	210	20.1%	687	45.8%
Total Fats [a]	36	4.6%	41	3.9%	39	2.6%
Age 2 to <3 years (g/day, as consumed)						
Total Foods	601	100.0%	942	100.0%	1,589	100.0%
Total Dairy	308	51.2%	352	37.4%	384	24.1%
Total Meats	53	8.8%	59	6.3%	64	4.0%
Total Fish	2	0.3%	4	0.5%	5	0.3%
Total Eggs	14	2.3%	18	2.0%	20	1.3%
Total Grains	72	12.0%	80	8.5%	91	5.7%
Total Vegetables	81	13.4%	141	15.0%	202	12.7%
Total Fruits	24	4.0%	237	25.1%	765	48.1%
Total Fats [a]	38	6.3%	40	4.2%	46	2.9%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/kg-day, as consumed)						
Total Foods	21	100.0%	57	100.0%	100	100.0%
Total Dairy	10	48.1%	19	33.2%	18	17.9%
Total Meats	0.73	3.6%	2	4.3%	4	3.8%
Total Fish	0.088	0.4%	0.063	0.1%	0.018	0.0%
Total Eggs	0.34	1.7%	0.59	1.0%	0.73	0.7%
Total Grains	2	11.4%	4	6.5%	5	4.6%
Total Vegetables	2	9.3%	10	16.9%	19	19.0%
Total Fruits	2	8.4%	18	30.8%	50	49.5%
Total Fats [a]	3	16.8%	4	6.6%	4	3.9%
Age 1 to <2 years (g/kg-day, as consumed)						
Total Foods	68	100.0%	88	100.0%	133	100.0%
Total Dairy	49	71.8%	44	49.6%	39	29.5%
Total Meats	3	4.7%	4	4.5%	5	3.6%
Total Fish	0.16	0.2%	0.24	0.3%	0.31	0.2%
Total Eggs	0.77	1.1%	1	1.2%	2	1.2%
Total Grains	4	6.2%	6	6.9%	7	5.2%
Total Vegetables	5	7.1%	11	12.6%	15	11.6%
Total Fruits	2	3.4%	18	20.5%	60	45.4%
Total Fats [a]	3	4.7%	3	3.7%	4	2.7%
Age 2 to <3 years(g/kg-day, as consumed)						
Total Foods	43	100.0%	69	100.0%	114	100.0%
Total Dairy	22	51.3%	27	39.3%	27	23.6%
Total Meats	4	8.8%	4	6.0%	4	3.8%
Total Fish	0.14	0.3%	0.25	0.4%	0.40	0.4%
Total Eggs	0.99	2.3%	1	1.9%	2	1.4%
Total Grains	5	12.0%	6	8.6%	7	5.7%
Total Vegetables	6	13.8%	10	14.0%	14	12.4%
Total Fruits	2	3.7%	17	24.6%	56	49.1%
Total Fats [a]	3	6.3%	3	4.1%	3	2.9%

Table 14-10. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/day, as consumed)						
Total Foods	731	100.0%	1,014	100.0%	1,594	100.0%
Total Dairy	388	53.1%	385	38.0%	401	25.1%
Total Meats	60	8.2%	74	7.3%	81	5.1%
Total Fish	4	0.5%	7	0.7%	9	0.6%
Total Eggs	13	1.7%	14	1.4%	21	1.3%
Total Grains	92	12.5%	96	9.4%	113	7.1%
Total Vegetables	92	12.5%	174	17.1%	231	14.5%
Total Fruits	27	3.6%	199	19.6%	668	41.9%
Total Fats [a]	45	6.1%	49	4.9%	53	3.3%
Age 6 to <11 years (g/day, as consumed)						
Total Foods	784	100.0%	1,068	100.0%	1,664	100.0%
Total Dairy	385	49.2%	406	38.0%	448	26.9%
Total Meats	76	9.7%	88	8.3%	98	5.9%
Total Fish	5	0.6%	6	0.6%	8	0.5%
Total Eggs	16	2.1%	16	1.5%	17	1.0%
Total Grains	105	13.3%	117	11.0%	127	7.6%
Total Vegetables	103	13.2%	213	19.9%	313	18.8%
Total Fruits	26	3.4%	144	13.5%	559	33.6%
Total Fats [a]	48	6.2%	59	5.5%	64	3.9%
Age 11 to <16 years (g/day, as consumed)						
Total Foods	709	100.0%	1,149	100.0%	1,911	100.0%
Total Dairy	301	42.4%	362	31.5%	395	20.7%
Total Meats	91	12.8%	112	9.7%	146	7.7%
Total Fish	3	0.4%	10	0.8%	14	0.7%
Total Eggs	13	1.8%	20	1.7%	24	1.3%
Total Grains	106	15.0%	136	11.8%	165	8.6%
Total Vegetables	125	17.7%	286	24.9%	458	24.0%
Total Fruits	13	1.9%	136	11.8%	597	31.2%
Total Fats [a]	49	6.9%	66	5.8%	87	4.5%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/kg-day, as consumed)						
Total Foods	40	100.0%	58	100.0%	95	100.0%
Total Dairy	21	52.7%	22	38.2%	25	25.8%
Total Meats	3	8.6%	4	7.0%	5	4.8%
Total Fish	0.17	0.4%	0.32	0.6%	0.46	0.5%
Total Eggs	0.63	1.6%	0.81	1.4%	1	1.1%
Total Grains	5	12.4%	6	10.3%	7	6.8%
Total Vegetables	5	13.0%	10	16.5%	13	13.9%
Total Fruits	1	3.4%	11	19.5%	41	42.5%
Total Fats [a]	2	6.1%	3	4.9%	3	3.3%
Age 6 to <11 years (g/kg-day, as consumed)						
Total Foods	23	100.0%	38	100.0%	64	100.0%
Total Dairy	11	47.0%	14	37.6%	18	27.5%
Total Meats	2	10.1%	3	8.9%	4	5.7%
Total Fish	0.18	0.8%	0.15	0.4%	0.30	0.5%
Total Eggs	0.53	2.3%	0.58	1.5%	0.76	1.2%
Total Grains	3	13.8%	5	11.8%	5	8.1%
Total Vegetables	3	13.8%	7	19.1%	11	17.7%
Total Fruits	0.82	3.6%	5	13.3%	22	33.6%
Total Fats [a]	1	6.4%	2	5.4%	3	3.9%
Age 11 to <16 years (g/kg-day, as consumed)						
Total Foods	12	100.0%	23	100.0%	39	100.0%
Total Dairy	5	42.0%	8	33.1%	9	22.3%
Total Meats	1	12.4%	2	9.8%	3	6.4%
Total Fish	0.054	0.5%	0.12	0.5%	0.21	0.5%
Total Eggs	0.22	1.9%	0.40	1.7%	0.59	1.5%
Total Grains	2	14.8%	3	12.1%	3	8.8%
Total Vegetables	2	18.2%	5	23.0%	9	22.4%
Total Fruits	0.25	2.2%	3	12.3%	13	32.3%
Total Fats [a]	0.81	7.0%	1	5.9%	2	4.2%

Table 14-10. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers		Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent		Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/day, as consumed)							Age 16 to <21 years (g/kg-day, as consumed)						
Total Foods	624	100.0%	970	100.0%	2,353	100.0%	Total Foods	9	100.0%	16	100.0%	34	100.0%
Total Dairy	238	38.1%	203	21.0%	449	19.1%	Total Dairy	4	39.0%	3	21.0%	6	17.8%
Total Meats	76	12.2%	112	11.5%	245	10.4%	Total Meats	1	11.7%	2	12.7%	3	9.6%
Total Fish	8	1.2%	15	1.6%	17	0.7%	Total Fish	0.13	1.4%	0.13	0.8%	0.21	0.6%
Total Eggs	21	3.3%	16	1.6%	30	1.3%	Total Eggs	0.31	3.4%	0.41	2.5%	0.33	1.0%
Total Grains	100	16.1%	138	14.2%	211	9.0%	Total Grains	1	16.2%	2	14.6%	3	10.0%
Total Vegetables	109	17.5%	283	29.2%	615	26.1%	Total Vegetables	2	17.9%	5	30.7%	9	25.8%
Total Fruits	18	2.9%	121	12.5%	644	27.4%	Total Fruits	0.17	1.8%	1	9.1%	10	30.0%
Total Fats [a]	46	7.3%	66	6.8%	116	4.9%	Total Fats [a]	0.66	7.2%	1	7.5%	2	4.4%

[a] Includes added fats such as butter, margarine, dressings and sauces, vegetable oil, etc.; does not include fats eaten as components of other foods such as meats.

[b] All individuals in this sample group below the 75th percentile consumed 0 grams/day of fruits and vegetables. Therefore, only high-end and low-end consumer groups are reported.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

Table 14-11. 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

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/day, as consumed)						
Total Foods	12	100.0%	60	100.0%	185	100.0%
Total Dairy	0	0.0%	40	67.3%	127	69.0%
Total Meats	0	0.0%	0	0.0%	0	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.031	0.3%	0	0.0%	4	2.2%
Total Vegetables	8	66.1%	2	3.4%	0.78	0.4%
Total Fruits	0	0.0%	0	0.0%	0	0.0%
Total Fats [a]	3	27.1%	18	29.2%	52	28.4%
Age 1 to <3 months (g/day, as consumed)						
Total Foods	36	100.0%	84	100.0%	166	100.0%
Total Dairy	0	0.0%	19	22.4%	109	65.6%
Total Meats	0	0.0%	0	0.0%	0.037	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.32	0.9%	1	1.2%	0	0.8%
Total Vegetables	21	58.8%	42	50.7%	4	2.7%
Total Fruits	2	4.3%	0.034	0.0%	6	3.7%
Total Fats [a]	10	26.7%	21	25.4%	45	27.2%
Age 3 to <6 months (g/day, as consumed)						
Total Foods	132	100.0%	217	100.0%	346	100.0%
Total Dairy	0	0.0%	59	27.0%	160	46.3%
Total Meats	0.59	0.4%	2	1.0%	4	1.1%
Total Fish	0	0.0%	0	0.0%	0.44	0.1%
Total Eggs	0	0.0%	0.38	0.2%	0.64	0.2%
Total Grains	6	4.5%	8	3.8%	12	3.4%
Total Vegetables	46	34.9%	37	17.0%	26	7.6%
Total Fruits	58	44.1%	84	38.8%	87	25.1%
Total Fats [a]	16	11.9%	26	12.1%	55	15.8%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age Birth to <1month (g/kg-day, as consumed)						
Total Foods	4	100.0%	18	100.0%	56	100.0%
Total Dairy	0	0.0%	12	67.1%	39	69.0%
Total Meats	0	0.0%	0	0.0%	0	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.0086	0.2%	0	0.0%	1	2.1%
Total Vegetables	2	64.4%	0.65	3.7%	0.26	0.5%
Total Fruits	0	0.0%	0	0.0%	0	0.0%
Total Fats [a]	1	27.5%	5	29.2%	16	28.4%
Age 1 to <3 months (g/kg-day, as consumed)						
Total Foods	7	100.0%	14	100.0%	41	100.0%
Total Dairy	0	0.0%	3	24.0%	26	64.1%
Total Meats	0	0.0%	0	0.0%	0.012	0.0%
Total Fish	0	0.0%	0	0.0%	0	0.0%
Total Eggs	0	0.0%	0	0.0%	0	0.0%
Total Grains	0.054	0.8%	0.29	2.0%	0.26	0.6%
Total Vegetables	4	57.8%	7	48.7%	0.43	1.1%
Total Fruits	0.37	5.4%	0.0067	0.0%	3	7.7%
Total Fats [a]	2	26.4%	4	25.0%	11	26.5%
Age 3 to <6 months (g/kg-day, as consumed)						
Total Foods	19	100.0%	32	100.0%	44	100.0%
Total Dairy	0	0.0%	8	24.8%	24	54.9%
Total Meats	0.10	0.5%	0.22	0.7%	0.45	1.0%
Total Fish	0	0.0%	0	0.0%	0.056	0.1%
Total Eggs	0	0.0%	0.11	0.3%	0.057	0.1%
Total Grains	0.84	4.5%	1	3.8%	2	3.4%
Total Vegetables	7	35.6%	4	13.7%	2	5.0%
Total Fruits	8	43.0%	14	45.8%	7	15.9%
Total Fats [a]	2	12.2%	3	10.7%	8	19.2%

Table 14-11. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/day, as consumed)						
Total Foods	317	100.0%	368	100.0%	1,285	100.0%
Total Dairy	0.045	0.0%	71	19.2%	833	64.8%
Total Meats	11	3.4%	16	4.4%	41	3.2%
Total Fish	0.0086	0.0%	1	0.3%	0.28	0.0%
Total Eggs	3	0.9%	5	1.4%	6	0.5%
Total Grains	27	8.6%	23	6.3%	46	3.6%
Total Vegetables	114	35.9%	75	20.4%	106	8.2%
Total Fruits	137	43.3%	147	39.9%	211	16.4%
Total Fats [a]	20	6.4%	30	8.2%	40	3.1%
Age 1 to <2 years (g/day, as consumed)						
Total Foods	601	100.0%	989	100.0%	1,700	100.0%
Total Dairy	40	6.7%	451	45.6%	1,170	68.8%
Total Meats	43	7.1%	51	5.2%	45	2.6%
Total Fish	3	0.5%	4	0.4%	3	0.2%
Total Eggs	14	2.3%	15	1.5%	18	1.1%
Total Grains	57	9.5%	65	6.5%	63	3.7%
Total Vegetables	139	23.1%	120	12.1%	112	6.6%
Total Fruits	268	44.7%	240	24.3%	226	13.3%
Total Fats [a]	29	4.8%	38	3.8%	58	3.4%
Age 2 to <3 years (g/day, as consumed)						
Total Foods	661	100.0%	996	100.0%	1,528	100.0%
Total Dairy	48	7.3%	348	34.9%	885	57.9%
Total Meats	61	9.3%	63	6.3%	55	3.6%
Total Fish	2	0.3%	6	0.6%	5	0.3%
Total Eggs	25	3.8%	20	2.1%	19	1.3%
Total Grains	78	11.9%	82	8.2%	86	5.6%
Total Vegetables	163	24.7%	144	14.5%	137	9.0%
Total Fruits	237	35.8%	279	28.0%	277	18.1%
Total Fats [a]	37	5.5%	41	4.1%	55	3.6%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 6 to <12 months (g/kg-day, as consumed)						
Total Foods	36	100.0%	43	100.0%	135	100.0%
Total Dairy	0.0062	0.0%	8	18.2%	87	64.8%
Total Meats	1	3.5%	2	4.8%	4	3.0%
Total Fish	0	0.0%	0.15	0.3%	0.029	0.0%
Total Eggs	0.35	1.0%	0.92	2.1%	0.66	0.5%
Total Grains	3	7.9%	3	7.7%	5	3.5%
Total Vegetables	13	35.3%	8	17.9%	11	8.2%
Total Fruits	16	44.6%	18	40.7%	22	16.6%
Total Fats [a]	2	6.3%	4	8.1%	4	3.1%
Age 1 to <2 years (g/kg-day, as consumed)						
Total Foods	55	100.0%	86	100.0%	154	100.0%
Total Dairy	3	6.1%	38	44.0%	106	68.5%
Total Meats	4	7.2%	4	4.8%	4	2.6%
Total Fish	0.28	0.5%	0.50	0.6%	0.18	0.1%
Total Eggs	1	2.3%	2	1.8%	1	0.8%
Total Grains	5	9.5%	6	6.9%	6	3.7%
Total Vegetables	12	21.8%	11	13.0%	10	6.7%
Total Fruits	25	46.3%	21	24.5%	21	13.8%
Total Fats [a]	3	4.7%	3	3.7%	5	3.4%
Age 2 to <3 years(g/kg-day, as consumed)						
Total Foods	47	100.0%	72	100.0%	114	100.0%
Total Dairy	3	7.2%	24	33.7%	67	58.4%
Total Meats	4	9.4%	4	6.2%	4	3.6%
Total Fish	0.16	0.3%	0.27	0.4%	0.28	0.2%
Total Eggs	2	3.7%	1	1.5%	1	1.3%
Total Grains	5	11.6%	6	8.5%	6	5.7%
Total Vegetables	12	24.6%	10	14.0%	11	9.3%
Total Fruits	17	36.4%	22	30.2%	20	17.3%
Total Fats [a]	3	5.5%	3	4.2%	4	3.6%

Table 14-11. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/day, as consumed)						
Total Foods	725	100.0%	1,047	100.0%	1,612	100.0%
Total Dairy	64	8.9%	355	33.9%	886	55.0%
Total Meats	75	10.4%	72	6.9%	70	4.3%
Total Fish	4	0.6%	6	0.5%	6	0.4%
Total Eggs	19	2.6%	15	1.4%	18	1.1%
Total Grains	87	12.1%	104	9.9%	116	7.2%
Total Vegetables	168	23.2%	173	16.5%	183	11.3%
Total Fruits	253	34.9%	257	24.5%	251	15.6%
Total Fats [a]	40	5.6%	49	4.7%	63	3.9%
Age 6 to <11 years (g/day, as consumed)						
Total Foods	766	100.0%	1,053	100.0%	1,722	100.0%
Total Dairy	63	8.2%	372	35.4%	892	51.8%
Total Meats	99	12.9%	80	7.6%	87	5.1%
Total Fish	6	0.8%	5	0.5%	6	0.4%
Total Eggs	17	2.2%	14	1.3%	17	1.0%
Total Grains	105	13.7%	113	10.7%	152	8.8%
Total Vegetables	221	28.9%	214	20.3%	242	14.0%
Total Fruits	194	25.3%	175	16.6%	227	13.2%
Total Fats [a]	49	6.4%	56	5.3%	70	4.1%
Age 11 to <16 years (g/day, as consumed)						
Total Foods	747	100.0%	1,094	100.0%	2,020	100.0%
Total Dairy	22	3.0%	307	28.0%	1,017	50.3%
Total Meats	102	13.6%	101	9.2%	134	6.7%
Total Fish	8	1.1%	9	0.8%	12	0.6%
Total Eggs	20	2.7%	18	1.6%	25	1.2%
Total Grains	104	13.9%	133	12.2%	181	9.0%
Total Vegetables	239	32.0%	265	24.2%	322	16.0%
Total Fruits	197	26.4%	180	16.4%	204	10.1%
Total Fats [a]	47	6.2%	62	5.6%	100	5.0%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 3 to <6 years (g/kg-day, as consumed)						
Total Foods	41	100.0%	58	100.0%	97	100.0%
Total Dairy	4	8.8%	20	34.2%	52	54.0%
Total Meats	4	10.6%	4	6.6%	4	4.4%
Total Fish	0.22	0.5%	0.29	0.5%	0.30	0.3%
Total Eggs	1	2.6%	0.87	1.5%	0.99	1.0%
Total Grains	5	12.1%	6	9.9%	7	7.2%
Total Vegetables	10	23.8%	9	16.3%	11	11.3%
Total Fruits	14	34.0%	14	24.7%	16	16.5%
Total Fats [a]	2	5.7%	3	4.7%	4	4.0%
Age 6 to <11 years (g/kg-day, as consumed)						
Total Foods	25	100.0%	38	100.0%	67	100.0%
Total Dairy	2	8.1%	13	34.2%	35	51.9%
Total Meats	3	13.2%	3	8.0%	3	4.9%
Total Fish	0.19	0.8%	0.19	0.5%	0.26	0.4%
Total Eggs	0.55	2.3%	0.67	1.8%	0.62	0.9%
Total Grains	3	13.6%	4	10.7%	6	9.0%
Total Vegetables	7	29.5%	8	19.7%	9	13.7%
Total Fruits	6	24.4%	7	17.8%	9	13.5%
Total Fats [a]	2	6.6%	2	5.2%	3	4.2%
Age 11 to <16 years (g/kg-day, as consumed)						
Total Foods	13	100.0%	22	100.0%	42	100.0%
Total Dairy	0.38	2.9%	6	27.3%	21	49.4%
Total Meats	2	13.8%	2	9.6%	3	6.4%
Total Fish	0.14	1.0%	0.14	0.6%	0.34	0.8%
Total Eggs	0.35	2.6%	0.36	1.7%	0.50	1.2%
Total Grains	2	13.7%	3	12.2%	4	9.1%
Total Vegetables	4	33.0%	5	23.3%	6	15.1%
Total Fruits	3	25.7%	4	17.8%	5	11.9%
Total Fats [a]	0.83	6.2%	1	5.9%	2	4.8%

Table 14-11. 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 (continued)

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/day, as consumed)						
Total Foods	647	100.0%	1,095	100.0%	2,233	100.0%
Total Dairy	8	1.2%	197	18.0%	950	42.5%
Total Meats	101	15.7%	125	11.4%	197	8.8%
Total Fish	8	1.2%	16	1.5%	8	0.4%
Total Eggs	12	1.8%	28	2.5%	27	1.2%
Total Grains	90	13.9%	162	14.8%	217	9.7%
Total Vegetables	228	35.2%	324	29.6%	438	19.6%
Total Fruits	152	23.5%	154	14.1%	249	11.2%
Total Fats [a]	37	5.8%	73	6.7%	114	5.1%

Food Group	Low-end Consumers		Mid-range Consumers		High-end Consumers	
	Intake	Percent	Intake	Percent	Intake	Percent
Age 16 to <21 years (g/kg-day, as consumed)						
Total Foods	10	100.0%	17	100.0%	33	100.0%
Total Dairy	0.12	1.2%	3	16.6%	14	42.8%
Total Meats	2	15.1%	2	13.6%	3	8.9%
Total Fish	0.11	1.1%	0.16	0.9%	0.11	0.3%
Total Eggs	0.17	1.7%	0.39	2.2%	0.40	1.2%
Total Grains	1	14.1%	2	14.0%	3	9.6%
Total Vegetables	4	35.8%	5	28.6%	7	20.0%
Total Fruits	2	23.9%	3	16.1%	3	10.6%
Total Fats [a]	0.58	5.6%	1	6.5%	2	5.1%

[a] Includes added fats such as butter, margarine, dressings and sauces, vegetable oil, etc.; does not include fats eaten as components of other foods such as meats.

Source: Based on U.S. EPA analysis of 1994-96, 1998 CSFII.

15 HUMAN MILK INTAKE

15.1 INTRODUCTION

Human lactation is known to impart a wide range of benefits to nursing infants, including protection against infection, increases in cognitive development, and avoidance of allergies due to intolerance to cow's milk (AAP, 2005). Ingestion of human milk has also been associated with a reduction in risk of postneonatal death in the U.S. (Chen and Rogan, 2004). The American Academy of Pediatrics recommends exclusive breastfeeding for approximately the first six months and supports the continuation of breastfeeding for the first year and beyond if desired by the mother and child (AAP, 2005). However, contaminants may find their way into human milk of lactating mothers because mothers are themselves exposed. Thus, making human milk a potential source of exposure to toxic substances for nursing infants. Lipid soluble chemical compounds accumulate in body fat and may be transferred to breast-fed infants in the lipid portion of human milk. Water soluble chemicals may also partition into the aqueous phase and be excreted via human milk. Because nursing infants obtain most (if not all) of their dietary intake from human milk, they are especially vulnerable to exposures to these compounds. Estimating the magnitude of the potential dose to infants from human milk requires information on the milk intake rate (quantity of human milk consumed per day) and the duration (months) over which breast-feeding occurs. Information on the fat content of human milk is also needed for estimating dose from human milk residue concentrations that have been indexed to lipid content.

Several studies have generated data on human milk intake. Typically, human milk intake has been measured over a 24-hour period by weighing the infant before and after each feeding without changing its clothing (test weighing). The sum of the difference between the measured weights over the 24-hour period is assumed to be equivalent to the amount of human milk consumed daily. Intakes measured using this procedure are often corrected for evaporative water losses (insensible water losses) between infant weighings (NAS, 1991). Neville et al. (1988) evaluated the validity of the test weight approach among bottle-fed infants by comparing the weights of milk taken from bottles with the differences between the infants' weights before and after feeding. When test weight data were corrected for insensible weight loss, they were not significantly different from bottle weights. Conversions between weight and volume of human milk consumed are made using the density of human milk (approximately 1.03 g/mL) (NAS, 1991). Techniques for measuring human milk intake using stable isotopes such as deuterium have been developed. The advantages of these techniques over test weighing procedures are that they are less burdensome for the mother and do not interfere with normal behavior (Albernaz et al., 2002). However, few data based on this technique were found in the literature.

Among infants born in 2004, 73.8% were breastfed postpartum, 41.5.% at 6 months, and 20.9% at 12 months. Studies among nursing mothers in industrialized countries have shown that average intakes among infants ranged from approximately 500 to 800 mL/day, with the highest intake reported for infants 3 to < 6 months old (see Table 15-1).

The recommendations for human milk intake rates and lipid intake rates are provided in the next section along with a summary of the confidence ratings for these recommendations. The recommended values are based on key studies identified by EPA for this factor. Following the recommendations, key studies on human milk intake are summarized. Relevant data on lipid content and fat intake, breast-feeding duration, and the estimated percentage of the U.S. population that breast-feeds are also presented.

A number of other studies exist in the literature, but they focus on other aspects of lactation such as growth patterns of nursing infants, supplementary food and energy intake, and nutrition of lactating mothers (Dewey et al., 1992; Drewett et al.,1993; Gonzalez-Cossio et al., 1998). These studies are not included in this chapter because they do no focus on the exposure factor of interest. Other studies in the literature focus on formula intake. Since some baby formula are prepared by adding water, these data are presented in chapter 3 - Water Intake.

15.2 RECOMMENDATIONS

The studies described in Section 15.3 were used in selecting recommended values for human milk intake and lipid intake. Although different survey designs, testing periods, and populations were utilized by the studies to estimate intake, the mean and standard deviation estimates reported in these studies are relatively consistent. There are, however, limitations with the data. With the exception of Butte et al. (1984)

and Arcus-Arth et al. (2005), data were not presented on a body weight basis. This is particularly important since intake rates may be higher on a body weight basis for younger infants. Also, the data used to derive the recommendations are over 15 years old and the sample size of the studies was small. Other populations of concern such as mothers highly committed to breastfeeding, sometimes for periods longer than 1 year, may not be captured by the studies presented in this chapter.

15.2.1 Human Milk Intake

A summary of recommended values for human milk and lipid intake rates is presented in Table 15-1 and the confidence ratings for these recommendations are presented in Table 15-2. The human milk intake rates for nursing infants that have been reported in the studies described in this section are summarized in Table 15-3 in units of mL/day and in Table 15-4 in units of mL/kg-day (i.e., indexed to body weight). It should be noted that the decrease in human milk with age is likely a result of complementary foods being introduced as the child grows and not necessarily a decrease in total energy intake. In order to conform to the new standardized age groupings used in this handbook (see Chapter 1), data from Pao et al. (1980), Dewey and Lönnerdal (1983), Butte et al. (1984), Neville et al. (1988), Dewey et al. (1991a), Dewey et al. (1991b), Butte et al. (2000) and Arcus-Arth et al. (2005) were compiled for each month of the first year of life. Recommendations were converted to mL/day using a density of human milk of 1.03 g/mL rounded up to two significant figures. Only two studies (i.e., Butte et al., 1984 and Arcus-Arth et al., 2005) provided data on a body weight basis. For some months multiple studies were available; for others only one study was available. Weighted means were calculated for each age in months. When upper percentiles were not available from a study, these were estimated by adding two standard deviations to the mean value. Recommendations for upper percentiles, when multiple studies were available, were calculated as the midpoint of the range of upper percentile values of the studies available for each age in months. These month-by-month intakes were composited to yield intake rates for the standardized age groups by calculating a weighted average. Recommendations are provided for the population of exclusively breastfed infants since this population may have higher exposures than partially breastfed infants. **Exclusively breastfed in this chapter refers to infants whose sole source of milk comes from human milk, with no other milk substitutes. Partially breastfed refers to infants whose source of milk comes from both human milk and other milk substitutes (i.e., formula).** Note that some studies define partially breastfed as infants whose dietary intake comes from not only human milk and formula, but also from other solid foods (e.g., strained fruits, vegetables, meats).

15.2.2 Lipid Content and Lipid Intake

Recommended lipid intake rates are presented in Table 15-5. The table parallels the human milk intake tables (Table 15- 3). With the exception of the data from Butte et al. (1984), the rates were calculated assuming a lipid content of 4% (Butte et al.,1984; NAS, 1991; Maxwell and Burmaster, 1993). In the case of the Butte et al. (1984) study, lipid intake rates were provided, and were used in place of the estimated lipid intakes. Lipid intake rates on a body weight basis are presented in Table 15-6. These were calculated from the values presented in Table 15-4 multiplied by 4% lipid content.

Table 15-1. Recommended Values for Human Milk And Lipid Intake Rates for Exclusively Breastfed Infants

Age Group	Mean		Upper Percentile[a]		Source
	mL/day	mL/kg-day	mL/day	mL/kg-day	
Human Milk Intake					
Birth to <1 month	510	150	950	220	b
1 to <3 months	690	140	980	190	b, c, d, e,f
3 to <6 months	770	110	1,000	150	b, c, d, e, f, g
6 to <12 months	620	83	1,000	130	b, c, e, g
Lipid Intake [h]					
Birth to <1 month	20	6.0	38	8.7	i
1 to <3 months	27	5.5	40	8.0	d, i
3 to <6 months	30	4.2	42	6.0	d, i
6 to <12 months	25	3.3	42	5.2	i

[a] Upper percentile is reported as mean plus 2 standard deviations.
[b] Neville et al., 1988.
[c] Pao et al., 1980.
[d] Butte et al., 1984.
[e] Dewey and Lönnerdal, 1983.
[f] Butte et al., 2000.
[g] Dewey et al., 1991b.
[h] The recommended value for the lipid content of human milk is 4.0 percent. See Section 15.5.
[i] Arcus- Arth et al., 2005.

Table 15-2. Confidence in Recommendations for Human Milk Intake

General Assessment Factors	Rationale	Rating
Soundness		Medium
Adequacy of Approach	Methodology uses changes in body weight as a surrogate for total ingestion. More sophisticated techniques measuring stable isotopes have been developed, but data with this technique were not available. Sample sizes were relatively small (7-108). Mothers selected for the studies were volunteers. The studies analyzed primary data.	
Minimal (or defined) Bias	Mothers were instructed in the use of infant scales to minimize measurement errors. Three out of the 8 studies indicated correcting data for insensible water loss. Some biases may be introduced by including partially-breastfed infants.	
Applicability and Utility		Medium
Exposure Factor of Interest	The studies focused on estimating human milk intake.	
Representativeness	Most studies focused on the U.S. population, but were not national samples. Population studied were mainly from high socioeconomic status. One study included populations from Sweden and Finland. However, this may not affect the amount of intake, but rather the prevalence and initiation of lactation.	
Currency	Studies were conducted between 1980-2000. However, this may not affect the amount of intake, but rather the prevalence and initiation of lactation.	
Data Collection Period	Infants were not studied long enough to fully characterize day to day variability.	
Clarity and Completeness		Medium
Accessibility	All key studies are available from the peer reviewed literature.	
Reproducibility	The methodology was clearly presented, but some studies did not discuss adjustments due to insensible weight loss.	
Quality Assurance	Some steps were taken to ensure data quality. For example, mothers were trained to use the scales. However, this element could not be fully evaluated from the information presented in the published studies.	
Variability and Uncertainty		Low
Variability in Population	Not very well characterized. Mothers committed to breastfeeding over 1 year were not captured.	
Uncertainty	Not correcting for insensible water loss may underestimate intake.	

Table 15-2. Confidence in Recommendations for Human Milk Intake (continued)		
General Assessment Factors	Rationale	Rating
Evaluation and Review		High
Peer Review	The studies appeared in peer review journals.	
Number and Agreement of Studies	There are 8 key studies. The results of studies from different researchers are in agreement.	
Overall Rating		**Medium**

Table 15-3. Human Milk Intake Rates Derived from Key Studies for Exclusively Breast-fed Infants (mL/day)

Age (months)	Number of Children	Mean Intake (mL/day)	Upper Percentile Consumption (mL/day)[a]	Source	Weighted Mean Intake and Upper Percentile Consumption (across all Key Studies) (mL/day)			
					Individual Age		Composite Age Groups	
					Mean[b]	Upper[c]	Mean	Upper[c]
0 <1	6 to 13	511	951	Neville et al., 1988	511	951	511	951
1	11	600	918	Pao et al., 1980	670	961	692	977
	37	729	981	Butte et al., 1984				
	12	679[d]	889	Neville et al., 1988				
	16	673	1,057	Dewey and Lönnerdal, 1983				
2	10 to 12	679[d]	889	Neville et al., 1988	713	992		
	19	756	1,096	Dewey and Lönnerdal, 1983				
	40	704	958	Butte et al., 1984				
3	2	833	-[e]	Pao et al., 1980	758	1,025	769	1,024
	37	702	924	Butte et al., 1984				
	10	713	935	Neville et al., 1988				
	16	782	1,126	Dewey and Lönnerdal, 1983				
	73	788	1,047	Dewey et al., 1991b				
	40	728	988	Butte et al., 2000				
4	12	690	888	Neville et al., 1988	739	991		
	13	810	1,094	Dewey and Lönnerdal, 1983				
	41	740	996	Butte et al., 1984				
5	12	814	1,074	Neville et al., 1988	810	1,057		
	11	805	1,039	Dewey and Lönnerdal, 1983				
6	1	682	-ed	Pao et al., 1980	741	1,000	622	1,024
	13	744	978	Neville et al., 1988				
	11	896	1,140	Dewey and Lönnerdal, 1983				
	60	747	1,079	Dewey et al., 1991b				
	30	637	1,050	Butte et al., 2000				
7	12	700	1,000	Neville et al., 1988	700	1,006		
8	9	604	1,012	Neville et al., 1988	604	1,012		
9	12	600	1,028	Neville et al., 1988	614	1,039		
	50	627	1,049	Dewey et al., 1991b				
10	11	535	989	Neville et al., 1988	535	989		
11	8	538	1,004	Neville et al., 1988	538	1,004		
12	8	391	877	Neville et al., 1988	410	904	410	904
	42	435	922	Dewey et al., 1991a; 1991b				
	13	403	931	Butte et al., 2000				

[a] Calculated as the mean of the means.
[b] Upper percentile is reported as mean plus 2 standard deviations.
[c] Middle of the range of upper percentiles.
[d] Calculated for infants 1 to < 2 months old.
[e] Standard deviations and upper percentiles not calculated for small sample sizes.

Table 15-4. Human Milk Intake Rates Derived from Key Studies for Exclusively Breast-fed Infants (mL/kg/day)

Age (months)	Number of Children	Mean Intake (mL/kg-day)	Upper Percentile Consumption (mL/kg-day)[a]	Source	Weighted Mean Intake and Upper Percentile Consumption (across all Key Studies) (mL/kg-day)			
					Individual Age		Composite Age Groups	
					Mean[b]	Upper[c]	Mean	Upper[c]
0 <1	9 to 25	150	217	Arcus-Arth et al, 2005	150	217	150	217
1	37	154	200	Butte et al., 1984	152	199	144	187
	25	150	198	Arcus-Arth et al, 2005				
2	40	125	161	Butte et al., 1984	135	175		
	25	144	188	Arcus-Arth et al, 2005				
3	37	114	152	Butte et al., 1984	121	158	111	149
	108	127	163	Arcus-Arth et al, 2005				
4	41	108	142	Butte et al., 1984	110	145		
	57	112	148	Arcus-Arth et al, 2005				
5	26	100	140	Arcus-Arth et al, 2005	100	140		
6	39	101	141	Arcus-Arth et al, 2005	101	141	83	130
7	8	75	125	Arcus-Arth et al, 2005	75	125		
9	57	72	118	Arcus-Arth et al, 2005	72	118		
12	42	47	101	Arcus-Arth et al, 2005	47	101	47	101

[a] Calculated as the mean of the means.
[b] Upper percentile is reported as mean plus 2 standard deviations.
[c] Middle of the range of upper percentiles.

Table 15-5. Lipid Intake Rates Derived from Key Studies for Exclusively Breastfed Infants (mL/day)[a]

Age (months)	Number of Children	Mean Intake (mL/day)	Upper Percentile Consumption (mL/day)[b]	Source	Weighted Mean Intake and Upper Percentile Consumption (across all Key Studies) (mL/day)			
					Individual Age		Composite Age Groups	
					Mean[c]	Upper[d]	Mean[c]	Upper[d]
0 <1	6 to 13	20	38	Neville et al., 1988	20	38	20	38
1	11	24	37	Pao et al., 1980	26	39	27	40
	37	27	43	Butte et al., 1984				
	10 to 12	27	36	Neville et al., 1988				
	16	27	42	Dewey and Lönnerdal, 1983				
2	10 to 12	27	36	Neville et al., 1988	27	40		
	19	30	44	Dewey and Lönnerdal, 1983				
	40	24	38	Butte et al., 1984				
3	2	33	-[e]	Pao et al., 1980	30	41	30	42
	37	23	37	Butte et al., 1984				
	10	29	37	Neville et al., 1988				
	16	31	45	Dewey and Lönnerdal, 1983				
	73	32	42	Dewey et al., 1991b				
	40	29	40	Butte et al. 2000				
4	12	28	36	Neville et al., 1988	28	40		
	13	32	44	Dewey and Lönnerdal, 1983				
	41	25	41	Butte et al., 1984				
5	12	33	43	Neville et al., 1988	33	43		
	11	32	42	Dewey and Lönnerdal, 1983				
6	1	27	-[e]	Pao et al., 1980	30	40	25	42
	13	30	39	Neville et al., 1988				
	11	36	46	Dewey and Lönnerdal, 1983				
	60	30	43	Dewey et al., 1991b				
	30	25	42	Butte et al., 2000				
7	12	28	40	Neville et al., 1988	28	40		
8	9	24	40	Neville et al., 1988	24	41		
9	12	24	41	Neville et al., 1988	24	41		
	50	25	42	Dewey et al., 1991b				
10	11	21	40	Neville et al., 1988	21	40		
11	9	22	40	Neville et al., 1988	22	40		
12	9	17	35	Neville et al., 1988	16	36	16	36
	42	17	37	Dewey et al., 1991a; 1991b				
	13	16	37	Butte et al., 2000				

[a] Except for Butte et al. 1984, values were calculated from table 15-3 using 4% lipid content.
[b] Upper percentile is reported as mean plus 2 standard deviations.
[c] Calculated as the mean of the means.
[d] Middle of the range of upper percentiles.
[e] Standard deviations and upper percentiles not calculated for small sample sizes.

Table 15-6. Lipid Intake Rates Derived from Key Studies for Exclusively Breast-fed Infants (mL/kg/day)[a]

Age (months)	Number of Children	Mean Intake (mL/kg-day)	Upper Percentile Consumption (mL/kg-day)[b]	Source	Weighted Mean Intake and Upper Percentile Consumption[b] (across all Key Studies) (mL/kg-day)			
					Individual Age		Composite Ages Groups	
					Mean[c]	Upper[d]	Mean[e]	Upper[d]
0 <1	9 to 25	6.0	8.7	Arcus-Arth et al, 2005	6.2	8.7	6.0	8.7
1	37 25	5.7 6.0	9.1 8.7	Butte et al., 1984 Arcus-Arth et al, 2005	5.9	8.9	5.5	8.0
2	40 25	4.3 5.8	6.7 7.5	Butte et al., 1984 Arcus-Arth et al, 2005	5.1	7.1		
3	37 108	3.7 5.1	6.1 6.5	Butte et al., 1984 Arcus-Arth et al, 2005	4.4	6.3	4.2	6.0
4	41 57	3.7 4.5	6.3 5.9	Butte et al., 1984 Arcus-Arth et al, 2005	4.1	6.1		
5	26	4.0	5.6	Arcus-Arth et al, 2005	4.0	5.8		
6	39	4.0	5.6	Arcus-Arth et al, 2005	4.0	5.6	3.3	5.2
7	8	3.0	5.0	Arcus-Arth et al, 2005	3.0	5.0		
9	57	2.9	4.7	Arcus-Arth et al, 2005	2.9	4.7		
12	42	1.9	4.0	Arcus-Arth et al, 2005	1.9	4.0	1.9	4.1

[a] Except for Butte et al. 1984, values were calculated from table 15-4 using 4% lipid content.
[b] Upper percentile is reported as mean plus 2 standard deviations.
[c] Calculated as the mean of the means.
[d] Middle of the range of upper percentiles.

15.3 KEY STUDIES ON HUMAN MILK INTAKE

15.3.1 Pao et al., 1980 - Milk Intakes and Feeding Patterns of Breast-fed Infants

Pao et al. (1980) conducted a study of 22 healthy nursing infants to estimate human milk intake rates. Infants were categorized as completely breast-fed or partially breast-fed. Breastfeeding mothers were recruited through LaLeche League groups. Except for one black infant, all other infants were from white middle-class families in southwestern Ohio. The goal of the study was to enroll infants as close to one month of age as possible and to obtain records near one, three, six, and nine months of age (Pao et al., 1980). However, not all mother/infant pairs participated at each time interval. Data were collected for these 22 infants using the test weighing method. Records were collected for three consecutive 24-hour periods at each test interval. The weight of human milk was converted to volume by assuming a density of 1.03 g/mL. Daily intake rates were calculated for each infant based on the mean of the three 24-hour periods. Mean daily human milk intake rates for the infants surveyed at each time interval are presented in Table 15-7. These data (Table 15-7) are presented as they are reported in Pao et al. (1980). For completely breast-fed infants, the mean intake rates were 600 mL/day at 1 month of age, 833 mL/day at 3 months of age, and 682 mL/day at 6 months of age. Partially breast-fed infants had mean intake rates of 485 mL/day, 467 mL/day, 395 mL/day, and <554 mL/day at 1, 3, 6, and 9 months of age, respectively. Pao et al. (1980) also noted that intake rates for boys in both groups were slightly higher than for girls.

The advantage of this study is that data for both exclusively and partially breast-fed infants were collected for multiple time periods. Also, data for individual infants were collected over 3 consecutive days which would account for some individual variability. However, the number of infants in the study was relatively small. In addition, this study did not account for insensible weight loss which may underestimate the amount of human milk ingested.

15.3.2 Dewey and Lönnerdal, 1983 - Milk and Nutrient Intake of Breast-fed Infants from 1 to 6 Months: Relation to Growth and Fatness

Dewey and Lönnerdal (1983) monitored the dietary intake of 20 nursing infants between the ages of 1 and 6 months. The number of study participants dropped to 13 by the end of the sixth month. Most of the infants in the study were exclusively breast-fed. One infant's intake was supplemented by formula during the first and second month of life. During the third, fourth, and fifth months, three, four, and five infants, respectively, were given some formula to supplement their intake. Two infants were given only formula (no human milk) during the sixth month. According to Dewey and Lönnerdal (1983), the mothers were all well educated and recruited through Lamaze childbirth classes in the Davis area of California. Human milk intake volume was estimated based on two 24-hour test weighings per month. Human milk intake rates for the various age groups are presented in Table 15-8. Human milk intake averaged 673, 782, and 896 mL/day at 1, 3, and 6 months of age, respectively.

The advantage of this study is that it evaluated nursing infants for a period of 6 months based on two 24-hour observations per infant per month. However, corrections for insensible weight loss apparently were not made. Also, the number of infants in the study was relatively small and the study participants were not representative of the general population. Some infants during the study period were given some formula (i.e., up to 5 infants during the fifth month). Without the raw data, these subjects could not be excluded from the study results. Thus, these subjects may affect the results when deriving recommendations for exclusively breastfed infants.

15.3.3 Butte et al., 1984 - Human Milk Intake and Growth in Exclusively Breast-fed Infants

Human milk intake was studied in exclusively breast-fed infants during the first 4 months of life (Butte et al., 1984). Nursing mothers were recruited through the Baylor Milk Bank Program in Texas. Forty-five mother/infant pairs participated in the study. However, data for some time periods (i.e., 1, 2, 3, or 4 months) were missing for some mothers as a result of illness or other factors. The mothers were from the middle- to upper-socioeconomic stratum and had a mean age of 28.0 ± 3.1 years. A total of 41 mothers were white, 2 were Hispanic, 1 was Asian, and 1 was West Indian. Infant growth progressed satisfactorily over the course of the study.

The amount of milk ingested over a 24-hour period was determined by weighing the infant before and after feeding. The study did not indicate whether the data were corrected for insensible water or weight loss. The mean and standard deviation milk intake difference based on weighing the bottle before and after nine successive feedings, was estimated to be 3.2 ± 3.1 g. Test weighing occurred over a 24-hour period for most study participants, but intake among several infants was studied over longer periods (48 to 96 hours) to assess individual variation in intake. It was reported that eight of the infants received some food supplementation during the study period. Six of them received less than 60 kcal/day of formula, oatmeal, glucose water, or rice water for 1 or 2 days. One infant received an additional 90 kcal/day of infant formula and rice water for 6 days during the fourth month because of inadequate milk production. Converting values reported as g/day to mL/day, using a conversion factor of 1.03 g/mL, mean human milk intake ranged from 702 mL/day at 3 months to 729 mL/day at 1 month, with an overall mean of 712 mL/day for the entire study period (Table 15-9). Intakes were also calculated on the basis of body weight (Table 15-9). Based on the results of test weighings conducted over 48 to 96 hours, the overall mean variation in individual daily intake was estimated to be 7.9 ± 3.6 percent.

The advantage of this study is that data for a larger number of exclusively breast-fed infants were collected than in previous studies. However, data were collected for infants up to 4 months and day-to-day variability was not characterized for all infants. It was reported that eighteen percent (i.e., 8 out of 45) of the infants received some formula supplementation during the study period. Without the raw data, these subjects could not be excluded from the study results. Therefore, values derived from this study for exclusively breastfed infants may be somewhat underestimated.

15.3.4 Neville et al., 1988 - Studies in Human Lactation: Milk Volumes in Lactating Women During the Onset of Lactation and Full Lactation

Neville et al. (1988) studied human milk intake among 13 infants during the first year of life. The mothers were all multiparous, nonsmoking, Caucasian women of middle- to upper-socioeconomic status living in Denver, CO. All women in the study practiced exclusive breast-feeding for at least 5 months. Solid foods were introduced at mean age of 7 months. Daily milk intake was estimated by the test weighing method with corrections for insensible weight loss. Data were collected daily from birth to 14 days, weekly from weeks 3 through 8, and monthly until the study period ended at 1 year after inception. One infant was weaned at 8 months, while all others were weaned on or after the 12 months. Formula was used occasionally (≤ 240 mL/wk) after 4 months in three infants. The estimated human milk intakes for this study are listed in Table 15-10. Converting values reported as g/day to mL/day, using a conversion factor of 1.03 g/mL, mean human milk intakes were 748 mL/day, 713 mL/day, 744 mL/day, and 391 mL/day at 1, 3, 6, and 12 months of age, respectively.

In comparison to the previously described studies, Neville et al. (1988) collected data on numerous days over a relatively long time period (12 months) and they were corrected for insensible weight loss. However, the intake rates presented in Table 15-10 are estimated based on intake during only a 24-hour period. Consequently, these intake rates are based on short-term data that do not account for day-to-day variability among individual infants. Also, a smaller number of subjects was included than in the previous studies. Three infants were given some formula after 4 months. Without the raw data, these subjects could not be excluded from the study results. Thus, data presented for infants between 5 and 12 months may be an underestimate for the intake of exclusively breastfed infants.

15.3.5 Dewey et al., 1991a, b - (a) Maternal Versus Infant Factors Related to Human Milk Intake and Residual Volume: The DARLING Study; (b) Adequacy of Energy Intake Among Breast-fed Infants in the DARLING Study: Relationships to Growth, Velocity, Morbidity, and Activity Levels

The Davis Area Research on Lactation, Infant Nutrition and Growth (DARLING) study was conducted in 1986 to evaluate growth patterns, nutrient intake, morbidity, and activity levels in infants who were breast-fed for at least the first 12 months of life (Dewey et al., 1991a, b). Subjects were non-randomly selected through letters to new parents using birth listing. One of the criteria used for selection was that mothers did not plan to feed their infants more than 120 mL/day of other milk or formula for the first 12 months of life. Seventy-three infants aged 3 months were included in the study. At subsequent time intervals, the number of infants included in the study was somewhat lower as a result of attrition. All infants in the study were healthy and of normal gestational age and weight at birth, and did not consume solid foods until after the first 4 months of age. The mothers were highly educated and of "relatively high socioeconomic status."

Human milk intake was estimated by weighing the infants before and after each feeding and correcting for insensible water loss. Test weighings were conducted over a 4-day period every 3 months. The results of the study indicate that human milk intake declines over the first 12 months of life. This decline is associated with the intake of solid food. Converting values reported as g/day to mL/day, using a conversion factor of 1.03 g/mL, mean human milk intake was estimated to be 788 mL/day at 3 months and 435 mL/day at 12 months (Table 15-11). Based on the estimated intakes at 3 months of age, variability between individuals (coefficient of variation ([CV] = 16.3%) was higher than the average day-to-day variability ([CV] = 8.9 ± 5.4%) for the infants in the study (Dewey et al., 1991a).

The advantages of this study are that data were collected over a relatively long-time (4 days) period at each test interval, which would account for some day-to-day infant variability, and corrections for insensible water loss were made. Data from this study are assumed to represent exclusively breastfed infants, since mothers were specifically recruited for that purpose. It is, however, unclear from the Dewey et al., 1991a if this criterion was met throughout the length of the study period.

15.3.6 Butte, et al., 2000 - Infant Feeding Mode Affects Early Growth and Body Composition

Butte et al. (2000) conducted a study to assess the impact of infant feeding mode on growth and body composition during the first two years of life. The study was conducted in the Houston, Texas area, recruited through the Children's Nutrition Research Center (CNRC) referral system. The study was approved by the Baylor Affiliates Review Boards for Human Subject Research. The overall sample was 76 healthy term infants at 0.5, 3, 6, 9, 12, 18, and 24 months of age. The sample size varied between 71 to 76 infants for each age group. Repeated measurements for body composition and anthropometric were performed. The mothers agreed to either exclusively breast feed or formula feed the infants for the first 4 months of life.

At 3-month or 6-month study intervals, the feeding history was taken. The mothers or caretakers were questioned about breastfeeding frequency, and the use of formula, milk, juice, solids, water and vitamin or mineral supplements. Also, infant food intake was quantified at 3, 6, 12, and 24 months with a 3-day weighted intake record completed by the mother or caretaker (Butte et al., 2000). The intake of human milk was assessed by test weighing; the infant weights were measured before and after each feeding. Using a pre-weighing and post-weighing method, the intake of formula and other foods and beverages was determined for 3 days by the mothers using a digital scale and recorded on predetermined forms.

The average duration of breastfeeding was 11.4 months (SD = 5.8). Butte et al.(2000) reported that infants were exclusively breastfed for at least the first four months except for the following: one was weaned at 109 days, another received formula at 102 days and another given cereal at 106 days. The infant feeding characteristics are shown in Table 15-12. The intake of human milk for the infants are shown in Table 15-13. Converting values reported as g/day to mL/day, using a conversion factor of 1.03 g/mL, mean human milk intake was estimated to be 728 mL/day at 3 months (weighted average of boys and girls), 637 mL/day at 6 months (weighted average of boys and girls), and 403 mL/day at 12 months (weighted average of boys and girls) (Table 15-13). Feeding practices by percent for infants are shown in Table 15-14. The mean weights are provided in Table 15-15.

Advantages of this study are that it provides intake data for breastfed infants for the first four months of life. The study also provides the mean weights for the infants by feeding type and by gender. The limitations of the study are that the sample size is small and it is limited to one geographical location. The authors did not indicate if results were corrected for insensible weight loss. Since mothers could introduce formula after 4 months, only the data for the 3-month old infants can be considered exclusively breastfed.

15.3.7 Arcus-Arth et al., 2005 - Human Milk and Lipid Intake Distributions for Assessing Cumulative Exposure and Risk

Arcus-Arth et al. (2005) derived population distributions for average daily milk and lipid intakes in g/kg day for infants 0-6 months and 0-12 months of age for infants fed according to the American Academy of Pediatrics (AAP) recommendations. The AAP recommends exclusively breastfeeding for the first 6 months of life, human milk as the only source of milk age 1 year, with the introduction of solid foods after 6 months. The distributions were derived based on data in the peer reviewed literature and datasets supplied by the publication authors for infants 7 days and older (Arcus-Arth et al., 2005). As cited in Arcus-Arth et al. (2005), data sources included Dewey et al. (1991a, 199b), Hofvander et al. (1982), Neubauer et al. (1993), Ferris et al. (1993), Salmenpera et al. (1985), and Stuff and Nichols (1989). The authors also evaluated intake rates for infants breastfed exclusively over the first year and provides a regression line of intake versus age for estimating short-term exposures. Arcus-Arth derived human milk intake rates for the entire infant population (nursing and non-nursing) from U.S. data on consumption, prevalence and duration. Arcus-Arth et al. (2005) defined exclusive breastfeeding (EBF) as "breast milk is the sole source of calories, with no or insignificant calories form other liquid or solid food sources." Predominant breastfeeding was described by Arcus-Arth et al. (2005) as "breast milk is the sole milk source with significant calories from other foods." The data that were consistent with AAP advice were used to construct the AAP dataset (Arcus-Arth et al., 2005). The 0-12 months EBF dataset was created using 0-6 month AAP data and data from the EBF infants older than 6 months of age. Because there are no data in the AAP dataset for any individual infant followed at regular, frequent intervals over the 12 month period, population distributions were derived with assumptions regarding individual intake variability over time (Arcus-Arth et al., 2005). Two methods were used. In Method 1, the average population daily intake at each age is described by a regression line, assuming normality. Arcus-Arth et al. (2005) noted that age specific intake data were consistent with the assumption of normality. In Method 2, intake over time is simulated for 2500 hypothetical infants and the distribution intakes derived from 2500 individual intakes (Arcus-Arth et al., 2005). The population intake distribution was derived following Method 1. Table 15-16 presents the means, and standard deviations for intake data at different ages; the variability was greatest for the 2 youngest and 3 oldest age groups. The values in Table 15-6 using Method 1 were used to derive recommendations presented in Table 15-4 since it provides data for the fine age categories. Converting values reported as g/day to mL/day, using a conversion factor of 1.03 g/mL, mean human milk intake was estimated to be 150 mL/kg-day at 1 month, 127 mL/kg-day at 3 months, 101 mL/kg-day at 6 months, and 47 mL/kg-day at 12 months (Table 15-16). Time weighted average intakes for larger age groups (i.e., 0 - 6 months, 0 - 12 months) are presented in Table 15-17.

An advantage of this study is that it was designed to represent the infant population whose mothers follow the AAP recommendations. Intake was calculated on a body weight basis. In addition, the data used to derive the distributions were from peer reviewed literature and datasets supplied by the publication authors. The distributions were derived from data for infants fed in accordance to AAP recommendations, and they most likely represent daily average milk intake for a significant portion of breastfed infants today (Arcus-Arth et al., 2005). The limitations of the study are that the data used were from mothers that were predominantly white, well nourished and from mid or high socioeconomic status. Arcus-Arth et al. (2005) also included data from Sweden and Finland. However human milk volume in mL/day is similar among all women except for severely malnourished women (Arcus-Arth et al., 2005). According to Arcus-Arth et al. (2005), "Although few infants are exclusively breastfed for 12 months, the EBF distributions may represent a more highly exposed subpopulation of infants exclusively breastfed in excess of 6 months."

15.4 KEY STUDIES ON LIPID CONTENT AND LIPID INTAKE FROM HUMAN MILK

Human milk contains over 200 constituents including lipids, various proteins, carbohydrates, vitamins, minerals, and trace elements as well as enzymes and hormones. The lipid content of human milk varies according to the length of time that an infant nurses, and increases from the beginning to the end of a single nursing session (NAS, 1991). The lipid portion accounts for approximately 4% of human milk (3.9%

± 0.4%) (NAS, 1991). This value is supported by various studies that evaluated lipid content from human milk. Several studies also estimated the quantity of lipid consumed by breast-feeding infants. These values are appropriate for performing exposure assessments for nursing infants when the contaminant(s) have residue concentrations that are indexed to the fat portion of human milk.

15.4.1 Butte et al., 1984 - Human Milk Intake and Growth in Exclusively Breast-fed Infants

Butte et al. (1984) analyzed the lipid content of human milk samples taken from women who participated in a study of human milk intake among exclusively breast-fed infants. The study was conducted with over 40 women during a 4-month period. The mean lipid content of human milk at various infants' ages is presented in Table 15-18. The overall lipid content for the 4-month study period was 3.43 ± 0.69 % (3.4%). Butte et al. (1984) also calculated lipid intakes from 24-hour human milk intakes and the lipid content of the human milk samples. Lipid intake was estimated to range from 22.9 mL/day (3.7 mL/kg-day) to 27.2 mL/day (5.7 mL/kg-day).

The number of women included in this study was small, and these women were selected primarily from middle to upper socioeconomic classes. Thus, data on human milk lipid content from this study may not be entirely representative of human milk lipid content among the U.S. population. Also, these estimates are based on short-term data, and day-to-day variability was not characterized.

15.4.2 Mitoulas et al., 2002 - Variation in Fat, Lactose, and Protein in Human Milk Over 24 h and Throughout the First Year of Lactation

Mitoulas et al. (2002) conducted a study of healthy nursing women to determine the volume and composition of human milk during the first year of lactation. Nursing mothers were recruited through the Nursing Mothers' Association of Australia. All infants were completely breastfed on demand for at least 4 months. Complementary solid food was introduced between 4-6 months of age. Mothers consumed their own *ad libitum* diets throughout the study. Seventeen mothers initially provided data for milk production and fat content, whereas lactose, protein, and energy were initially obtained from nine mothers. The number of mothers participating in the study decreased at 6 months due to the cessation of sample collection from 11 mothers, the maximum period of exclusive breast-feeding.

Milk samples were collected before and after each feed from each breast over a 24-28 hour period. Milk yield was determined by weighing the mother before and after each feed from each breast. Insensible water loss was accounted for by weighing the mother 20 minutes after the end of each feeding. The rate of water loss during this 20 minutes was used to calculate insensible water loss during the feeding. Samples of milk produced at the beginning of the feeding (foremilk) and at the end of the feeding (hindmilk) were averaged to provide the fat, protein, lactose, and energy content for each feed. In all cases the left and right breasts were treated separately, therefore, n, represents the number of individual breasts sampled.

Mean human milk production and composition at each age interval are presented in Table 15-19. The mean 24 hour milk production from both breasts was 798 (SD= 232) mL. The mean fat, lactose, and protein contents (g/L) were 37.4 (SE= 0.6), 61.4 (SE =0.6), and 9.16 (SE= 0.19), respectively. Composition did not vary between left and right breasts or preferred and non-preferred breasts. Milk production was constant for the first 6 months and thereafter steadily declined. The fat content of milk decreased between 1 and 4 months, before increasing to 12 months of lactation. The concentration of protein decreased to 6 months and then remained steady. Lactose remained constant throughout the 12 months of lactation. The decrease of energy at 2 months and subsequent increase by 9 months can be attributed to the changes in fat content. Milk production, as well as concentrations of fat, lactose, protein, and energy, differed significantly between women.

The focus of this study was on human milk composition and production, not on infant's human milk intake. The advantage of this study is that it evaluated nursing mothers for a period of 12 months. However, the number of mother-infant pairs in the study was small (17 mothers with infants) and may not be entirely representative of the U.S. population. This study accounted for insensible water loss which increases the accuracy of the amount of human milk produced.

15.4.3 Mitoulas et al., 2003 - Infant Intake of Fatty Acids from Human Milk Over the First Year of Lactation

Mitoulas et al. (2003) conducted a study of 5 healthy nursing women to determine the content of fat in human milk and fat intake by infants during the first year of lactation. Nursing mothers were recruited through the Australian Breastfeeding Association or from private healthcare facilities. All infants were completely breastfed on demand for at least 4 months. Complementary solid food was introduced between 4-6 months of age. Mothers consumed their own *ad libitum* diets throughout the study.

Milk samples were collected before and after each feed from each breast over a 24-28 hour period. Fore- and hind-milk samples were averaged to provide the fat content for each feed. Milk yield was determined by weighing the mother before and after each feed from each breast. Insensible water loss was accounted for by weighing the mother 20 minutes after the end of each feeding. The rate of water loss during this 20 minutes was used to calculate insensible water loss during the feeding.

Changes in volume of human milk produced and milk fat content over the first year of lactation is presented in Table 15-20. The mean volumes of milk produced for both breasts combined were 812.13, 790.34, 911.38, 810.20, 677.35, and 505.10 mL/day at 1, 2, 4, 6, 9,and 12 months, respectively. The average daily intake over the 12 months was 751.09 mL/day with a mean fat content of 35.52 g/L. Their was a significant difference in the proportional composition of fatty acids over the course of lactation. Table 15-21 provides average fatty acid composition over the first 12 months of lactation. Additionally, fatty acid composition varied over the course of the day.

The focus of this study was on human milk composition and production, not on infant's human milk intake. The advantage of this study is that it evaluated the human milk composition for a period of 12 months. However, the number of mother-infant pairs in the study was small (5 mothers with infants) and may not be entirely representative of the entire U.S. population. This study accounted for insensible water loss which increases the accuracy of the amount of human milk produced.

15.4.4 Arcus-Arth et al., 2005 - Human Milk and Lipid Intake Distributions for Assessing Cumulative Exposure and Risk

Arcus-Arth et al. (2005) derived population distributions for average daily milk and lipid intakes in g/kg day for infants 0-6 months and 0-12 months of age for infants fed according to the American Academy of Pediatrics (AAP) recommendations. Lipid intakes were calculated from lipid content and milk intakes were measured on the same infant (Arcus-Arth et al., 2005). Table 15-22 provides lipid intakes based on data from Dewey et al. 1991a and Table 15-23 provides lipid intakes calculated assuming 4% lipid content and milk intake in the AAP dataset. Arcus-Arth et al. (2005) noted that the distributions presented are intended to represent the U.S. infant population.

An advantage of this study is that it was designed to represent the population of infants who are breastfed according to the AAP recommendations. In addition, the data used to derive the distributions were from peer review literature and datasets supplied by the publication authors. The limitation of the study are that the data used were from mothers that were predominantly white, well nourished and from mid- or upper-socioeconomic status, however human milk volume in mL/day is similar among all women except for severely malnourished women (Arcus-Arth et al., 2005). The authors noted that "although few infants are exclusively breastfed for 12 months, the exclusively breastfed distributions may represent a more highly exposed subpopulation of infants exclusively breastfed in excess of 6 months." The distributions were derived from data for infants fed in accordance to AAP recommendations, and they most likely represent daily average milk intake for a significant portion of breastfed infants today (Arcus-Arth et al., 2005).

15.4.5 Kent et al., 2006 - Volume and Frequency of Breastfeeding and Fat Content of Breast Milk Throughout the Day

Kent et al. (2006) collected data from 71 Australian mothers who were exclusively nursing their 1 to 6 months old infants. The study focused on examining the variation of milk consumed from each breast, the degree of fullness of each breast before and after feeding, and the fat content of milk consumed from each breast during daytime and nighttime feedings. The volume of milk was measured using test-weighing procedures with no correction for infant insensible water loss. On average, infants had 11 ± 3 breastfeedings per day (range= 6 to18). The intervals between feedings was 2 hours and 18 minutes ± 43 minutes (range = 4 minutes to 10 hours and 58 minutes). The 24-hour average human milk intake was 765 ± 164 mL/day (range = 464 to 1,317 mL/day). The fat content of milk ranged from 22.3 g/L to 61.6 g/L (2.2% - 6.0 %) with an average of 41.1 g/L (4.0%).

This study examined breastfeeding practices of volunteer mothers in Australia. Although amounts of milk consumed by Australian infants may be similar to infants in the U.S. population, results could not be broken out by smaller age groups to examine variability with age. The study provides estimates of fat content from a large number of samples.

15.5 RELEVANT STUDY ON LIPID INTAKE FROM HUMAN MILK

15.5.1 Maxwell and Burmaster, 1993 - A Simulation Model to Estimate a Distribution of Lipid Intake from Human Milk During the First Year of Life

Maxwell and Burmaster (1993) used a hypothetical population of 5000 infants between birth and 1 year of age to simulate a distribution of daily lipid intake from human milk. The hypothetical population represented both bottle-fed and breast-fed infants aged 1 to 365 days. A distribution of daily lipid intake was developed, based on data in Dewey et al. (1991b) on human milk intake for infants at 3, 6, 9, and 12 months and human milk lipid content, and survey data in Ryan et al. (1991) on the percentage of breast-fed infants under the age of 12 months (i.e., approximately 22%). A model was used to simulate intake among 1113 of the 5000 infants that were expected to be breast-fed. The results of the model indicated that lipid intake among nursing infants under 12 months of age can be characterized by a normal distribution with a mean of 26.0 mL/day and a standard deviation of 7.2 mL/day (Table 15-24). The model assumes that nursing infants are completely breast-fed and does not account for infants who are breast-fed longer than 1 year. Based on data collected by Dewey et al. (1991b), Maxwell and Burmaster (1993) estimated the lipid content of human milk to be 36.7 g/L at 3 months (35.6 mg/g or 3.6%), 39.2 g/L at 6 months (38.1 mg/g or 3.8%), 41.6 g/L at 9 months (40.4 mg/g or 4.0%), and 40.2 g/L at 12 months (39.0 mg/g or 3.9%).

The limitation of this study is that it provides a "snapshot" of daily lipid intake from human milk for breast-fed infants. These results are also based on a simulation model and there are uncertainties associated with the assumptions made. Another limitation is that lipid intake was not derived for the EPA recommended age categories. The estimated mean lipid intake rate represents the average daily intake for nursing infants under 12 months of age. The study did not generate "new" data. A reanalysis of previously reported data on human milk intake and human milk lipid intake were provided.

15.6 OTHER FACTORS

There are many factors that influence the initiation, continuation, and amount of human milk intake. These factors are complex and may include considerations such as: maternal nutritional status, parity, parental involvement, support from lactation consultants, mother's working status, infant's age, weight, gender, food supplementation, the frequency of breast-feeding sessions per day, the duration of breast-feeding per event, the duration of breast-feeding during childhood, ethnicity, geographic area, and other socioeconomic factors. For example, a study conducted in the United Kingdom found that social and educational factors most influenced the initiation and continuation of lactation (Wright et al. 2006). Prenatal and postnatal lactation consultant intervention was found to be effective in increasing lactation duration and intensity (Bonuck et al. 2005).

15.6.1 Population of Nursing Infants

To monitor progress towards achieving the CDC *Healthy People 2010* breastfeeding objectives (initiation and duration), Scanlon et al. (2007) analyzed data from the National Immunization Survey (NIS). NIS uses random-digit dialing to survey households to survey age eligible children, followed by a mail survey to eligible children's vaccination providers to validate the vaccination information. NIS is conduced annually by the CDC to obtain national, state, and selected urban area estimation on vaccinations rates among U.S. children age 19-35 months. The interview response rate for years 2001-2006 ranged between 64.5% and 76.1%. Questions regarding breastfeeding were added to the NIS survey in 2001. The sample population was infants born during 2000-2004. Scanlon et al. (2007), noted that because data in their analysis are for children aged 19-35 months at the time of the NIS interview, each cross-sectional survey includes children from birth cohorts that span 3 calendar years; the breastfeeding data were analyzed by year of birth during 2000-2004 (birth year cohort instead if survey year).

Among infants born in 2000, breastfeeding rates were 70.9% (CI= 69.0-72.8) for the postpartum period (in hospital before discharge), 34.2% (CI= 32.2-36.2) at 6 months, and 15.7 (CI= 14.2-17.2) at 12 months. For infants born in 2004, these rates had increased to 73.8% (CI= 72.8-74.8) for the postpartum period, 41.5% (CI= 40.4-42.6) at 6 months, and 20.9 (CI= 20.0-21.8) at 12 months. Rates of breastfeeding through 3 months were lowest among black infants (19.8%), infants whose mothers were <20 years of age (16.8%), those whose mothers had a high school education or less (22.9% and 23.9%), those whose mothers were unmarried (18.8%), those who resided in rural areas (23.9%), and those whose families had an income-to-poverty ratio of <100% (23.9%). Table 15-25 provides data for exclusive breastfeeding through 3 and 6 months by socioeconomic characteristics for infants born in 2004.

Scanlon et al. (2007) noted the following limitations that could affect the utility of these data: (1) breastfeeding behavior was based on retrospective self-report by mothers or other caregivers, whose responses might be subject to recall bias, (2) the NIS question that defines early postpartum breastfeeding or initiation, "Was [child's name] ever breastfed or fed breast milk?" collects information that might differ from the HP2010 objective for initiation, and (3) although survey data were weighted to make them representative of all U.S. children aged 19-35 months, some bias might remain. The advantage of the study is that is representative of the U.S. infant population.

The rate of breastfeeding initiation in the United States is near the national goal of 75% established in *Healthy People 2010* (Ruowei et al. 2005). Using the data obtained from the NIS survey conducted throughout 2002 for children who were 19 to 35 months old, Ruowi et al. (2005) shows that overall, 71.4% of children surveyed had ever been breastfed. The percentage of children who are breastfed drops to 35.1% at 6 months and to 16.1% at 12 months (Rouwei et al. 2005). These data also revealed significant differences in breastfeeding participation related to race/ethnicity, day care and WIC participation, maternal age, socioeconomic status, and geographical area. Overall, 51.5% of mothers of non-Hispanic black children reported to ever breastfed their infants compared to 72.1% of mothers of non-Hispanic white children. Non-Hispanic black infants were exclusively breastfed at 6 months at a rate of 5.4% compared to 14.6% of non-Hispanic white infants and 13.8% of Hispanic infants. Infants who attended day care and infants whose mothers received WIC benefits were less likely to have ever been breastfed. Mothers with higher socioeconomic status and older mothers were more likely to have ever breastfed their infants.

CDC (2007) developed the breastfeeding report card. The CDC National Immunization Program in partnership with the CDC National Center for Health Statistics, conducts the NIS within all 50 states, District of Columbia, and selected geographic areas within the states. Five breastfeeding goals are in the Healthy People 2010 report. The Breastfeeding Report Card presents data for each state for the following categories of infants: ever breastfed, breastfed at 6 months, breastfed at 12 months, exclusive breastfeeding through 3 month, and exclusive breastfeeding through 6 months. These indicators are used to measure a state's ability to promote, protect, and support breastfeeding. These data for the estimated percentage of infants born in 2004 are presented in Table 15-26. The weighted sample number is 17,654 for the U.S. population. The advantage of this report is that it provides data for each state and is representative of the U.S. infant population.

Analysis of breastfeeding practices in other developing countries was also found in the literature. Marriott et al. (2007) researched feeding practices in developing countries in the first year of life, based on 24-hour recall data. Marriott et al. (2007), used secondary data from the Demographic and Health Surveys (DHS) for more than 35,000 infants in twenty countries. This survey has conducted since 1986 and was expanded to provide a standardized survey instrument that can be used by developing countries to collect data on maternal/infant health, intake and household variables and to build national health statistics (Marriott et al., 2007). The analysis was based on the responses of the survey mothers for questions on whether they were currently breasfeeding and had fed other liquids and solid foods to their infants in the previous 24 hours. The data incorporated were from between 1999 and 2003. Marriott et al. (2007) selected the youngest child less than 1 year old in each of the families; multiples were included such as twins or triplets. Separate analyses were conducted for infants less than 6 months old and infants 6 months and older, but less than 12 months old. Food and liquid variables other than water and infant formulas were collapsed into broader food categories for cross-country comparisons (Marriott et al., 2007). Tinned, powdered, and any other specified animal milks were collapsed. In addition, all other liquids such as herbal teas, fruit juices, and sugar water (excluding unique country-specific liquids) were collapsed into other liquids and the 10 types of solid food groups into an any-solid-foods category (Marriott et al., 2007). Data were pooled from the 20 countries to provide a large sample size and increase statistical power. Tables 15-27 and 15-28 present the percentage of mothers that were currently breastfeeding and separately had fed their infants other liquids or solid food by age groups. Table 15-29 presents the pooled data summary for the study period. The current breastfeeding was consistent across countries for both age groups; the countries that reported the highest percentages of current breastfeeding for the 0 to 6 months old infants also reported the highest percentages in the 6 to12 month old infants. Pooled data show that 96.6% of the 0 to 6 months old infants and 87.9% of the 6 to 12 month old infants were breastfeeding. Feeding of other fluids was lowest in the 0 to 6 months infants, with the percentage feeding water the highest of this category. The percentage of mothers feeding commercial infant formulas was the lowest in most countries.

There are other older studies that analyze ethnic and racial differences in breastfeeding practices. Li and Grummer-Strawn (2002) investigated ethnic and racial disparities in lactation in the United States using data from the Third National Health and Nutrition Examinations Survey (NHANES III) that was conducted between 1988-1994. NHANES II participants were ages 2 months and older. The data were collected during a home interview from a parent or a proxy respondent for the child (Li and Grummer-Strawn, 2002). The sample population consisted of children 12 to 71 months of age at time of interview. The NHANES III response rate for children participating was approximately 94 percent (Li and Grummer-Strawn, 2002). Data for a total of 2,863 exclusively breastfed, 6,140 ever breastfed, and 6,123 continued breastfed children were included in the analysis (Li and Grummer-Strawn, 2002). The proportion of children ever-breastfed was 60% among non-Hispanic whites, 26% among non-Hispanic blacks, and 54% among Mexican Americans. This number decreased to 27, 9, and 23 respectively by 6 months. Children fed exclusively human milk at 4 months was also significantly lower for blacks at 8.5%, compared to 22.6% for whites and 14.1% for Mexican-Americans. The racial and ethnic differences in proportion of children ever breastfed is presented in Table 15-30, the proportion of children who received any breast milk at 6 months are presented in Table 15-31, and the proportion of children exclusively breastfed at 4 months is presented in Table 15-32.

Li and Grummer-Strawn (2002) noted that there may have been some lag time between birth and the time of the interview. This may have caused misclassification if the predicator variables changed considerably between birth and the time of interview. Also, NHANES III did not collect information on maternal education. Instead, the educational level of household head was used as a proxy. The advantages of this study is that it is representative of the U.S. children's population.

Data from some older studies provide historical information on breastfeeding practices in the U.S. These data are provided here to show trends in the U.S. population. In 1991, the National Academy of Sciences (NAS) reported that the percentage of breast-feeding women has changed dramatically over the years (NAS, 1991). The Ross Products Division of Abbott Laboratories conducted a large national mail survey in 1995 to determine patterns of breastfeeding during the first 6 months of life. The Ross Laboratory Mothers's Survey was first developed in 1955 and has been expanded to include many more infants. Before 1991, the survey was conducted on a quarterly basis, and approximately 40,000 to 50,000 questionnaires were mailed each quarter (Ryan, 1997). Beginning in 1991, the survey was conducted monthly; 35,000 questionnaires were mailed each month. Over time, the response rate has been consistently in the range of 50 ± 5%. In 1989 and 1995, 196,000 and 720,000 questionnaires were mailed, respectively. Ryan (1997) reported rates of breast-feeding through 1995 and compared them with those in 1989.

The survey demonstrates increases in both the initiation of breast-feeding and continued breast-feeding at 6 months of age between 1989 and 1991. Table 15-33 presents the percent of breast-feeding in hospitals and at 6 months of age by selected demographic characteristics. In 1995, the incidence of breast-feeding at birth and at 6 months for all infants was approximately 59.7% and 21.6 %, respectively. The largest increases in the initiation of breast-feeding between 1989 and 1995 occurred among women who were Black, were less than 20 years of age, earned less than $10,000 per year, had no more than a grade school education, were living in the South Atlantic region of the U.S., had infants of low birth weight, were employed full time outside the home at the time they received the survey, and participated in the Women, Infants, and Children program (WIC). In 1995, as in 1989, the initiation of breast-feeding was highest among women who were greater than 35 years of age, earned more than $25,000 per year, and were college educated, did not participate in the WIC program, and were living in the Mountain and Pacific regions of the U.S.

Data on the actual length of time that infants continue to breast-feed beyond 5 or 6 months were limited (NAS, 1991). However, Maxwell and Burmaster (1993) estimated that approximately 22 percent of infants under 1 year of age are breast-fed. This estimate was based on a reanalysis of survey data in Ryan et al. (1991) collected by Ross Laboratories (Maxwell and Burmaster, 1993). Studies have also indicated that breast-feeding practices may differ among ethnic and socioeconomic groups and among regions of the United States. More recently, the Ross Products Division of Abbott Laboratories reported the results of their ongoing "Ross Mothers Survey" in 2003 (Abbott 2003). The percentages of mothers who breast feed, based on ethnic background and demographic variables, are presented in Table 15-34. These data update the values presented in the NAS 1991 report.

15.6.2 Intake Rates Based on Nutritional Status

Information on differences in the quality and quantity of human milk on the basis of ethnic or socioeconomic characteristics of the population is limited. Lönnerdal et al. (1976) studied human milk volume and composition (nitrogen, lactose, proteins) among underprivileged and privileged Ethiopian mothers. No significant differences were observed between the data for these two groups. Similar data were observed for well-nourished Swedish mothers. Lönnerdal et al. (1976) stated that these results indicate that human milk quality and quantity are not affected by maternal malnutrition. However, Brown et al. (1986a, b) noted that the lactational capacity and energy concentration of marginally-nourished women in Bangladesh were “modestly less than in better nourished mothers.” Human milk intake rates for infants of marginally-nourished women in this study were 690 ± 122 g/day at 3 months, 722 ± 105 g/day at 6 months, and 719 ± 119 g/day at 9 months of age (Brown et al., 1986a). Brown et al. (1986a) observed that human milk from women with larger measurements of arm circumference and triceps skinfold thickness had higher concentrations of fat and energy than mothers with less body fat. Positive correlations between maternal weight and milk fat concentrations were also observed. These results suggest that milk composition may be affected by maternal nutritional status.

15.6.3 Frequency and Duration of Feeding

Hofvander et al. (1982) reported on the frequency of feeding among 25 bottle-fed and 25 breast-fed infants at ages 1, 2, and 3 months. The mean number of meals for these age groups was approximately 5 meals/day (Table 15-35). Neville et al. (1988) reported slightly higher mean feeding frequencies. The mean number of meals per day for exclusively breast-fed infants was 7.3 at ages 2 to 5 months and 8.2 at ages 2 weeks to 1 month. Neville et al. (1988) reported that, for infants between the ages of 1 week and 5 months, the average duration of a breastfeeding session is 16-18 minutes.

Buckley (2001) studied the breastfeeding patterns, dietary intake, and growth measurement of children who continued to breastfeed beyond 1 year of age. The sample was 38 mother-child pairs living in the Washington, DC area. The criteria for inclusion in the study were that infants or their mothers had no hospitalization of either subject 3 months prior to the study and that the mother was currently breastfeeding a 1-year old or older child (Buckley, 2001). The participants were recruited through local medical consultants and the La Leche League members. The children selected as the final study subjects consisted of 22 boys and 16 girls with ages ranging from 12 to 43 month old. The data were collected using a 7-day breastfeeding diary. The frequency and length of breastfeeding varied with the age of the child (Buckley, 2001). The author noted a statistically significant difference in the mean number of breastfeeding episodes per day and the average total minutes of breastfeeding between the 1, 2, and 3 year old groups. Table 15-36 provides the comparison of breastfeeding patterns between age groups. An advantage of this study is that the frequency and duration data are based primarily on a 7-day diary and some dietary recall. Limitations of the study are the small sample size and that it is limited to one geographical area.

15.7 REFERENCES FOR CHAPTER 15

AAP (2005) Breast feeding and the use of human milk. Policy Statement. Pediatrics. 115(2): 496-506. available on line at http://aappolicy.aappublications.org/cgi/content/full/pediatrics;115/2/496

Abbott Laboratories (2003) Breastfeeding Trends - 2003. Ross Mothers Survey, Ross Products Division,Columbus, OH.

Albernaz, E.;Victora, C.G.; Haisma, H.; Wright, A.; Coward, W.A. (2003) Lactation counseling increases breast-feeding duration but not breastmilk intake as measured by isotopic methods. J Nutr. 133: 205–210.

Arcus-Arth, A.; Krowech, G.; Zeise, L. (2005) Human milk and Lipid Intake Distributions for assessing Cumulative Exposure and Risk. J Expos Anal Environ Epidemiol. 15: 357-365.

Bonuck, K.A.; Trombley, M.; Freeman, K.; Mckee, D. (2005) Randomized, controlled trial of a prenatal and postnatal lactation consultant intervention on duration and intensity of breastfeeding up to 12 months. Pediatrics. 116: 1413-1426.

Brown, K.H.; Akhtar, N.A.; Robertson, A.D.; Ahmed, M.G. (1986a) Lactational capacity of marginally nourished mothers: relationships between maternal nutritional status and quantity and proximate composition of milk. Pediatrics. 78: 909-919.

Brown, K.H.; Robertson, A.D.; Akhtar, N.A. (1986b) Lactational capacity of marginally nourished mothers: infants' milk nutrient consumption and patterns of growth. Pediatrics. 78: 920-927.

Butte, N.F.; Garza, C.; Smith, E.O.; Nichols, B.L. (1984) Human milk intake and growth in exclusively breast-fed infants. J Pediatr. 104:187-195.

Butte, N.; Wong, W.; Hopkinson, J.; Smith E.; Ellis, J. (2000) Infant feeding mode affects early growth and body composition. Pediatrics. 106; 1355-1366.

Buckley, K. (2001) Long-term breastfeeding: nourishment or nurtance. J Hum Lactat. 17(4):304-311.

CDC. (2007) Breastfeeding report card 2007. Breastfeeding practices-results from the National Immunization Survey. Available on line at http://www.cdc.gov/breastfeeding/data

Chen, A.; Rogan, W.J. (2004) Breastfeeding and the risk of postneonatal death in the United States. Pediatrics. 113: 435-439.

Dewey, K.G.; Lönnerdal, B. (1983) Milk and nutrient intake of breast-fed infants from 1 to 6 months:relation to growth and fatness. J Pediatr Gastroenterol Nutr. 2:497-506.

Dewey, K.G.; Heinig, J.; Nommsen, L.A.; Lönnerdal, B. (1991a) Maternal versus infant factors related to human milk intake and residual volume: the DARLING study. Pediatrics. 87:829-837.

Dewey, K.G.; Heinig, J.; Nommsen, L.; Lönnerdal, B. (1991b) Adequacy of energy intake among breast-fed infants in the DARLING study: relationships to growth, velocity, morbidity, and activity levels. J Pediatr. 119:538-547.

Dewey, K.G.; Peerson, J.M.; Heinig, M.J.; Nommsen, L.A.; Lonnerdal, B. (1992) Growth patterns of breast-fed infants in affluent (United States) and poor (Peru) communities: implications for timing of complementary feeding. Am J Clin Nutr. 56: 1012-1018.

Drewett, R.; Amatayakul, K.; Wongsawasdii, L.; Mangklabruks, A.; Ruckpaopunt, S.; Ruangyuttikarn, C.; Baum, D., Imong, S.; Jackson, D.; Woolridge, M. (1993) Nursing frequency and the energy intake from breast milk and supplementary food in a rural Thai population: a longitudinal study. Eur J Clin Nutr. 47: 880-891.

Ferris, A.M.; Neubauer, S.H.; Bendel, R.B.; Green, K.W.; Ingardia, C.J.; Reece, E.A. (1993) Perinatal lactation protocol and outcome in mothers with and without insulin-dependent diabetes mellitus. Am J Clin Nutr. 58: 43–48.

Gonzalez-Cossio,T.; Habicht, J.P.; Rasmussen, K.M.; Delgado, H.L. (1998) Impact of food supplementation during lactation on infant breast-milk intake and on the proportion of infants exclusively breast-fed. J Nutr. 128:1692-1702.

Hofvander, Y.; Hagman, U.; Hillervik, C.; Siolin, S. (1982) The amount of milk consumed by 1-3 months old breast or bottled-fed infants. Acta Paediatrica Scand. 71: 953-958.

Kent, J.C.; Mitoulas, L.R.; Cregan, M.D.; Ramsay, D.T.; Doherty, D.A.; Hartmann, P.E. (2006) Volume and frequency of breastfeeding and fat content of breast milk throughout the day. Pediatrics. 117:387-395.

Li, R.; Grummer-Strawn, L. (2002) Racial and ethnic disparities in breastfeeding among Unites States infants: third national health and nutrition examination survey, 1988-1994. Birth. 29(4):251-257.

Lönnerdal, B.; Forsum, E.; Gebre-Medhim, M.; Hombraes, L. (1976) Human milk composition in Ethiopian and Swedish mothers: lactose, nitrogen, and protein contents. Am J Clin Nutr. 29:1134-1141.

Marriott, M.; Campbell, L.; Hirsch, E.; and Wilson, D. (2007) Preliminary data from demographic and health surveys on infant feeding in 20 developing countries. J. Nutr. Vol 137: 518S-523S.

Maxwell, N.I.; Burmaster, D.E. (1993) A simulation model to estimate a distribution of lipid intake from human milk during the first year of life. J Expo Anal Environ Epidemiol. 3:383-406.

Mitoulas, L.; Kent, J.; Cox, D.; Owens, R.; Sherriff, J.; Hartman, P. (2002) Variation in fat, lactose, and protein in human milk over 24 h and throughout the first year of lactation. Br J Nutr. 88:29-37.

Mitoulas, L.; Gurrin, L.; Doherty, D.; Sherriff, J.; Hartman, P. (2003) Infant intake of fatty acids from human milk over the first year of lactation. Br J Nutr. 90:979-986.

National Academy of Sciences (NAS). (1991) Nutrition during lactation. Washington, DC. National Academy Press.

Neubauer, S. H.; Ferris, A.M.; Chase, C.G.; Fanelli J., Thompson, C.A.; Lammi-Keefe, C.J.; Clark, R. M.; Jensen, R. G.; Bendel, R. B.; Green, K. W. (1993) Delayed lactogenesis in women with insulin-dependent diabetes mellitus. Am J Clin Nutr. 1993: 58:54–60.

Neville, M.C.; Keller, R.; Seacat, J.; Lutes, V.; Neifert, M.; et al. (1988) Studies in human lactation: milk volumes in lactating women during the onset of lactation and full lactation. Am J Clin Nutr. 48:1375-1386.

Pao, E.M.; Hines, J.M.; Roche, A.F. (1980) Milk intakes and feeding patterns of breast-fed infants. J Am Diet Assoc. 77:540-545.

Ryan, A.S.; Rush, D.; Krieger, F.W.; Lewandowski, G.E. (1991) Recent declines in breastfeeding in the United States, 1984-1989. Pediatrics. 88:719-727.

Ryan, A.S. (1997) The resurgence of breastfeeding in the United States. Pediatrics. 99(4):e12. http://www.pediatrics.org/cqi/content/full/99/4/e12.

Salmenpera, L.; Perheentupa, J.,; Siimes, M.A. (1985) Exclusively breast-fed healthy infants grow slower than reference infants. Pediatr Res. 19: 307–312.

Scanlon, K.S.; Grummer-Strawn, L.; Shealy, K.R.; Jefferds, M.E.; Chen, J.; Singleton, J.A.. (2007) Breastfeeding Trends and Updated National Health Objectives for Exclusive Breastfeeding - United States, Birth Years 2000-2004. MMWR 56(30):760-763.

Stuff J.E.; Nichols B.L. (1989) Nutrient intake and growth performance of older infants fed human milk. J Pediatr. 1989: 115:959–968.

Wright, C.M.; Parkinson, K.; Scott, J. (2006) Breast-feeding in a UK urban context: who breast-feeds, for how long and does it matter? Public Health Nutr. 9(6):686-691.

Table 15-7. Daily Intakes of Human Milk

Age	Number of Infants	Intake Mean ± SD (mL/day) [a]	Intake Range (mL/day)
Completely Breast-fed			
1 month	11	600 ± 159	426 - 989
3 months	2	833	645 - 1,000
6 months	1	682	616 - 786
Partially Breast-fed			
1 month	4	485 ± 79	398 - 655
3 months	11	467 ± 100	242 - 698
6 months	6	395 ± 175	147 - 684
9 months	3	<554	451 - 732

[a] Data expressed as mean ± standard deviation.

Source: Pao et al., 1980.

Table 15-8. Human Milk Intakes for Infants Aged 1 to 6 Months

Age	Number of Infants	Intake Mean ± SD (mL/day)	Intake Range (mL/day)
1 month	16	673 ± 192	341-1,003
2 months	19	756 ± 170	449-1,055
3 months	16	782 ± 172	492-1,053
4 months	13	810 ± 142	593-1,045
5 months	11	805 ± 117	554-1,045
6 months	11	896 ± 122	675-1,096

Source: Dewey and Lönnerdal, 1983.

Table 15-9. Human Milk Intake Among Exclusively Breast-fed Infants During the First 4 Months of Life

Age	Number of Infants	Intake (mL/day)[a] Mean ± SD	Intake (mL/kg-day)[a] Mean ± SD	Feedings/Day	Body Weight[b] (kg)
1 month	37	729 ± 126	154 ± 23	8.3 ± 1.9	4.7
2 months	40	704 ± 127	125 ± 18	7.2 ±1.9	5.6
3 months	37	702 ± 111	114 ± 19	6.8 ± 1.9	6.2
4 months	41	718 ± 124	108 ± 17	6.7 ± 1.8	6.7

[a] Values reported by the author in units of g/day and g/kg-day were converted to units of mL/day and mL/kg-day by dividing by 1.03 g/mL (density of human milk).
[b] Calculated by dividing human milk intake (g/day) by human milk intake (g/kg-day).
SD = Standard deviation.

Source: Butte et al., 1984.

Table 15-10. Human Milk Intake During a 24-hour Period

Age (days)	Number of Infants	Intake (mL/day)[a] Mean ± SD	Intake (mL/day)[a] Range	Intake by Age Category (mL/day)[a,c]
1	6	43 ± 68	-30-145 [b]	
2	9	177 ± 83	43-345	
3	10	360 ± 149	203-668	
4	10	438 ± 171	159-674	
5	11	483 ± 125	314-715	
6	9	493 ± 162	306-836	
7	7	556 ± 162	394-817	
8	8	564 ± 154	398-896	511 ± 220
9	9	563 ± 74	456-699	
10	9	569 ± 128	355-841	
11	8	597 ± 163	386-907	
14	9	634 ± 150	404-895	
21	10	632 ± 82	538-763	
28	13	748 ± 174	481-1,111	
35	12	649 ± 114	451-903	
42	12	690 ± 108	538-870	679 ± 105
49	10	688 ± 112	543-895	
56	12	674 ± 95	540-834	
90	10	713 ± 111	595-915	713 ± 111
120	12	690 ± 97	553-822	690 ± 97
150	12	814 ± 130	668-1,139	814 ± 130
180	13	744 ± 117	493-909	744 ± 117
210	12	700 ± 150	472-935	700 ± 150
240	9	604 ± 204	280-973	604 ± 204
270	12	600 ± 214	217-846	600 ± 214
300	11	535 ± 227	125-868	535 ± 227
330	8	538 ± 233	117-835	538 ± 233
360	8	391 ± 243	63-748	391 ± 243

[a] Values reported by the author in units of g/day were converted to units of mL/day by dividing by 1.03 g/mL (density of human milk).

[b] Negative value due to insensible weight loss correction.

[c] Multiple data sets were combined by producing simulated data sets fitting the known mean and SD for each age, compositing the data sets to correspond to age groups of 0 to <1 month and 1 to <2 months, and calculating new means and SD's on the composited data.

SD = Standard deviation.

Source: Neville et al., 1988.

Table 15-11. Human Milk Intake Estimated by the Darling Study

Age	Number of Infants	Intake (mL/day) Mean ± SD
3 months	73	788 ± 129
6 months	60	747 ± 166
9 months	50	627 ± 211
12 months	42	435 ± 244

[a] Values reported by the author in units of g/day were converted to units of mL/day by dividing by 1.03 g/mL (density of human milk).
SD = Standard deviation.

Source: Dewey et al., 1991b.

Table 15-12. Mean Breastfed Infants Characteristics [a]

	Boys (N=14)	Girls (N=26)
Ethnicity (White, Black, Hispanic, Asian) (N)	10/1/2/1	21/1/3/1
Duration of Breastfeeding (days)	315 ± 152	362 ± 190
Duration of Formula Feeding (days)	184 ± 153	105 ± 121
Age at Introduction of Formula (months)	6.2 ± 2.9	5.2 ± 2.3
Age at Introduction of Solids (months)	5.0 ± 1.5	5.0 ± 0.09
Age at Introduction of Cow's Milk (months)	13.1 ± 3.1	12.5 ± 3.8

[a] Mean ± standard deviation.
N = Number of infants.

Source: Butte et al., 2000.

Table 15-13. Mean Human Milk Intake of Breastfed Infants (mL/day)[a]		
Age Group	Boys	Girls
3 months	790 ± 172 (N=14)	694 ± 108 (N=26)
6 months	576 ± 266 (N=12)	678 ±250 (N=18)
12 months	586 ±286 (N=2)	370± 260 (N=11)
24 months	-	-

[a] 3-day average; values reported by the author in units of g/day were converted to units of mL/day by dividing by 1.03 g/mL (density of human milk); mean ± standard deviation.
N = Number of infants.

Source: Butte et al., 2000.

Table 15-14. Feeding Practices by Percent of Infants

Infants	Age					
	3 months	6 months	9 months	12 months	18 months	24 months
	Percentage					
Infants Still Breastfed	100	80	58	38	25	5
Breastfed Infants Given Formula	0	40	48	30	10	2
Formula-fed Infants Given Breast Milk	100	100	94	47	6	0
Use of Cow's Milk for Breastfed Infants	-	-	8	65	82	88
Use of Cow's Milk for Formula-fed Infants	-	-	28	67	89	92

Source: Butte et al., 2000.

Table 15-15. Body Weight of Breastfed Infants[a]

Age	Weight (kg)	
	Boys	Girls
0.5 months	3.9 ± 0.4 (n=14)	3.7 ± 0.5 (n=19)
3 months	6.4 ± 0.6 (n=14)	6.0 ± 0.6 (n=19)
6 months	8.1 ± 0.8 (n=14)	7.5 ± 0.6 (n=18)
9 months	9.3 ± 1.0 (n=14)	8.4 ± 0.6 (n=19)
12 months	10.1 ± 1.1 (n=14)	9.2 ± 0.7 (n=19)
18 months	11.6 ± 1.2 (n=14)	10.7 ± 1.0 (n=19)
24 months	12.7 ± 1.3 (n=12)	11.8 ± 1.1 (n=19)

[a] Mean ± standard deviation.
N = Number of infants.

Source: Butte et al., 2000.

Table 15-16. AAP Dataset Milk Intake Rates at Different Ages

Age	Mean (mL/kg day)[a]	SD (mL/kg day)[a]	CV	Skewness Statistic[b]	N
7 days	143	37	0.26	0.598	10
14 days	156	40	0.26	-1.39	9
30 days	150	24	0.16	0.905	25
60 days	144	22	0.15	0.433	25
90 days	127	18	0.14	-0.168	108
120 days	112	18	0.16	0.696	57
150 days	100	21	0.21	-1.077	26
180 days	101	20	0.20	-1.860	39
210 days	75	25	0.33	-0.844	8
270 days	72	23	0.32	-0.184	57
360 days	47	27	0.57	0.874	42

[a] Values reported by the author in units of g/kg-day were converted to units of mL/kg-day by dividing by 1.03 g/mL (density of human milk).
[b] Statistic/SE: -2 < Statistic/SE < +2 suggests a normal distribution
SD = Standard deviation.
CV = Coefficient of variation.
N = Number of infants.

Source: Arcus-Arth et al., 2005.

Table 15-17. Average Daily Human Milk Intake (mL/kg day) [a]

Averaging Period	Mean (SD)	Population Percentile							
		5	10	25	50	75	90	95	99
AAP 0 to 6 months									
Method 1	126 (21)	92	99	112	126	140	152	160	174
Method 2	123 (7)	112	114	118	123	127	131	133	138
AAP 0 to 12 months									
Method 1	98 (22)	61	69	83	98	113	127	135	150
Method 2	99 (5)	90	92	95	99	102	105	107	110
EBF 0 to 12 months	110 (21)	75	83	95	110	124	137	144	159
General Pop.									
0 to 6 months	79	0	0	24	92	123	141	152	170
0 to 12 months	51	0	0	12	49	85	108	119	138

[a] Values reported by the author in units of g/kg-day were converted to units of mL/kg-day by dividing by 1.03 g/mL (density of human milk).

Source: Arcus-Arth et al., 2005.

Table 15-18. Lipid Content of Human Milk and Estimated Lipid Intake Among Exclusively Breast-fed Infants

Age (months)	Number of Observations	Lipid Content (mg/g) Mean ± SD	Lipid Content % [a]	Lipid Intake (mL/day)[b] Mean ± SD	Lipid Intake (mL/kg-day)[b] Mean ± SD
1	37	36.2 ± 7.5	3.6	27 ± 8	5.7 ± 1.7
2	40	34.4 ± 6.8	3.4	24 ± 7	4.3 ± 1.2
3	37	32.2 ± 7.8	3.2	23 ± 7	3.7 ± 1.2
4	41	34.8 ± 10.8	3.5	25 ± 8	3.7 ± 1.3

[a] Percents calculated from lipid content reported in mg/g.

[b] Values reported by the author in units of g/day and g/kg-day were converted to units of mL/day and mL/kg-day by dividing by 1.03 g/mL (density of human milk).

Source: Butte et al., 1984.

Table 15-19. Human Milk Production and Composition Over the First 12 Months of Lactation [a]

Age Group (months)	Volume, per Breast (mL/24h)			Fat (g/L)			Lactose (g/L)			Protein (g/L)			Energy (kJ/mL)		
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N
1	416	24	34	39.9	1.4	34	59.7	0.8	18	10.5	0.4	18	2.7	0.06	18
2	408	23	34	35.2	1.4	34	60.4	1.1	18	9.6	0.4	18	2.5	0.06	18
4	421	20	34	35.4	1.4	32	62.6	1.3	16	9.3	0.4	18	2.6	0.09	16
6	413	25	30	37.3	1.4	28	62.5	1.7	16	8.0	0.4	16	2.6	0.09	16
9	354	47	12	40.7	1.7	12	62.8	1.5	12	8.3	0.5	12	2.8	0.09	12
12	252	51	10	40.9	3.3	10	61.4	2.9	10	8.3	0.6	10	2.8	0.14	10
1 to 12	399	11	154	37.4	0.6	150	61.4	0.6	90	9.2	0.2	92	2.7	0.04	90

[a] Infants were completely breast-fed to 4 months and complementary solid food was introduced between 4-6 months.
SE = Standard error.
N = Number of infants.

Source: Mitoulas et al., 2002.

Table 15-20. Changes in Volume of Human Milk Produced and Milk Fat Content Over the First Year of Lactation [a]

Age Group (months)		Volume, Left Breast (mL/day)		Volume, Right Breast (mL/day)		Fat, Left Breast (g/L)		Fat, Right Breast (g/L)	
	N	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	5	338	52	475	69	38	1.5	38	2.6
2	5	364	52	427	42	31	2.2	30	2.9
4	5	430	51	482	58	32	3.3	29	2.6
6	5	373	75	437	56	33	2.5	33	2.5
9	5	312	65	365	94	43	2.2	38	3.3
12	5	203	69	302	85	40	4.8	42	5.0
1 to 12	30	337	26	414	28	36	1.4	35	1.5
Statistical significance: P		NS		NS		0.004		0.008	

[a] Infants were completely breast-fed to 4 months, and complementary solid food was introduced between 4-6 months.
SE = Standard error.
NS = No statistical difference.
P = Probability.

Source: Mitoulas et al., 2003.

Table 15-21. Changes in Fatty Acid Composition of Human Milk Over the First Year of Lactation (g/100 g total fatty acids)

	1 month		2 months		4 months		6 months		9 months		12 months	
Fatty Acid	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Medium-chain Saturated	14.2	0.4	13.9	0.6	12.0	0.5	11.5	0.2	14.1	0.3	17.0	0.4
Odd-chain Saturated	0.9	0.01	0.9	0.02	0.8	0.02	0.8	0.03	0.8	0.02	0.8	0.02
Long-chain Saturated	34.1	0.3	33.7	0.3	32.8	0.3	31.8	0.6	31.4	0.6	33.9	0.6
Mono-unsaturated	37.5	0.2	33.7	0.4	38.6	0.5	37.5	0.5	37.3	0.5	33.0	0.5
Trans-	2.0	0.08	2.2	0.1	2.2	0.09	4.6	0.02	1.7	0.2	1.8	0.09
Poly-unsaturated	12.7	0.2	9.5	0.2	11.8	0.4	13.4	0.6	8.0	0.1	6.7	0.03

SE = Standard error.

Source: Mitoulas et al., 2003.

Table 15-22. Comparison of Lipid Content Assumptions (mL/kg-day)[a]

Lipid Content Used in Calculation	Mean	Population Percentile							
		5	10	25	50	75	90	95	99
Measured Lipid Content[b]	3.6	2.0	2.3	2.9	3.6	4.3	4.9	5.2	5.9
4% Lipid Content[c]	3.9	2.5	2.8	3.3	3.8	4.4	4.9	5.2	5.8

[a] Values reported by the author in units of g/kg-day were converted to units of mL/kg-day by dividing by 1.03 g/mL (density of human milk).
[b] Lipid intake derived from lipid content and milk intake measurements.
[c] Lipid intake derived using 4% lipid content value and milk intake.

Source: Arcus-Arth et al., 2005.

Table 15-23. Distribution of Average Daily Lipid Intake (mL/kg day) assuming 4% Milk Lipid Content

	Mean	Population Percentile							
		5	10	25	50	75	90	95	99
AAP Infants 0 to 12 months	3.9	2.4	2.8	3.3	3.9	4.5	5.1	5.4	6.0

[a] Values reported by the author in units of g/kg-day were converted to units of mL/kg-day by dividing by 1.03 g/mL (density of human milk).

Source: Arcus-Arth et al., 2005.

Table 15-24. Predicted Lipid Intakes for Breast-fed Infants Under 12 Months of Age

Statistic	Value
Number of Observations in Simulation	1,113
Minimum Lipid Intake	1.0 mL/day[a]
Maximum Lipid Intake	51.0 mL/day[a]
Arithmetic Mean Lipid Intake	26.0 mL/day[a]
Standard Deviation Lipid Intake	7.2 mL/day[a]

[a] Values reported by the author in units of g/day were converted to units of mL/day by dividing by 1.03 g/mL (density of human milk).

Source: Maxwell and Burmaster, 1993.

Table 15-25. Socio-economic Characteristics of Exclusively Breastfed Infants Born in 2004

	Percent of Exclusive Breastfeeding Infants Through 3 and 6 Months			
	3 months		6 months	
Characteristic	%	95% CI	%	95% CI
U.S. Overall (N=17,654)	30.5	29.4-31.6	11.3	10.5-12.1
Infant Sex				
Male	30.7	29.1-32.3	10.8	9.8-11.8
Female[a]	30.3	28.7-31.9	11.7	10.5-12.9
Race/Ethnicity (child)				
Hispanic	30.8	28.3-33.3	11.5	9.7-13.3
White, non-Hispanic[a]	33.0	31.6-34.4	11.8	10.9-12.7
Black, non-Hispanic	19.8 [b]	17.0-22.6	7.3 [b]	5.5-9.1
Asian, non-Hispanic	30.6	25.0-36.2	14.5	10.0-19.0
Other	29.3	24.9-33.7	12.2	9.2-15.2
Maternal Age (years)				
<20	16.8 [b]	10.3-23.3	6.1 [b]	1.5-10.7
20 to 29	26.2 [b]	24.4-28.0	8.4 [b]	7.3-9.5
≥30[a]	34.6	33.2-36.0	13.8	12.7-14.9
Household Head Education				
<High school	23.9 [b]	21.0-26.8	9.1 [b]	7.1-11.1
High school	22.9 [b]	20.9-24.9	8.2 [b]	7.0-9.4
Some college	32.8 [b]	30.3-35.3	12.3 [b]	10.2-14.4
College graduate[a]	41.5	39.7-43.3	15.4	14.1-16.7
Marital Status				
Married[a]	35.4	34.0-36.8	13.4	12.4-14.4
Unmarried	18.8 [b]	16.9-20.7	6.1 [b]	5.0-7.2
Residence				
MSA, center city[a]	30.7	29.0-32.4	11.7	10.5-12.9
MSA, non-center city	32.8	30.9-34.7	12.1	10.8-13.4
Non-MSA	23.9 [b]	21.8-26.0	8.2 [b]	6.9-9.5
Poverty income ratio (%)				
<100	23.9 [b]	21.6-26.2	8.3 [b]	6.9-9.7
100 to <184	26.6 [b]	23.8-29.4	8.9 [b]	7.2-10.6
185 to <349	33.2 [b]	30.9-35.5	11.8 [b]	10.3-13.3
≥350[a]	37.7	35.7-39.7	14.0	12.6-15.4

[a] Referent group.
[b] $p<0.05$ by chi-square test, compared with referent group.
N = Number of infants.
MSA = Metropolitan statistical area.

Source: Scanlon et al., 2007.

Table15-26. Geographic-specific Breastfeeding Percent Rates Among Children Born in 2004 [a]

State	N	Ever Breastfed	Breastfed at 6 Months	Breastfed at 12 Months	Exclusive Breastfeeding Through 3 Months	Exclusive Breastfeeding Through 6 Months
U.S. National	17,654	73.8	41.5	20.9	30.5	11.3
Alabama	310	52.1	25.4	11.5	19.3	4.9
Alaska	217	84.8	60.9	31.8	47.2	24.3
Arizona	543	83.5	46.5	23.4	38.8	14.3
Arkansas	200	59.2	23.2	8.5	15.8	6.2
California	1,702	83.8	52.9	30.4	38.7	17.4
Colorado	249	85.9	42	23.6	36.2	10.8
Connecticut	249	79.5	44.6	23.7	35.6	10.1
Delaware	213	63.6	35.7	14.6	26.3	11.4
Dist of Columbia	292	68.0	40.0	21.4	27.8	9.8
Florida	955	77.9	37.5	15.6	27.8	9.1
Georgia	582	68.2	38.0	16.8	25.6	11
Hawaii	221	81	50.5	35.5	37.8	15.8
Idaho	183	85.9	49.0	22.6	38.7	10.3
Illinois	561	72.5	40.9	17.6	31.6	10
Indiana	472	64.7	34.6	18.0	28.3	10.4
Iowa	193	74.2	44.9	20.0	37.6	11.6
Kansas	480	74.4	42.2	16.9	30.0	9.2
Kentucky	245	59.1	26.4	14.4	25.3	7.5
Louisiana	429	50.7	19.2	8.3	15.2	2.8
Maine	203	76.3	46.6	27.6	42.1	15.9
Maryland	512	71.0	40.2	21.2	32.1	8.6
Massachusetts	469	72.4	42.1	19.0	32.7	11.9
Michigan	604	63.4	36.4	18.6	27.4	8.3
Minnesota	202	80.9	46.5	23.8	33.9	16.1
Mississippi	287	50.2	23.3	8.2	19.0	8
Missouri	327	67.3	32.5	15.8	26.6	7.4
Montana	232	87.7	53.8	28.8	50.9	18.3
Nebraska	228	79.3	47.6	21.8	31.7	9.8
Nevada	281	79.7	45.6	21.9	31.9	10.3
New Hampshire	228	73.7	48.7	27.5	34.3	13.6
New Jersey	631	69.8	45.1	19.4	27.0	11.8
New Mexico	420	80.7	41.2	21.1	32.9	14.3
New York	533	73.8	50.0	26.9	26.0	11.4
North Carolina	220	72.0	34.2	18.3	23.0	6.9
North Dakota	285	73.1	45.1	19.5	39.4	15.4
Ohio	617	59.6	33.3	12.9	27.2	9.8
Oklahoma	280	67.1	29.6	12.7	23.0	10.6
Oregon	191	88.3	56.4	33.5	41.5	19.9
Pennsylvania	757	66.6	35.2	16.8	27.1	8
Rhode Island	291	69.1	31.2	14.0	31.2	9.5
South Carolina	314	67.4	30.0	11.1	26.6	5.4
South Dakota	315	71.1	40.5	23.4	32.2	12.2
Tennessee	671	71.2	32.6	16.6	26.7	11.9
Texas	1,439	75.4	37.3	18.7	25.2	7.1
Utah	190	84.5	55.6	28.1	39.8	10.2
Vermont	190	85.2	55.3	34.1	47.3	15.9
Virginia	259	79.1	49.8	25.6	32.6	13.4
Washington	615	88.4	56.6	32.3	49.6	22.5
West Virginia	224	59.3	26.8	14.0	21.3	5.2
Wisconsin	478	72.1	39.6	19.0	32.5	13.4
Wyoming	246	80.5	42.9	18.5	36.2	11.4

[a] Exclusive breastfeeding information is from the 2006 NIS survey data only and is defined as ONLY breast milk- No solids, no water, no other liquids. Sample sizes appearing in the NIS breastfeeding tables are slightly smaller than the numbers published in other NIS publications due to the fact that in the DNPA breastfeeding analyses, the sample was limited to records with valid responses to the breastfeeding questions.

N = Number of infants.

Source: CDC, 2007.

Table 15-27. Percentage of Mothers in Developing Countries by Feeding Practices for Infants 0 to 6 Months Old [a]

Country	Breastfeeding	Water	Milk	Formula	Other Liquids	Solid Foods
Ethiopia	98.8	26.3	19	0	10.8	5.3
Ghana	99.6	41.9	6.7	3.5	4.3	15.6
Kenya	99.7	60	35.1	4.8	35.9	46.3
Malarwi	100	46	1.4	1.7	5.2	42.3
Nambia	95.3	65.4	0	0	17.9	33.4
Nigeria	99.1	78.2	9.2	12.7	17.9	18.5
Uganda	98.7	15.1	20.3	1.5	10.3	11.4
Zamibia	99.6	52.6	2.1	2.7	6.7	31.2
Zimbabwe	100	63.9	1.6	3.2	9	43.7
Armenia	86.1	62.7	22.9	13.1	48.1	23.9
Egypt	95.5	22.9	11.1	4.3	27.6	13.2
Jordan	92.4	58.5	3	25.1	13.8	20.2
Bangladesh	99.6	30.2	13.6	5.3	19.7	20.3
Cambodia	98.9	87.9	2.1	3.3	6.7	16.6
India	98.1	40.2	21.2	0	7.1	6.5
Indonesia	92.8	37	0.7	24.2	8.7	43
Nepal	100	23.3	12.3	0	2.8	9.3
Philippines	80.5	53.4	4.4	30	12.4	16.8
Vietnam	98.7	45.9	16.9	0.8	8.9	18.7
Kazakhstan	94.4	53.7	21.4	8.2	37.4	15.4
Pooled	96.6	45.9	11.9	9	15.1	21.9

[a] Percentage of mothers who stated that they currently breast-feed and separately had fed their infants 4 categories of liquid or solid food in the past 24 hours by country for infants age 0 to 6 months old.

Source: Marriott et al., 2007.

Table 15-28. Percentage of Mothers in Developing Countries by Feeding Practices for Infants 6 to 12 Months Old[a]

Country	Breastfeeding	Water	Milk	Formula	Other Liquids	Solid Foods
Ethiopia	99.4	69.2	37.6	0	23.9	54.7
Ghana	99.3	88.8	14.6	9.6	23.9	71.1
Kenya	96.5	77.7	58.7	6	56.4	89.6
Malarwi	99.4	93.5	5.9	3.2	31.2	94.9
Nambia	78.7	91.9	0	0	42.7	79.5
Nigeria	97.8	91.6	14.4	13.4	27.4	70.4
Uganda	97.4	65.9	32.1	1.6	56.2	82.1
Zamibia	99.5	91.7	8.2	5	25.9	90.2
Zimbabwe	96.7	92.5	8.7	2.4	49.9	94.8
Armenia	53.4	91.1	56.9	11.6	85.3	88.1
Egypt	89.1	85.9	36.8	16.7	48.5	75.7
Jordan	65.7	99.3	24.3	28.8	57.7	94.9
Bangladesh	96.2	87.7	29.8	10.1	21.9	65.2
Cambodia	94.4	97.5	3.7	6.7	29	81
India	94.9	81.4	45	0	25.2	44.1
Indonesia	84.8	85.4	4.9	38.8	35.4	87.9
Nepal	98.8	84.3	32	0	15.8	71.5
Philippines	64.4	95.1	12.2	47.1	31	88
Vietnam	93.2	95	36.1	5.3	37.9	85.8
Kazakhstan	81.2	74.3	85.4	11.4	91.8	85.9
Pooled	87.9	87.4	29.6	15.1	41.6	80.1

[a] Percentage of mothers who stated that they currently breast-feed and separately had fed their infants 4 categories of liquid or solid food in the past 24 hours by country for infants age 6 to 12 months old.

Source: Marriott et al., 2007.

Table 15-29. Population Weighted Averages of Mothers Who Reported Selected Feeding Practices During the Previous 24-hours

Feeding Practices	Infant Age	
	0 to 6 months	6 to 12 months
	Percentage (weighted N)	
Current Breast-feeding	96.6 (22,781)	87.9 (18,944)
Gave Infant:		
Water	45.9 (10,767)	87.4 (18,6663)
Tinned, Powdered, or Other Milk	11.9 (2,769)	29.6 (6,283)
Commercial Formula	9.0 (1,261)	15.1 (1,911)
Other Liquids	15.1 (3,531)	41.6 (8,902)
Any Solid Food	21.9 (5,131)	80.1 (17,119)

N = Number of infants.

Source: Marriott et al., 2007.

Table 15-30. Racial and Ethnic Differences in Proportion of Children Ever Breastfed, NHANES III (1988-1994)

	Non-Hispanic White			Non-Hispanic Black			Mexican American			Absolute Difference (%,SE)[a]			
										White vs Black		White vs Mexican American	
Characteristic	N	%	(SE)	N	%	(SE)	N	%	(SE)	%	(SE)	%	(SE)
All infants	1,869	60.3	2.0	1,845	25.5	1.4	2,118	54.4	1.9	34.8	(2.0)[b]	6.0	(2.3)[a]
Infant sex													
Male	901	60.4	2.6	913	24.4	1.6	1,033	53.8	1.8	35.9	(2.9)[b]	6.6	(2.8)[a]
Female	968	60.3	2.3	932	26.7	1.9	1,085	54.9	2.9	33.7	(2.6)[b]	5.4	(3.4)[c]
Infant birth weight (g)													
<2,500	118	40.1	5.3	221	14.9	2.6	165	34.1	3.9	25.1	(5.8)[b]	5.9	(6.4)[c]
≥2,500	1,738	62.1	2.1	1,584	26.8	1.6	1,838	55.7	2.0	35.3	(2.1)[b]	6.4	(2.5)[a]
Maternal age (years)													
<20	175	33.7	4.4	380	13.1	2.1	381	43.7	3.0	20.6	(4.8)[b]	-10	(5.1)[c]
20 to 24	464	48.3	3.0	559	22.0	2.0	649	54.8	2.6	26.4	(3.7)[b]	-6.4	(4.2)[c]
25 to 29	651	65.4	2.2	504	30.6	2.5	624	56.9	3.3	34.8	(3.1)[b]	8.6	(4.0)[a]
≥30	575	71.9	2.7	391	36.1	2.3	454	59.6	2.8	35.8	(3.4)[b]	12.3	(3.4)[b]
Household head education													
<High school	313	32.3	4.0	583	14.7	2.5	1,262	51.0	2.6	17.6	(5.0)[b]	-18.8	(4.8)[b]
High school	623	52.6	2.8	773	21.9	2.0	479	51.4	3.4	30.7	(3.2)[b]	1.2	(4.1)[c]
Some college	397	63.8	2.3	317	37.2	3.5	226	68.0	5.2	26.6	(3.7)[b]	-4.1	(5.6)[c]
College graduate	505	83.0	2.4	139	54.4	4.9	74	78.3	7.4	28.6	(5.3)[b]	4.6	(7.6)[c]
Smoking during pregnancy													
Yes	526	39.8	3.0	403	18.0	2.1	198	31.2	3.9	21.8	(3.7)[b]	8.6	(4.7)[c]
No	1,334	68.2	2.0	1,429	27.8	1.7	1,917	56.7	1.9	40.4	(2.1)[b]	11.5	(2.5)[b]
Maternal body mass index													
<25.0	1,331	64.9	2.0	872	26.8	2.0	961	54.1	2.5	38.0	(2.5)[b]	10.8	(2.7)[b]
25.0 to 29.9	283	50.9	3.4	484	24.1	3.2	534	57.8	2.1	26.8	(4.5)[b]	-6.8	(4.1)[c]
≥30	204	48.6	4.8	415	24.3	2.7	359	47.1	4.4	24.3	(5.3)[b]	1.5	(6.1)[c]
Residence													
Metropolitan	762	67.2	3.0	943	32.0	1.9	1,384	56.1	2.0	35.3	(2.6)[b]	11.2	(2.9)[b]
Rural	1,107	54.9	3.1	902	18.3	1.9	734	51.3	3.1	36.6	(2.7)[b]	3.6	(4.0)[c]
Region													
Northeast	317	51.6	4.6	258	34.2	4.4	12	74.1	10.4	17.3	(3.6)[b]	-22.5	(14.5)[c]
Midwest	556	61.7	2.3	346	26.5	2.4	170	51.5	3.7	35.2	(3.3)[b]	10.2	(5.0)[a]
South	748	52.7	2.7	1,074	19.4	2.0	694	42.7	3.5	33.3	(2.7)[b]	10	(4.6)[a]
West	248	82.4	3.9	167	45.1	5.1	1,242	59.1	2.2	37.3	(7.1)[b]	23.4	(3.3)[b]
Poverty income ratio (%)													
<100	257	38.5	4.2	905	18.2	1.9	986	48.2	2.8	20.3	(4.4)[b]	-9.6	(4.7)[a]
100 to <185	388	55.7	2.6	391	26.8	2.1	490	54.1	3.4	28.9	(3.5)[b]	1.5	(4.2)[c]
185 to <350	672	61.9	2.5	294	32.0	3.0	288	64.7	4.7	30.0	(3.7)[b]	2.8	(5.3)[c]
≥350	444	77.0	2.5	105	58.1	5.1	74	71.9	9.0	19.0	(5.6)[b]	5.2	(9.0)[c]
Unknown	108	44.7	7.1	150	25.5	3.9	280	59.5	2.8	19.2	(7.9)[a]	-14.8	(7.9)[c]

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] No statistical difference.
N = Number of infants.
SE = Standard error.
Source: Li and Grummer-Strawn, 2002.

Table 15-31. Racial and Ethnic Differences in Proportion of Children Who Received Any Human Milk at 6 Months (NHANES III, 1988-1994)

	Non-Hispanic White			Non-Hispanic Black			Mexican American			Absolute Difference (%,SE)			
										White vs Black		White vs Mexican American	
Characteristic	N	%	(SE)	No.	%	(SE)	N	%	(SE)	%	(SE)	%	(SE)
All infants	1863	26.8	1.6	1,842	8.5	0.9	2,112	23.1	1.4	18.3	(1.7)[b]	3.7	(2.1)[c]
Infant sex													
Male	900	27.6	2.3	912	8.5	1.1	1,029	22.3	1.6	19.1	(2.6)[b]	5.2	(2.6)[a]
Female	963	26.1	1.8	930	8.6	1.1	1,083	24.0	2.0	17.5	(2.1)[a]	2.1	(2.7)[c]
Infant birth weight (g)													
<2,500	118	10.9	3.1	221	4.2	1.8	165	15.2	4.7	6.7	(3.3)[a]	-4.3	(5.7)[c]
≥2,500	1,733	28.3	1.8	1,581	9.0	0.9	1,832	23.1	1.7	19.3	(1.8)[b]	5.2	(2.3)[a]
Maternal age (years)													
<20	174	10.2	2.9	380	4.7	1.4	380	11.6	1.7	5.5	(3.0)[c]	-1.3	(3.8)[c]
20 to 24	461	13.4	2.4	559	7.5	1.1	646	23.8	2.4	5.9	(2.5)[a]	-10.4	(3.3)[b]
25 to 29	651	29.3	2.6	503	10.9	2.0	624	24.6	2.6	18.4	(3.5)[b]	4.8	(3.6)[c]
≥30	573	39.0	2.6	389	10.7	1.7	452	30.0	2.8	28.4	(3.3)[b]	9.0	(3.6)[a]
Household head education													
<High school	312	14.6	3.8	582	4.4	1.2	1,258	20.7	1.4	10.2	(4.5)[a]	-6.2	(4.1)[c]
High school	622	19.9	1.7	771	5.0	1.0	478	22.4	2.5	14.9	(2.0)[b]	2.5	(3.1)[c]
Some college	396	26.8	2.4	317	16.6	2.5	225	28.4	5.3	10.2	(3.5)[b]	-1.6	(6.1)[c]
College graduate	502	42.2	2.9	139	21.1	3.2	74	45.5	7.3	21.1	(5.2)[b]	3.4	(7.6)[c]
Smoking during pregnancy													
Yes	524	11.3	1.5	402	4.3	1.1	198	9.3	2.2	7.0	(1.9)[b]	2.1	(2.7)[c]
No	1,331	32.7	2.1	1,427	9.8	1.1	1,911	24.5	1.5	22.9	(2.3)[b]	8.1	(2.6)[b]
Maternal body mass index													
<25.0	1,326	29.6	1.8	871	8.9	1.2	959	21.9	2.1	20.7	(2.1)[b]	7.8	(2.7)[b]
25.0 to 29.9	282	19.0	2.4	482	8.2	1.9	534	26.4	1.9	10.8	(3.2)[b]	7.4	(3.0)[a]
≥30	204	20.4	4.1	415	7.3	1.6	357	17.2	3.0	13.1	(4.4)[b]	3.3	(5.2)[c]
Residence													
Metropolitan	760	29.7	2.5	941	11.8	1.3	1,378	23.5	1.7	17.9	(2.4)[b]	6.1	(3.1)[c]
Rural	1,103	24.6	2.4	901	4.9	0.9	734	22.5	2.8	19.7	(2.2)[b]	2.2	(3.4)[c]
Region													
Northeast	316	21.0	2.2	258	9.7	1.8	12	43.6	16.0	11.3	(1.8)[b]	-22.6	(16.5)[c]
Midwest	553	28.8	2.1	344	9.8	2.4	170	18.2	4.7	19.0	(3.7)[b]	10.6	(6.2)[c]
South	746	20.1	2.8	1,073	5.9	1.0	693	17.2	2.8	14.3	(2.8)[b]	2.9	(4.2)[c]
West	248	42.7	4.7	167	19.3	3.3	1,237	25.9	1.4	23.4	(5.3)[b]	16.8	(5.1)[b]
Poverty income ratio (%)													
100 to <185	387	23.5	2.9	390	9.9	1.8	486	23.4	2.7	13.6	(3.9)[b]	0	(4.1)[c]
185 to <350	670	30.4	2.7	293	10.0	2.4	287	27.6	4.4	20.4	(4.0)[b]	2.9	(4.8)[c]
≥350	443	33.0	3.0	105	15.2	2.8	74	32.3	9.0	17.8	(4.2)[b]	0.7	(9.5)[c]
Unknown	108	13.3	3.8	149	6.4	2.9	280	26.7	4.5	7.0	(5.3)[c]	-13.4	(6.6)[a]

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] No statistical difference.
N = Number of individuals.
SE = Standard error.
Source: Li and Grummer-Strawn, 2002.

Table 15-32. Racial and Ethnic Differences in Proportion of Children Exclusively Breastfed at 4 Months (NHANES III, 1991-1994)

	Non-Hispanic White			Non-Hispanic Black			Mexican American			Absolute Difference (%,SE)			
										White vs Black		White vs Mexican American	
Characteristic	N	%	(SE)	N	%	(SE)	N	%	(SE)	%	(SE)	%	(SE)
All infants	824	22.6	1.7	906	8.5	1.5	957	20.4	1.4	14.1	(2.2)[b]	2.3	(1.6)[c]
Infant sex													
Male	394	22.3	1.9	454	7.0	1.6	498	20.7	1.5	15.3	(2.6)[b]	1.5	(1.8)[c]
Female	430	23.0	2.2	452	10.0	2.2	459	20.0	1.8	12.9	(3.0)[b]	3.0	(2.1)[c]
Infant birth weight (g)													
<2500	50	15.2	7.1	118	7.0	2.3	66	5.6	1.8	8.2	(8.1)[c]	9.5	(6.9)[c]
≥2500	774	23.1	1.8	786	8.8	1.6	880	21.6	1.4	14.4	(2.2)[b]	1.5	(1.6)[c]
Maternal age (years)													
<20	76	6.6	3.2	172	6.4	2.1	170	12.1	2.5	0.2	(3.7)[c]	-5.6	(3.8)[c]
20 to 24	205	11.4	2.2	273	7.4	2.4	319	21.0	2.3	4.0	(2.7)[c]	-9.6	(3.2)[b]
25 to 29	271	21.6	2.3	254	8.6	2.5	256	22.1	2.5	13.0	(3.2)[b]	-0.5	(3.2)[c]
≥30	270	34.8	2.7	201	11.9	2.6	210	23.6	3.1	22.9	(4.2)[b]	11.1	(3.7)[b]
Household head education													
<High school	146	9.5	3.5	256	2.0	0.7	563	19.7	1.8	7.5	(3.6)[a]	-10.2	(4.0)[a]
High school	277	14.5	2.7	406	7.1	2.1	222	18.8	3.6	7.4	(3.2)[a]	-4.3	(4.7)[c]
Some college	175	30.8	3.8	141	17.4	3.0	120	21.0	3.9	13.4	(4.7)[b]	9.8	(6.1)[c]
College graduate	219	34.1	3.9	92	17.4	4.7	37	31.5	4.5	16.7	(6.9)[a]	2.6	(6.3)[c]
Smoking during pregnancy													
Yes	224	10.0	2.8	168	5.4	2.2	64	3.2	1.8	4.6	(3.7)[c]	6.8	(3.4)[c]
No	596	27.2	2.1	730	9.4	1.9	892	21.7	1.5	17.8	(2.8)[b]	5.6	(2.0)[a]
Maternal body mass index													
<25.0	597	24.8	2.1	407	8.0	1.9	417	19.4	1.9	16.8	(3.0)[b]	5.4	(2.3)[a]
25.0 to 29.9	117	19.7	4.3	230	8.6	1.9	261	23.1	3.4	11.1	(4.6)[a]	-3.4	(4.9)[c]
≥30	91	15.4	3.8	230	9.0	2.9	184	15.9	2.3	6.4	(5.2)[c]	-0.5	(4.6)[c]
Residence													
Metropolitan	312	24.4	3	535	11.0	2.0	608	19.6	1.6	13.4	(3.5)[b]	4.8	(2.8)[c]
Rural	512	21.3	1.8	371	4.2	1.3	349	22.3	3.3	17.1	(1.8)[b]	-1.1	(3.0)[c]
Region													
Northeast	138	20.0	1.4	131	11.1	2.9	10	9.4	9.5	8.8	(2.2)[b]	10.6	(8.7)[c]
Midwest	231	26.5	3.2	143	12.6	5.6	98	19.2	4.1	13.9	(7.6)[c]	7.4	(3.7)[c]
South	378	14.1	2.8	574	5.9	1.4	383	15.9	3.1	8.2	(1.9)[b]	-1.8	(3.7)[c]
West	77	34.7	2.7	58	12.5	5.0	466	23.0	1.3	22.2	(5.4)[b]	11.7	(2.5)
Poverty income ratio (%)													
<100	116	13.1	3.3	448	5.7	1.6	471	18.4	1.8	7.4	(3.5)[a]	-5.3	(3.1)[c]
100 to <185	166	18.9	3.2	197	10.6	2.8	234	21.9	4.1	8.3	(3.3)[a]	-3	(6.1)[c]
185 to <350	274	25.1	3.2	145	12.9	4.3	132	26.4	4.2	12.2	(5.0)[a]	-1.3	(4.1)[c]
≥350	235	27.4	4.1	57	12.8	3.5	37	17.0	5.0	14.6	(5.0)[b]	10.4	(5.2)[c]
Unknown	33	16.5	7.6	59	7.3	3.7	83	16.1	5.1	9.2	(8.6)[c]	0.4	(9.5)[c]

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] No statistical difference.
N = Number of individuals.
SE = Standard error.
Source: Li and Grummer-Strawn, 2002.

Table 15-33. 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

Characteristic	Percentage of Mothers Breast-Feeding					
	In Hospital			At 6 Months		
	1989	1995	Change[a]	1989	1995	Change[a]
All Infants	52.2	59.7	14.4	18.1	21.6	19.3
White	58.5	64.3	9.9	21.0	24.1	14.8
Black	23.0	37.0	60.9	6.4	11.2	75.0
Hispanic	48.4	61.0	26.0	13.9	19.6	41.0
Maternal Age (years)						
<20	30.2	42.8	41.7	5.6	9.1	62.5
20 to 24	45.2	52.6	16.4	11.5	14.6	27.0
25 to 29	58.8	63.1	7.3	21.1	22.9	8.5
30 to 34	65.5	68.1	4.0	29.3	29.0	(1.0)[b]
35+	66.5	70.0	5.3	34.0	33.8	(0.6)[b]
Total Family Income						
<$10,000	31.8	41.8	31.4	8.2	11.4	39.0
$10,000 to $14,999	47.1	51.7	9.8	13.9	15.4	10.8
$15,000 to $24,999	54.7	58.8	7.5	18.9	19.8	4.8
≥25,000	66.3	70.7	6.6	25.5	28.5	11.8
Maternal Education						
Grade School	31.7	43.8	38.2	11.5	17.1	48.7
High School	42.5	49.7	16.9	12.4	15.0	21.0
College	70.7	74.4	5.2	28.8	31.2	8.3
Maternal Employment						
Employed Full Time	50.8	60.7	19.5	8.9	14.3	60.7
Employed Part Time	59.4	63.5	6.9	21.1	23.4	10.9
Not Employed	51.0	58.0	13.7	21.6	25.0	15.7
Birth Weight						
Low (≤2,500 g)	36.2	47.7	31.8	9.8	12.6	28.6
Normal	53.5	60.5	13.1	18.8	22.3	18.6
Parity						
Primiparous	52.6	61.6	17.1	15.1	19.5	29.1
Multiparous	51.7	57.8	11.8	21.1	23.6	11.8
WIC Participation[c]						
Participant	34.2	46.6	36.3	8.4	12.7	51.2
Nonparticipant	62.9	71.0	12.9	23.8	29.2	22.7
U.S. Census Region						
New England	52.2	61.2	17.2	18.6	22.2	19.4
Middle Atlantic	47.4	53.8	13.5	16.8	19.6	16.7
East North Central	47.6	54.6	14.7	16.7	18.9	13.2
West North Central	55.9	61.9	10.7	18.4	21.4	16.3
South Atlantic	43.8	54.8	25.1	13.7	18.6	35.8
East South Central	37.9	44.1	16.4	11.5	13.0	13.0
West South Central	46.0	54.4	18.3	13.6	17.0	25.0
Mountain	70.2	75.1	7.0	28.3	30.3	7.1
Pacific	70.3	75.1	6.8	26.6	30.9	16.2

[a] The percent change was calculated using the following formula: % breastfed in 1984 - % breastfed in 1989 / % breastfed in 1984.
[b] Figures in parentheses indicate a decrease in the rate of breastfeeding from 1989 to 1995.
[c] WIC indicates Women, Infants, and Children supplemental food program.

Source: Ryan, 1997.

Table 15-34. Percentage of Mothers Breast-feeding Newborn Infants in the Hospital and Infants at 6 and 12 Months of Age in the United States in 2003, by Ethnic Background and Selected Demographic Variables

Characteristic	Percentage of Mothers Breast-Feeding		
	In Hospital	At 6 Months	At 12 Months
All Infants	44	18	10
White	53	20	12
Black	26	10	5
Hispanic	33	15	12
Asian	39	23	12
Maternal Age (years)			
<20	28	9	4
20 to 24	40	13	8
25 to 29	48	20	10
30 to 34	50	23	14
35+	47	23	14
Maternal Education			
Any Grade School	26	13	17
Any High School	35	12	8
No College	35	12	8
College	55	24	14
Maternal Employment			
Employed Full Time	44	11	6
Employed Part Time	49	19	11
Total Employed	45	14	8
Not Employed	43	21	13
Low Birth Weight <5 lbs 9oz	27	10	6
Parity			
Primiparous	48	17	10
Multiparous	43	19	11
WIC Participation [a]			
Participant	32	11	7
Nonparticipant	55	25	14
U.S. Census Region			
New England	52	22	11
Middle Atlantic	36	17	9
East North Central	44	17	9
West North Central	55	18	9
South Atlantic	42	16	10
East South Central	37	11	7
West South Central	37	15	8
Mountain	53	23	16
Pacific	50	24	15

[a] WIC indicates Women, Infants, and Children supplemental food program.

Source: Abbott, 2003.

Table 15-35. Number of Meals Per Day

Age (months)	Bottle-fed Infants (meals/day) [a]	Breast-fed (meals/day) [a]
1	5.4 (4-7)	5.8 (5-7)
2	4.8 (4-6)	5.3 (5-7)
3	4.7 (3-6)	5.1 (4-8)

[a] Data expressed as mean with range in parentheses.

Source: Hofvander et al., 1982.

Table 15-36. Comparison of Breastfeeding Patterns Between Age and Groups (Mean ±SD)

Breastfeeding Episodes per Day	5.8 ± 2.6	6.8 ± 2.4	2.5 ± 2.0
Total Time Breastfeeding (min/day)	65.2 ± 44.0	102.2 ± 51.4	31.2 ± 24.6
Length of Breastfeeding (min/episode)	10.8 ± 6.1	14.2 ± 6.1	11.6 ± 5.6

SD = Standard deviation

Source: Buckley, 2001.

16 ACTIVITY FACTORS

16.1 INTRODUCTION

As a consequence of a child's immaturity and small stature, certain activities and behaviors specific to children place them at higher risk to certain environmental agents (Chance and Harmsen, 1998). Individual or group activities are important determinants of potential exposure, because toxic chemicals introduced into the environment may not cause harm to a child until an activity is performed that subjects the child to contact with those contaminants. An activity or time spent in a given activity will vary among children on the basis of, for example, culture, ethnicity, hobbies, location, gender, age, socioeconomic characteristics, and personal preferences. However, limited information is available regarding ethnic, cultural and socioeconomic differences in children's choice of activities or time spent in a given activity.

It is difficult to accurately collect/record data for a child's activity patterns (Hubal et al., 2000). Children engage in more contact activities than adults; therefore, a much wider distribution of activities need to be considered when assessing children's exposure (Hubal et al., 2000). Behavioral patterns, preferred activities, and developmental stages result in different exposures for children than for adults (Chance and Harmsen, 1998). Other factors that may affect children's activity patterns include: social status, economics, and the cultural practices of their families.

This chapter summarizes data on how much time children spend participating in various activities in various microenvironments. Information on the frequency of performing various activities is also provided. The data in this chapter cover a wide range of activities and populations, arranged by age group when such data are available. One of the objectives of this handbook is to provide recommended exposure factor values using a consistent set of age groups. In this chapter, several studies are used as sources for activity pattern data. In some cases, the source data could be retrieved and analyzed using the standard age groupings recommended in *Guidance for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). In other cases, the original source data were not available, and the study results are presented here using the same age groups as the original study, whether or not they conform to the standard age groupings.

The recommendations for activity factors are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on key studies identified by U.S. EPA for this factor. Following the recommendations, key studies on activity patterns are summarized. Relevant data on activity patterns are also presented to provide the reader with added perspective on the current state-of-knowledge pertaining to activity patterns in children.

16.2 RECOMMENDATIONS

Assessors are commonly interested in quantitative information describing several types of time use data for children including: time spent indoors and outdoors; time spent bathing, showering, and swimming; and time spent playing on various types of surfaces. The recommended values for these factors are summarized in Table 16-1. Note that, except for swimming, all activity factors are reported in units of minutes/day. Time spent swimming is reported in units of minutes/month. These data are based on two key studies presented in this chapter: a study of children's activity patterns in California (Wiley et al., 1991) and the National Human Activity Pattern Survey (NHAPS) (U.S. EPA, 1996). Both mean and 95th percentile recommended values are provided. However, because these recommendations are based on short-term survey data, 95th percentile values may be misleading for estimating chronic (i.e., long term) exposures and should be used with caution. Also, the upper percentile values for some activities are truncated as a result of the maximum response included in the survey (e.g., durations of more than 120 minutes/day were reported as 121 minutes/day), and could not be further refined). The confidence ratings for the recommendations are presented in Table 16-2.

The recommendations for total time spent indoors and the total time spent outdoors are based on U.S. EPA re-analysis of the source data from Wiley et al. (1991) for children < 1 year of age and U.S. EPA (1996) for age groups > 1 year of age. Although Wiley et al. (1991) is a study of California children and the sample size was very small for infants, it provides data for children's activities for the younger age groups.

Data from U.S. EPA (1996) are representative of the U.S. general population. In some cases, however, the time spent indoors or outdoors would be better addressed on a site-specific basis since the times are likely to vary depending on the climate, residential setting (i.e., rural versus urban), personal traits (e.g., health status) and personal habits. The recommended values for time spent indoors at a residence, duration of showering and bathing, and time spent swimming are based on a U.S. EPA re-analysis of the source data from U.S. EPA (1996). Likewise, the recommended values for time spent playing on sand, gravel, grass or dirt are based on a U.S. EPA re-analysis of the source data from U.S. EPA (1996).

Table 16-1. Recommended Values for Activity Factors

Age Group	Mean	95th Percentile	Source
Time Indoors (total) minutes/day			
Birth to <1 month	1,440	-	U.S. EPA analysis of source data from Wiley et al., 1991 for age groups from birth to < 12 months. Average for boys and girls. See Table 16-10. U.S. EPA re-analysis of source data from U.S. EPA, 1996 for age groups from 1 to < 21 years. See Table 16-14.
1 to <3 months	1,432	-	
3 to <6 months	1,414	-	
6 to <12 months	1,301	-	
1 to <2 years	1,353	-	
2 to <3 years	1,316	-	
3 to <6 years	1,278	-	
6 to <11 years	1,244	-	
11 to <16 years	1,260	-	
16 to <21 years	1,248	-	
Time Outdoors (total) minutes/day			
Birth to <1 month	0	-	U.S. EPA analysis of source data from Wiley et al., 1991 for age groups from birth to < 12 months. Average for boys and girls. See Table 16-10. U.S. EPA re-analysis of source data from U.S. EPA, 1996 for age groups from 1 to < 21 years. See Table 16-14.
1 to <3 months	8	-	
3 to <6 months	26	-	
6 to <12 months	139	-	
1 to <2 years	36	-	
2 to <3 years	76	-	
3 to <6 years	107	-	
6 to <11 years	132	-	
11 to <16 years	100	-	
16 to <21 years	102	-	
Time Indoors (at residence) minutes/day			
Birth to <1year	1,108	1,440	U.S. EPA re-analysis of source data from U.S. EPA, 1996. Doers only. See Table 16-11.
1 to <2 years	1,065	1,440	
2 to <3 years	979	1,296	
3 to <6 years	957	1,355	
6 to <11 years	893	1,275	
11 to <16 years	889	1,315	
16 to <21 years	833	1,288	
Showering minutes/day			
Birth to <1year	15	-	U.S. EPA re-analysis of source data from U.S. EPA, 1996. Doers only. See Table 16-18.
1 to <2 years	20	-	
2 to <3 years	22	44	
3 to <6 years	17	34	
6 to <11 years	18	41	
11 to <16 years	18	40	
16 to <21 years	20	45	

Table 16-1. Recommended Values for Activity Factors (continued)			
Age Group	Mean	95th Percentile	Source
Bathing minutes/day			
Birth to <1 year	19	30	U.S. EPA re-analysis of source data from U.S. EPA, 1996. Doers only. See Table 16-18.
1 to <2 years	23	32	
2 to <3 years	23	45	
3 to <6 years	24	60	
6 to <11 years	24	46	
11 to <16 years	25	43	
16 to <21 years	33	60	
Swimming minutes/month			
Birth to <1 year	96	-	U.S. EPA re-analysis of source data from U.S. EPA, 1996. Doers only. See Table 16-21.
1 to < 2 years	105	-	
2 to <3 years	116	181	
3 to <6 years	137	181	
6 to <11 years	151	181	
11 to <16 years	139	181	
16 to <21 years	145	181	
Playing on Sand/Gravel minutes/day			
Birth to <1 year	18	-	U.S. EPA re-analysis of source data from U.S. EPA, 1996. Doers only. See Table 16-22.
1 to < 2 years	43	121	
2 to <3 years	53	121	
3 to <6 years	60	121	
6 to <11 years	67	121	
11 to <16 years	67	121	
16 to <21 years	83	-	
Playing on Grass minutes/day			
Birth to <1 year	52	-	U.S. EPA re-analysis of source data from U.S. EPA, 1996. Doers only. See Table 16-22.
1 to < 2 years	68	121	
2 to <3 years	62	121	
3 to <6 years	79	121	
6 to <11 years	73	121	
11 to <16 years	75	121	
16 to <21 years	60	-	

Table 16-1. Recommended Values for Activity Factors (continued)			
Age Group	Mean	95th Percentile	Source
Playing on Dirt minutes/day			
Birth to <1 year	33	-	U.S. EPA re-analysis of source data from U.S. EPA, 1996. Doers only. See Table 16-22.
1 to < 2 years	56	121	
2 to <3 years	47	121	
3 to <6 years	63	121	
6 to <11 years	63	121	
11 to <16 years	49	120	
16 to <21 years	30	-	

\- Percentiles were not calculated for sample sizes less than 10.

Note: All activities are reported in units of minutes/day, except swimming, which is reported in units of minutes/month. There are 1,440 minutes in a day. Time indoors and outdoors may not add up to 1,440 minutes due to activities that could not be classified as either indoors or outdoors.

Table 16-2. Confidence in Recommendations for Activity Factors

General Assessment Factors	Rationale	Rating
Soundness		High
Adequacy of Approach	The survey methodologies and data analyses were adequate. In the U.S. EPA (1996) study, responses were weighted according to this demographic data. The California children's activity pattern survey design (Wiley et al., 1991) and NHAPS (U.S. EPA, 1996) consisted of large overall sample sizes that varied with age. Data were collected via questionnaires and interviews.	
Minimal (or Defined) Bias	Measurement or recording error may have occurred since the diaries were based on 24 hour recall. The sample sizes for some age groups were small for some activity factors. The upper ends of the distributions were truncated for some factors. The data were based on short-term data.	
Applicability and Utility		Medium
Exposure Factor of Interest	The key studies focused on activities of children.	
Representativeness	U.S. EPA (1996) was a nationally representative survey of the U.S. population; the Wiley et al. (1991) survey was conducted in California and it was not representative of the U.S. population.	
Currency	The Wiley et al. (1991) study was conducted between April 1989 and February 1990; the U.S. EPA (1996) study was conducted between October 1992 and September 1994.	
Data Collection Period	Data were collected for a 24-hour period.	
Clarity and Completeness		Medium
Accessibility	The original studies are widely available to the public; U.S. EPA analysis of the original raw data from U.S. EPA (1996) is available upon request.	
Reproducibility	The methodologies were clearly presented; enough information was included to reproduce the results.	
Quality Assurance	Quality assurance methods were not well described in study reports.	
Variability and Uncertainty		Medium
Variability in Population	Variability was characterized across various age categories of children.	
Uncertainty	The studies were based on short term recall data, and the upper ends of the distributions were truncated.	
Evaluation and Review		Medium
Peer Review	The original studies received a high level of peer review. The re-analysis of the U.S. EPA (1996) data to conform to the standardized age categories was not peer-reviewed.	
Number and Agreement of Studies	There were 2 key studies.	
Overall Rating		**Medium for the mean; low for upper percentile**

16.3 ACTIVITY PATTERNS

This section briefly describes published time-use studies that provide information on time-activity patterns of children in the U.S. For a detailed description of the studies, the reader is referred to the Exposure Factors Handbook (U.S. EPA, 1997).

16.3.1 KEY STUDIES

16.3.1.1 *Wiley et al., 1991 - Study of Children's Activity Patterns*

The California Study of Children's Activity Patterns survey (Wiley et al., 1991) provided estimates of the time children spent in various activities and locations (microenvironments) on a typical day. The sample population consisted of 1,200 children, under 12 years of age, selected from English-speaking households using Random Digit Dial (RDD) methods. This represented a survey response rate of 77.9 percent. One child was selected from each household. If the selected child was 8 years old or less, the adult in the household who spent the most time with the child responded. However, if the selected child was between 9 and 11 years old, that child responded. The population was also stratified to provide representative estimates for major regions of the state. The survey questionnaire included a time diary which provided information on the children's activity and location patterns based on a 24-hour recall period. In addition, the survey questionnaire included questions about potential exposure to sources of indoor air pollution (e.g., presence of smokers) on the diary day, and the socio-demographic characteristics of children and adult respondents. The questionnaires and the time diaries were administered via a computer-assisted telephone interviewing (CATI) technology (Wiley et al., 1991). The telephone interviews were conducted during April 1989 to February 1990 over four seasons: spring (April to June 1989), summer (July to September 1989), fall (October to December 1989), and winter (January to February 1990).

The data obtained from the survey interviews resulted in ten major activity categories, 113 detailed activity codes, 6 major categories of locations, and 63 detailed location codes. The time respondents under 12 years of age spent in the 10 activity categories (plus a "don't know" or non-coded activity category) are presented in Table 6-3. For each of the 10 activity categories, this table presents the mean duration for all survey participants, the percentage of respondents who reported participating in the activity (i.e., percent doers), and the mean, median, and maximum duration for only those survey respondents who engaged in the activity (i.e., doers). It also includes the detailed activity with the highest mean duration of time for each activity category. The activity category with the highest time expenditure was personal needs and care, with a mean of 794 minutes/day (13.2 hours/day). Night sleep was the detailed activity that had the highest mean duration in that activity category. The activity category "don't know" had a mean duration of about 2 minutes/day and only 4 percent of the respondents reported missing activity time.

Table 16-4 presents the mean time spent in the 10 activity categories by age and gender. Because the original source data were available, U.S. EPA re-analyzed the data according to the standardized age categories used in this handbook. Differences between activity patterns in boys and girls tended to be small. Table 16-5 presents the mean time spent in the 10 activity categories grouped by season and geographic region in the state of California. There were seasonal differences for 5 activity categories: personal needs and care, education, entertainment/social, recreation, and communication/passive leisure. Time expenditure differences in various regions of the state were minimal for childcare, work-related, goods/services, personal needs and care, education, entertainment/social, and recreation.

Table 16-6 presents the distribution of time across six location categories. The mean duration for all survey participants, the percent of respondents engaging in the activity (i.e., percent doers); the mean, median, and maximum duration for doers only; and the detailed locations with the highest average time expenditure are shown. For all survey respondents, the largest mean amount of time spent was at home (1,078 minutes/day); 99 percent of respondents spent time at home (mean of 1,086 minutes/day for these individuals only). Tables 16-7 and 16-8 show the average time spent in the six locations grouped by age and gender, and season and region, respectively. Again, because the original source data were available, the age categories used by Wiley et al. (1991) have been replaced in Table 16-7 by the standardized age categories used in this handbook. There were relatively large differences among the age groups in time expenditure for educational settings (Table 16-7). There were small differences in time expenditure at the six locations by region, but time spent in school decreased in the summer months compared to other seasons (Table 16-8).

Table 16-9 shows the average time children spent in proximity to gasoline fumes and gas oven fumes. In general, the sampled children spent more time closer to gasoline fumes than to gas oven fumes. The age categories in Table 16-9 have been modified to conform to the standardized categories used in this handbook.

The U.S. EPA estimated the total time indoors and outdoors using the data from the Wiley et al. (1991) study. Activities performed indoors were assumed to include household work, child care, personal needs and care, education, and communication/passive leisure. The average times spent in these indoor activities and half the time spent in each activity which could have occurred either indoors or outdoors (i.e., work-related, goods/services, organizational activities, entertainment/social, don't know/not coded) were summed. Table 16-10 summarizes the results of this analysis using the standard age groups.

A limitation of this study is that the sampling population was restricted to only English-speaking households; therefore, the data obtained do not represent the diverse population group present in California. Another limitation is that time use values obtained from this survey were based on short-term recall (24-hr) data; therefore, the data set obtained may be biased. Other limitations are: the survey was conducted in California and is not representative of the national population, and the significance of the observed differences in the data obtained (i.e., gender, age, seasons, and regions) were not tested statistically. An advantage of this study is that time expenditure in various activities and locations were presented for children grouped by age, gender, and season. Also, potential exposures of respondents to pollutants were explored in the survey. Another advantage is the use of the CATI program in obtaining time diaries, which allows automatic coding of activities and locations onto a computer tape, and allows activities forgotten by respondents to be inserted into their appropriate position during interviewing.

16.3.1.2 *U.S. EPA, 1996 - National Human Activity Pattern Survey (NHAPS)*

U.S. EPA (1996) analyzed data collected by the National Human Activity Pattern Survey (NHAPS). This survey was conducted by U.S. EPA and is the largest and most current human activity pattern survey available (U.S. EPA, 1996). Data for 9,386 respondents in the 48 contiguous United States were collected via minute-by-minute 24-hour diaries. NHAPS was conducted from October 1992 through September 1994 by the University of Maryland's Survey Research Center using CATI technology to collect 24-hour retrospective diaries and answers to a number of personal and exposure related questions from each respondent. Detailed data were collected for a maximum of 82 different possible locations, and a maximum of 91 different activities. Participants were selected using a RDD method. The response rate was 63 percent, overall. If the chosen respondent was a child too young to interview, an adult in the household gave a proxy interview. Each participant was asked to recount their entire daily routine from midnight to midnight immediately previous to the day that they were interviewed. The survey collected information on duration and frequency of selected activities and of the time spent in selected microenvironments. In addition, demographic information was collected for each respondent to allow for statistical summaries to be generated according to specific subgroups of the U.S. population (i.e., by gender, age, race, employment status, census region, season, etc.). The participants' responses were weighted according to geographic, socioeconomic, time/season, and other demographic factors to ensure that results were representative of the U.S. population. The weighted sample matched the 1990 U.S. census population for each gender, age group, census region, and the day-of-week and seasonal responses were equally distributed. Saturdays and Sundays were over sampled to ensure an adequate weekend sample.

Tables 16-11 through 16-24 provide data from the NHAPS study. In most cases, the source data from U.S. EPA have been reviewed and re-analyzed by U.S. EPA to conform to the age categories recommended in *Guidance for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005) and used in this handbook. Because no data were available on subjects' age in months, age groups less than 1 year old were consolidated into a single group. These tables provide statistics for 24-hour cumulative time spent (mean, minimum, percentiles, and maximum) in selected locations or engaging in selected activities. For each location or activity, statistics were calculated for the entire survey population (i.e., whole population) and for the subset of the survey population that reported being in the location or doing the activity in question (i.e., doers only). When the sample size was 10 persons or fewer, percentile values were not calculated. Also note that some of these activities were not necessarily mutually exclusive (e.g. time spent in active sports likely overlaps with exercise time).

Table 16-11 presents data for the time children spent in various rooms of the house (i.e., kitchen, living room, dining room, bathroom, bedroom, and garage), and all rooms combined. Table 16-12 presents data for time spent in other indoor locations (i.e., restaurants, indoors at school, and grocery/convenience stores). Table 16-13 presents data for the time children spent outdoors on school grounds/playgrounds, parks or golf courses, or pool rivers, or lakes. Table 16-14 provides data on time spent in indoor and outdoor environments. The U.S. EPA estimated the time spent indoors by adding the average times spent indoors at the respondents' home (kitchen, living room, bathroom, etc.), at other houses, and inside other locations such as school, restaurants, etc. Time outdoors was estimated by adding the average time spent outdoors at the respondents' pool and yard, others' pool and yard, and outside other locations such as sidewalk, street, neighborhood, parking lot, service station/gas station, school grounds, park/golf course, pool, river, lake, farm, etc. Table 16-15 presents data for the time spent in various types of vehicles (i.e., car, truck/van, bus), and in all vehicles combined. Table 16-16 presents data for the time children spent in various major activity categories (i.e., sleeping, napping, eating, attending school, outdoor recreation, active sports, exercise, and walking).

Table 16-17 through 16-19 provide data related to showering, bathing, and handwashing activities. Tables 16-20 and 16-21 provide data on monthly swimming (in a freshwater pool) frequency by the number of respondents and swimming duration, respectively. Table 16-22 provides data on the time children spent playing on dirt, sand/gravel, or grass, and Table 16-23 provides data on the number of minutes spent near excessive dust. Table 16-24 provides information on time spent in the presence of smokers. For this data set, the authors' original age categories were used because the methodology used to generate the data could not be reproduced.

The advantages of the NHAPS data set are that it is representative of the U.S. population and it has been adjusted to be balanced geographically, seasonally, and for day/time. Also, it is inclusive of all ages, genders, and races. A disadvantage of the study is that for the standard age categories, the number of respondents is small for the "doers" of many activities. In addition, the durations exceeding 60, 120, and 181 minutes were not collected for some activities. Therefore, the actual time spent at the high end of the distribution for these activities could not be accurately estimated.

16.3.2 RELEVANT STUDIES

16.3.2.1 *Timmer et al., 1985 - How Children Use Time*

Timmer et al. (1985) conducted a study using the data obtained on children's time use from a 1981-1982 panel study. Data were obtained for 389 children between 3 and 17 years of age. Data were collected using a time diary and a standardized interview. The time diary involved children reporting their activities beginning at 12:00 a.m. the previous night, the duration and location of each activity, the presence of another individual, and whether they were performing other activities at the same time. The standardized interview was administered to the children to gather information about their psychological, intellectual (using reading comprehension tests), and emotional well-being; their hopes and goals; their family environment; and their attitudes and beliefs.

For preschool children, parents provided information about the child's previous day's activities. Children in first through third grades completed the time diary with their parents assistance and, in addition, completed reading tests. Children in fourth grade and above provided their own diary information and participated in the interview. Parents were asked to assess their children's socioemotional and intellectual development, and a survey form was sent to a teacher of each school-age child to evaluate their socioemotional and intellectual development. The activity descriptor codes used in this study were developed by Juster et al. (1983).

The mean time spent performing major activities on weekdays and weekends by age, sex, and type of day is presented in Table 16-25. On weekdays, children spend about 40 percent of their time sleeping, 20 percent in school, and 10 percent eating, and performing personal care activities (Timmer et al., 1985). The data in Table 16-25 indicate that girls spent more time than boys performing household work and personal care activities and less time playing sports. Also, the children spent most of their free time watching television.

Table 16-26 presents the mean time children spent during weekdays and weekends performing major activities by five different age groups. The significant effects of each variable (i.e., age and sex) are also shown. Older children spent more time performing household and market work, studying, and watching television and less time eating, sleeping, and playing. The authors estimated that, on average, boys spent 19.4 hours a week and girls spent 17.8 hours per week watching television.

U.S. EPA estimated the total time indoors and outdoors using the Timmer et al. (1985) data. Activities performed indoors were assumed to include household work, personal care, eating, sleeping, attending school, studying, attending church, watching television, and engaging in household conversations. The average times spent in these indoor activities and half the time spent in each activity which could have occurred indoors or outdoors (e.g., market work, sports, hobbies, art activities, playing, reading, and other passive leisure) were summed. Table 16-27 summarizes the results of this analysis by age group and time of the week.

A limitation associated with this study is that it was conducted in 1981. It is likely that activity patterns of children have changed from 1981 to the present. Thus, the application of these data to current exposure assessments may bias their results. Another limitation is that the data do not provide overall annual estimates of children's time use since data were collected only during the time of the year when children attended school and not during school vacations. An advantage of this survey is that diary recordings of activity patterns were kept and the data obtained were not based entirely on recall. Another advantage is that because parents assisted younger children with keeping their diaries and with interviews, any bias that may have been created by having younger children record their data should have been minimized.

16.3.2.2 *Robinson and Thomas, 1991 - Time Spent in Activities, Locations, and Microenvironments: A California-National Comparison*

Robinson and Thomas (1991) reviewed and compared data from the 1987-88 California Air Resources Board (CARB) time-activity study for California residents and from a similar 1985 national study, *Americans' Use of Time*, conducted at the University of Maryland. Both studies used the diary approach to collect data. Time- use patterns were collected for individuals aged 12 years and older. Telephone interviews based on the RDD procedure were conducted for 1,762 and 2,762 respondents for the CARB study and the national study, respectively. Of these respondents, 183 were children, ages 12 to17 years in the CARB study and 340 were children, ages 12 to 17 years, in the national study. Robinson and Thomas (1991) defined a set of 16 microenvironments based on the activity and location codes employed in the two studies. The mean durations of time spent in the 16 microenvironments by children, ages 12 to 17 years, are presented in Table 16-28. In both studies, children spent the majority of their time sleeping, and engaging in leisure and work/study-related activities.

The limitations associated with the Robinson and Thomas (1991) study are that the CARB survey was performed in California only and may not be representative of the U.S. population as a whole. In addition, the studies were conducted in the 1980s and activity patterns may have changed over time. Another limitation is that the data are based on short-term studies. Finally, the available data could not be re-analyzed to conform to the standardized age categories used in this handbook.

16.3.2.3 *Funk et al., 1998 - Quantifying the Distribution of Inhalation Exposure in Human Populations: Distribution of Time Spent by Adults, Adolescents, and Children at Home, at Work, and at School*

Funk et al. (1998) used the data from the CARB study to determine distributions of exposure time by tracking the time spent participating in daily at-home and at-school activities for male and female children and adolescents. CARB performed two studies from 1987 to 1990; the first was focused on adults (18 years and older) and adolescents (12-17 years old), and the second focused on children (6-11 years old). The targeted groups were noninstitutionalized English speaking Californians with telephones in their residences. Individuals were contacted by telephone and asked to account for every minute within the previous 24 hours, including the amount of time spent on an activity and the location of the activity. The surveys were conducted on different days of the week as well as different seasons of the year.

Using the location descriptors provided in the CARB study, Funk et al. (1998) categorized the activities into two groups, "at home" (any activity at principal residence) and "away." Each activity was assigned to one of three inhalation rate levels (low, moderate, or high) based on the level of exertion expected from the activity. Ambiguous activities were assigned to moderate inhalation rate levels. Among the adolescents and children studied, means were determined for the aggregate age groups, as shown in Table 16-29.

Funk et al. (1998) used several statistical methods, such as Chi-square, Kolmogorov-Smirnov, and Anderson-Darling, to determine whether the time spent in an activity group had a known distribution. Most of the activities performed by children were assigned a low or moderate inhalation rate rate (Table 16-30).

The aggregate time periods spent at home in each activity are shown in Table 16-31. Aggregate time spent at home performing different activities was compared between genders. There were no significant differences between adolescent males and females in any of the activity groups (Table 16-32). In children, ages 6-11 years, differences between gender and age were observed at the low inhalation rate levels. There were significant differences between two age groups (6-8 years, and 9-11 years) and gender at the moderate inhalation rate level (Table 16-33).

A limitation of this study was that large proportions of the respondents in the study did not participate in high-inhalation rate-level activities. The Funk et al. (1998) study was based on data from one geographic location, collected more that a decade ago. Thus, it may not be representative of current activities among the general population of the U.S.

16.3.2.4 *U.S. EPA, 2000 - Consolidated Human Activity Database (CHAD)*

The Consolidated Human Activity Database (CHAD), available online at http://www.epa.gov/chadnet1/, was developed by the U.S. EPA's National Exposure Research Laboratory (NERL) to provide access to existing human activity data for use in exposure and risk assessment efforts. Data from twelve activity pattern studies conducted at the city, state, and national levels are included in CHAD. CHAD contains both the original raw data from each study and data modified based on predefined format requirements. Modifications made to data included: recoding of variables to fit into them a common activity/location code system, and standardization of time diaries to an exact 24-hour length. Detailed information on the coding system and the studies included in CHAD is available in the CHAD User Manual, available at http://oaspub.epa.gov/chad/CHAD_Datafiles$.startup#Manual, and in McCurdy et al. (2000).

A total of 144 activity codes and 115 location codes were used in CHAD (McCurdy et al., 2000). Although some participants in a study conducted multiple activities, many activities were only conducted within a few studies. The same is true for activity locations. The selection of exposure estimates for a particular activity or particular location should be based on study parameters that closely relate to the exposure scenario being assessed. The maximum amount of time, on average, within a majority of the studies was sleeping or taking a nap, while the maximum amount of time spent at a particular location was at home or at work, depending on the study.

Many of the limitations of CHAD data arise from the incorporation of multiple studies into the time diary functions specified in CHAD. Activities and locations were coded similarly to the NHAPS study; studies with differing coding systems were modified to fit the NHAPS codes. In some cases start times and end times from a study had to be adjusted to fit a 24-hour period. Respondents were not randomly distributed in CHAD. For example, some cities or states were over sampled because entire studies were carried out in those places. Other studies excluded large groups of people such as smokers, or non-English speakers, or people without telephones. Many surveys were age-restricted, or they preferentially sampled certain target groups. As a result, users are cautioned against using random individuals in CHAD to represent the U.S. population as a whole (Glenn et al., 2000).

16.3.2.5 *Hubal et al., 2000 - Children's Exposure Assessment: A Review of Factors Influencing Children's Exposure and the Date Available to Characterize and Assess that Exposure*

Hubal et al. (2000) reviewed available data from CHAD, including activity pattern data, to characterize and assess environmental exposures to children. CHAD contains 3,009 person-days of macroactivity data for 2,640 children less than 12 years of age (Hubal et al., 2000) (Table 16-34). The number of hours these children spent in various microenvironments are shown in Table 16-35 and the time they spent in various activities indoors at home is shown in Table 16-36.

Hubal et al. (2000) noted that CHAD contains approximately "140 activity codes and 110 location codes, but the data generally are not available for all activity locations for any single respondent. In fact, not all of the codes were used for most of the studies. Even though many codes are used in macroactivity studies, many of the activity codes do not adequately capture the richness of what children actually do. They are much too broadly defined and ignore many child-oriented behaviors. Thus, there is a need for more and better-focused research into children's activities."

U.S. EPA updated the analysis performed by Hubal et al. (2000) using CHAD data downloaded in 2000, sorted according to the age groups recommended in *Guidance for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005). The results are shown in Tables 16-37 and 16-38. In this analysis, individual study participants within CHAD whose behavior patterns were measured over multiple days were treated as multiple one-day activity patterns. This is a potential source of error or bias in the results because a single individual may contribute multiple data sets to the aggregate population being studied.

16.3.2.6 *Wong et al., 2000 - Adult Proxy Responses to a Survey of Children's Dermal Soil Contact Activities*

Wong et al. (2000) conducted telephone surveys to gather information on children's activity patterns as related to dermal contact with soil during outdoor play on bare dirt or mixed grass and dirt surfaces. This study, the second Soil Contact Survey (SCS-II), was a follow-up to the initial Soil Contact Survey (SCS-I), conducted in 1996, that primarily focused on assessing adult behavior related to dermal contact with soil and dust (Garlock et al., 1999). As part of SCS-I, information was gathered on the behavior of children under the age of 18 years, however, the questions were limited to clothing choices and the length of time between soil contact and hand washing. Questions were posed for SCS-II to further define children's outdoor activities and hand washing and bathing frequency. For both soil contact surveys households were randomly phoned in order to obtain nationally representative results. The adult respondents were questioned as surrogates for one randomly chosen child under the age of 18 residing within the household.

In the SCS-II, of 680 total adult respondents with a child in their household, 500 (73.5 percent) reported that their child played outdoors on bare dirt or mixed grass and dirt surfaces (identified as "players"). Those children that reportedly did not play outdoors ("non-players") were typically very young ($\leq$1 year) or relatively older ($\geq$14 years). Of the 500 children that played outdoors, 497 played outdoors in warm weather months (April through October) and 390 were reported to play outdoors during cold weather months (November through March). These results are presented in Table 16-39. The frequency (days/week), duration (hours/day), and total hours per week spent playing outdoors was determined for those children identified as "players" (Table 16-40). The responses indicated that children spent a relatively high percentage of time outdoors during the warmer months, and a lesser amount of time outdoors in cold weather. The median play frequency reported was 7 days/week in warm weather and 3 days/week in cold weather. Median play duration was 3 hours/day in warm weather and 1 hour/day during cold weather months.

Adult respondents were then questioned as to how many times per day their child washed his/her hands and how many times the child bathed or showered per week, during both warm and cold weather months. This information provided an estimate of the time between skin contact with soil and removal of soil by washing (i.e., exposure time). Hand washing and bathing frequencies for child players are reported in Table 16-41. Based on these results, hand washing occurred a median of 4 times per day during both warm and cold weather months. The median frequency for baths and showers was estimated to be 7 times per week for both warm and cold weather.

Based on reported household incomes, the respondents sampled in SCS-II tended to have higher incomes than that of the general population. This may be explained by the fact that phone surveys cannot sample households without telephones. Additional uncertainty or error in the study results may have occurred as a result of the use of surrogate respondents. Adult respondents were questioned regarding child activities that may have occurred in prior seasons, introducing the chance of recall error. In some instances, a respondent did not know the answer to a question or refused to answer. Table 16-42 compares mean play duration data from SCS-II to similar activities identified in NHAPS (U.S. EPA, 1996). Table 16-43 compares the number of times per day a child washed his or her hands, based on data from SCS-II and NHAPS. As indicated in Tables 16-42 and 16-43, where comparison is possible, NHAPS and SCS-II results showed similarities in observed behaviors.

16.3.2.7 *Graham and McCurdy, 2004 - Developing Meaningful Cohorts for Human Exposure Models*

Graham and McCurdy (2004) used a statistical model [general linear model and analysis of variance (GLM/ANOVA)] to assess the significance of various factors in explaining variation in time spent outdoors, indoors and in motor vehicles. These factors, which are commonly used in developing cohorts for exposure modeling, included age, gender, weather, ethnicity, day type, and precipitation. Activity pattern data from CHAD, containing 30 or more records per day, were used in the analysis (Graham and McCurdy, 2004).

Data on time spent outdoors for people who spent >0 time outdoors (i.e., doers) are presented in Table 16-44. Graham and McCurdy (2004) found that all the factors evaluated were significant ($p<0.001$) in explaining differences in time spent outdoors (Graham and McCurdy, 2004). An evaluation of gender differences in time spent outdoors by age cohorts was also conducted. Table 16-45 presents descriptive statistics and the results of the two-sample Kolmogorov-Smirnov (KS) test for this evaluation. As shown in Table 16-45, there were statistically significant gender differences in time spent outdoors starting with the 6 to 10 year old age category. In addition, Graham and McCurdy (2004) evaluated the effect of physical activity and concluded that this was the most important factor in explaining time spent outdoors. For time spent indoors (Table 16-46), there were statistically significant effects for all the factors evaluated, with gender, weather, and day type being the most important variables. Regarding time spent in motor vehicles (Table 16-47), precipitation was the only factor found to have no significant effects (Graham and McCurdy, 2004).

Based on the results of these analysis, Graham and McCurdy (2004) noted that "besides age and gender, other important attributes for defining cohorts are the physical activity level of individuals, weather factors such as daily maximum temperature in combination with months of the year, and combined weekday/weekend with employment status." The authors also noted that even though the factors evaluated were found to be statistically significant in explaining differences in time spent outdoors, indoors, and in motor vehicles, "parameters such as lifestyle and life stages that are absent from CHAD might have reduced the amount of unexplained variance." The authors recommended that, in defining cohorts for exposure modeling, age and gender should be used as ''first-order'' attributes, followed by physical activity level, daily maximum temperature, and day type (weekend/weekday or day-of-the-week/working status) (Graham and McCurdy, 2004).

16.3.2.8 *Vandewater et al., 2004 - Linking Obesity and Activity Level with Children's Television and Video Game Use*

Vandewater et al. (2004) evaluated children's media use and participation in active and sedentary activities using 24-hour time-use diaries collected in 1997, as part of the Child Development Supplement (CDS) to the Panel Study of Income Dynamics (PSID). The PSID is a ongoing, longitudinal study of U.S. individuals and their families conducted by the Survey Research Center of the University of Michigan. In 1997, PSID families with children younger than 12 years of age completed the CDS and reported all activities performed by the children on one randomly selected weekday and one randomly selected weekend day. Since minorities, low income families, and less educated individuals were oversampled in the PSID, sample weights were applied to the data (Vandewater et al., 2004). More information on the CDS can be found on-line at http://psidonline.isr.umich.edu/CDS/.

Using time diary data from 2,831 children participating in the CDS, Vandewater et al., (2004) estimated the time in minutes over the two-day study period (i.e., sum of time spent on one weekday and one weekend day) that children spent watching television, playing games on video games consoles or computers, reading, and using computers for other purposes besides playing games. In addition, the time spent participating in highly active (i.e., playing sports), moderately active (i.e., fishing, boating, camping, taking music lessons, and singing), and sedentary (i.e., using the phone, doing puzzles, playing board games, and relaxing) activities was determined. Table 16-48 presents the means and standard deviations for the time spent in the selected activities by age and gender.

A limitation of this study is that the survey was not designed for exposure assessment purposes. Therefore, the time use data set may be biased. However, the survey provides a database of current information on various human activities. This information can be used to assess various exposure pathways and scenarios associated with these activities.

16.3.2.9 *Juster et al. (2004) - Changing Times of American Youth: 1983-2003*

Juster et al. (2004) evaluated changes in time use patterns of children by comparing data collected in a 1981-1982 pilot study of children ages 6 to 17 to data from the 2002-2003 Child Development Supplement (CDS) to the Panel Study of Income Dynamics (PSID). The 1981-1982 pilot study is the same study described in Timmer et al. (1985). The 2002-2003 CDS gathered 24-hour time diary data on 2,908 children ages 6 to 17; as was done in the 1997 CDS, information was collected on one randomly selected weekday and one randomly selected weekend day (Juster et al., 2004).

Tables 16-49 and 16-50 present the mean time children spent (in minutes/day) performing major activities on weekdays and weekend days, respectively, for the years 1981-82 and 2002-2003. Table 16-51 shows the weekly time spent in these activities for the years 1981-82 and 2002-2003. Juster et al. (2004) noted that the time spent in school and studying increased while time spent in active sports and outdoors activities decreased during the period studied.

16.3.2.10 *U.S. Department of Labor, 2007 - American Time Use Survey, 2006 Results*

The American Time Use Study (ATUS) has been conducted annually since 2003 by the U.S. Department of Labor's Bureau of Labor Statistics (U.S. DL, 2007). The purpose of the study is to collect "data on what activities people do during the day and how much time they spend doing them." In 2006, the survey focused on "the time Americans worked, did household activities, cared for household children, participated in educational activities, and engaged in leisure and sports activities." Approximately 13,000 individuals, 15 years of age and older, were interviewed during 2006. Participants were randomly selected and interviewed using the CATI method and were asked to recall their activities on the day before the interview. Data were collected for all days of the week, including weekends (i.e., 10 percent of the individuals were interviewed about their activities on one of the five weekdays, and 25 percent of the individuals were interviewed about their activities on one of the two weekend days). Demographic information, including age, gender, race/ethnicity, marital status, and educational level were also collected, and sample weights were applied to records to "reduce bias in the estimates due to differences in sampling and response rates across subpopulations and days of the week." Data were collected for 17 major activities, that were subsequently composited into 12 categories for publication of the results. Estimates of time use in these 12 major categories are presented in Table 16-52. These data represent the average hours per day spent by male, female, and all children ages 15 to 19 years in the various categories. Table 16-52 also provides a more detailed breakdown of the Leisure and Sports category for all children, ages 15 to 19 years old.

16.3.2.11 *Nader et al. 2008 - Moderate-to-Vigorous Physical Activity from Ages 9 to 15 years*

Nader et al. (2008) conducted a longitudinal study of 1,032 children from ages 9 to 15 years. The purpose of the study was to determine the amount of time children 9 to 15 years of age engaged in moderate-to-vigorous activities (MVPA) and compare results with the recommendations issued by the U.S. Department of Health and Human Services and the U.S. Department of Agriculture of a minimum of 60 minutes per day. Children's activity levels were recorded for four to seven days using an accelerometer. The study participants included 517 boys and 515 girls. The study found that at age 9 children engaged in 3 hours of MVPA per day. By age 15, the amount of time engaged in MVPA was dropped to 49 minutes/day on weekdays and 35 minutes per day on weekends. Boys spent 18 more minutes/day of MVPA than girls on weekdays and 13 more minutes/day on weekends. Estimates of the mean time spent in moderate-to-vigorous activities by various age groups are presented in Table 16-53. The study did not provide information about the amount of time spent at specific activities.

16.4 REFERENCES FOR CHAPTER 16

Chance, W.G.; Harmsen, E. (1998) Children are different: environmental contaminants and children's health. Can J Public Health 89(Supplement):59-513.

Funk, L.; Sedman, R.; Beals, J.A.J.; Fountain, R. (1998) Quantifying the distribution of inhalation exposure in human populations: distributions of time spent by adults, adolescents, and children at home, at work, and at school. Risk Anal 18(1):47-56.

Garlock, T.J.; Shirai, J.H.; Kissel, J.C. (1999) Adult responses to a survey of soil contact related behaviors. J Expo Anal Environ Epidemiol 9:134-142.

Glenn, G.; Stallings, C.; Tippett, J.; Smith, L. (2000) CHAD's user guide: Extracting human activity information from CHAD on the PC. Prepared for the U.S. EPA National Exposure Research Laboratory by ManTech Environmental Technology, Inc.

Graham, S.E.; McCurdy, T. (2004) Developing meaningful cohorts for human exposure models. J Expo Anal Environ Epidemiol 14:23-43.

Hubal, E.A.; Sheldon, L.S.; Burke, J.M.; McCurdy, T.R.; Berry, M.R.; Rigas, M.L.; Zartarian, V.G.; Freeman, N.G. (2000) Children's exposure assessment: a review of factors influencing children's exposure and the data available to characterize and assess that exposure. Environ Health Persp 108:475-485.

Johnson, T. (1989) Human Activity Patterns in Cincinnati, Ohio. Palo Alto, CA: Electric Power Research Institute.

Juster, F.T.; Hill, M.S.; Stafford, F.P.; Parsons, J.E. (1983) Study description. 1975-1981 time use longitudinal panel study. Ann Arbor, MI: The University of Michigan, Survey Research Center, Institute for Social Research.

Juster, T.; Ono, H.; Stafford, F. (2004) Changing times of American youth: 1981-2003. Institute for Social Research, University of Michigan, Ann Arbor, Michigan. Available on-line at http://www.umich.edu/news/Releases/2004/Nov04/teen_time_report.pdf

McCurdy, T.; Glen, G.; Smith, L.; Lakkadi, Y. (2000) The National Exposure Research Laboratory's Consolidated Human Database. J Expo Anal Environ Epidemiol 10:566-578.

Nader , P.R.; Bradley, R.H.; Houts, R.M.; McRitchie, S.L.; O'Brien, M. (2008) Moderate-to-vigorous physical activity from ages 9 to 15 years. JAMA, 300(3):295-305.

Robinson, J.P.; Thomas, J. (1991) Time spent in activities, locations, and microenvironments: a California-National Comparison Project report. Las Vegas, NV: U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory.

Timmer, S.G.; Eccles, J.; O'Brien, K. (1985) How children use time. In: Juster, F.T.; Stafford, F.P.; eds. Time, goods, and well-being. Ann Arbor, MI: University of Michigan, Survey Research Center, Institute for Social Research, pp. 353-380.

U.S. Department of Health and Human Services and U.S. Department of Agriculture. (2005) Dietary Guidelines for Americans, 2005. 6th edition, Washington, DC, Government Printing Office. Available online at http://www.health.gov/dietaryguidelines/dga2005/document/pdf/DGA2005.pdf U.S.

Department of Labor (U.S. DL), Bureau of Labor Statistics. (2007) American Time Use Survey - 2006 Results. News release issued at http://www.bls.gov/tus on June 28, 2007.

U.S. EPA (1996) Descriptive statistics tables from a detailed analysis of the National Human Activity Pattern Survey (NHAPS) data. Washington, DC: Office of Research and Development. EPA/600/R-96/148.

U.S. EPA (1997) Exposure Factors Handbook. Washington, DC: National Center for Environmental Assessment, Office of Research and Development. EPA/600/P-95/002Fa,b,c.

U.S. EPA (2000) Consolidated Human Activity Database (CHAD). U.S. EPA/NERL. Available online at http://www.epa.gov/chadnet1/

U.S. EPA. (2005) Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants. U.S. Environmental Protection Agency, Washington, D.C., EPA/630/P-03/003F.

Vandewater, E.A.; Shim, M.; Caplovitz, A.G. (2004) Linking obesity and activity level with children's television and video game use. J Adolesc 27:71-85.

Wiley, J.A.; Robinson, J.P.; Cheng, Y.; Piazza, T.; Stork, L.; Plasden, K. (1991) Study of children's activity patterns. California Environmental Protection Agency, Air Resources Board Research Division. Sacramento, CA.

Wong, E.Y.; Shirai, J.H; Garlock, T.J.; Kissel, J.C. (2000) Adult proxy responses to a survey of children's dermal soil contact activities. J Expo Anal Environ Epidemiol 10:509-517.

Table 16-3. Mean Time (minutes/day) Children Under 12 Years of Age Spent in Ten Major Activity Categories, for All Respondents and Doers

Activity Category	Mean Duration (All)	% Doers[a]	Mean Duration (Doers)[a]	Median Duration (Doers)[a]	Maximum Duration (Doers)[a]	Detailed Activity with Highest Average Minutes
Work-related[b]	10	25	39	30	405	Eating at Work/School/Daycare
Household[c]	53	86	61	40	602	Travel to Household
Childcare[d]	<1	<1	83	30	290	Other Child Care
Goods/Services [e]	21	26	81	60	450	Errands
Personal Needs and Care[f]	794	100	794	770	1,440	Night Sleep
Education[g]	110	35	316	335	790	School Classes
Organizational Activities[h]	4	4	111	105	435	Attend Meetings
Entertain/Social [i]	15	17	87	60	490	Visiting with Others
Recreation [j]	239	92	260	240	835	Games
Communication/Passive Leisure [k]	192	93	205	180	898	TV Use
Don't know/Not coded	2	4	41	15	600	-
All Activities	1,440	-	-	-	-	-

a Doers indicate the respondents who reported participating in each activity category.
b Includes: travel to and during work/school; children's paid work; eating at work/school/daycare; and accompanying or watching adult at work.
c Includes: food preparation; meal cleanup; cleaning; clothes care; car and home repair/painting; building a fire; plant and pet care; and traveling to household.
d Includes: baby and child care; helping/teaching children; talking and reading; playing while caring for children; medical care; travel related to child care; and other care.
e Includes: shopping; medical appointments; obtaining personal care services (e.g., haircuts), government and financial services, and repairs; travel related to goods an services; and errands.
f Includes: bathing, showering, and going to bathroom; medical care; help and care; meals; night sleep and daytime naps, dressing and grooming; and travel for personal care.
g Includes: student and other classes; daycare; homework; library; and travel for education.
h Includes: attending meetings and associated travel.
i Includes: sports events; eating and amusements; movies and theater; visiting museums, zoos, art galleries, etc.; visiting others; parties and other social events; and travel to social activities.
j Includes: active sports; leisure; hobbies; crafts; art; music/drama/dance; games; playing; and travel to leisure activities.
k Includes: radio and television use; reading; conversation; paperwork; other passive leisure; and travel to passive leisure activities.

Source: Wiley et al., 1991.

Table 16-4. Mean Time (minutes/day) Children Under 12 Years of Age Spent in Ten Major Activity Categories, by Age and Gender

Activity Category[a]	Boys									
	Birth to 1 Month	1 to <3 Months	3 to <6 Months	6 to <12 Months	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 Years[b]	Birth to 11 Years
Work-related	0	0	0	1	8	9	10	12	13	11
Household	12	30	49	28	35	44	44	61	63	58
Childcare	0	0	0	0	0	0	0	0	3	2
Goods/Services	0	16	14	28	27	14	28	22	24	26
Personal Needs and Care	910	1,143	937	919	903	889	802	726	707	802
Education	180[c]	0	75	70	33	69	67	120	120	100
Organizational Activities	0	0	0	0	7	0	5	11	16	6
Entertainment/Social	0	0	0	0	8	6	15	15	43	18
Recreation	0	0	26	104	314	304	294	265	227	228
Communication/Passive Leisure	338	250	339	292	106	103	175	208	226	226
Sample Sizes (Unweighted)	3	7	15	31	54	62	151	239	62	624

Activity Category[a]	Girls									
	Birth to 1 Month	1 to <3 Months	3 to <6 Months	6 to <12 Months	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 Years[b]	Birth to 11 Years
Work-related	0	0	5	1	3	22	9	10	19	11
Household	28	29	23	25	45	65	49	67	78	58
Childcare	0	0	0	0	0	0	0	2	9	2
Goods/Services	0	18	14	24	24	34	31	26	15	26
Personal Needs and Care	1,123	1,115	971	922	894	858	820	747	703	802
Education	0	0	110	94	25	40	81	134	151	100
Organizational Activities	0	0	0	0	0	2	3	8	13	6
Entertainment/Social	0	0	0	1	13	6	16	17	52	18
Recreation	0	0	10	147	256	305	270	224	175	228
Communication/Passive Leisure	290	278	308	226	179	107	161	203	225	189
Sample Sizes (Unweighted)	4	10	11	23	43	50	151	225	59	576

[a] See Table 16-3 for a description of what is included in each activity category.

[b] The source data end at 11 years of age, so the 11 to <16 year category is truncated and the 16 to <21 year category is not included.

[c] The data for this age group and category are two values of zero and one of 540.

Note: Column totals may not sum to 1,440 due to rounding.

Source: U.S. EPA analysis of source data used by Wiley et al., 1991.

Table 16-5. Mean Time (minutes/day) Children Under 12 Years of Age Spent in Ten Major Activity Categories, Grouped by Seasons and Regions

Activity Category[a]	Season					Region of California			
	Winter (Jan-Mar)	Spring (Apr-June)	Summer (July-Sept)	Fall (Oct-Dec)	All Seasons	Southern Coast	Bay Area	Rest of State	All Regions
Work-related	10	10	6	13	10	10	10	8	10
Household	47	58	53	52	53	45	62	55	53
Childcare	<1	1	<1	<1	<1	<1	<1	1	<1
Goods/Services	19	17	26	23	21	20	21	23	21
Personal Needs and Care	799	774	815	789	794	799	785	794	794
Education	124	137	49	131	110	109	115	109	110
Organizational Activities	3	5	5	3	4	2	6	6	4
Entertainment/Social	14	12	12	22	15	17	10	16	15
Recreation	221	243	282	211	239	230	241	249	239
Communication/ Passive Leisure	203	180	189	195	192	206	190	175	192
Don't know/Not coded	<1	2	3	<1	2	1	1	3	2
All Activities[b]	1,442	1,439	1,441	1,441	1,441	1,440	1,442	1,439	1,441
Sample Sizes (Unweighted)	318	204	407	271	1,200	224	263	713	1,200

[a] See Table 16-3 for a description of what is included in each activity category.
[b] The column totals may not be equal to 1,440 due to rounding.

Source: Wiley et al., 1991.

Table 16-6. Time (minutes/day) Children Under 12 Years of Age Spent in Six Major Location Categories, for All Respondents and Doers

Location Category	Mean Duration (All)	% Doers[a]	Mean Duration (Doers)[a]	Median Duration (Doers)[a]	Maximum Duration (Doers)[a]	Detailed Location with Highest Average Time
Home	1,078	99	1,086	1,110	1,440	Home - Bedroom
School/Childcare	109	33	330	325	1,260	School or Daycare Facility
Friend's/Other's House	80	32	251	144	1,440	Friend's/Other's House - Bedroom
Stores, Restaurants, Shopping Places	24	35	69	50	475	Shopping Mall
In-transit	69	83	83	60	1,111	Traveling in Car
Other Locations	79	57	139	105	1,440	Park, Playground
Don't Know/Not Coded	<1	1	37	30	90	-
All Locations	1,440	-	-	-	-	-

[a] Doers indicate the respondents who reported participating in each activity category.

Source: Wiley et al., 1991.

Table 16-7. Mean Time (minutes/day) Children Under 12 Years of Age Spent in Six Location Categories, Grouped by Age and Gender

Location Category	Boys									
	Birth to 1 Month	1 to <3 Months	3 to <6 Months	6 to <12 Months	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 Years[a]	Birth to 11 Years
Home	938	1,295	1,164	1,189	1,177	1,161	1,102	1,016	1,010	1,079
School/Childcare	0	1	26	53	73	86	79	110	99	89
Friend's/Other's House	418	40	127	63	54	69	89	110	111	95
Stores, Restaurants, Shopping Places	0	14	21	36	29	22	24	23	20	24
In-transit	77	51	69	63	56	61	67	64	72	65
Other Locations	7	40	33	36	52	41	78	116	127	88
Don't Know/Not Coded	0	0	0	0	0	0	0	0	0	0
Sample Sizes (Unweighted)	3	7	15	31	54	62	151	239	62	624
Location Category	**Girls**									
	Birth to 1 Month	1 to <3 Months	3 to <6 Months	6 to <12 Months	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 Years[a]	Birth to 11 Years
Home	1,285	1,341	1,151	1,192	1,162	1,065	1,118	1,012	862	1,058
School/Childcare	0	0	109	99	56	61	78	116	128	95
Friend's/Other's House	0	12	44	32	109	103	66	119	193	103
Stores, Restaurants, Shopping Places	0	13	20	15	21	40	32	25	24	27
In-transit	73	56	42	58	55	86	78	70	95	74
Other Locations	83	19	73	43	38	86	67	97	137	84
Don't Know/Not Coded	0	0	0	0	0	0	1	0	0	0
Sample Sizes (Unweighted)	4	10	11	23	43	50	151	225	59	576

[a] The source data end at 11 years of age, so the 11 to <16 year category is truncated and the 16 to <21 year category is not included.

Note: Column totals may not sum to 1,440 due to rounding.

Source: U.S. EPA analysis of source data used by Wiley et al., 1991.

Table 16-8. Mean Time (minutes/day) Children Under 12 Years of Age Spent in Six Location Categories, Grouped by Season and Region

Location Category	Season					Region of California			
	Winter (Jan-Mar)	Spring (Apr-June)	Summer (July-Sept)	Fall (Oct-Dec)	All Seasons	Southern Coast	Bay Area	Rest of State	All Regions
Home	1,091	1,042	1,097	1,081	1,078	1,078	1,078	1,078	1,078
School/Childcare	119	141	52	124	109	113	103	108	109
Friend's/Other's House	69	75	108	69	80	73	86	86	80
Stores, Restaurants, Shopping Places	22	21	30	24	24	26	23	23	24
In transit	75	75	60	65	69	71	73	63	69
Other Locations	63	85	93	76	79	79	76	81	79
Don't Know/Not Coded	<1	<1	<1	<1	<1	<1	<1	<1	<1
All Locations[a]	1,439	1,439	1,440	1,439	1,439	1,439	1,440	1,440	1,439
Sample Sizes (Unweighted N's)	318	204	407	271	1,200	224	263	713	1,200

[a] The column totals may not sum to 1,440 due to rounding.

Source: Wiley et al., 1991.

Table 16-9. Mean Time (minutes/day) Children Under 12 Years of Age Spent in Proximity to Two Potential Sources of Exposure, Grouped by All Respondents, Age, and Gender

Potential Exposures	Boys									
	Birth to 1Month	1 to <3 Months	3 to <6 Months	6 to <12 Months	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 Years[a]	Birth to 11 Years
Gasoline Fumes	3	9	0	2	1	4	2	2	7	3
Gas Oven Fumes	0	0	2	2	1	3	0	1	0	1
Sample Sizes (Unweighted N's)	3	7	15	31	54	62	151	239	62	624
Potential Exposures	Girls									
	Birth to 1Month	1 to <3 Months	3 to <6 Months	6 to <12 Months	1 to <2 Years	2 to <3 Years	3 to <6 Years	6 to <11 Years	11 Years[a]	Birth to 11 Years
Gasoline Fumes	0	3	0	3	1	2	1	2	1	2
Gas Oven Fumes	0	0	0	0	0	3	2	1	0	1
Sample Sizes (Unweighted N's)	4	10	11	23	43	50	151	225	59	576

[a] The source data end at 11 years of age, so the 11 to <16 year category is truncated and the 16 to <21 year category is not included.

Source: U.S. EPA analysis of source data used by Wiley et al., 1991.

Table 16-10. Mean Time (minutes/day) Children Under 12 Years of Age Spent Indoors and Outdoors, Grouped by Age and Gender

Age Group	Boys			Girls		
	N	Indoors[a]	Outdoors[b]	N	Indoors[a]	Outdoors[b]
Birth to <1 Month	3	1,440	0	4	1,440	0
1 to <3 Months	7	1,432	8	10	1,431	9
3 to <6 Months	15	1,407	33	11	1,421	19
6 to <12 Months	31	1,322	118	23	1,280	160
1 to <2 Years	54	1,101	339	43	1,164	276
2 to <3 Years	62	1,121	319	50	1,102	338
3 to <6 Years	151	1,117	323	151	1,140	300
6 to <11 Years	239	1,145	295	225	1,183	255
11 Years[c]	62	1,166	274	59	1,215	225
All Ages	624	1,181	258	576	1,181	258

[a] Time indoors was estimating by adding the average times spent performing indoor activities (household work, child care, personal needs and care, education, and communication/passive leisure) and half the time spent in each activity which could have occurred either indoors or outdoors (i.e., work-related, goods/services, organizational activities, entertainment/social, don't know/not coded).

[b] Time outdoors was estimated by adding the average time spent in recreation activities and half the time spent in each activity which could have occurred either indoors or outdoors (i.e., work-related, goods/services, organizational activities, entertainment/social, don't know/not coded).

[c] The source data end at 11 years of age, so the 11 to <16 year category is truncated and the 16 to <21 year category is not included.

N = Sample size.

Note: Indoor and outdoor minutes/day may not sum to 1,440 minutes/day due to rounding.

Source: U.S. EPA analysis of source data used by Wiley et al., 1991.

Table 16-11. Time Spent (minutes/day) in Various Rooms at Home and in All Rooms Combined
Whole Population and Doers Only

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Kitchen - Whole Population															
Birth to <1	63	36	0	0	0	0	0	0	10	70	109	125	134	158	195
1 to <2	118	56	0	0	0	0	0	0	40	90	132	195	232	242	392
2 to <3	118	48	0	0	0	0	0	0	30	75	120	146	173	188	215
3 to <6	357	47	0	0	0	0	0	0	30	75	105	150	180	222	362
6 to <11	497	42	0	0	0	0	0	0	30	60	105	135	150	196	690
11 to <16	466	37	0	0	0	0	0	0	24	55	90	130	180	249	450
16 to <21	481	34	0	0	0	0	0	0	15	50	90	130	170	195	545
Kitchen - DOERS ONLY															
Birth to <1	33	69	10	10	10	13	15	30	70	90	124	133	157	176	195
1 to <4	76	87	10	10	13	19	30	45	70	110	173	214	240	281	392
2 to <3	80	70	10	10	11	15	15	30	60	105	136	155	184	195	215
3 to <6	252	67	2	5	10	15	15	30	60	90	133	165	210	232	362
6 to <11	342	61	1	2	5	10	15	30	50	79	120	145	172	229	690
11 to <16	323	54	1	2	4	5	10	20	40	65	114	150	218	281	450
16 to <21	305	54	1	2	3	5	10	20	35	65	120	159	194	209	545
Living Room/Family Room/Den - Whole Population															
Birth to <1	63	279	0	0	0	0	0	90	210	420	666	724	788	938	1,180
1 to <2	118	172	0	0	0	0	0	25	120	279	410	533	616	652	810
2 to <3	118	173	0	0	0	0	0	56	138	239	346	499	599	680	1,125
3 to <6	357	164	0	0	0	0	0	45	122	240	376	476	680	742	900
6 to <11	497	137	0	0	0	0	0	30	95	210	322	420	547	612	695
11 to <16	466	170	0	0	0	0	0	36	120	240	395	570	687	774	1,305
16 to <21	481	157	0	0	0	0	0	0	120	240	370	501	690	819	1,080
Living Room/Family Room/Den - DOERS ONLY															
Birth to <1	54	326	25	28	31	57	90	136	268	450	686	744	789	973	1,180
1 to <2	93	219	10	15	19	25	60	90	180	310	444	540	642	667	810
2 to <3	105	195	1	5	10	22	34	90	150	255	377	527	603	691	1,125
3 to <6	290	202	5	8	19	30	50	90	153	270	415	498	705	778	900
6 to <11	403	169	5	10	10	20	30	60	130	240	349	449	579	655	695
11 to <16	380	209	2	10	16	30	45	85	165	275	436	594	705	776	1,305
16 to <21	352	214	5	10	15	24	40	85	165	285	440	547	720	909	1,080

Table 16-11. Time Spent (minutes/day) in Various Rooms at Home and in All Rooms Combined
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Dining Room - Whole Population															
Birth to <1	63	9	0	0	0	0	0	0	0	0	30	70	86	96	105
1 to <2	118	19	0	0	0	0	0	0	0	17	60	90	176	260	315
2 to <3	118	19	0	0	0	0	0	0	0	30	80	105	118	146	150
3 to <6	357	17	0	0	0	0	0	0	0	10	60	96	133	150	300
6 to <11	497	13	0	0	0	0	0	0	0	5	57	70	120	135	225
11 to <16	466	11	0	0	0	0	0	0	0	0	33	65	119	164	390
16 to <21	481	7	0	0	0	0	0	0	0	0	30	45	90	112	330
Dining Room - DOERS ONLY															
Birth to <1	9	60	15	-	-	-	-	-	-	-	-	-	-	-	105
1 to <2	32	72	10	12	13	16	30	34	53	66	110	237	287	301	315
2 to <3	34	65	15	15	15	18	29	30	60	90	105	134	150	150	150
3 to <6	93	65	10	10	10	15	16	30	55	85	120	150	209	286	300
6 to <11	126	53	5	5	5	6	15	30	45	60	98	135	150	196	225
11 to <16	90	59	5	5	5	10	15	30	38	69	122	166	202	283	390
16 to <21	67	50	5	5	7	15	15	20	35	60	90	124	135	201	330
Bathroom - Whole Population															
Birth to <1	63	16	0	0	0	0	0	0	0	30	40	59	81	87	90
1 to <2	118	26	0	0	0	0	0	0	15	30	45	60	80	239	600
2 to <3	118	29	0	0	0	0	0	1	20	30	60	62	138	290	345
3 to <6	357	22	0	0	0	0	0	0	15	30	49	65	90	120	270
6 to <11	497	22	0	0	0	0	0	0	15	30	45	60	81	118	535
11 to <16	466	20	0	0	0	0	0	0	15	30	45	60	86	97	220
16 to <21	481	26	0	0	0	0	0	10	20	32	59	65	105	123	547
Bathroom - DOERS ONLY															
Birth to <1	31	32	5	7	8	10	15	18	30	40	60	78	87	89	90
1 to <2	77	39	6	6	8	10	15	15	30	30	57	60	176	349	600
2 to <3	88	38	2	3	5	12	15	15	30	45	60	70	208	319	345
3 to <6	240	33	1	1	2	5	11	15	30	38	60	75	112	123	270
6 to <11	356	31	1	2	3	5	9	15	25	35	50	60	90	180	535
11 to <16	335	29	1	2	2	5	6	12	20	35	50	64	90	100	220
16 to <21	392	31	1	2	5	5	10	15	25	40	60	72	111	135	547

Table 16-11. Time Spent (minutes/day) in Various Rooms at Home and in All Rooms Combined
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Bedroom - Whole Population															
Birth to <1	63	749	0	0	104	468	566	653	750	863	972	1,092	1,119	1,179	1,275
1 to <2	118	771	0	56	340	443	559	645	808	884	975	1,029	1,190	1,325	1,440
2 to <3	118	701	0	5	91	419	517	618	718	835	894	931	979	990	1,040
3 to <6	357	696	0	92	210	432	540	630	695	790	875	945	1,033	1,135	1,440
6 to <11	497	653	0	0	0	304	480	585	660	735	840	906	1,005	1,096	1,440
11 to <16	466	626	0	0	20	134	403	543	645	745	860	950	1,027	1,118	1,277
16 to <21	481	588	0	0	0	60	335	475	595	720	855	960	1,082	1,146	1,375
Bedroom - DOERS ONLY															
Birth to <1	61	774	435	453	470	495	590	660	750	865	975	1,095	1,119	1,182	1,275
1 to <2	116	785	330	362	384	450	570	656	810	885	975	1,030	1,191	1,328	1,440
2 to <3	116	713	30	215	266	484	520	620	720	836	896	931	981	990	1,040
3 to <6	353	704	165	210	268	464	540	630	695	790	875	945	1,034	1,137	1,440
6 to <11	486	667	120	183	261	439	513	599	660	735	843	912	1,005	1,100	1,440
11 to <16	457	638	15	55	115	179	430	550	646	750	860	951	1,029	1,122	1,277
16 to <21	463	611	15	34	100	273	395	480	600	725	859	974	1,090	1,147	1,375
Garage - Whole Population															
Birth to <1	63	1	0	0	0	0	0	0	0	0	0	0	0	34	89
1 to <2	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 to <3	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 to <6	357	1	0	0	0	0	0	0	0	0	0	0	0	7	165
6 to <11	497	0	0	0	0	0	0	0	0	0	0	0	0	0	120
11 to <16	466	2	0	0	0	0	0	0	0	0	0	0	19	51	240
16 to <21	481	0	0	0	0	0	0	0	0	0	0	0	0	0	60
Garage - DOERS ONLY															
Birth to <1	1	-	89	-	-	-	-	-	-	-	-	-	-	-	89
1 to <2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 to <3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 to <6	4	-	15	-	-	-	-	-	-	-	-	-	-	-	165
6 to <11	3	-	30	-	-	-	-	-	-	-	-	-	-	-	120
11 to <16	12	79	10	11	11	13	16	20	40	139	183	210	228	234	240
16 to <21	4	-	10	-	-	-	-	-	-	-	-	-	-	-	60

Table 16-11. Time Spent (minutes/day) in Various Rooms at Home and in All Rooms Combined
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles 1	2	5	10	25	50	75	90	95	98	99	Max
All Rooms Combined - Whole Population															
Birth to <1	63	1,091	0	391	631	742	786	943	1,105	1,258	1,440	1,440	1,440	1,440	1,440
1 to <2	118	1,047	0	63	377	651	705	915	1,050	1,239	1,440	1,440	1,440	1,440	1,440
2 to <3	118	971	0	66	342	640	727	852	995	1,120	1,232	1,295	1,354	1,369	1,440
3 to <6	357	951	0	284	402	621	716	810	930	1,110	1,245	1,354	1,440	1,440	1,440
6 to <11	497	873	0	0	0	420	631	758	880	1,005	1,175	1,275	1,374	1,440	1,440
11 to <16	466	876	0	0	117	370	575	751	871	1,043	1,215	1,314	1,440	1,440	1,440
16 to <21	481	819	0	0	165	375	510	645	810	995	1,170	1,287	1,419	1,440	1,440
All Rooms Combined- DOERS ONLY															
Birth to <1	62	1,108	630	633	658	751	821	956	1,108	1,259	1,440	1,440	1,440	1,440	1,440
1 to <2	116	1,065	370	399	495	674	715	923	1,050	1,243	1,440	1,440	1,440	1,440	1,440
2 to <3	117	979	30	288	551	650	746	857	1,005	1,120	1,232	1,296	1,355	1,369	1,440
3 to <6	355	957	150	352	451	634	720	810	930	1,110	1,245	1,355	1,440	1,440	1,440
6 to <11	486	893	190	335	389	541	655	765	885	1,009	1,177	1,275	1,385	1,440	1,440
11 to <16	459	889	40	141	300	441	590	758	875	1,046	1,218	1,315	1,440	1,440	1,440
16 to <21	473	833	85	206	321	433	525	660	815	1,000	1,170	1,288	1,420	1,440	1,440

N = Sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes less than 10.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-12. Time Spent (minutes/day) at Selected Indoor Locations
Whole Population and Doers Only

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Restaurants - Whole Population															
Birth to <1	63	13	0	0	0	0	0	0	0	0	45	69	105	194	330
1 to <2	118	7	0	0	0	0	0	0	0	0	30	62	88	102	120
2 to <3	118	9	0	0	0	0	0	0	0	0	45	62	92	111	120
3 to <6	357	7	0	0	0	0	0	0	0	0	21	52	90	120	130
6 to <11	497	6	0	0	0	0	0	0	0	0	15	45	85	110	180
11 to <16	466	10	0	0	0	0	0	0	0	0	35	60	90	137	315
16 to <21	481	35	0	0	0	0	0	0	0	20	105	240	380	466	645
Restaurants - DOERS ONLY															
Birth to <1	10	85	10	-	-	-	-	-	-	-	-	-	-	-	330
1 to <2	15	58	5	6	8	12	21	33	55	83	99	110	116	118	120
2 to <3	17	63	20	21	22	24	28	45	60	80	102	116	118	119	120
3 to <6	43	57	4	7	9	10	16	30	45	90	120	120	122	126	130
6 to <11	57	54	5	5	6	10	15	30	45	60	107	124	140	158	180
11 to <16	78	59	2	3	7	10	18	30	45	65	102	141	223	283	315
16 to <21	135	126	1	4	5	10	17	30	60	170	334	437	537	546	645
School - Whole Population															
Birth to <1	63	4	0	0	0	0	0	0	0	0	0	0	46	100	165
1 to <2	118	13	0	0	0	0	0	0	0	0	0	22	156	453	665
2 to <3	118	23	0	0	0	0	0	0	0	0	0	193	414	503	545
3 to <6	357	75	0	0	0	0	0	0	0	0	416	540	569	589	630
6 to <11	497	187	0	0	0	0	0	0	0	397	444	480	552	601	665
11 to <16	466	201	0	0	0	0	0	0	0	420	459	495	578	630	855
16 to <21	481	131	0	0	0	0	0	0	0	308	430	495	566	629	855
School - DOERS ONLY															
Birth to <1	2	-	60	-	-	-	-	-	-	-	-	-	-	-	165
1 to <2	8	-	5	-	-	-	-	-	-	-	-	-	-	-	665
2 to <3	11	251	10	10	10	10	10	83	269	388	510	528	538	542	545
3 to <6	71	379	5	23	34	110	160	228	418	540	570	590	615	627	630
6 to <11	235	396	5	64	129	195	305	370	400	435	480	540	612	643	665
11 to <16	229	409	15	38	96	132	290	395	420	450	495	559	631	696	855
16 to <21	171	367	15	22	31	90	185	270	388	440	525	576	726	801	855

Table 16-12. Time Spent (minutes/day) at Selected Indoor Locations
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Grocery/Convenience Stores, Other Stores, and Malls - Whole Population															
Birth to <1	63	39	0	0	0	0	0	0	0	30	98	178	224	241	250
1 to <2	118	16	0	0	0	0	0	0	0	0	62	87	146	202	255
2 to <3	118	18	0	0	0	0	0	0	0	0	60	86	133	250	360
3 to <6	357	17	0	0	0	0	0	0	0	0	62	111	189	223	420
6 to <11	497	14	0	0	0	0	0	0	0	0	49	101	167	225	320
11 to <16	466	18	0	0	0	0	0	0	0	0	54	122	204	300	413
16 to <21	481	36	0	0	0	0	0	0	0	15	120	230	402	484	960
Grocery/Convenience Stores, Other Stores, and Malls - DOERS ONLY															
Birth to <1	21	88	5	5	5	5	24	30	55	130	190	235	244	247	250
1 to <2	23	81	5	7	9	17	30	55	65	93	152	205	235	245	255
2 to <3	27	80	10	11	13	20	33	45	60	82	120	234	313	337	360
3 to <6	64	96	5	5	5	16	23	50	73	116	204	236	339	382	420
6 to <11	91	76	3	3	5	5	14	20	60	110	170	230	255	262	320
11 to <16	104	82	1	2	5	10	10	20	45	120	199	300	359	383	413
16 to <21	146	120	2	4	5	5	10	22	60	149	330	456	517	562	960

N = Sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes less than 10.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-13. Time Spent (minutes/day) in Selected Outdoor Locations
Whole Population and Doers Only

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
School Grounds/Playground - Whole Population															
Birth to <1	63	2	0	0	0	0	0	0	0	0	0	0	0	53	140
1 to <2	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 to <3	118	4	0	0	0	0	0	0	0	0	0	0	50	131	175
3 to <6	357	5	0	0	0	0	0	0	0	0	0	0	64	127	625
6 to <11	497	8	0	0	0	0	0	0	0	0	10	60	121	170	315
11 to <16	466	10	0	0	0	0	0	0	0	0	20	80	120	160	570
16 to <21	481	8	0	0	0	0	0	0	0	0	0	50	135	180	510
School Grounds/Playground - DOERS ONLY															
Birth to <1	1	-	140	-	-	-	-	-	-	-	-	-	-	-	140
1 to <2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 to <3	5	-	10	-	-	-	-	-	-	-	-	-	-	-	175
3 to <6	12	138	20	22	24	31	42	59	118	138	150	364	521	573	625
6 to <11	52	80	10	10	10	10	15	30	59	106	169	217	280	298	315
11 to <16	62	72	3	4	5	5	5	21	53	95	149	178	217	360	570
16 to <21	34	116	10	10	10	13	18	46	95	161	201	305	418	464	510
Parks or Golf Courses - Whole Population															
Birth to <1	63	3	0	0	0	0	0	0	0	0	0	0	45	63	85
1 to <2	118	3	0	0	0	0	0	0	0	0	0	0	0	25	360
2 to <3	118	12	0	0	0	0	0	0	0	0	0	24	126	246	755
3 to <6	357	10	0	0	0	0	0	0	0	0	0	71	163	220	585
6 to <11	497	16	0	0	0	0	0	0	0	0	0	72	328	483	665
11 to <16	466	19	0	0	0	0	0	0	0	0	0	114	265	452	1,065
16 to <21	481	22	0	0	0	0	0	0	0	0	0	150	381	546	870
Parks or Golf Courses - DOERS ONLY															
Birth to <1	3	-	30	-	-	-	-	-	-	-	-	-	-	-	85
1 to <2	2	-	30	-	-	-	-	-	-	-	-	-	-	-	360
2 to <3	7	-	21	-	-	-	-	-	-	-	-	-	-	-	755
3 to <6	26	144	25	26	28	31	44	63	113	165	273	388	505	545	585
6 to <11	34	236	25	30	35	43	52	73	123	394	568	644	662	663	665
11 to <16	38	237	15	15	15	15	27	86	164	266	470	851	954	1,010	1,065
16 to <21	47	225	1	7	14	15	24	60	160	308	557	633	677	773	870

Table 16-13. Time Spent (minutes/day) in Selected Outdoor Locations
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Pool, River, or Lake - Whole Population															
Birth to <1	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 to <2	118	1	0	0	0	0	0	0	0	0	0	0	0	0	118
2 to <3	118	12	0	0	0	0	0	0	0	0	0	14	228	352	435
3 to <6	357	5	0	0	0	0	0	0	0	0	0	0	85	163	630
6 to <11	497	9	0	0	0	0	0	0	0	0	0	0	220	295	375
11 to <16	466	4	0	0	0	0	0	0	0	0	0	0	60	160	235
16 to <21	481	8	0	0	0	0	0	0	0	0	0	0	145	240	570
Pool, River, or Lake - DOERS ONLY															
Birth to <1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1 to <2	1	-	118	-	-	-	-	-	-	-	-	-	-	-	118
2 to <3	6	-	95	-	-	-	-	-	-	-	-	-	-	-	435
3 to <6	9	-	45	-	-	-	-	-	-	-	-	-	-	-	630
6 to <11	24	178	25	26	27	32	46	75	155	294	319	359	370	373	375
11 to <16	16	121	58	58	59	59	60	60	85	206	225	228	232	234	235
16 to <21	22	179	20	22	24	31	40	55	125	238	415	548	564	567	570

N = Sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes less than 10.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-14. Mean Time Spent (minutes/day) Inside and Outside, by Age Category

Age (years)	N	Average Indoor Minutes[a]	Average Outdoor Minutes[b]	Average Unclassified Minutes[c]
Birth to <1	25	1,353	44	43
1 to < 2	90	1,353	36	51
2 to <3	131	1,316	76	48
3 to <6	360	1,278	107	54
6 to <11	511	1,244	132	64
11 to <16	449	1,260	100	80
16 to <21	493	1,248	102	90

[a] Time indoors was estimating by adding the average times spent indoors at the respondents' home (kitchen, living room, bathroom, etc.), at other houses, and inside other locations such as school, restaurants, etc.

[b] Time outdoors was estimated by adding the average time spent outdoors at the respondents' pool and yard, others' pool and yard, and outside other locations such as sidewalk, street, neighborhood, parking lot, service station/gas station, school grounds, park/golf course, pool, river, lake, farm, etc.

[c] Includes time spent in vehicles or in activities that could not be assigned an indoor or outdoor location.

N = Sample size.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-15. Time Spent (minutes/day) in Selected Vehicles and All Vehicles Combined
Whole Population and Doers Only

Age (years)	N	Mean	Min	Percentiles 1	2	5	10	25	50	75	90	95	98	99	Max
Car - Whole Population															
Birth to <1	63	36	0	0	0	0	0	0	10	49	107	171	208	220	235
1 to <2	118	41	0	0	0	0	0	0	20	60	98	151	246	336	390
2 to <3	118	33	0	0	0	0	0	0	20	50	90	126	163	187	215
3 to <6	357	43	0	0	0	0	0	0	20	60	117	155	221	272	620
6 to <11	497	37	0	0	0	0	0	0	15	55	102	146	185	212	630
11 to <16	466	39	0	0	0	0	0	0	15	55	99	150	254	302	900
16 to <21	481	61	0	0	0	0	0	8	40	90	155	195	249	321	380
Car - DOERS ONLY															
Birth to <1	35	65	2	5	7	10	14	20	40	73	159	203	218	227	235
1 to <2	68	72	5	8	10	10	15	30	58	85	147	186	323	363	390
2 to <3	73	54	4	4	4	8	10	24	42	65	118	141	181	197	215
3 to <6	227	67	4	4	5	7	10	25	45	88	150	180	267	327	620
6 to <11	317	58	1	2	2	5	10	20	40	82	127	163	202	300	630
11 to <16	286	64	1	3	5	5	10	20	40	75	122	193	279	338	900
16 to <21	364	81	2	9	10	10	17	30	60	105	180	210	275	334	380
Truck (Pickup or Van) - Whole Population															
Birth to <1	63	2	0	0	0	0	0	0	0	0	0	0	0	42	110
1 to <2	118	2	0	0	0	0	0	0	0	0	0	0	52	81	90
2 to <3	118	14	0	0	0	0	0	0	0	0	14	31	124	201	955
3 to <6	357	5	0	0	0	0	0	0	0	0	0	30	60	114	245
6 to <11	497	7	0	0	0	0	0	0	0	0	15	45	95	110	240
11 to <16	466	9	0	0	0	0	0	0	0	0	15	59	153	181	352
16 to <21	481	11	0	0	0	0	0	0	0	0	25	90	150	190	445
Truck (Pickup or Van) - DOERS ONLY															
Birth to <1	1	-	110	-	-	-	-	-	-	-	-	-	-	-	110
1 to <2	5	-	20	-	-	-	-	-	-	-	-	-	-	-	90
2 to <3	15	109	10	10	10	10	11	15	30	53	188	434	746	851	955
3 to <6	34	53	1	2	4	8	10	16	30	59	117	207	222	233	245
6 to <11	69	48	1	4	6	10	10	15	30	65	110	124	151	186	240
11 to <16	62	67	5	5	5	5	7	15	35	89	180	185	258	299	352
16 to <21	70	78	5	5	5	10	11	22	54	115	170	213	238	304	445

Table 16-15. Time Spent (minutes/day) in Selected Vehicles and All Vehicles Combined
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Bus - Whole Population															
Birth to <1	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 to <2	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 to <3	118	1	0	0	0	0	0	0	0	0	0	0	0	25	120
3 to <6	357	2	0	0	0	0	0	0	0	0	0	0	30	47	80
6 to <11	497	11	0	0	0	0	0	0	0	0	50	70	90	110	140
11 to <16	466	16	0	0	0	0	0	0	0	15	60	89	119	148	370
16 to <21	481	6	0	0	0	0	0	0	0	0	0	45	108	135	225
Bus - DOERS ONLY															
Birth to <1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1 to <2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 to <3	2	-	30	-	-	-	-	-	-	-	-	-	-	-	120
3 to <6	14	40	15	16	16	18	21	30	33	49	67	74	77	79	80
6 to <11	115	49	5	5	6	14	17	25	43	67	90	107	120	122	140
11 to <16	130	58	7	10	10	10	15	30	54	71	101	131	159	175	370
16 to <21	41	75	10	12	14	20	25	30	60	100	135	175	193	209	225
All Vehicles - Whole Population															
Birth to <1	63	39	0	0	0	0	0	0	20	60	113	171	208	220	235
1 to <2	118	44	0	0	0	0	0	0	28	60	98	151	246	336	390
2 to <3	118	50	0	0	0	0	0	0	30	60	120	151	203	214	955
3 to <6	357	50	0	0	0	0	0	0	30	65	122	167	238	272	620
6 to <11	497	57	0	0	0	0	0	15	40	85	124	155	212	289	630
11 to <16	466	67	0	0	0	0	0	15	45	85	155	206	291	383	900
16 to <21	481	84	0	0	0	0	0	25	62	120	180	239	328	382	675
All Vehicles - DOERS ONLY															
Birth to <1	37	66	2	5	8	10	16	20	46	75	151	202	217	226	235
1 to <2	72	72	5	9	10	10	20	30	60	85	143	178	316	362	390
2 to <3	86	69	4	4	5	10	10	26	45	83	128	166	212	326	955
3 to <6	261	68	1	4	6	10	13	30	46	85	150	190	261	309	620
6 to <11	417	68	1	2	4	10	14	25	55	90	130	161	240	306	630
11 to <16	383	82	1	5	5	10	16	30	60	99	177	235	314	392	900
16 to <21	428	94	5	8	10	15	20	40	75	120	190	240	345	386	675

N = Sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes less than 10.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-16. Time Spent (minutes/day) in Selected Activities
Whole Population and Doers Only

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Sleeping/Napping - Whole Population															
Birth to <1	63	782	485	519	546	579	613	668	762	873	1,011	1,080	1,121	1,144	1,175
1 to <2	118	779	360	483	510	579	627	700	780	855	925	962	987	1098	1,320
2 to <3	118	716	270	365	470	523	594	635	708	805	870	917	937	944	990
3 to <6	357	681	0	480	510	539	573	630	675	735	795	840	893	916	1,110
6 to <11	497	613	120	295	390	458	510	570	625	660	720	750	831	868	945
11 to <16	466	569	0	320	376	415	450	510	558	630	705	762	809	907	1,015
16 to <21	481	537	0	239	295	360	390	450	525	615	690	750	840	906	1,317
Sleeping/Napping - DOERS ONLY															
Birth to <1	63	782	485	519	546	579	613	668	762	873	1,011	1,080	1,121	1,144	1,175
1 to <2	118	779	360	483	510	579	627	700	780	855	925	962	987	1,098	1,320
2 to <3	118	716	270	365	470	523	594	635	708	805	870	917	937	944	990
3 to <6	356	683	420	491	510	540	578	630	675	738	795	840	893	916	1,110
6 to <11	497	613	120	295	390	458	510	570	625	660	720	750	831	868	945
11 to <16	465	571	150	341	379	415	450	510	560	630	705	762	809	907	1,015
16 to <21	480	538	85	252	299	360	390	450	525	615	690	751	840	906	1,317
Eating - Whole Population															
Birth to <1	63	117	0	6	12	36	45	73	110	145	194	224	334	345	345
1 to <2	118	98	0	10	10	29	40	60	90	120	167	206	233	244	270
2 to <3	118	92	15	15	15	20	30	60	89	120	157	176	198	208	270
3 to <6	357	78	0	0	0	15	28	45	75	105	135	150	180	217	265
6 to <11	497	65	0	0	0	10	20	35	60	88	115	139	155	176	255
11 to <16	466	52	0	0	0	0	10	30	45	74	100	120	146	162	205
16 to <21	481	52	0	0	0	0	0	20	40	65	105	135	192	210	630
Eating - DOERS ONLY															
Birth to <1	62	118	10	16	23	40	46	77	110	148	195	224	335	345	345
1 to <2	117	99	10	10	12	30	40	60	90	120	167	206	234	244	270
2 to <3	118	92	15	15	15	20	30	60	89	120	157	176	198	208	270
3 to <6	349	80	2	10	15	20	30	45	75	105	135	150	180	218	265
6 to <11	480	67	5	10	10	15	20	40	60	90	115	140	157	179	255
11 to <16	432	56	2	5	7	10	20	30	50	75	100	125	148	163	205
16 to <21	426	59	2	5	9	10	15	30	45	75	105	144	197	210	630

Table 16-16. Time Spent (minutes/day) in Selected Activities
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Attending School Full-Time - Whole Population															
Birth to <1	63	11	0	0	0	0	0	0	0	0	0	0	83	265	550
1 to <2	118	28	0	0	0	0	0	0	0	0	0	204	546	594	665
2 to <3	118	65	0	0	0	0	0	0	0	0	334	502	564	618	710
3 to <6	357	73	0	0	0	0	0	0	0	0	392	510	558	581	630
6 to <11	497	183	0	0	0	0	0	0	0	390	435	460	525	570	645
11 to <16	466	187	0	0	0	0	0	0	0	409	445	464	487	500	595
16 to <21	481	117	0	0	0	0	0	0	0	270	408	445	489	551	825
Attending School Full-Time - DOERS ONLY															
Birth to <1	3	-	60	-	-	-	-	-	-	-	-	-	-	-	550
1 to <2	9	-	20	-	-	-	-	-	-	-	-	-	-	-	665
2 to <3	20	385	20	37	53	103	119	226	458	520	576	632	679	694	710
3 to <6	71	366	30	37	66	128	165	203	395	510	558	583	615	627	630
6 to <11	234	389	60	125	164	211	311	370	390	425	460	497	570	600	645
11 to <16	217	401	10	86	108	270	343	385	415	440	467	485	505	548	595
16 to <21	162	347	20	46	78	126	195	270	370	420	459	519	567	609	825
Outdoor Recreation -Whole Population															
Birth to <1	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 to <2	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 to <3	118	4	0	0	0	0	0	0	0	0	0	0	15	28	370
3 to <6	357	6	0	0	0	0	0	0	0	0	0	0	60	172	630
6 to <11	497	7	0	0	0	0	0	0	0	0	0	0	142	226	574
11 to <16	466	6	0	0	0	0	0	0	0	0	0	0	142	191	465
16 to <21	481	6	0	0	0	0	0	0	0	0	0	0	103	189	570
Outdoor Recreation - DOERS ONLY															
Birth to <1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1 to <2	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 to <3	4	-	15	-	-	-	-	-	-	-	-	-	-	-	370
3 to <6	11	207	30	30	30	30	30	60	150	240	585	608	621	626	630
6 to <11	17	204	60	60	60	60	66	120	165	245	351	403	506	540	574
11 to <16	22	138	5	5	5	5	11	60	126	180	234	411	446	456	465
16 to <21	13	228	30	35	41	57	77	130	180	300	420	480	534	552	570

Table 16-16. Time Spent (minutes/day) in Selected Activities
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Active Sports - Whole Population															
Birth to <1	63	15	0	0	0	0	0	0	0	0	60	90	131	143	155
1 to <2	118	20	0	0	0	0	0	0	0	0	68	131	180	201	270
2 to <3	118	27	0	0	0	0	0	0	0	0	110	180	257	319	390
3 to <6	357	40	0	0	0	0	0	0	0	30	135	242	330	408	630
6 to <11	497	51	0	0	0	0	0	0	0	60	172	272	371	435	975
11 to <16	466	53	0	0	0	0	0	0	0	74	168	245	309	425	1,065
16 to <21	481	35	0	0	0	0	0	0	0	0	145	180	285	386	565
Active Sports - DOERS ONLY															
Birth to <1	13	75	25	26	26	28	31	40	60	90	132	143	150	153	155
1 to <2	24	96	10	15	19	30	33	60	73	131	180	201	240	255	270
2 to <3	26	124	15	18	20	26	30	41	98	179	253	314	360	375	390
3 to <6	97	149	15	20	29	30	30	60	120	180	315	354	559	625	630
6 to <11	175	146	2	12	15	20	30	60	110	193	312	393	450	522	975
11 to <16	179	137	5	5	15	15	30	60	115	180	261	314	442	533	1,065
16 to <21	117	143	5	15	15	20	30	60	120	180	272	371	501	519	565
Exercise - Whole Population															
Birth to <1	63	13	0	0	0	0	0	0	0	0	0	0	122	354	670
1 to <2	118	2	0	0	0	0	0	0	0	0	0	0	25	30	150
2 to <3	118	1	0	0	0	0	0	0	0	0	0	0	0	0	60
3 to <6	357	3	0	0	0	0	0	0	0	0	0	0	0	54	525
6 to <11	497	5	0	0	0	0	0	0	0	0	0	0	100	137	450
11 to <16	466	5	0	0	0	0	0	0	0	0	0	30	70	114	245
16 to <21	481	8	0	0	0	0	0	0	0	0	0	60	151	176	300
Exercise - DOERS ONLY															
Birth to <1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1 to <2	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 to <3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 to <6	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6 to <11	20	124	15	17	19	25	30	60	100	146	226	284	384	417	450
11 to <16	28	75	20	21	23	27	30	42	60	101	128	148	194	219	245
16 to <21	41	99	15	15	15	25	30	40	90	145	180	240	260	280	300

Table 16-16. Time Spent (minutes/day) in Selected Activities
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Walking - Whole Population															
Birth to <1	63	6	0	0	0	0	0	0	0	0	9.2	29	64	104	160
1 to <2	118	2	0	0	0	0	0	0	0	0	0	10	40	58	60
2 to <3	118	3	0	0	0	0	0	0	0	0	10	17	45	54	60
3 to <6	357	3	0	0	0	0	0	0	0	0	4	20	35	60	60
6 to <11	497	4	0	0	0	0	0	0	0	0	14	30	40	55	170
11 to <16	466	10	0	0	0	0	0	0	0	0	30	55	79	130	190
16 to <21	481	8	0	0	0	0	0	0	0	0	20	45	90	127	410
Walking - DOERS ONLY															
Birth to <1	9	-	4	-	-	-	-	-	-	-	-	-	-	-	160
1 to <2	9	-	4	-	-	-	-	-	-	-	-	-	-	-	60
2 to <3	19	19	1	1	1	2	2	7	10	28	51	56	58	59	60
3 to <6	44	20	1	1	1	1	2	5	15	30	56	60	60	60	60
6 to <11	118	18	1	1	1	2	2	5	10	25	40	51	65	94	170
11 to <16	190	25	1	1	1	2	3	5	14	30	60	78	134	154	190
16 to <21	128	30	1	1	2	2	3	5	18	32	62	120	148	175	410

N = Sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes less than 10.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-17. Number of Showers Taken per Day, by Number of Respondents						
Age (years)	N	Showers per Day				
		0	1	2	3	Don't Know
Birth to <1	37	36	1	0	0	0
1 to <2	53	48	5	0	0	0
2 to <3	67	54	10	2	0	1
3 to <6	187	153	25	7	1	1
6 to <11	245	122	95	25	1	2
11 to <16	258	51	150	53	3	1
16 to <21	232	23	147	57	5	0

N = Total number.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-18. Time Spent (minutes) Bathing, Showering, and in Bathroom Immediately after Bathing and Showering

Age (years)	N	Mean	Min	Percentiles 1	2	5	10	25	50	75	90	95	98	99	Max
Duration of Bath (minutes)															
Birth to <1	26	19	5	5	5	6	8	10	18	28	30	30	45	53	60
1 to <2	37	23	10	10	10	10	10	15	20	30	30	32	41	43	45
2 to <3	48	23	1	2.9	5	7	10	15	20	30	30	45	60	60	60
3 to <6	125	24	5	5	5	6	10	15	25	30	35	60	60	61	61
6 to <11	89	24	5	5	5	10	10	15	20	30	31	46	60	60	61
11 to <16	38	25	5	6	6	10	10	16	20	30	40	43	60	61	61
16 to <21	17	33	10	11	12	14	18	20	30	45	60	60	61	61	61
Duration in Bathroom Immediately Following a Bath (minutes)															
Birth to <1	26	2	0	0	0	0	0	0	1	3	9	10	10	10	10
1 to <2	37	3	0	0	0	0	0	1	2	5	5	6	10	10	10
2 to <3	48	4	0	0	0	0	0	0	1.5	5	10	15	15	18	20
3 to <6	125	4	0	0	0	0	0	1	2	5	10	15	15	19	30
6 to <11	89	4	0	0	0	0	0	1	3	5	10	10	16	21	30
11 to <16	38	9	0	0	0	1	1	2	5	14	20	26	33	36	40
16 to <21	17	11	0	0	1	2	3	5	10	10	19	29	39	42	45
Sum of Duration in Bath and in Bathroom Immediately Following Bath (minutes)															
Birth to <1	26	22	6	7	8	9	10	12	19	29	32	38	55	63	70
1 to <2	37	26	10	10	11	12	16	17	30	32	35	41	46	48	50
2 to <3	48	26	6	7	8	10	14	16	23	34	45	50	60	61	61
3 to <6	125	28	5	6	7	10	12	18	30	32	48	60	66	69	76
6 to <11	89	28	6	6	9	10	13	20	25	33	41	60	63	71	80
11 to <16	38	33	7	8	10	12	16	23	31	41	52	64	70	70	70
16 to <21	17	45	15	15	16	17	21	30	40	60	73	77	82	83	85

Table 16-18. Time Spent (minutes) Bathing, Showering, and in Bathroom Immediately after Bathing and Showering (continued)

Age (years)	N	Mean	Min	Percentiles 1	2	5	10	25	50	75	90	95	98	99	Max
Duration of Shower (minutes)															
Birth to <1	1	15	15	-	-	-	-	-	-	-	-	-	-	-	15
1 to <2	5	20	5	-	-	-	-	-	-	-	-	-	-	-	30
2 to <3	12	22	5	5	5	5	6	14	20	30	30	44	53	57	60
3 to <6	33	17	3	4	4	5	5	10	15	20	30	34	47	54	60
6 to <11	119	18	4	5	5	5	7	10	15	20	30	41	57	60	60
11 to <16	204	18	3	4	5	5	6	10	15	20	30	40	50	60	60
16 to <21	207	20	3	5	5	5	8	10	15	30	40	45	60	60	61
Duration in Shower Room Immediately Following a Shower (minutes)															
Birth to <1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	1
1 to <2	5	10	0	-	-	-	-	-	-	-	-	-	-	-	45
2 to <3	12	5	0	0	0	1	1	1	4	6	10	12	14	14	15
3 to <6	33	7	0	0	1	2	2	3	5	10	15	20	22	23	25
6 to <11	119	6	0	0	0	0	1	2	5	10	13	16	26	30	30
11 to <16	204	8	0	0	0	0	1	3	5	10	19	30	40	45	60
16 to <21	207	8	0	0	0	0	1	3	5	10	15	20	30	39	61
Sum of Shower Duration and Time Spent in Shower Room Immediately Following Shower (minutes)															
Birth to <1	1	16	16	-	-	-	-	-	-	-	-	-	-	-	16
1 to <2	5	30	6	-	-	-	-	-	-	-	-	-	-	-	60
2 to <3	12	27	6	6	7	8	11	19	21	33	44	56	65	67	70
3 to <6	33	24	8	8	8	8	8	13	25	30	40	45	57	64	70
6 to <11	119	24	5	6	6	8	10	15	20	30	43	50	61	68	90
11 to <16	204	26	4	5	7	10	11	15	22	35	50	60	65	70	70
16 to <21	207	28	4	5	7	10	10	15	25	35	50	60	74	89	121

N = Doer sample size.
Min = Minimum.
Max = Maximum.
- = Percentiles were not calculated for sample sizes less than 10.
Note: A value of "61" was used for any shower, bath, or bathroom stay longer than 60 minutes. A value of "121" for the sum of shower duration and time spent in bathroom following shower (or the sum of bath duration and time spent in bathroom following bath) signifies that more than 120 minutes were spent.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-19. Range of Number of Times Washing the Hands at Specified Daily Frequencies by the Number of Respondents

Age (years)	N	Number of Times/Day							
		0	1-2	3-5	6-9	10-19	20-29	30+	DK
Birth to <1	37	2	15	12	2	1	1	0	4
1 to <2	53	7	8	23	8	4	0	2	1
2 to <3	67	0	15	39	10	0	1	0	2
3 to <6	187	2	37	101	27	10	1	2	7
6 to <11	245	2	47	131	34	16	3	1	11
11 to <16	258	8	37	128	49	22	5	2	7
16 to <21	232	0	23	115	47	38	4	3	2

N = Total number.
DK = Respondents answered "don't know".

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-20. Number of Times Swimming in a Month in Freshwater Swimming Pool by the Number of Respondents

Age (years)	N	Times/Month															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Birth to <1	10	1	4	1	0	0	2	0	0	0	1	0	0	0	0	0	0
1to < 2	8	2	3	1	0	1	0	0	1	0	0	0	0	0	0	0	0
2 to <3	18	3	4	1	0	1	1	0	1	1	2	0	2	0	0	1	0
3 to <6	45	5	7	6	5	2	1	1	2	0	2	0	0	1	1	5	0
6 to <11	76	15	10	5	5	5	3	1	3	0	6	0	5	0	0	7	2
11 to <16	66	19	10	6	3	5	4	1	3	1	4	0	1	0	0	2	0
16 to <21	50	6	6	2	6	6	2	2	1	0	5	1	1	0	0	0	0

Age (years)	N	Times/Month															
		18	20	23	24	25	26	28	29	30	32	40	42	45	50	60	DK
Birth to <1	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1to < 2	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 to <3	18	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
3 to <6	45	0	2	0	0	1	0	0	0	3	1	0	0	0	0	0	0
6 to <11	76	0	3	0	1	1	0	0	0	3	0	0	0	0	1	0	0
11 to <16	66	1	2	0	0	0	0	0	0	2	0	0	0	0	0	1	1
16 to <21	50	0	6	0	0	1	2	0	0	3	0	0	0	0	0	0	0

N = Doer sample size.
DK = Respondents answered “don't know”.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-21. Time Spent (minutes/month) Swimming in Freshwater Swimming Pool

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Birth to <1	10	96	6	-	-	-	-	-	-	-	-	-	-	-	181
1 to <2	7	105	45	-	-	-	-	-	-	-	-	-	-	-	181
2 to <3	18	116	15	16	17	19	27	60	120	181	181	181	181	181	181
3 to <6	42	137	6	8	9	12	40	83	181	181	181	181	181	181	181
6 to <11	72	151	8	13	17	30	60	150	181	181	181	181	181	181	181
11 to <16	65	139	4	8	11	20	30	90	181	181	181	181	181	181	181
16 to <21	50	145	2	3	5	25	39	124	181	181	181	181	181	181	181

N = Doer sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes of 10 or fewer.
Note: A value of 181 for number of minutes signifies that more than 180 minutes were spent.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-22. Time Spent (minutes/day) Playing on Dirt, Sand/Gravel, or Grass
Whole Population and Doers only

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Playing on Dirt - Whole Population															
Birth to <1	11	15	0	0	0	0	0	0	0	10	20	71	101	111	121
1 to <2	37	20	0	0	0	0	0	0	0	10	84	121	121	121	121
2 to <3	61	18	0	0	0	0	0	0	0	20	60	120	121	121	121
3 to <6	179	29	0	0	0	0	0	0	0	59	120	121	121	121	121
6 to <11	98	28	0	0	0	0	0	0	0	60	120	121	121	121	121
11 to <16	35	25	0	0	0	0	0	0	1	30	77	120	120	121	121
16 to <21	7	9	0	-	-	-	-	-	-	-	-	-	-	-	30
Playing on Dirt - DOERS ONLY															
Birth to <1	5	33	2	-	-	-	-	-	-	-	-	-	-	-	121
1 to <2	13	56	5	5	5	5	6	10	45	120	121	121	121	121	121
2 to <3	24	47	5	5	5	5	7	15	30	60	121	121	121	121	121
3 to <6	82	63	1	1	1	1	6	30	60	120	121	121	121	121	121
6 to <11	44	63	2	3	5	10	15	30	60	120	121	121	121	121	121
11 to <16	18	49	1	2	2	4	9	19	30	60	120	120	121	121	121
16 to <21	2	30	30	-	-	-	-	-	-	-	-	-	-	-	30
Playing on Sand/Gravel - Whole Population															
Birth to <1	10	4	0	-	-	-	-	-	-	-	-	-	-	-	20
1 to <2	37	17	0	0	0	0	0	0	0	30	60	84	121	121	121
2 to <3	58	24	0	0	0	0	0	0	0	30	120	121	121	121	121
3 to <6	186	30	0	0	0	0	0	0	2	60	120	121	121	121	121
6 to <11	101	30	0	0	0	0	0	0	0	60	120	121	121	121	121
11 to <16	36	30	0	0	0	0	0	0	0	38	120	121	121	121	121
16 to <21	8	42	0	-	-	-	-	-	-	-	-	-	-	-	121
Playing on Sand/Gravel - DOERS ONLY															
Birth to <1	2	18	15	-	-	-	-	-	-	-	-	-	-	-	20
1 to <2	15	43	5	5	5	5	7	15	30	60	103	121	121	121	121
2 to <3	26	53	1	1	1	1	3	10	30	120	121	121	121	121	121
3 to <6	93	60	3	3	3	5	8	25	60	90	121	121	121	121	121
6 to <11	46	67	5	7	10	11	15	30	60	120	121	121	121	121	121
11 to <16	16	67	1	3	5	12	15	26	60	120	121	121	121	121	121
16 to <21	4	83	30	-	-	-	-	-	-	-	-	-	-	-	121

Table 16-22. Time Spent (minutes/day) Playing on Dirt, Sand/Gravel, or Grass
Whole Population and Doers Only (continued)

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Playing on Grass - Whole Population															
Birth to <1	11	43	0	0	0	0	0	2	30	73	121	121	121	121	121
1 to <2	38	62	0	0	0	0	9	16	60	120	121	121	121	121	121
2 to <3	59	55	0	0	0	0	1	15	30	120	121	121	121	121	121
3 to <6	180	69	0	0	0	0	0	28	60	121	121	121	121	121	121
6 to <11	99	62	0	0	0	0	0	20	60	120	121	121	121	121	121
11 to <16	36	67	0	0	0	0	1	30	60	120	121	121	121	121	121
16 to <21	8	45	0	-	-	-	-	-	-	-	-	-	-	-	120
Playing on Grass - DOERS ONLY															
Birth to <1	9	52	1	-	-	-	-	-	-	-	-	-	-	-	121
1 to <2	35	68	5	7	8	10	15	25	60	120	121	121	121	121	121
2 to <3	53	62	1	2	3	3	5	20	60	120	121	121	121	121	121
3 to <6	157	79	1	2	2	10	15	60	70	121	121	121	121	121	121
6 to <11	85	73	1	5	9	11	17	30	60	120	121	121	121	121	121
11 to <16	32	75	1	5	10	23	30	30	60	120	121	121	121	121	121
16 to <21	6	60	15	-	-	-	-	-	-	-	-	-	-	-	120

N = Sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes of 10 or fewer.
Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-23. Time Spent (minutes/day) Working or Being Near Excessive Dust in the Air

Age (years)	N	Mean	Min	Percentiles											Max
				1	2	5	10	25	50	75	90	95	98	99	
Birth to <1	2	63	5	-	-	-	-	-	-	-	-	-	-	-	121
1 to <2	5	44	0	-	-	-	-	-	-	-	-	-	-	-	121
2 to <3	1	121	121	-	-	-	-	-	-	-	-	-	-	-	121
3 to <6	15	63	0	0	1	1	2	8	60	121	121	121	121	121	121
6 to <11	12	60	0	0	0	1	2	5	45	121	121	121	121	121	121
11 to <16	14	53	0	0	0	1	2	6	38	113	121	121	121	121	121
16 to <21	14	65	2	2	3	4	7	16	53	121	121	121	121	121	121

N = Doer sample size.
Min = Minimum.
Max = Maximum.
\- = Percentiles were not calculated for sample sizes of 10 or fewer.
Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent.

Source: U.S. EPA re-analysis of source data from U.S. EPA, 1996 (NHAPS).

Table 16-24. Time Spent (minutes/day) with Smokers Present

Age (years)	N	Mean	SD	SE	Min	Percentiles								Max
						5	25	50	75	90	95	98	99	
1 to 4	155	367	325	26	5	30	90	273	570	825	1,010	1,140	1,305	1,440
5 to 11	224	318	314	21	1	25	105	190	475	775	1,050	1,210	1,250	1,440
12 to 17	256	246	244	15	1	10	60	165	360	595	774	864	1,020	1,260

N = Doer sample size.
Min = Minimum.
Max = Maximum.

Source: U.S. EPA, 1996 (NHAPS).

Table 16-25. Mean Time Spent (minutes/day) Performing Major Activities, by Age, Sex and Type of Day

Activity	Age (3 to 11 years)				Age (12 to 17 years)			
	Weekdays		Weekends		Weekdays		Weekends	
	Boys (N=118)	Girls (N=111)	Boys (N=118)	Girls (N=111)	Boys (N=77)	Girls (N=83)	Boys (N=77)	Girls (N=83)
Market Work	16	0	7	4	23	21	58	25
Household Work	17	21	32	43	16	40	46	89
Personal Care	43	44	42	50	48	71	35	76
Eating	81	78	78	84	73	65	58	75
Sleeping	584	590	625	619	504	478	550	612
School	252	259	-	-	314	342	-	-
Studying	14	19	4	9	29	37	25	25
Church	7	4	53	61	3	7	40	36
Visiting	16	9	23	37	17	25	46	53
Sports	25	12	33	23	52	37	65	26
Outdoors	10	7	30	23	10	10	36	19
Hobbies	3	1	3	4	7	4	4	7
Art Activities	4	4	4	4	12	6	11	9
Playing	137	115	177	166	37	13	35	24
TV	117	128	181	122	143	108	187	140
Reading	9	7	12	10	10	13	12	19
Household Conversations	10	11	14	9	21	30	24	30
Other Passive Leisure	9	14	16	17	21	14	43	33
NA	22	25	20	29	14	17	10	4
Percent of Time Accounted for by Activities Above	94	92	93	89	93	92	88	89

N = Sample size.
NA = Unknown.
\- = No data.

Source: Timmer et al., 1985.

Table 16-26. Mean Time Spent (minutes/day) in Major Activities, by Type of Day for Five Different Age Groups

Activity	Weekday					Weekend					Significant Effects[a]
	Age (years)					Age (years)					
	3-5	6-8	9-11	12-14	15-17	3-5	6-8	9-11	12-14	15-17	
Market Work	-	14	8	14	28	-	4	10	29	48	
Personal Care	41	49	40	56	60	47	45	44	60	51	A,S,AxS (F>M)
Household Work	14	15	18	27	34	17	27	51	72	60	A,S, AxS (F>M)
Eating	82	81	73	69	67	81	80	78	68	65	A
Sleeping	630	595	548	473	499	634	641	596	604	562	A
School	137	292	315	344	314	-	-	-	-	-	
Studying	2	8	29	33	33	1	2	12	15	30	A
Church	4	9	9	9	3	55	56	53	32	37	A
Visiting	14	15	10	21	20	10	8	13	22	56	A (Weekend Only)
Sports	5	24	21	40	46	3	30	42	51	37	A,S (M>F)
Outdoor Activities	4	9	8	7	11	8	23	39	25	26	
Hobbies	0	2	2	4	6	1	5	3	8	3	
Art Activities	5	4	3	3	12	4	4	4	7	10	
Other Passive Leisure	9	1	2	6	4	6	10	7	10	18	A
Playing	218	111	65	31	14	267	180	92	35	21	A,S (M>F)
TV	111	99	146	142	108	122	136	185	169	157	A,S, AxS (M>F)
Reading	5	5	9	10	12	4	9	10	10	18	A
Being Read to	2	2	0	0	0	3	2	0	0	0	A
NA	30	14	23	25	7	52	7	14	4	9	A

[a] Effects are significant for weekdays and weekends, unless otherwise specified. A = age effect, P<0.05, for both weekdays and weekend activities; S = sex effect P<0.05, F>M, M>F = females spend more time than males, or vice versa; and AxS = age by sex interaction, P<0.05.

NA = Unknown.

\- = No data.

Source: Timmer et al., 1985.

Table 16-27. Mean Time Spent (hours/day) Indoors and Outdoors, by Age and Day of the Week

Age Group	Indoors[a]		Outdoors[b]	
	Weekday	Weekend	Weekday	Weekend
3 to 5 years	19.4	18.9	2.5	3.1
6 to 8 years	20.7	18.6	1.8	2.5
9 to 11 years	20.8	18.6	1.3	2.3
12 to 14 years	20.7	18.5	1.6	1.9
15 to 17 years	19.9	17.9	1.4	2.3

[a] Time indoors was estimated by adding the average times spent performing indoor activities (household work, personal care, eating, sleeping, attending school, studying, attending church, watching television, and engaging in conversation) and half the time spent in each activity which could have occurred either indoors or outdoors (i.e., market work, sports, hobbies, art activities, playing, reading, and other passive leisure).

[b] Time outdoors was estimated by adding the average time spent in outdoor activities and half the time spent in each activity which could have occurred either indoors or outdoors (i.e., market work, sports, hobbies, art activities, playing, reading, and other passive leisure).

Source: Adapted from Timmer et al., 1985.

Table 16-28. Mean Time Spent (minutes/day) in Various Microenvironments, Children Ages 12 to 17 Years National and California Surveys

Microenvironment	National Data Mean (Standard Error)[a]	
	All N = 340	Doers Only[b]
Autoplaces	2 (1)	73
Restaurant/Bar	9 (2)	60
In-vehicle/Internal Combustion	79 (7)	88
In-Vehicle/Other	0 (0)	12
Physical/Outdoors	32 (8)	130
Physical/Indoors	15 (3)	87
Work/Study-Residence	22 (4)	82
Work/Study-Other	159 (14)	354
Cooking	11 (3)	40
Other Activities/Kitchen	53 (4)	64
Chores/Child	91 (7)	92
Shop/Errands	26 (4)	68
Other/Outdoors	70 (13)	129
Social/Cultural	87 (10)	120
Leisure-Eat/Indoors	237 (16)	242
Sleep/Indoors	548 (31)	551
Microenvironment	**CARB Data Mean (Standard Error)[a]**	
	All N = 183	Doer Only[b]
Autoplaces	16 (8)	124
Restaurant/Bar	16 (4)	44
In-Vehicle/Internal Combustion	78 (11)	89
In-Vehicle/Other	1 (0)	19
Physical/Outdoors	32 (7)	110
Physical/Indoors	20 (4)	65
Work/Study-Residence	25 (5)	76
Work/Study-Other	196 (30)	339
Cooking	3 (1)	19
Other Activities/Kitchen	31 (4)	51
Chores/Child	72 (11)	77
Shop/Errands	14 (3)	50
Other/Outdoors	58 (8)	78
Social/Cultural	63 (14)	109
Leisure-Eat/Indoors	260 (27)	270
Sleep/Indoors	557 (44)	560

[a] Weighted values.
[b] Doers only = respondents who reported participating in each activity/microenvironment.

Source: Robinson and Thomas, 1991.

Table 16-29. Gender and Age Groups

Age Group [a]	N
6 to 8 years (males)	145
6 to 8 years (females)	124
9 to 11 years (males)	156
9 to 11 years(females)	160
12 to 17 years (males)	98
12 to 17 years (females)	85

[a] Children under the age of 6 were excluded because there were too few responses in the CARB study.
N = Sample size.

Source: Funk et al., 1998.

Table 16-30. Assignment of At-Home Activities to Inhalation Rate Levels for Children

Low	Moderate
Watching child care	Outdoor cleaning
Night sleep	Food Preparation
Watch personal care	Metal clean-up
Homework	Cleaning house
Radio use	Clothes care
TV use	Car/boat repair
Records/tapes	Home repair
Reading books	Plant care
Reading magazines	Other household
Reading newspapers	Pet care
Letters/writing	Baby care
Other leisure	Child care
Homework/watch TV	Helping/teaching
Reading/TV	Talking/reading
Reading/listen music	Indoor playing
Paperwork	Outdoor playing
	Medical child care
	Washing, hygiene
	Medical care
	Help and care
	Meals at home
	Dressing
	Visiting at home
	Hobbies
	Domestic crafts
	Art
	Music/dance/drama
	Indoor dance
	Conservations
	Painting room/home
	Building fire
	Washing/dressing
	Outdoor play
	Playing/eating
	Playing/talking
	Playing/watch TV
	TV/eating
	TV/something else
	Reading book/eating
	Read magazine/eat
	Read newspaper/eat

Source: Funk et al., 1998.

Table 16-31. Aggregate Time Spent (minutes/day) At-Home in Activity Groups, by Adolescents and Children[a]

Activity Group	Adolescents		Children	
	Mean	SD	Mean	SD
Low	789	230	823	153
Moderate	197	131	241[b]	136
High	1	11	3	17
$High_{participants}$[c]	43	72	58	47

[a] Time spent engaging in all activities embodied by inhalation rate category (minutes/day).
[b] Significantly different from adolescents ($p < 0.05$).
[c] Represents time spent at-home by individuals participating in high inhalation rate level activities (i.e., doers).
SD = Standard deviation.

Source: Funk et al., 1998.

Table 16-32. Comparison of Mean Time Spent (minutes/day) At-Home, by Gender (Adolescents)

Activity Group	Male		Female	
	Mean	SD	Mean	SD
Low	775	206	804	253
Moderate	181	126	241	134
High	2	16	0	0

SD = Standard deviation.

Source: Funk et al., 1998.

Table 16-33. Comparison of Mean Time Spent (minutes/day) At-Home, by Gender and Age for Children[a]

Activity Group	Males				Females			
	6-8 Years		9-11 Years		6-8 Years		9-11 Years	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low	806	134	860	157	828	155	803	162
Moderate	259	135	198	111	256	141	247	146
High	3	17	7	27	1	9	2	10
$High_{participant}$[b]	77	59	70	54	68	11	30	23

a Time spent engaging in all activities embodied by inhalation rate category (minutes/day).
b Participants in high inhalation rate activities (i.e., doers).
SD = Standard deviation.

Source: Funk et al., 1998.

Table 16-34. Number of Person-Days/Individuals[a] for Children in CHAD Database

Age Group	All Studies	California[b]	Cincinnati[c]	NHAPS-Air	NHAPS-Water
0 Year	223/199	104	36/12	39	44
0 to 6 Months	-	50	15/5	-	-
6 to 12 Months	-	54	21/7	-	-
1 Year	259/238	97	31/11	64	67
12 to 18 Months	-	57	-	-	-
18 to 24 Months	-	40	-	-	-
2 Years	317/264	112	81/28	57	67
3 Years	278/242	113	54/18	51	60
4 Years	259/232	91	41/14	64	63
5 Years	254/227	98	40/14	52	64
6 Years	237/199	81	57/19	59	40
7 Years	243/213	85	45/15	57	56
8 Years	259/226	103	49/17	51	55
9 Years	229/195	90	51/17	42	46
10 Years	224/199	105	38/13	39	42
11 Years	227/206	121	32/11	44	30
Total	3,009/2,640	1,200	556/187	619	634

[a] The number of person-days of data are the same as the number of individuals for all studies except for the Cincinnati study. Since up to three days of activity pattern data were obtained from each participant in this study, the number of person-days of data is approximately three times the number of individuals.

[b] The California study referred to in this table is the Wiley et al. (1991) study.

[c] The Cincinnati study referred to in this table is the Johnson (1989) study.

\- = No data.

Source: Hubal et al., 2000.

Table 16-35. Time Spent (hours/day) in Various Microenvironments, by Age

Age (years)	Average Time ± Standard Deviation (Percent >0 Hours)				
	Indoors at Home	Outdoors at Home	Indoors at School	Outdoors at Park	In Vehicle
0	19.6 ± 4.3 (99)	1.4 ± 1.5 (20)	3.5 ± 3.7 (2)	1.6 ± 1.5 (9)	1.2 ± 1.0 (65)
1	19.5 ± 4.1 (99)	1.6 ± 1.3 (35)	3.4 ± 3.8 (5)	1.9 ± 2.7 (10)	1.1 ± 0.9 (66)
2	17.8 ± 4.3 (100)	2.0 ± 1.7 (46)	6.2 ± 3.3 (9)	2.0 ± 1.7 (17)	1.2 ± 1.5 (76)
3	18.0 ± 4.2 (100)	2.1 ± 1.8 (48)	5.7 ± 2.8 (14)	1.5 ± 0.9 (17)	1.4 ± 1.9 (73)
4	17.3 ± 4.3 (100)	2.4 ± 1.8 (42)	4.9 ± 3.2 (16)	2.3 ± 1.9 (20)	1.1 ± 0.8 (78)
5	16.3 ± 4.0 (99)	2.5 ± 2.1 (52)	5.4 ± 2.5 (39)	1.6 ± 1.5 (28)	1.3 ± 1.8 (80)
6	16.0 ± 4.2 (98)	2.6 ± 2.2 (48)	5.8 ± 2.2 (34)	2.1 ± 2.4 (32)	1.1 ± 0.8 (79)
7	15.5 ± 3.9 (99)	2.6 ± 2.0 (48)	6.3 ± 1.3 (40)	1.5 ± 1.0 (28)	1.1 ± 1.1 (77)
8	15.6 ± 4.1 (99)	2.1 ± 2.5 (44)	6.2 ± 1.1 (41)	2.2 ± 2.4 (37)	1.3 ± 2.1 (82)
9	15.2 ± 4.3 (99)	2.3 ± 2.8 (49)	6.0 ± 1.5 (39)	1.7 ± 1.5 (34)	1.2 ± 1.2 (76)
10	16.0 ± 4.4 (96)	1.7 ± 1.9 (40)	5.9 ± 1.5 (39)	2.2 ± 2.3 (40)	1.1 ± 1.1 (82)
11	14.9 ± 4.6 (98)	1.9 ± 2.3 (45)	5.9 ± 1.5 (41)	2.0 ± 1.7 (44)	1.6 ± 1.9 (74)

Source: Hubal et al., 2000.

Table 16-36. Mean Time Children Spent (hours/day) Doing Various Macroactivities While Indoors at Home

Age (years)	Mean Time (Percent >0 Hours)						
	Eat	Sleep or Nap	Shower or Bathe	Play Games	Watch TV or Listen to Radio	Read, Write, Homework	Think, Relax, Passive
0	1.9 (96)	12.6 (99)	0.4 (44)	4.3 (29)	1.1 (9)	0.4 (4)	3.3 (62)
1	1.5 (97)	12.1 (99)	0.5 (56)	3.9 (68)	1.8 (41)	0.6 (19)	2.3 (20)
2	1.3 (92)	11.5 (100)	0.5 (53)	2.5 (59)	2.1 (69)	0.6 (27)	1.4 (18)
3	1.2 (95)	11.3 (99)	0.4 (53)	2.6 (59)	2.6 (81)	0.8 (27)	1.0 (19)
4	1.1 (93)	10.9 (100)	0.5 (52)	2.6 (54)	2.5 (82)	0.7 (31)	1.1 (17)
5	1.1 (95)	10.5 (98)	0.5 (54)	2.0 (49)	2.3 (85)	0.8 (31)	1.2 (19)
6	1.1 (94)	10.4 (98)	0.4 (49)	1.9 (35)	2.3 (82)	0.9 (38)	1.1 (14)
7	1.0 (93)	9.9 (99)	0.4 (56)	2.1 (38)	2.5 (84)	0.9 (40)	0.6 (10)
8	0.9 (91)	10.0 (96)	0.4 (51)	2.0 (35)	2.7 (83)	1.0 (45)	0.7 (7)
9	0.9 (90)	9.7 (96)	0.5 (43)	1.7 (28)	3.1 (83)	1.0 (44)	0.9 (17)
10	1.0 (86)	9.6 (94)	0.4 (43)	1.7 (38)	3.5 (79)	1.5 (47)	0.6 (10)
11	0.9 (89)	9.3 (94)	0.4 (45)	1.9 (27)	3.1 (85)	1.1 (47)	0.6 (10)

Source: Hubal et al., 2000.

Table 16-37. Time Children Spent (hours/day) in Various Microenvironments, by Age Recast into New Standard Age Categories

Age Group	N	Indoors at Home		Outdoors at Home		Indoors at School		Outdoors at Park		In Vehicle	
		Mean Time	% Doing	Mean TIme	% Doing	Mean Time	% Doing	Mean Time	% Doing	Mean TIme	% Doing
Birth to <1 month	123	19.6	98	1.7	21	4.3	3	1.3	3	1.3	63
1 to <3 months	33	20.9	100	1.8	9	0.2	3	1.6	9	1.3	27
3 to <6 months	120	19.6	100	0.8	8	7.8	7	1.3	6	1.1	14
6 to <12 months	287	19.1	99	1.1	15	7.6	8	1.8	5	1.3	14
1 to <2 years	728	19.2	99	1.4	34	6.4	9	1.5	5	1.1	27
2 to <3 years	765	18.2	99	1.8	38	6.8	12	2.1	7	1.3	28
3 to <6 years	2,110	17.3	100	1.9	43	5.9	26	1.6	10	1.3	29
6 to <11 years	3,283	15.7	99	1.9	40	6.5	44	2.1	17	1.1	29
11 to <16 years	2,031	15.5	97	1.7	30	6.6	45	2.6	15	1.3	42
16 to <21 years	1,005	14.6	98	1.4	20	5.7	33	3.1	10	1.7	90

N = Sample size.

Source: Based on data source used by Hubal et al., 2000 (CHAD).

Table 16-38. Time Children Spent (hours/day) in Various Macroactivities While Indoors at Home Recast Into New Standard Age Categories

Age Group	N	Eat		Sleep or Nap		Shower or Bathe		Play Games		Watch TV/ Listen to Radio		Read, Write, Homework		Think, Relax, Passive	
		Mean Time	% Doing	Mean Time	% Doing	Mean Time	% Doing	Mean Time	% Doing	Mean Time	% Doing	Mean Time	% Doing	Mean TIme	% Doing
Birth to <1 month	123	2.2	98	13.0	100	0.5	41	5.0	53	1.3	8	0.7	2	2.7	48
1 to <3 months	33	2.4	100	14.8	100	0.4	24	0.7	6	1.6	15	0.0	0	3.5	79
3 to <6 months	120	2.0	100	13.5	100	0.5	9	1.3	31	1.0	21	1.1	3	2.5	59
6 to <12 months	287	1.8	100	12.9	100	0.4	11	1.1	30	1.3	25	0.5	4	2.5	35
1 to <2 years	728	1.7	99	12.5	100	0.5	21	3.2	45	1.8	52	0.6	13	1.4	26
2 to <3 years	765	1.5	98	12.0	100	0.5	22	2.6	45	2.0	77	0.6	18	0.8	30
3 to <6 years	2,110	1.4	99	11.2	100	0.5	38	2.5	38	2.3	86	0.7	25	0.8	28
6 to <11 years	3,283	1.2	98	10.2	100	0.4	54	2.0	28	2.6	84	1.0	43	0.8	20
11 to <16 years	2,031	1.1	94	9.7	98	0.4	50	1.8	18	3.0	85	1.4	45	0.8	20
16 to <21 years	1,005	1.0	84	8.9	98	0.4	45	1.9	5	3.2	73	2.2	37	1.3	24

N = Sample size.

Source: Based on data source used by Hubal et al., 2000 (CHAD).

Table 16-39. Number and Percentage of Respondents with Children and Those Reporting Outdoor Play[a] Activities in both Warm and Cold Weather

Source	Respondents with Children	Child Players[a]		Child non-Players		Warm Weather Playersa	Cold Weather Players	Players in Both Seasons
	N	N	%	N	%	N	N	%
SCS-II base	197	128	65.0	69	35.0	127	100	50.8
SCS-II over sample	483	372	77.0	111	23.0	370	290	60.0
Total	680	500	73.5	180	26.5	497	390	57.4

[a] "Play" and "player" refer specifically to participation in outdoor play on bare dirt or mixed grass and dirt.
[b] Does not include three "Don't know/refused" responses regarding warm weather play.
N = Sample size.

Source: Wong et al., 2000.

Table 16-40. Play Frequency and Duration for all Child Players (from SCS-II data)						
Statistic	Cold Weather			Warm Weather		
	Frequency (days/week)	Duration (hours/day)	Total (hours/week)	Frequency (days/week)	Duration (hours/day)	Total (hours/week)
N	372	374	373	488	479	480
5th Percentile	1	1	1	2	1	4
50th Percentile	3	1	5	7	3	20
95th Percentile	7	4	20	7	8	50

N = Sample size.

Source: Wong et al., 2000.

Table 16-41. Hand Washing and Bathing Frequency for all Child Players (from SCS-II data)				
Statistic	Cold Weather		Warm Weather	
	Hand washing (times/day)	Bathing (times/week)	Hand washing (times/day)	Bathing (times/week)
N	329	388	433	494
5th Percentile	2	2	2	3
50th Percentile	4	7	4	7
95th Percentile	10	10	12	14

N = Sample size.

Source: Wong et al., 2000.

Table 16-42. NHAPS and SCS-II Play Duration[a] Comparison

Data Source	Mean Play Duration (minutes/day)			X^2 test[b]
	Cold Weather	Warm Weather	Total	
NHAPS	114	109	223	p<0.0001
SCS-II	102	206	308	

[a] Selected previous day activities in NHAPS; average day outdoor play on bare dirt or mixed grass and dirt in SCS-II.
[b] 2x2 Chi-square test for contingency between NHAPS and SCS-II.

Source: Wong et al., 2000.

Table 16-43. NHAPS and SCS-II Hand Wash Frequency[a] Comparison

Data Source	Season	Percent[b] Reporting Frequency (times/day) of:								X^2 test[c]
		0	1-2	3-5	6-9	10-19	20-29	30+	"Don't Know"	
NHAPS	Cold	3	18	51	17	7	1	1	3	p = 0.06
SCS-II	Cold	1	16	50	11	7	1	0	15	
NHAPS	Warm	3	18	51	15	7	2	1	4	p = 0.001
SCS-II	Warm	0	12	46	16	10	1	0	13	

[a] Selected previous day activities in NHAPS; average day outdoor play on bare dirt or mixed grass and dirt in SCS-II.
[b] Results are reported as percentage of total for clarity. Incidence data were used in statistical tests.
[c] 2x2 Chi-square test for contingency between NHAPS and SCS-II.

Source: Wong et al., 2000.

Table 16-44. Time Spent (minutes/day) Outdoors Based on CHAD Data (Doers Only)[a]

Age Group	N	Time Spent Outdoors					COV(%)	Participation[b] (%)
		Minimum	Median	Maximum	Mean	SD		
<1 month	57	2	60	700	99	124	125	47
1 to 2 months	5	4	60	225	102	90	89	36
3 to 5 months	27	10	90	510	114	98	86	23
6 to 11 months	91	5	60	450	91	76	84	33
1 year	389	1	75	1,035	102	99	97	58
2 years	448	1	100	550	134	108	80	64
3 to 5 years	1,336	1	120	972	146	117	80	68
6 to 10 years	2,216	1	120	1,440	162	144	89	71
11 to 15 years	1,423	1	110	1,440	154	163	106	73
16 to 17 years	356	1	85	1,083	129	145	112	81
18 to 20 years	351	1	70	788	132	155	118	72

[a] Only data for individuals that spent >0 time outdoors and had 30 or more records are included in the analysis.

[b] Participation rates or percent of sample days in the study spending some time (>0 minutes per day) outdoors. The mean time spent outdoors for the age group may be obtained by multiplying the participation rate by the mean time shown above.

SD = Standard deviation.

COV = Coefficient of variation (SD/mean x 100).

Source: Graham and McCurdy, 2004.

Table 16-45. Comparison of Daily Time Spent Outdoors (minutes/day), Considering Gender and Age Cohort (Doers Only)[a]

Age Group	Gender	N	Time Spent Outdoors in Minutes					COV (%)	K-S Test[b]			
			Minimum	Median	Maximum	Mean	SD		Dn	χ^2	ρ	Reject H_0
< 1 month	Male	35	7	68	700	116	144	125	0.24	0.90	0.3964	No
	Female	22	2	58	333	73	78	106	-	-	-	-
1 to 2 months	Male	4	4	58	165	71	68	95		Cannot Test		
	Female	1	225	225	225	225	-	0				
3 to 5 months	Male	20	10	86	210	89	56	63	0.42	0.96	0.3158	No
	Female	7	50	140	510	187	153	81				
6 to 11 months	Male	53	10	60	450	95	83	87	0.07	1.00	0.3200	No
	Female	38	5	68	270	86	67	77				
1 year	Male	184	1	80	1,035	110	114	104	0.07	0.71	0.6896	No
	Female	205	4	70	511	95	82	86				
2 years	Male	232	1	105	550	136	105	77	0.09	1.00	0.2705	No
	Female	216	2	90	525	131	111	84				
3 to 5 years	Male	723	1	120	972	146	119	81	0.04	0.74	0.6465	No
	Female	612	2	120	701	144	113	78				
6 to 10 years	Male	1228	1	132	1,440	173	148	86	0.09	2.05	0.0004	Yes
	Female	987	2	115	1,380	148	138	93				
11 to 15 years	Male	779	1	125	1,440	171	169	99	0.17	3.12	< 0.0001	Yes
	Female	640	1	90	1,371	134	153	114				
16 to 17 years	Male	168	2	113	810	151	147	97	0.19	1.80	0.0030	Yes
	Female	188	1	68	1,083	109	141	129				
18 to 20 years	Male	184	2	95	788	162	176	109	0.20	1.84	0.0023	Yes
	Female	167	1	50	606	99	119	120				

[a] Only data for individuals that spent >0 time outdoors and had 30 or more records are included in the analysis.
[b] The two-sample Kolmogorov-Smirnov (K-S) test H_0 is that the distribution of variable 1 is the same as variable 2, using a $\chi 2$ test statistic at $\propto$=0.050.
SD = Standard deviation.
COV = Coefficient of variation (SD/mean x 100).

Source: Graham and McCurdy, 2004.

Table 16-46. Time Spent (minutes/day) Indoors
Based on CHAD Data (Doers Only)[a]

Age Group	N	Time Spent Indoors					COV(%)	Participation[b] (%)
		Minimum	Median	Maximum	Mean	SD		
<1 month	121	490	1,380	1,440	1,336	137	10	100.0
1 to 2 months	14	1,125	1,380	1,440	1,348	105	8	100.0
3 to 5 months	115	840	1,385	1,440	1,359	93	7	100.0
6 to 11 months	278	840	1,370	1,440	1,353	81	6	100.0
1 year	668	315	1,350	1,440	1,324	107	8	100.0
2 years	700	290	1,319	1,440	1,286	138	11	100.0
3 to 5 years	1,977	23	1,307	1,440	1,276	136	11	100.0
6 to 10 years	3,118	7	1,292	1,440	1,256	153	12	100.0
11 to 15 years	1,939	69	1,300	1,440	1,255	160	13	99.8
16 to 17 years	438	161	1,296	1,440	1,251	171	14	100.0
18 to 20 years	485	512	1,310	1,440	1,242	180	15	100.0

a Only data for individuals that spent >0 time indoors and had 30 or more records are included in the analysis.
b Participation rates or percent of sample days in the study spending some time (>0 minutes per day) indoors. The mean time spent indoors for the age group may be obtained by multiplying the participation rate (as a decimal) by the mean time shown above.
N = Sample size.
SD = Standard deviation.
COV = Coefficient of variation (SD/mean x 100).

Source: Graham and McCurdy, 2004.

Table 16-47. Time Spent (minutes/day) in Motor Vehicles Based on CHAD Data (Doers Only)[a]

Age Group	N	Time Spent in Motor Vehiicles					COV(%)	Participation[b] (%)
		Minimum	Median	Maximum	Mean	SD		
<1 month	80	2	68	350	86	68	79	66
1 to 2 months	9	20	83	105	67	32	48	64
3 to 5 months	75	13	60	335	71	49	69	65
6 to 11 months	226	4	51	425	62	47	76	81
1 year	515	1	52	300	67	50	76	77
2 years	581	2	54	955	73	76	104	83
3 to 5 years	1,702	1	55	1,389	70	70	99	86
6 to 10 years	2,766	1	58	1,214	71	68	95	89
11 to 15 years	1,685	1	60	825	76	74	97	87
16 to 17 years	400	4	73	1,007	92	90	98	91
18 to 20 years	449	4	76	852	109	106	98	93

[a] Only data for individuals that spent >0 time in motor vehicles and had 30 or more records are included in the analysis.

[b] Participation rates or percent of sample days in the study spending some time (>0 minutes per day) in motor vehicles. The mean time spent in motor vehicles for the age group may be obtained by multiplying the participation rate (as a decimal) by the mean time shown above.

N = Sample size.

SD = Standard deviation.

COV = Coefficient of variation (SD/mean x 100).

Source: Graham and McCurdy, 2004.

Table 16-48. Time Spent (minutes/two-day period)[a] in Various Activities by Children Participating in the Panel Study of Income Dynamics (PSID), 1997 Child Development Supplement (CDS)

Age Group	Boys (N = 1,444)		Girls (N = 1,387)	
	Mean[a]	Standard Deviation	Mean[a]	Standard Deviation
Television Use				
1 to 5 years	197	168	184	163
6 to 8 years	263	165	239	159
9 to 12 years	251	185	266	194
Electronic Game Use				
1 to 5 years	8	38	5	40
6 to 8 years	44	113	14	39
9 to 12 years	57	102	18	47
Computer Use				
1 to 5 years	7	28	7	35
6 to 8 years	13	43	8	28
9 to 12 years	27	71	15	43
Print Use[b]				
1 to 5 years	21	32	23	34
6 to 8 years	20	37	20	32
9 to 12 years	19	47	29	56
Highly Active Activities[c]				
1 to 5 years	42	74	34	78
6 to 8 years	107	123	62	92
9 to 12 years	137	149	63	88
Moderately Active Activities[d]				
1 to 5 years	55	81	59	92
6 to 8 years	31	65	37	69
9 to 12 years	40	73	46	89
Sedentary Activities[e]				
1 to 5 years	55	71	54	71
6 to 8 years	75	77	80	84
9 to 12 years	110	109	122	111

[a] Means represent minutes spent in each activity over a 2-day period (one weekday and one weekend day).
[b] Print use represents time spent using print media including reading and being read to.
[c] Includes all sport activities such as basketball, soccer, swimming, running or bicycling.
[d] Includes activities such as singing, camping, taking music lessons, fishing, and boating.
[e] Includes activities such as playing board games, doing puzzles, talking on the phone, and relaxing.
N = Sample size.

Source: Vanderwater et al., 2004.

Table 16-49. Mean Time Spent (minutes/day) in Various Activity Categories, by Age - Weekday								
Activity Category	2002-2003				1981-1982			
	6 to 8 years	9 to 11 years	12 to 14 years	15 to 17 years	6 to 8 years	9 to 11 years	12 to 14 years	15 to 17 years
Market work	0	0	1	22	-	-	-	28
Household work	25	32	38	39	15	18	27	34
Personal care	68	66	68	73	49	40	56	60
Eating	60	57	54	49	81	73	69	67
Sleeping, naps	607	583	542	515	595	548	473	499
School	406	398	395	352	292	315	344	314
Studying	29	39	49	50	8	29	33	33
Church	4	5	5	3	9	9	9	3
Visiting, socializing	16	25	25	53	-	-	-	-
Sports	10	17	33	33	24	21	40	46
Outdoor Activities	6	6	4	6	9	8	7	11
Hobbies	1	1	1	2	2	2	4	6
Art Activities	8	7	7	4	4	3	3	12
Television	94	106	111	115	99	146	142	108
Other passive leisure	9	10	24	39	-	-	-	-
Playing	74	56	45	35	111	65	31	14
Reading	11	12	11	7	5	9	10	12
Being read to	2	1	0	0	-	-	-	-
Computer activities	6	10	25	38	-	-	-	-
Missing data	4	8	4	6	-	-	-	-

- = Data not provided.

Source: Juster et al., 2004.

Table 16-50. Mean Time Spent (minutes/day) in Various Activity Categories, by Age - Weekend Day

Activity Category	2002-2003				1981-1982			
	6 to 8 years	9 to 11 years	12 to 14 years	15 to 17 years	6 to 8 years	9 to 11 years	12 to 14 years	15 to 17 years
Market work	0	0	9	39	-	-	-	48
Household work	81	91	100	79	27	51	72	60
Personal care	78	72	73	77	45	44	60	51
Eating	89	80	69	64	80	78	68	65
Sleeping, naps	666	644	633	629	641	596	604	562
School	3	6	7	7	-	-	-	-
Studying	5	9	20	24	2	12	15	30
Church	41	37	36	30	56	53	32	37
Visiting, socializing	61	66	58	91	-	-	-	-
Sports	23	40	40	27	30	42	51	37
Outdoor Activities	12	12	12	11	23	39	25	26
Hobbies	2	1	4	5	5	3	8	3
Art Activities	11	7	9	6	4	4	7	10
Television	155	184	181	162	136	185	169	157
Other passive leisure	14	15	40	54	-	-	-	-
Playing	163	134	148	59	180	92	35	21
Reading	14	15	13	7	9	10	10	18
Being read to	1	1	0	0	-	-	-	-
Computer activities	12	19	39	58	-	-	-	-
Missing data	9	8	9	11	-	-	-	-

- = Data not provided.

Source: Juster et al., 2004.

Table 16-51. Mean Time Spent (minutes/week) in Various Activity Categories for Children, Ages 6 to 17 Years

Activity Category	2002-2003	1981-1982
Market work	53	126
Household work	343	223
Personal care	493	356
Eating	426	508
Sleeping, naps	4,092	3,758
School	1,947	1,581
Studying	238	158
Church	94	125
Visiting, socializing	287	132
Sports	179	244
Outdoor Activities	50	100
Hobbies	12	27
Art Activities	48	40
Television	876	944
Other passive leisure	166	39
Playing	485	440
Reading	77	69
Being read to	5	3
Computer activities	165	0
Missing data	45	1,206

Source: Juster et al., 2004.

Table 16-52. Mean Time Use (hours/day) by Children, Ages 15 to 19 Years

Activity	hours/day		
	Male	Female	All
Personal Care[a]	10.26	10.34	10.30
Eating and Drinking[b]	1.02	1.11	1.07
Household Activities[c]	0.61	0.92	0.76
Purchasing Goods and Services[d]	0.38	0.74	0.56
Caring for and Helping Household Members[e]	0.10	0.19	0.15
Caring for and Helping Non-Household Members[f]	0.20	0.23	0.21
Working on Work-related Activities[g]	1.53	1.24	1.39
Educational Activities[h]	3.08	3.51	3.29
Organizational Civic and Religious Activities[i]	0.34	0.33	0.34
Leisure and Sports[j]	6.02	4.75	5.40
total leisure and sports - weekdays	-	-	4.85
total leisure and sports - weekends	-	-	6.68
sports, exercise, recreation - weekdays	-	-	0.58
sports, exercise, recreation - weekends/holidays	-	-	0.69
socializing and communicating - weekdays	-	-	0.76
socializing and communicating, - weekends/holidays	-	-	1.32
watching TV - weekdays	-	-	1.96
watching TV - weekends/holidays	-	-	2.45
reading - weekdays	-	-	0.11
reading - weekends/holidays	-	-	0.11
relaxing, thinking - weekdays	-	-	0.15
relaxing, thinking - weekends/holidays	-	-	0.13
playing games, computer use for leisure - weekdays	-	-	0.69
playing games, computer use for leisure - weekends/holidays	-	-	1.00
other sports/leisure including travel - weekdays	-	-	0.61
other sports/leisure including travel - weekends/holidays	-	-	0.98
Telephone Calls, Mail, and E-mail[k]	0.24	0.42	0.33
Other Activities not Elsewhere Classified[l]	0.23	0.21	0.22

[a] Includes sleeping, bathing, dressing, health-related self care, and personal and private activities.

[b] Includes time spent eating or drinking (except when identified as part of work or volunteer activity); does not include time spent purchasing meals, snacks, or beverages.

[c] Includes housework, cooking, yard care, pet care, vehicle maintenance and repair, home maintenance, repair, decoration, and renovation.

[d] Includes purchase of consumer goods, professional (e.g., banking, legal, medical, real estate) and personal care services (e.g., hair salons, barbershops, day spas, tanning salons), household services (e.g., housecleaning, lawn care and landscaping, pet care, dry cleaning, vehicle maintenance, construction), and government services (e.g., applying for food stamps, government required licenses or paying fines).

[e] Includes time spent caring or helping to care for child or adult household member (e.g., physical care, playing with children, reading to child or adult, attending to health care needs, dropping off, picking up or waiting for children).

[f] Includes time spent caring or helping to care for child or adult who is not a household member (e.g., physical care, playing with children, reading to child or adult, attending to health care needs, dropping off, picking up or waiting for children). Does not include activities done through a volunteer organization.

[g] Includes time spent as part of the job, income-generating activities, or job search activities. Also includes travel time for work-related activities.

[h] Includes taking classes, doing research and homework, registering for classes, and before and after school extra-curricular activities, except sports.

[i] Includes time spent volunteering for or through civic obligations (e.g., jury duty, voting, attending town hall meetings), or through participating in religious or spiritual activities (e.g., church choir, youth groups, praying).

[j] Includes sports, exercise, and recreation. This category is broken down into subcategories for the 15 to 19 years old age category.

[k] Includes telephone use, mail and e-mail. Does not include communications related to purchase of goods and services or those related to work or volunteering.

[l] Includes residual activities that could not be coded or where information was missing.

Source: U.S. DL, 2007.

Table 16-53. Mean Time Spent (minutes/day) in Moderate-to-Vigorous Physical Activity						
Age (years)	Weekday Mean (SD)			Weekend Mean (SD)		
	Boys	Girls	Both	Boys	Girls	Both
9	190.8(53.2)	173.3(46.4)	181.8(50.6)	184.3(68.6)	173.3(64.3)	178.6(66.6)
11	133.0(42.9)	115.6(36.3)	124.1(40.6)	127.1(59.5)	112.6(53.2)	119.7(56.8)
12	105.3(40.2)	86.0(32.5)	95.6(37.8)	93.4(55.3)	73.9(45.8)	83.6(51.7)
15	58.2(31.8)	38.7(23.6)	49.2(29.9)	43.2(38.0)	25.5(23.3)	35.1(33.3)

SD = Standard deviation.

Source: Nader et al. 2008.

17 CONSUMER PRODUCTS

17.1 INTRODUCTION

Consumer products may contain toxic or potentially toxic chemical constituents to which children may be exposed as a result of their use. For example, household cleaners can contain ammonia, alcohols, acids, and/or organic solvents which may pose health concerns. Potential routes of exposure to consumer products or chemicals released from consumer products during use include ingestion, inhalation, and dermal contact. Children can be in environments where adults use household consumer products such as cleaners, solvents, and paints. As such, children can be passively exposed to chemicals in these products. Since children spend a large amount of time indoors, the use of household chemicals in the indoor environment can be a principal source of exposure (Franklin, 2008).

Very little information is available on the exact way the different kinds of products are used by consumers, including the many ways in which these products are handled, the frequency and duration of contact, and the measures consumers may take to minimize exposure/risk (Steenbekkers, 2001). In addition, the factors that influence these behaviors are not well studied, but some studies have shown there is a large variation in behavior between persons (Steenbekkers, 2001). This chapter presents available information on the amounts, frequency, and duration of use for various consumer products found in typical households.

The studies presented in the following sections represent readily available surveys from which data were collected on the frequency and duration of use and amount of use of cleaning products, household solvent products, cosmetic and other personal care products, and pesticides. For a more detailed presentation of data on the use of consumer products among the general population, the reader is referred to the *Exposure Factors Handbook* (U.S. EPA, 1997).

The National Library of Medicine Household Products Database is a consumer guide that provides information on the potential health effects of chemicals contained in more than 7,000 common household products used inside and around the home. Although, this database does not provide exposure factor information, it contains information on chemical ingredients and their percentages in consumer products, which products contain specific chemical ingredients, acute and chronic effects of chemical ingredients, and manufacturer information. These data could be useful when conducting an exposure assessment for a specific chemical/active ingredient. The product categories are: auto products, inside the home, pesticides, landscape/yard, personal care, home maintenance, arts and crafts, pet care, and home office. The database can be searched by product name, product type, manufacturer, and ingredient. This database can be found at http://hpd.nlm.nih.gov. Table 17-1 provides a list of household consumer products found in some U.S. households (U.S. EPA, 1987). It should be noted, however, that this list was compiled by U.S. EPA in 1987 and consumer use of some products listed may have changed (e.g., aerosol product use has declined). Therefore, the reader is referred to the National Library of Medicine database as a source of more current information.

The U.S. EPA Source Ranking Database (SRD) is another source of information on consumer products, but does not provide exposure factor data. SRD can be used to perform systematic screening-level reviews of more than 12,000 potential indoor pollution sources to identify high-priority product and material categories for further evaluation. It also can be used to identify products that contain a specific chemical. Information on the SRD can be found at:
http://www.epa.gov/oppt/exposure/pubs/srd.htm.

The Soaps and Detergents Association (SDA) developed a peer-reviewed document that presents methodologies and specific exposure information that can be used for screening-level risk assessments from exposures to high production volume chemicals. The document addresses the use of consumer products, including laundry, cleaning, and personal care products. It includes data for daily frequency of use, and amount of product used. The data used were compiled from a number of sources including, the *Exposure Factors Handbook* (U.S. EPA, 1997), cosmetic associations, and data from the SDA. The document entitled "Exposure and Risk Screening Methods for Consumer Product Ingredients" can be found on the SDA website under:
http://www.cleaning101.com/files/Exposure_and_Risk_Screening_Methods_for_Consumer_Product_Ingredients.pdf.

17.2 RECOMMENDATIONS

Due to the large range and variation among consumer products and their exposure pathways, it is not feasible to recommend specific exposure values as has been done in other chapters of this handbook. The user is referred to the contents/references of this chapter and Chapter 17 of the *Exposure Factors Handbook* (U.S. EPA, 1997) to derive appropriate exposure factors. The following sections of this chapter provide summaries of data from surveys involving the use of consumer products.

17.3 CONSUMER PRODUCTS USE STUDIES

17.3.1 CTFA, 1983 - Cosmetic, Toiletry, and Fragrance Association, Inc. - Summary of Results of Surveys of the Amount and Frequency of Use of Cosmetic Products by Women

The Cosmetic, Toiletry, and Fragrance Association Inc. (CTFA, 1983), a major manufacturer and a market research bureau, conducted surveys to obtain information on frequency of use of various cosmetic products. Three surveys were conducted to collect data on the frequency of use of various cosmetic products and selected baby products. In the first of these three surveys CTFA (1983) conducted a one-week prospective survey of 47 female employees and relatives of employees between the ages of 13 and 61 years. In the second survey, a cosmetic manufacturer conducted a retrospective survey of 1,129 of its customers. The third survey was conducted by a market research bureau which sampled 19,035 female consumers nationwide over a 9-1/2 month period. Of the 19,035 females interviewed, responses from only 9,684 females were tabulated (CTFA, 1983). The third survey was designed to reflect the sociodemographic (i.e., age, income, etc) characteristics of the entire U.S. population. The respondents in all three surveys were asked to record the number of times they used the various products in a given time period (i.e., a week, a day, a month, or a year).

To obtain the average frequency of use for each cosmetic product, responses were averaged for each product in each survey. Thus, the averages were calculated by adding the reported number of uses per given time period for each product, dividing by the total number of respondents in the survey, and then dividing again by the number of days in the given time period (CTFA, 1983). The average frequency of use of cosmetic products was determined for both "users" and "non-users." The frequency of use of baby products was determined among "users" only. The upper 90th percentile frequency of use values were determined by eliminating the top ten percent most extreme frequencies of use. Therefore, the highest remaining frequency of use was recorded as the upper 90th percentile value. Table 17-2 presents the amount of product used per application (grams) and the average and 90th percentile frequency of use per day for baby products and various cosmetic products for all the surveys.

An advantage of the frequency data obtained from the third survey (market research bureau) is that the sample population was more likely to be representative of the U.S. population. Another advantage of the third dataset is that the survey was conducted over a longer period of time when compared with the other two frequency datasets. Also, the study provided empirical data which will be useful in generating more accurate estimates of consumer exposure to cosmetic products. In contrast to the large market research bureau survey, the CTFA employee survey is very small and both that survey and the cosmetic company survey are likely to be biased toward high end users. Therefore, data from these two surveys should be used with caution. While the data in this study were not tabulated by age of the population, the study included some individuals in the age groups of interest for this handbook.

17.3.2 U.S. EPA, 1996 - National Human Activity Pattern Survey (NHAPS)

U.S. EPA (1996) collected data on the duration and frequency of selected activities and the time spent in selected microenvironments via 24-hour diaries as part of the National Human Activity Pattern Survey (NHAPS). More than 9,000 individuals from various age groups in 48 contiguous states participated in NHAPS. Children represented approximately 2,000 of the respondents (499 respondents under 5 years of age; 703 respondents between 5 and 11 years; 589 respondents between 12 and 17 years; and 799 respondents between 18 and 24 years). The survey was conducted between October 1992 and September 1994. Individuals were interviewed to categorize their 24-hour routines (diaries) and/or to answer follow-up questions that were related to exposure events. For children under 10 years of age, adult members of the households gave proxy interviews. Demographic, including socioeconomic (gender, age, race, education, etc.), geographic (census region, state, etc.), and temporal (day of week, month, season) data were included in the study. Data were collected for a maximum of 82 possible microenvironments and 91 different activities.

As part of the survey, data were also collected on duration and frequency of use of selected consumer products. Tables 17-3 through 17-10 present data on the number of minutes that survey respondents spent in activities working with or being near certain consumer products, including: freshly applied paints; household cleaning agents such as scouring powders or ammonia; floor wax, furniture wax, or shoe polish; glue; solvents, fumes, or strong smelling chemicals; stain or spot removers; gasoline, diesel-powered equipment, or automobiles; and pesticides, bug sprays, or bug strips. These data are presented according to the age categories used in NHAPS (1 to 4 years, 5 to11 years, 12 to17 years, and 18 to 64 years). Table 17-11 through 17-15 present data on the number of respondents in these age categories that used fragrances, aerosol sprays, pesticides (professionally-applied and consumer-applied), and humidifiers. Because the age categories used by the study authors did not coincide with the standardized age categories recommended in U.S. EPA (2005) and used elsewhere in this handbook, the source data from NHAPS on pesticide use (professionally applied and consumer-applied) were re-analyzed by U.S. EPA to generate data for the standardized age categories. These data are presented in Tables 17-16 and 17-17 for age groups less than 1 year, 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. Data for subsets of the first year of life (e.g., 1 to 2 months, 3 to 5 months, etc.) were not available.

As discussed in previous chapters of this handbook that used NHAPS as a data source, the primary advantage of NHAPS is that the data were collected for a large number of individuals and the survey was designed to be representative of the U.S. general population. However, due to the wording of questions in the survey, precise data were not available for consumers who spent more than 60 or 120 minutes (depending on the activity) using some consumer products. This prevents accurate characterization of the high end of the distribution and may also introduce error into the calculation of the mean.

17.3.3 Bass et al., 2001 - What's Being Used at Home: A Household Pesticide Survey

Bass et al. (2001) conducted a survey to assess the use of pesticide products in homes with children in March 1999. The study obtained information on what pesticides were used, where they were used, and how frequently they were used. A total of 107 households in Arizona that had a least one child less than ten years of age in the household, and had used a pesticide within the last six months, were surveyed (Bass et al., 2001). The survey population was predominantly female Hispanic and represented a survey response rate of approximately 74 percent. Study participants were selected by systematic random sampling. Among the households sampled, 3 percent had one child less than 10 years old, 42 percent had two children less than 10 years old, and 23 percent had three to five children in this age bracket. Pesticide use was assessed by a one-on-one interview in the home. Survey questions pertained to household pesticides used inside the house for insect control and outside the house for the control of weeds in the garden and to repel animals from the garden. As part of the interview, information was gathered on the frequency of use.

Table 17-18 presents information on the type, characteristics, and frequency of pesticide use, as well as information on the demographics of the survey population. A total of 148 pesticide products were used in the 107 households surveyed. Respondents had used pesticides in the kitchen, bathroom, floors, baseboards, and cabinets with dishes or cookware. The frequency of use data showed the following: 13.5 percent of the households used pesticides more than once per week; 18.2 percent used the products once per week; 28.4 percent used the products once per month; 15.5 percent used the products once in three months; 10.8 percent used the products once in six months; and 8.8 percent used the products once per year (Bass et al., 2001).

Although this study was limited to a selected area in Arizona, it provides useful information on the frequency of use of pesticides among households with children. This may be useful for populations in similar geographical locations where site-specific data are not available. However, these data are the result of a community-based survey and are not representative of the U.S. general population.

17.3.4 Loretz et al., 2005 - Exposure Data for Cosmetic Products: Lipstick, Body Lotion, and Face Cream

Loretz et al. (2005) conducted a nationwide survey to estimate the usage (i.e., frequency of application and amount used per application) of lipstick, body lotion, and face cream. The study was conducted from April to June 2000. Three hundred and sixty study subjects were recruited in ten U.S. cities (Atlanta, Georgia; Boston, Massachusetts; Chicago, Illinois; Denver, Colorado; Houston, Texas; Minneapolis, Minnesota; St. Louis, Missouri; San Bernadino, California; Tampa, Florida; and Seattle, Washington). The survey participants were women, ages 19-65 years, who regularly used the products of interest. Typical cosmetic formulations of the three product types were weighed and provided to the women for use over a two-week period. Subjects recorded information on product usage (e.g., whether the product was used, number of applications, time of applications) on a daily basis in a diary provided to them. At the end of the two-week period, unused portions of product were returned and weighed. The amount of product used was estimated as the difference between the weight of product at the beginning and end of the survey period. Of the 360 subjects recruited, 86.4 percent, 83.3 percent, and 85.6 percent completed the study and returned the diaries for lipstick, body lotion, and face cream, respectively (Loretz et al., 2005).

The survey data are presented in Table 17-19 and 17-20. Table 17-19 provides the mean, median, and standard deviations for the frequency of use. Table 17-20 provides distribution data for the total amount applied, the average amount applied per use day, and the average amount applied per application.

An advantage of this study is that the survey population covered a diverse geographical area of the U.S. and was not based on recall data. A limitation of the study is that the short duration (two weeks) may not accurately reflect long-term usage patterns. Another limitation is that the study only included women who already used the products; therefore, the usage patterns are not representative of the entire female population. Also, the data are not presented by age group, but the study does provide information on a population that includes the ages of interest for this document. Data for children could not be separated from that of the rest of the survey population.

17.3.5 Loretz et al., 2006 - Exposure Data for Personal Care Products: Hairspray, Spray Perfume, Liquid Foundation, Shampoo, Body Wash, and Solid Antiperspirant

Loretz et al. (2006) conducted a nationwide survey to determine the usage (i.e., frequency of use and amount used) of hairspray, spray perfume, liquid foundation, shampoo, body wash, and solid antiperspirant. The survey was similar to that described by Loretz et al. (2005). This study was conducted between October 2001 and October 2002. A total of 360 women were recruited from ten U.S. cities (Atlanta, Georgia; Boston, Massachusetts; Chicago, Illinois; Denver, Colorado; Houston, Texas; Minneapolis, Minnesota; St. Louis, Missouri; San Bernadino, California; Tampa, Florida; and Seattle, Washington). The survey participants were women, ages 19-65 years old, who regularly used the test products. Subjects kept daily records on product usage (whether the product was used, number of applications, time of applications) in a diary. For spray perfume, liquid foundation, and body wash, subjects recorded the body area(s) where these products were applied. For shampoo, subjects recorded information on their hair type (length, thickness, oiliness, straight or curly, and color treated or not). At the end of the two week period, unused portions of products were returned and weighed. Of the 360 subjects recruited per product, the study was completed by 329 participants for hairspray, 327 for spray perfume, 326 for liquid foundation, and 340 participants for shampoo, body wash, and solid antiperspirant.

The survey data are presented in Tables 17-21 through 17-23. Table 17-21 provides the minimum, maximum, mean, and standard deviations for the frequency of use. Table 17-22 provides percentile values for the amount of product applied per application. Table 17-23 provides distribution data for the amount applied per use day.

An advantage of this study is that the survey population covered a diverse geographical range of the U.S. and did not rely on recall data. A limitation of the study is that the short duration (two weeks) may not accurately reflect long-term usage patterns. Another limitation is that the study only included women who already used these products; therefore, the usage patterns are not entirely representative of the entire female population. Also, the data are not presented by age group, but the study does provide information on a population that includes the ages of interest for this document. Data for children could not be separated from that of the rest of the survey population.

17.3.6 Loretz et al., 2008 - Exposure Data for Cosmetic Products: Facial Cleanser, Hair Conditioner, and Eye Shadow

Loretz et al. (2008) used the data from a study conducted in January 2005 to estimate frequency of use and usage amount for facial cleanser, hair conditioner, and eye shadow. The study was conducted in a similar manner as Loretz et al. (2005; 2006). A total of 360 women, ages 18 to 69 years of age, were recruited by telephone to provide diary records of product use over a two-week period. The study subjects were representative of four U.S. Census regions (Northeast, Midwest, South, and West). A total of 295, 297, and 299 completed the study for facial cleanser, hair conditioner, and eye shadow, respectively.

The participants recorded daily in a diary whether the product was used that day, the number of applications, and the time of application(s) over a two-week period. Products were weighed at the start and completion of the study to determine the amount used. A statistical analysis of the data was conducted to provide summary distributions of use patterns, including number of applications, amount used per day, and amount of product used per application for each product. Data on the number of applications per day are provided in Table 17-24. The average amounts of product applied per use day are shown in Table 17-25, and the average amounts of product applied per application are shown in Table 17-26.

The advantages of this study are that it is representative of the U.S. female population for users of the products studied, it provides data for frequency of use and amount used, and it provides distribution data. The limitations of the study are that the data were not provided by age group, but included ages in the study group that are relevant for this handbook. In addition, the participants were regular users of the product, so the amount applied and the frequency of use may be higher than for other individuals who may use the products. According to Loretz et al. (2008) "variability in amount used by the different subjects is high, but consistent with the data from other cosmetic and personal care studies." The authors also noted that it was not clear if the high-end users of products represented true usage.

17.3.7 Sathyanarayana et al., 2008 - Baby Care Products; Possible Sources of Infant Phthalate Exposure

Sathyanarayana et al. (2008) investigated dermal exposure to phthalates via the dermal application of personal care products. The study was conducted on 163 infants born between the year 2000 and 2005. The products studied were baby lotion, baby powder, baby shampoo, diaper cream, and baby wipes. Infants were recruited through Future Families, a multicenter pregnancy cohort study, at prenatal clinics in Los Angeles, California; Minneapolis, Minnesota; and Columbia, Missouri. Although the study was designed to assess exposure to phthalates, the authors collected information on the percentage of the total participants that used the baby products. Data were collected from questionnaire responses of the mothers and at study visits. The characteristics and the percent of the population using the studied baby products are shown in Table 17-27. Of the 163 infants studied, 94 percent of the participants used baby wipes and 54 percent used infant shampoo.

The advantages of this study are that it specifically targeted consumer products used by children. The percent of the study population using these products was captured and the data were collected from a diverse ethnic population. The limitations are that these data may not be entirely representative of the U.S. population because the study population was from only three states and the sample size was small.

17.4 REFERENCES FOR CHAPTER 17

Bass, J.; Ortega, L.; Rosales, C.; Petersen, N., Philen, R. (2001) What's being used at home: a household pesticide survey. Pub Health 9(3):138-144.

Cosmetic, Toiletry and Fragrance Association (CTFA). (1983) Summary of the results of surveys of the amount and frequency of use of cosmetic products by women. Prepared by Environ Corporation, Washington, DC for CTFA Inc., Washington, DC.

Franklin, P. (2008) Household chemicals: good housekeeping or occupational hazard. Eur Respir J 31:489-491.

Loretz, L.; Api, A.; Barraj, L.; Burdick, J.; Dressler, W.; Gettings, S.; Hsu, H.; Pan, Y.; Re, T.; Renskers, K.; Rothenstein, A.; Scrafford, C.; Sewall, C. (2005) Exposure data for cosmetic products: lipstick, body lotion, and face cream. Food Chem Toxicol 43:279-291.

Loretz, L.; Api, A.; Barraj, L.; Burdick, J.; Davis, D.; Dressler, W.; Gilberti, E.; Jarrett, G.; Mann, S.; Pan, Y.; Re, T.; Renskers, K.; Scrafford, C.; Vater, S. (2006) Exposure data for personal care products: Hairspray, spray perfume, liquid foundation, shampoo, body wash, and solid antiperspirant. Food Chem Toxicol 44:2008-2018.

Loretz, L.; Api, A.; Babcock, L; Barraj, L.; Burdick, J.; Cater, K.; Jarrett, G.; Mann, s.; Pan, Y.; Re, T.; Renskers, K.; Scrafford, C. (2008) Exposure data for cosmetic products: Facial cleanser, hair conditioner, and eye shadow. Food Chem Toxicol 46:1516-1524.

Sathyanarayana, S.; Karr, C.; Lozano, P., Brown, E.; Calafat, M. (2008) Baby care products; possible sources of infant phthalate exposure. Pedriatrics 121:260-268.

Steenbekkers, L.P. (2001) Methods to study everyday use of products un households: The Wageningen mouthing study. Am Occup Hyg 45(1001):125-129.

U.S. EPA (1987) Methods for assessing exposure to chemical substances - Volume 7 - Methods for assessing consumer exposure to chemical substances. Washington, DC: Office of Toxic Substances. EPA/560/5-85/007.

U.S. EPA (1996) Descriptive statistics tables from a detailed analysis of the National Human Activity Pattern Survey (NHAPS) data. Washington, DC: Office of Research and Development. EPA/600/R-96/148.

U.S. EPA (1997) Exposure Factors Handbook. Washington, DC: National Center for Environmental Assessment, Office of Research and Development. EPA/600/P-95/002FC.

U.S. EPA. (2005) Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants. U.S. Environmental Protection Agency, Washington, DC: EPA/630/P-03/003F.

Table 17-1. Consumer Products Commonly Found in Some U.S. Households[a]

Consumer Product Category	Consumer Product
Cosmetics Hygiene Products	Adhesive bandages
	Bath additives (liquid)
	Bath additives (powder)
	Cologne/perfume/aftershave
	Contact lens solutions
	Deodorant/antiperspirant (aerosol)
	Deodorant/antiperspirant (wax and liquid)
	Depilatories
	Facial makeup
	Fingernail cosmetics
	Hair coloring/tinting products
	Hair conditioning products
	Hairsprays (aerosol)
	Lip products
	Mouthwash/breath freshener
	Sanitary napkins and pads
	Shampoo
	Shaving creams (aerosols)
	Skin creams (non-drug)
	Skin oils (non-drug)
	Soap (toilet bar)
	Sunscreen/suntan products
	Talc/body powder (non-drug)
	Toothpaste
	Waterless skin cleaners
Household Furnishings	Carpeting
	Draperies/curtains
	Rugs (area)
	Shower curtains
	Vinyl upholstery, furniture
Garment Conditioning Products	Anti-static spray (aerosol)
	Leather treatment (liquid and wax)
	Shoe polish
	Spray starch (aerosol)
	Suede cleaner/polish (liquid and aerosol)
	Textile water-proofing (aerosol)

Table 17-1. Consumer Products Commonly Found in Some U.S. Households[a] (continued)

Consumer Product Category	Consumer Product
Household Maintenance Products	Adhesive (general) (liquid)
	Bleach (household) (liquid)
	Bleach (see laundry)
	Candles
	Cat box litter
	Charcoal briquets
	Charcoal lighter fluid
	Drain cleaner (liquid and powder)
	Dishwasher detergent (powder)
	Dishwashing liquid
	Fabric dye (DIY)[b]
	Fabric rinse/softener (liquid)
	Fabric rinse/softener (powder)
	Fertilizer (garden) (liquid)
	Fertilizer (garden) (powder)
	Fire extinguishers (aerosol)
	Floor polish/wax (liquid)
	Food packaging and packaged food
	Furniture polish (liquid)
	Furniture polish (aerosol)
	General cleaner/disinfectant (liquid)
	General cleaner (powder)
	General cleaner/disinfectant (aerosol and pump)
	General spot/stain remover (liquid)
	General spot/stain remover (aerosol and pump)
	Herbicide (garden-patio) (liquid and aerosol)
	Insecticide (home and garden) (powder)
	Insecticide (home and garden) (aerosol and pump)
	Insect repellent (liquid and aerosol)
	Laundry detergent/bleach (liquid)
	Laundry detergent (powder)
	Laundry pre-wash/soak (powder)
	Laundry pre-wash/soak (liquid)
	Laundry pre-wash/soak (aerosol and pump)
	Lubricant oil (liquid)
	Lubricant (aerosol)
	Matches
	Metal polish
	Oven cleaner (aerosol)
	Pesticide (home) (solid)
	Pesticide (pet dip) (liquid)
	Pesticide (pet) (powder)
	Pesticide (pet) (aerosol)
	Pesticide (pet) (collar)
	Petroleum fuels (home (liquid and aerosol)
	Rug cleaner/shampoo (liquid and aerosol)
	Rug deodorizer/freshener (powder)
	Room deodorizer (solid)
	Room deodorizer (aerosol)
	Scouring pad
	Toilet bowl cleaner
	Toiler bowl deodorant (solid)
	Water-treating chemicals (swimming pools)

Table 17-1. Consumer Products Commonly Found in Some U.S. Households[a] (continued)

Consumer Product Category	Consumer Product
Home Building/Improvement Products (DIY)[b]	Adhesives, specialty (liquid) Ceiling tile Caulks/sealers/fillers Dry wall/wall board Flooring (vinyl) House Paint (interior) (liquid) House Paint and Stain (exterior) (liquid) Insulation (solid) Insulation (foam) Paint/varnish removers Paint thinner/brush cleaners Patching/ceiling plaster Roofing Refinishing products (polyurethane, varnishes, etc.) Spray paints (home) (aerosol) Wall paneling Wall paper Wall paper glue
Automobile-related Products	Antifreeze Car polish/wax Fuel/lubricant additives Gasoline/diesel fuel Interior upholstery/components, synthetic Motor oil Radiator flush/cleaner Automotive touch-up paint (aerosol) Windshield washer solvents
Personal Materials	Clothes/shoes Diapers/vinyl pants Jewelry Printed material (colorprint, newsprint, photographs) Sheets/towels Toys (intended to be placed in mouths)

[a] A subjective listing based on consumer use profiles.
[b] DIY = Do It Yourself.

Source: U.S. EPA, 1987.

Table 17-2. Amount and Frequency of Use of Various Cosmetic and Baby Products

Product Type	Amount of Product Per Application[a] (grams)	Average Frequency of Use (per day)			Upper 90th Percentile Frequency of Use (per day)		
		Survey Type			Survey Type		
		CTFA	Cosmetic Co.	Market[b] Research Bureau	CTFA	Cosmetic Co.	Market Research Bureau
Baby Lotion - baby use[c]	1.4	0.38	1.0	–	0.57	2.0	--
Baby Lotion - adult use	1.0	0.22	0.19	0.24[d]	0.86	1.0	1.0[d]
Baby Oil - baby use[c]	1.3	0.14	1.2	–	0.14	3.0	--
Baby Oil - adult use	5.0	0.06	0.13	–	0.29	0.57	--
Baby Powder - baby use[c]	0.8	5.36	1.5	0.35[d]	8.43	3.0	1.0[d]
Baby Powder - adult use	0.8	0.13	0.22	–	0.57	1.0	--
Baby Cream - baby use[c]	–	0.43	1.3	–	0.43	3.0	--
Baby Cream - adult use	–	0.07	0.10	–	0.14	0.14[e]	--
Baby Shampoo - baby use[c]	0.5	0.14	–	0.11[f]	0.14	--	0.43[f]
Baby Shampoo - adult use	5.0	0.02	–	–	0.86[e]	--	--
Bath Oils	14.7	0.08	0.19	0.22[g]	0.29	0.86	1.0[g]
Bath Tablets	–	0.003	0.008	–	0.14[e]	0.14[e]	--
Bath Salts	18.9	0.006	0.013	–	0.14[e]	0.14[e]	--
Bubble Baths	11.8	0.088	0.13	–	0.43	0.57	--
Bath Capsules	–	0.018	0.019	–	0.29[e]	0.14[e]	--
Bath Crystals	–	0.006	–	–	0.29[e]	0.14[e]	--
Eyebrow Pencil	–	0.27	0.49	–	1.0	1.0	--
Eyeliner	–	0.42	0.68	0.27	1.43	1.0	1.0
Eye Shadow	–	0.69	0.78	0.40	1.43	1.0	1.0
Eye Lotion	–	0.094	0.34	–	0.43	1.0	--
Eye Makeup Remover	–	0.29	0.45	–	1.0	1.0	--
Mascara	–	0.79	0.87	0.46	1.29	1.0	1.5
Under Eye Cover	–	0.79	–	–	0.29	--	--
Blusher & Rouge	0.011	1.18	1.24	0.55	2.0	1.43	1.5
Face Powders	0.085	0.35	0.67	0.33	1.29	1.0	1.0
Foundations	0.265	0.46	0.78	0.47	1.0	1.0	1.5
Leg and Body Paints	–	0.003	0.011	–	0.14[e]	0.14[e]	--
Lipstick & Lip Gloss	–	1.73	1.23	2.62	4.0	2.86	6.0
Makeup Bases	0.13	0.24	0.64	–	0.86	1.0	--
Makeup Fixatives	–	0.052	0.12	–	0.14	1.0	--
Sunscreen	3.18	0.003	–	0.002	0.14[e]	–	0.005
Colognes & Toilet Water	0.65	0.68	0.85	0.56	1.71	1.43	1.5
Perfumes	0.23	0.29	0.26	0.38	0.86	1.0	1.5

Table 17-2. Amount and Frequency of Use of Various Cosmetic and Baby Products (ontinued)

Product Type	Amount of Product Per Application[a] (grams)	Average Frequency of Use (per day)			Upper 90th Percentile Frequency of Use (per day)		
		Survey Type			Survey Type		
		CTFA	Cosmetic Co.	Market[b] Research Bureau	CTFA	Cosmetic Co.	Market Research Bureau
Powders	2.01	0.18	0.39	–	1.0	1.0	--
Sachets	0.2	0.0061	0.034	–	0.14[e]	0.14[e]	--
Fragrance Lotion	–	0.0061	--	--	0.29[e]	–	--
Hair Conditioners	12.4	0.4	0.40	0.27	1.0	1.0	0.86
Hair Sprays	–	0.25	0.55	0.32	1.0	1.0	1.0
Hair Rinses	12.7	0.064	0.18	–	0.29	1.0	--
Shampoos	16.4	0.82	0.59	0.48	1.0	1.0	1.0
Tonics and Dressings	2.85	0.073	0.021	–	0.29	0.14[e]	--
Wave Sets	2.6	0.003[h]	0.040	--	--[h]	0.14	--
Dentifrices	–	1.62	0.67	2.12	2.6	2.0	4.0
Mouthwashes	–	0.42	0.62	0.58	1.86	1.14	1.5
Breath Fresheners	–	0.052	0.43	0.46	0.14	1.0	0.57
Nail Basecoats	0.23	0.052	0.13	–	0.29	0.29	--
Cuticle Softeners	0.66	0.040	0.10	–	0.14	0.29	--
Nail Creams & Lotions	0.56	0.070	0.14	–	0.29	0.43	--
Nail Extenders	–	0.003	0.013	--	0.14[e]	0.14[e]	--
Nail Polish & Enamel	0.28	0.16	0.20	0.07	0.71	0.43	1.0
Nail Polish & Enamel Remover	3.06	0.088	0.19	–	0.29	0.43	--
Nail Undercoats	–	0.049	0.12	–	0.14	0.29	--
Bath Soaps	2.6	1.53	0.95	–	3.0	1.43	--
Underarm Deodorants	0.52	1.01	0.80	1.10	1.29	1.29	2.0
Douches	–	0.013	0.089	0.085	0.14[e]	0.29	0.29
Feminine Hygiene Deodorants	–	0.021	0.084	0.05	1.0[e]	0.29	0.14
Cleansing Products (cold creams, cleansing lotions liquids & pads)	1.7	0.63	0.80	0.54	1.71	2.0	1.5
Depilatories	–	0.0061	0.051	0.009	0.016	0.14	0.033
Face, Body & Hand Preps (excluding shaving preps)	3.5	0.65	–	1.12	2.0	–	2.14
Foot Powder & Sprays	–	0.061	0.079	--	0.57[e]	0.29	--
Hormones	–	0.012	0.028	--	0.57[e]	0.14[e]	--
Moisturizers	0.53	0.98	0.88	0.63	2.0	1.71	1.5
Night Skin Care Products	1.33	0.18	0.50	–	1.0	1.0	–

Table 17-2. Amount and Frequency of Use of Various Cosmetic and Baby Products (continued)

Product Type	Amount of Product Per Application[a] (g)	Average Frequency of Use (per day)			Upper 90th Percentile Frequency of Use (per day)		
		Survey Type			Survey Type		
		CTFA	Cosmetic Co.	Market[b] Research Bureau	CTFA	Cosmetic Co.	Market Research Bureau
Paste Masks (mud packs)	3.7	0.027	0.20	–	0.14	0.43	--
Skin Lighteners	--	–	0.024	–	–[d]	0.14[d]	--
Skin Fresheners & Astringents	2.0	0.33	0.56	–	1.0	1.43	--
Wrinkle Smoothers (removers)	0.38	0.021	0.15	–	1.0[d]	1.0	--
Facial Cream	0.55	0.0061	–	–	0.0061	–	--
Permanent Wave	101	0.003	–	0.001	0.0082	–	0.005
Hair Straighteners	0.156	0.0007	–	--	0.005[d]	–	--
Hair Dye	--	0.001	–	0.005	0.004[d]	–	0.014
Hair Lighteners	--	0.0003	–	–	0.005[d]	–	--
Hair Bleaches	--	0.0005	–	–	0.02[d]	–	--
Hair Tints	–	0.0001	–	–	0.005[d]	–	--
Hair Rinse (coloring)	–	0.0004	–	–	0.02[d]	–	--
Shampoo (coloring)	–	0.0005	–	–	0.02[d]	–	--
Hair Color Spray	--	–	–	–	–[d]	–	--
Shave Cream	1.73	–	–	0.082	--	–	0.36

[a] Values reported are the averages of the responses reported by the twenty companies interviewed.
(--'s) indicate no data available.

[b] The averages shown for the Market Research Bureau are not true averages - this is due to the fact that in many cases the class of most frequent users were indicated by "1 or more" also ranges were used in many cases, i.e., "10-12." The average, therefore, is underestimated slightly. The "1 or more" designation also skew the 90th percentile figures in many instances. The 90th percentile values may, in actuality, be somewhat higher for many products.

[c] Average usage among users only for baby products.

[d] Usage data reflected "entire household" use for both baby lotion and baby oil.

[e] Fewer than 10% of individuals surveyed used these products. Value listed is lowest frequency among individuals reporting usage. In the case of wave sets, skin lighteners, and hair color spray, none of the individuals surveyed by the CTFA used this product during the period of the study.

[f] Usage data reflected "entire household" use.

[g] Usage data reflected total bath product usage.

[h] None of the individuals surveyed reported using this product.

Source: CTFA, 1983.

Table 17-3. Number of Minutes Spent in Activities Working With or Near Freshly Applied Paints (minutes/day)

Age Group		Percentiles											
	N	1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	7	3	3	3	3	5	15	121	121	121	121	121	121
5 to 11 years	12	5	5	5	15	20	45	120	120	121	121	121	121
12 to 17 years	20	0	0	0.5	3	8	45	75	121	121	121	121	121
18 to 64 years	212	0	0	1	2	11	60	121	121	121	121	121	121

Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-4. Number of Minutes Spent in Activities Working With or Near Household Cleaning Agents Such as Scouring Powders or Ammonia (minutes/day)

Age Group		Percentiles											
	N	1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	21	0	0	0	0	5	10	15	20	30	121	121	121
5 to 11 years	26	1	1	2	2	3	5	15	30	30	30	30	30
12 to 17 years	41	0	0	0	0	2	5	10	40	60	60	60	60
18 to 64 years	672	0	0	1	2	5	10	20	60	121	121	121	121

Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-5. Number of Minutes Spent in Activities (at home or elsewhere) Working With or Near Floorwax, Furniture Wax or Shoe Polish (minutes/day)

Age Group		Percentiles											
	N	1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	13	0	0	0	5	10	15	20	60	121	121	121	121
5 to 11 years	21	0	0	2	2	3	5	10	35	60	120	120	120
12 to 17 years	15	0	0	0	1	2	10	25	45	121	121	121	121
18 to 64 years	238	0	0	2	3	5	15	30	120	121	121	121	121

Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-6. Number of Minutes Spent in Activities Working With or Near Glue (minutes/day)

		Percentiles											
	N	1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	6	0	0	0	0	30	30	30	50	50	50	50	50
5 to 11 years	36	2	2	3	5	5	12.5	25	30	60	120	120	120
12 to 17 years	34	0	0	1	2	5	10	30	30	60	120	120	120
18 to 64 years	207	0	0	0	1	5	20	90	121	121	121	121	121

Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-7. Number of Minutes Spent in Activities Working With or Near Solvents, Fumes or Strong Smelling Chemicals (minutes/day)

Age Group		Percentiles											
	N	1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	7	0	0	0	0	1	5	60	121	121	121	121	121
5 to 11 years	16	0	0	0	2	5	5	17.5	45	70	70	70	70
12 to 17 years	38	0	0	0	0	5	10	60	121	121	121	121	121
18 to 64 years	407	0	0	1	2	5	30	121	121	121	121	121	121

Note: A Value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-8. Number of Minutes Spent in Activities Working With or Near Stain or Spot Removers (minutes/day)

Age Group		Percentiles											
	N	1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	3	0	0	0	0	0	0	3	3	3	3	3	3
5 to 11 years	3	3	3	3	3	3	5	5	5	5	5	5	5
12 to 17 years	7	0	0	0	0	5	15	35	60	60	60	60	60
18 to 64 years	87	0	0	0	0	2	5	15	60	121	121	121	121

Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-9. Number of Minutes Spent in Activities Working With or Near Gasoline or Diesel-powered Equipment, Besides Automobiles (minutes/day)

Age Group	N	Percentiles											
		1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	14	0	0	0	1	5	22.5	120	121	121	121	121	121
5 to 11 years	12	1	1	1	3	7.5	25	50	60	60	60	60	60
12 to 17 years	25	2	2	5	5	13	35	120	121	121	121	121	121
18 to 64 years	312	0	0	1	3	15	60	121	121	121	121	121	121

Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-10. Number of Minutes Spent in Activities Working With or Near Pesticides, Including Bug Sprays or Bug Strips (minutes/day)

Age Group	N	Percentiles											
		1	2	5	10	25	50	75	90	95	98	99	100
1 to 4 years	6	1	1	1	1	3	10	15	20	20	20	20	20
5 to 11 years	16	0	0	0	0	1.5	7.5	30	121	121	121	121	121
12 to 17 years	10	0	0	0	0	2	2.5	40	121	121	121	121	121
18 to 64 years	190	0	0	0	1	2	10	88	121	121	121	121	121

Note: A value of "121" for number of minutes signifies that more than 120 minutes were spent; N = doer sample size; percentiles are the percentage of doers below or equal to a given number of minutes.

Source: U.S. EPA, 1996.

Table 17-11. Number of Respondents Using Cologne, Perfume, Aftershave or Other Fragrances at Specified Daily Frequencies

Age Group	Total N	Number of Times Used in a Day				
		1-2	3-5	6-9	10+	Don't Know
5 to 11 years	26	24	2	*	*	*
12 to 17 years	144	133	9	*	1	1
18 to 64 years	1,735	1,635	93	3	1	3

* = Missing Data.
N = Number of respondents.

Source: U.S. EPA, 1996.

Table 17-12. Number of Respondents Using Any Aerosol Spray Product for Personal Care Item Such as Deodorant or Hair Spray at Specified Daily Frequencies

Age Group	Total N	Number of Times Used in a Day									
		1	2	3	4	5	6	7	10	10+	Don't Know
1 to 4 years	40	30	9	0	0	1	0	0	0	0	0
5 to 11 years	75	57	14	1	1	1	1	0	0	0	0
12 to 17 years	103	53	31	12	4	1	0	0	1	1	0
18 to 64 years	1,071	724	263	39	15	13	1	1	2	8	5

N = Number of respondents..

Source: U.S. EPA, 1996.

Table 17-13. Number of Respondents Using a Humidifier at Home

Age Group	Total N	Frequency				
		Almost Every Day	3-5 Times a Week	1-2 Times a Week	1-2 Times a Month	Don't Know
1 to 4 years	111	33	16	7	53	2
5 to 11 years	88	18	10	12	46	2
12 to 17 years	83	21	7	5	49	1
18 to 64 years	629	183	77	70	287	12

N = Number of respondents.

Source: U.S. EPA, 1996.

Table 17-14. Number of Respondents Indicating that Pesticides Were Applied by the Professional at Home to Eradicate Insects, Rodents, or Other Pests at Specified Frequencies

Age Group	Total N	Number of Times Over a 6-month Period Pesticides Were Applied by Professionals					
		None	1-2	3-5	6-9	10+	Don't Know
1 to 4 years	113	60	35	11	6	1	*
5 to 11 years	150	84	37	10	18	1	*
12 to 17 years	143	90	40	5	6	*	2
18 to 64 years	1,264	660	387	89	97	15	16

* = Missing data.
N = Number of respondents.

Source: U.S. EPA, 1996.

Table 17-15. Number of Respondents Reporting Pesticides Applied by the Consumer at Home To Eradicate Insects, Rodents, or Other Pests at Specified Frequencies

Age Group	Total N	Number of Times Over a 6-month Period Pesticides Applied by Resident					
		None	1-2	3-5	6-9	10+	Don't Know
1 to 4 years	113	46	46	15	3	3	*
5 to 11 years	150	50	70	24	1	4	1
12 to 17 years	143	45	64	21	5	8	*
18 to 64 years	1,264	473	477	192	48	55	19

Note: * = Missing Data
N = Number of respondents.

Source: U.S. EPA, 1996.

Table 17-16. Number of Respondents Indicating that Pesticides Were Applied by a Professional at Home to Eradicate Insects, Rodents, or Other Pests at Specified Frequencies

Age Group	Total N	Frequency (number of times over a six-month period that pesticides were applied by a professional)					
		None	1 to 2	3 to 5	6 to 9	10+	Don't Know
0 to <1 years	15	9	4	1	1	0	0
1to <2 years	23	13	5	3	1	1	0
2 to <3 years	32	9	15	5	3	0	0
3 to <6 years	80	51	22	5	2	0	0
6 to <11 years	106	59	22	7	17	1	0
11 to <16 years	115	68	35	4	6	0	2
16 to <21 years	87	40	36	2	5	1	3

N = Number of respondents.

Source: U.S. EPA re-analysis of NHAPS (U.S. EPA, 1996) data.

Table 17-17. Number of Respondents Reporting Pesticides Applied by the Consumer at Home to Eradicate Insects, Rodents, or Other Pests at Specified Frequencies

Age Group	Total N	Frequency (number of times over a six-month period that pesticides were applied by a resident)					
		None	1 to 2	3 to 5	6 to 9	10+	Don't Know
0 to <1 year	15	4	8	2	0	1	0
1to <2 years	23	11	10	1	0	1	0
2 to <3 years	32	18	9	2	2	1	0
3 to <6 years	80	26	35	18	1	0	0
6 to <11 years	106	37	49	14	1	4	1
11 to <16 years	115	37	50	18	4	6	0
16 to <21 years	87	36	33	9	4	4	1

N = Number of respondents.

Source: U.S. EPA re-analysis of NHAPS (U.S. EPA, 1996) data.

Table 17-18. Household Demographics, and Pesticide Types, Characteristics, and Frequency of Pesticide Use

Survey Population Demographics	Number[a]	Percent[a]
Gender		84.1
female	90	15.9
male	17	
Language of Interview		67.3
Spanish	72	32.7
English	35	
Reading Skills		66.4
able to read English	71	88.8
able to read Spanish	95	
Number in household		23.3
2-3 people	25	55.1
4-5 people	59	21.4
6-8 people	23	
Children under 10 years		34.6
1 child	37	42.1
2 children	45	23.3
3 to 5 children	25	
Type of home		70.1
single family detached	75	8.4
multi-family	9	8.4
trailer/mobile home	9	7.5
single-family attached	8	3.7
apartment/other	4	
Pets		51.4
pets kept in household	55	40.0
pesticides used on pets	22	
Pesticide Use		
Type of pesticide		
insecticide	135	91.2
rodenticide	10	6.8
herbicide	3	2.0
Storage of pesticide		
kitchen	67	45.3
garage/shed	30	20.3
laundry/washroom	14	9.4
other, inside home	11	7.4
other, outside home	7	4.7
bathroom	7	4.7
basement	4	2.7
closet	4	2.7
Storage precautions		
child-resistant container	83	56.1
pesticide locked away	55	37.2
Storage risks		
< 4 feet from ground	72	48.6
kept near food	5	3.4
kept near dishes/cookware	5	3.4
Disposal		
throw it away	132	89.2
wrap in separate container, throw away	10	6.8
other	5	3.4
Frequency of use		
more than once/week	20	13.5
once/week	27	18.2
once/month	42	28.4
once every 3 months	23	15.5
once every 6 months	16	10.8
once/year	13	8.8
Time stored in home		
< 6 months	75	50.7
6 to 12 months	24	15.2
12 to 24 months	17	11.5
> 24 months	16	10.8

[a] Totals may not add to 107 participants or 148 products, and percentages may not add to 100 due to some non-responses to survey questions.

Source: Bass et al., 2001.

Table 17-19. Frequency of Use of Cosmetic Products

Product Type	N	Number of Applications per Day		
		Mean	Median	SD
Lipstick	311	2.35	2	1.80
Body lotion, hands	308	2.12	2	1.59
Body lotion, arms	308	1.52	1	1.30
Body lotion, feet	308	0.95	1	1.01
Body lotion, legs	308	1.11	1	0.98
Body lotion, neck & throat	308	0.43	0	0.82
Body lotion, back	308	0.26	0	0.63
Body lotion, other	308	0.40	0	0.76
Face cream	300	1.77	2	1.16

N = Number of subjects (women, ages 19 to 65 years).
SD = Standard deviation.

Source: Loretz et al., 2005.

Table 17-20. Amount of Test Product used (grams) for Lipstick, Body Lotion and Face Cream

Summary Statistics	Total Amount Applied	Average[a] Amount Applied per Use Day	Average[b] Amount Applied per Application
Lipstick			
Minimum	0.001	0.000	0.000
Maximum	2.666	0.214	0.214
Mean	0.272	0.024	0.010
SD	0.408	0.034	0.018
Percentiles			
10th	0.026	0.003	0.001
20th	0.063	0.005	0.003
30th	0.082	0.008	0.004
40th	0.110	0.010	0.004
50th	0.147	0.013	0.005
60th	0.186	0.016	0.006
70th	0.242	0.021	0.009
80th	0.326	0.029	0.011
90th	0.655	0.055	0.024
95th	0.986	0.087	0.037
99th	2.427	0.191	0.089
Best Fit Distributions & Parameters[c]	Lognormal Distribution GM = 0.14 GSD = 3.56 P-value (Gof) = 0.01	Lognormal Distribution GM = 0.01 GSD = 3.45 P-value (Gof) <0.01	Lognormal Distribution GM = 0.01 GSD = 3.29 P-value (Gof) <0.01
Body Lotion			
Minimum	0.67	0.05	0.05
Maximum	217.66	36.31	36.31
Mean	103.21	8.69	4.42
SD	53.40	5.09	4.19
Percentiles			
10th	36.74	3.33	1.30
20th	51.99	4.68	1.73
30th	68.43	5.71	2.32
40th	82.75	6.74	2.76
50th	96.41	7.63	3.45
60th	110.85	9.25	4.22
70th	134.20	10.90	4.93
80th	160.26	12.36	6.14

Table 17-20. Amount of Test Product Used (grams) for Lipstick, Body Lotion and Face Cream (continued)

Summary Statistics	Total Amount Applied	Average[a] Amount Applied per Use Day	Average[b] Amount Applied per Application
90th	182.67	14.39	8.05
95th	190.13	16.83	10.22
99th	208.50	27.91	21.71
Best Fit Distributions & Parameters[c]	Beta Distribution[c] Alpha = 1.53 Beta = 1.77 Scale = 222.01 P-value (GoF) = 0.06	Gamma Distribution Location = -0.86 Scale = 2.53 Shape = 3.77 P-value (GoF) = 0.37	Lognormal Distribution GM = 3.26 GSD = 2.25 P-value (GoF) = 0.63
Face Cream			
Minimum	0.04	0.00	0.00
Maximum	55.85	42.01	21.01
Mean	22.36	2.05	1.22
SD	14.01	2.90	1.76
Percentiles			
10th	5.75	0.47	0.28
20th	9.35	0.70	0.40
30th	12.83	1.03	0.53
40th	16.15	1.26	0.67
50th	19.86	1.53	0.84
60th	23.79	1.88	1.04
70th	29.31	2.23	1.22
80th	36.12	2.90	1.55
90th	44.58	3.50	2.11
95th	48.89	3.99	2.97
99th	51.29	12.54	10.44
Best Fit Distributions & Parameters[c]	Triangle Distribution Minimum = -1.09 Maximum = 58.71 Likeliest = 7.53 P-value (GoF) = 0.27	Lognormal Distribution[c] GM = 1.39 GSD = 2.58 P-value (GoF) <0.01	Lognormal Distribution[c] GM = 0.80 GSD = 2.55 P-value (GoF) = 0.02

[a] Derived as the ratio of the total amount used to the number of use days.
[b] Derived as the ratio of the total amount used to the total number of applications during the survey.
[c] None of the tested distributions provided a good fit.
GM = Geometric mean.
GSD = Geometric standard deviation.
Gof = Goodness of fit.
Note: Data are for women, ages 19 to 65 years.

Source: Loretz et al., 2005.

Table 17-21. Frequency of Use of Personal Care Products

Product Type	N	Average Number of Applications per Use Day[a]			
		Mean	SD	Min	Max
Hairspray (aerosol)	165[b]	1.49	0.63	1.00	5.36
Hairspray (pump)	162	1.51	0.64	1.00	4.22
Liquid Foundation	326	1.24	0.32	1.00	2.00
Spray Perfume	326	1.67	1.10	1.00	11.64
Body wash	340	1.37	0.58	1.00	6.36
Shampoo	340	1.11	0.24	1.00	2.14
Solid antiperspirant	340	1.30	0.40	1.00	4.00

[a] Derived as the ratio of the number of applications to the number of use days.
[b] Subjects who completed the study but did not report their number of applications were excluded.
N = Number of subjects (women, ages 18 to 65 years).
SD = Standard deviation.

Source: Loretz et al., 2006.

Table 17-22. Average Amount of Product Applied per Application [a] (grams)

Summary Statistics	Hairspray (aerosol)	Hairspray (pump)	Spray Perfume	Liquid Foundation	Shampoo	Body Wash	Solid Antiperspirant
N	163[b]	161[b]	310[b]	321[b]	340	340	340
Mean	2.58	3.64	0.33	0.54	11.76	11.3	0.61
SD	2.26	3.50	0.41	0.52	8.77	6.9	0.56
Minimum	0.05	0.00	0.00	0.00	0.39	1.1	0.00
Maximum	14.08	21.44	5.08	2.65	67.89	58.2	5.55
Percentiles							
10th	0.66	0.70	0.06	0.08	3.90	4.6	0.14
20th	0.94	1.01	0.10	0.14	5.50	5.8	0.22
30th	1.26	1.59	0.13	0.19	6.78	7.1	0.30
40th	1.56	2.14	0.18	0.26	8.27	8.5	0.37
50th	1.83	2.66	0.23	0.36	9.56	9.5	0.45
60th	2.38	3.43	0.28	0.48	11.32	11.4	0.55
70th	2.87	3.84	0.36	0.63	13.29	13.4	0.69
80th	3.55	5.16	0.49	0.86	16.07	16.0	0.89
90th	5.33	7.81	0.68	1.23	22.59	21.1	1.25
95th	7.42	10.95	0.94	1.70	27.95	24.3	1.67
97.5th	8.77	14.68	1.25	2.07	35.65	28.4	2.15
99th[c]	11.30	15.52	1.73	2.36	51.12	35.1	2.52
Best fit distributions and parameters	Lognormal Distribution	Lognormal Distribution	Lognormal Distribution	Lognormal Distribution	Lognormal	Gamma	Lognormal Distribution
	GM = 1.84 GSD = 2.40	GM = 2.44 GSD = 2.67	GM =0.21 GSD = 3.01	GM = 0.33 GSD. = 2.99	GM = 9.32 GSD = 2.02	Location = 0.51 Scale = 3.92 Shape = 2.76	GM = 0.43 GSD = 2.37
P-value (Kolmogorov-Smirnov)	0.06	0.07	0.077	0.041	0.1328	0.486	0.339

[a] Derived as the ratio of the total amount used to the total number of applications.
[b] Subjects who completed the study, but did not report their number of applications, or who did not return the unused portion of the product, were excluded.
[c] Estimate does not meet the minimum sample size criteria (N=800) as set by the National Center for Health Statistics. For upper percentile (>0.75), the minimum sample size (N) satisfies the following rule: n [8/(1-p)]. http://www/cdc.gov/nchs/about/major/nhanes/nhanes3/nh3gui.pdf.
N = Number of subjects (women, ages 19 to 65 years).
GM = Geometric mean.
GSD = Geometric standard Deviation.

Source: Loretz et al., 2006.

Table 17-23. Average Amount of Product Applied per Use Day [a] (grams)

Summary Statistics	Hairspray (aerosol)	Hairspray (pump)	Spray Perfume	Liquid Foundation	Shampoo	Body Wash	Solid Antiperspirant
N	163[b]	161[b]	310[b]	321[b]	340	340	340
Mean	3.57	5.18	0.53	0.67	12.80	14.5	0.79
SD	3.09	4.83	0.57	0.65	9.11	8.5	0.78
Minimum	0.05	0.00	0.00	0.00	0.55	1.3	0.00
Maximum	18.25	24.12	5.08	3.00	67.89	63.4	5.55
Percentiles							
10th	0.84	0.91	0.08	0.10	4.12	5.7	0.17
20th	1.35	1.48	0.12	0.16	5.80	7.6	0.29
30th	1.65	2.33	0.19	0.23	7.32	9.3	0.38
40th	2.23	2.66	0.26	0.30	9.09	10.9	0.46
50th	2.71	3.74	0.34	0.45	10.75	12.9	0.59
60th	3.30	4.71	0.45	0.58	12.72	14.8	0.70
70th	3.89	5.67	0.61	0.76	14.73	17.4	0.86
80th	4.86	7.38	0.81	1.04	17.61	20.7	1.08
90th	7.73	12.22	1.45	1.76	23.63	25.5	1.70
95th	9.89	15.62	1.77	2.18	29.08	29.1	2.32
97.5th	13.34	19.41	1.86	2.40	36.46	35.6	3.33
99th[c]	15.05	23.98	2.01	2.70	51.12	43.5	4.42
Best fit distributions and parameters	Lognormal Distribution	Lognormal Distribution	Lognormal Distribution	Lognormal Distribution	Lognormal	Gamma	Lognormal Distribution
	GM= 2.57	GM = 3.45	GM= 0.30	GM = 0.40	Location = 0.38	Location = 0.67	GM = 0.56
	GSD = 2.37	GSD = 2.70	GSD = 3.36	GSD. = 3.10	Scale= 5.79	Scale = 4.89	GSD = 2.41
					Shape = 2.15	Shape = 2.84	
P-value (Kolmogorov-Smirnov)	0.05	0.05	0.075	0.047	0.8208	0.760	0.293

[a] Derived as the ratio of the total amount used to the total number of applications.
[b] Subjects who completed the study, but did not report their number of applications , or who did not return the unused portion of the product, were excluded.
[c] Estimate does not meet the minimum sample size criteria (n=800) as set by the National Center for Health Statistics. For upper percentile (>0.75), the minimum sample size (n) satisfies the following rule: n [8/(1-p)]. http://www/cdc.gov/nchs/about/major/nhanes/nhanes3/nh3gui.pdf.
N = Number of subjects (women, ages 19 to 65 years).
GM = Geometric mean.
GSD = Geometric standard deviation.

Source: Loretz et al., 2006.

Table 17-24. Average Number of Applications Per Use Day[a]

Summary Statistics	Facial Cleanser (Lathering and Non-Lathering)	Hair Conditioner	Eye Shadow
N	295	297	299
Mean	1.6	1.1	1.2
SD	0.52	0.19	0.33
Minimum	1.0	1.0	1.0
Maximum	3.2	2.4	2.7
Percentiles			
10th	1.0	1.0	1.0
20th	1.0	1.0	1.0
30th	1.2	1.0	1.0
40th	1.4	1.0	1.1
50th	1.7	1.0	1.1
60th	1.9	1.0	1.1
70th	2.0	1.0	1.2
80th	2.0	1.1	1.4
90th	2.2	1.2	1.7
95th	2.4	1.4	2.0
97.5th	2.9[b]	1.8[b]	2.2[b]
99th[b]	3.1[b]	2.1[b]	2.5[b]

[a] Derived as the ratio of the number of applications to the number of use days.
[b] Estimate does not meet the minimum sample size criteria (n=800) as set by the National Center for Health Statistics. For upper percentile (>0.75), the minimum sample size (n) satisfies the following rule: n [8/(1-p.] http://www/cdc/gov/nchs/about/major/nhanes/nhanes3/nh3gui.pdf..
N = Number of subjects (women, ages 18 to 69 years).
SD = Standard deviation.

Source: Loretz et al., 2008.

Table 17-25. Average Amount of Product Applied Per Use Day (grams)[a]

Summary Statistics	Facial Cleanser (Lathering and Non-Lathering)	Facial Cleanser (Lathering)	Facial Cleanser (Non-Lathering)	Hair Conditioner	Eye shadow
N	295	174	121	297	299
Mean	4.06	4.07	4.05	13.77	0.04
SD	2.78	2.87	2.67	11.50	0.11
Minimum	0.33	0.33	0.83	0.84	0.001
Maximum	16.70	15.32	16.70	87.86	0.74
Percentiles					
10th	1.41	1.23	1.50	3.71	0.003
20th	1.79	1.72	1.94	5.54	0.005
30th	2.18	2.15	2.22	6.95	0.007
40th	2.66	2.64	2.80	8.73	0.009
50th	3.25	3.19	3.33	10.62	0.010
60th	3.86	3.84	3.88	12.61	0.013
70th	4.62	4.71	4.59	15.54	0.017
80th	6.24	6.33	5.92	20.63	0.025
90th	8.28	8.24	8.40	28.20	0.052
95th	9.93	10.50	9.37[b]	33.19	0.096
97.5th	10.71[b]	11.47[b]	10.26[b]	45.68[b]	0.525[b]
99th[b]	12.44[b]	13.07[b]	15.29[b]	60.20[b]	0.673[b]
Best fit distributions and parameters	Lognormal distribution	Lognormal distribution	Lognormal distribution	Lognormal distribution	Lognormal distribution
	GM = 3.26	GM = 3.21	GM = 3.35	GM = 10.28	GM = 0.01
	GSD = 1.12	GSD = 2.03	GSD = 1.86	GSD - 2.20	GSD = 3.61
P-value (Chi-square test)	0.1251	0.4429	0.4064	0.8595	<0.0001

a Derived as the ratio of the total amount used to the number of use days.

b Estimate does not meet the minimum sample size criteria (n=800) as set by the National Center for Health Statistics. For upper percentile (>0.75), the minimum sample size (n) satisfies the following rule: n [8/(1-p)]. http://www/cdc.gov/nchs/about/major/nhanes/nhanes3/nh3gui.pdf.

N = Number of subjects (women, ages 18 to 69 years).

GM = Geometric mean.

GSD = Geometric standard deviation.

Source: Loretz et al., 2008.

Table 17-26. Average Amount of Product Applied Per Application (grams)[a]

Summary Statistics	Facial Cleanser (Lathering and Non-Lathering)	Facial Cleanser (Lathering)	Facial Cleanser (Non-Lathering)	Hair Conditioner	Eye Shadow
N	295	174	121	297	299
Mean	2.57	2.56	2.58	13.13	0.03
SD	1.78	1.78	1.77	11.22	0.10
Minimum	0.33	0.33	0.57	0.84	0.0004
Maximum	14.61	10.67	14.61	87.86	0.69
Percentiles					
10th	0.92	0.83	1.10	3.48	0.003
20th	1.32	1.26	1.35	5.34	0.004
30th	1.57	1.55	1.59	6.71	0.006
40th	1.85	1.84	1.89	8.26	0.007
50th	2.11	2.11	2.15	10.21	0.009
60th	2.50	2.50	2.51	12.24	0.011
70th	2.94	2.96	2.96	14.54	0.015
80th	3.47	3.56	3.40	18.88	0.022
90th	4.81	5.10	4.52	27.32	0.041
95th	5.89	6.37	5.11[b]	32.43	0.096
97.5th	7.16[b]	7.77[b]	6.29[b]	45.68[b]	0.488[b]
99th[b]	9.44[b]	9.61[b]	15.46[b]	60.20[b]	0.562[b]
Best fit distributions and parameters	Extreme value	Gamma	Extreme value	Lognormal distribution	Lognormal distribution
	Mode = 1.86	Loc = 0.28	Mode = 1.92	GM = 9.78	GM = 0.01
	Scale = 1.12	Scale = 1.29	Scale = 1.03	GSD = 2.20	GSD = 3.59
P-value (Chi-square test)	0.0464	0.6123	0.5219	0.9501	<0.0001

[a] Derived as the ratio of the total amount used to the total number of applications.

[b] Estimate does not meet the minimum sample size criteria (n=800) as set by the National Center for Health Statistics. For upper percentile (>0.75), the minimum sample size (n) satisfies the following rule: n [8/(1-p)]. Http://www/cdc.gov/nchs/about/major/nhanes/nhanes3/nh3gui.pdf.

N = Number of subjects (women, ages 18 to 69 years).

GM = Geometric mean.

SD = Geometric standard deviation.

Source: Loretz et al., 2008.

Table 17-27. Characteristics of the Study Population and the Percent Using Selected Baby Care Products

Characteristic	Sample Number (percent)
Number of Participants	
Los Angeles, California	43 (26)
Minneapolis, Minnesota	77 (47)
Columbia, Missouri	43 (26)
Gender	
Male	84 (52)
Female	79 (48)
Age (months)	
2-8	42 (26)
9-16	82 (50)
17-24	30 (18)
24-28	9 (6)
Infant Weight (kg)	
?10	84 (52)
> 10	79 (48)
Race	
White	131 (80)
Hispanic/Latino	17 (10)
Native American	3 (2)
Asian	8 (5)
Black	4 (3)
Product Use	Percent Using
Baby Lotion	36
Baby Shampoo	54
Baby Powder	14
Diaper Cream	33
Baby Wipes	94

Source: Sathyanarayana et al., 2008.

GLOSSARY OF TERMS

Activity pattern data - Information on human activities used in exposure assessments. These may include a description of the activity, frequency of activity, duration spent performing the activity, and the microenvironment in which the activity occurs.

Adherence factor - The amount of a material (e.g., soil) that adheres to the skin per unit of surface area.

Activity pattern (time use) data - Information on activities in which various individuals engage, length of time spent performing various activities, locations in which individuals spend time and length of time spent by individuals within those various environments.

Agricultural commodity - Used by U.S. EPA to mean plant (or animal) parts consumed by humans as food. When such items are raw or unprocessed, they are referred to as "raw agricultural commodities."

All water sources - Includes water from all supply sources such as community water supply (i.e., tap water), bottled water, etc.

Analytical uncertainty propagation - Examining how uncertainty in individual parameters affects the overall uncertainty of the exposure assessment.

Anthropometric - The study of human body measurements for use in anthropological classification and comparison.

As-consumed intake - Intake rate based on the weight of the food in the form that it is consumed (e.g., cooked or prepared).

Assessment - A determination or appraisal of possible consequences resulting from an analysis of data.

Average Daily Dose (ADD) - Dose rate averaged over a pathway-specific period of exposure expressed as a daily dose on a per-unit-body-weight basis. The ADD is used for exposure to chemicals with non-carcinogenic non-chronic effects. The ADD is usually expressed in terms of mg/kg-day or other mass/mass-time units.

Benchmark Dose (BMD) or Concentration (BMC) - A dose or concentration that produces a predetermined change in response rate of an adverse effect (called the benchmark response or BMR) compared to background.

Best Tracer Method (BTM) - Method for estimating soil ingestion that allows for the selection of the most recoverable tracer for a particular subject or group of subjects. Selection of the best tracer is made on the basis of the food/soil (F/S) ratio.

Bias - A systematic error inherent in a method or caused by some feature of the measurement system.

Bioavailability - The rate and extent to which an agent can be absorbed by an organism and is available for metabolism or interaction with biologically significant receptors. Bioavailability involves both release from a medium (if present) and absorption by an organism.

Biomarker model comparison - A methodology that compares results from a biokinetic exposure model to biomarker measurements children blood. The method is used to confirm assumptions about ingested soil and dust quantities in this handbook.

Basal Metabolic Rate (BMR) - Minimum level of energy required to maintain normal body functions.

Body Mass Index (BMI) - The ratio of weight and height squared.

Bootstrap - A statistical method of resampling data use to estimate variance and bias of an estimator and provide confidence intervals for parameters.

Bounding estimate - An estimate of exposure, dose, or risk that is higher or lower than that incurred by the person with the highest or lowest exposure, dose, or risk in the population being assessed. Bounding estimates are useful in developing statements that exposures, doses, or risks are "not greater than" or “less than” the estimated value, because assumptions are used which define the likely bounding conditions.

Central tendency exposure - A measure of the middle or the center of an exposure distribution. The mean is the most commonly used measure of central tendency.

Chronic exposure - Repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species).

Chronic intake - The long term period over which a substance crosses the outer boundary of an organism without passing an absorption barrier.

Classical statistical methods - Estimating the population exposure distribution directly, based on measured values from a representative sample.

Coating - Method used to measure skin surface area, in which either the whole body or specific body regions are coated with a substance of known density and thickness.

Community water - Includes tap water ingested from community or municipal water supply.

Comparability - The ability to describe likenesses and differences in the quality and relevance of two or more data sets.

Concentration - Amount of a material or agent dissolved or contained in unit quantity in a given medium or system.

Confidence intervals - An estimated range of values with a given probability of including the population parameter of interest. The range of values is usually based on the results of a sample that estimated the mean and the sampling error or standard error.

Consumer-only intake rate - The average quantity of food consumed per person in a population composed only of individuals who ate the food item of interest during a specified period.

Contaminant concentration - Contaminant concentration is the concentration of the contaminant in the medium (air, food, soil, etc.) contacting the body and has units of mass/volume or mass/mass.

Creel study - A study in which fishermen are interviewed while fishing.

Cumulative exposure - Exposure via mixtures of contaminants both indoors and outdoors. Exposure may also occur through more than one pathway. New directions in risk assessments in U.S. EPA put more emphasis on total exposures via multiple pathways.

Deposition - The removal of airborne substances to available surfaces that occurs as a result of gravitational settling and diffusion, as well as electrophoresis and thermophoresis.

Dermal absorption - A route of exposure by which substances can enter the body through the skin.

Dermal adherence - The loading of a substance onto the outer surface of the skin.

Diary study - Survey in which individuals are asked to record food intake, activities, or other factors in a diary which is later used to evaluate exposure factors associated with specific populations.

Direct water ingestion - Consumption of plain water as a beverage. It does not include water used for preparing beverages such as coffee or tea.

Distribution - A set of values derived from a specific population or set of measurements that represents the range and array of data for the factor being studied.

Doers - Survey respondents who report participating in a specified activity.

Dose - The amount of a substance available for interaction with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism. The potential dose is the amount ingested, inhaled, or applied to the skin. The applied dose is the amount of a substance presented to an absorption barrier and available for absorption (although not necessarily having yet crossed the outer boundary of the organism). The absorbed dose is the amount crossing a specific absorption barrier (e.g., the exchange boundaries of skin, lung, and digestive tract) through uptake processes. Internal dose is a more general term denoting the amount absorbed without respect to specific absorption barriers or exchange boundaries. The amount of a chemical available for interaction by any particular organ or cell is termed the delivered dose for that organ or cell.

Dose rate - Dose per unit time.

Dose-response assessment - Analysis of the relationship between the total amount of an agent administered to, taken up by, or absorbed by an organism, system, or (sub)population and the changes developed in that organism, system, or (sub)population in reaction to that agent, and inferences derived from such an analysis with respect to the entire population. Dose-response assessment is the second of four steps in risk assessment.

Dose-response curve- Graphical presentation of a dose-response relationship.

Dose-response relationship - The resulting biological responses in an organ or organism expressed as a function of a series of doses.

Dressed weight - The portion of the harvest brought into kitchens for use, including bones for particular species.

Dry weight intake rates - Intake rates that are based on the weight of the food consumed after the moisture content has been removed.

Dust Ingestion - Consumption of dust that results from various behaviors including, but not limited to, mouthing objects or hands, eating dropped food, consuming dust directly, or inhaling dust that passes from the respiratory system into the gastrointestinal tract.

Effect - Change in the state or dynamics of an organism, system, or (sub) population caused by exposure to an agent.

Energy expenditures - The amount of energy expended by an individual during activities.

Exposure - Contact of a chemical, physical, or biological agent with the outer boundary of an organism. Exposure is quantified as the concentration of the agent in the medium in contact integrated over the time duration of the contact.

Exposure assessment - The determination or estimation (qualitative or quantitative) of the magnitude, frequency, or duration, and route or exposure.

Exposure concentration - The concentration of a chemical in its transport or carrier medium at the point of contact.

Exposure duration - Length of time over which contact with the contaminant lasts.

Exposure event - The occurrence of continuous contact between an agent and a target.

Exposure frequency - The number of exposure events in an exposure duration.

Exposure loading - The exposure mass divided by the exposure surface area. For example, a dermal exposure measurement based on a skin wipe sample, expressed as a mass of residue per skin surface area, is an exposure loading.

Exposure pathway - The physical course a chemical takes from the source to the organism exposed.

Exposure route - The way a chemical pollutant enters an organism after contact, e.g., by ingestion, inhalation, or dermal absorption.

Exposure scenario - A set of facts, assumptions, and interferences about how exposure takes place that aids the exposure assessor in evaluating estimating, or quantifying exposures.

Fate - Pattern of distribution of an agent, its derivatives, or metabolites in an organism, system, compartment, or (sub)population of concern as a result of transport, partitioning, transformation, or degradation.

General population - The total of individuals inhabiting an area or making up a whole group.

Geometric mean - The n^{th} root of the product of n values.

Geophagy - A form of soil ingestion involving the intentional ingestion of earths, usually associated with cultural practices.

Hazard - Inherent property of an agent or situation having the potential to cause adverse effects when an organism, system, or (sub)population is exposed to that agent.

Hazard assessment - A process designed to determine the possible adverse effects of an agent or situation to which an organism, system, or (sub)population could be exposed. The process typically includes hazard identification, dose-response evaluation and hazard characterization. The process focuses on the hazard, in contrast to risk assessment, where exposure assessment is a distinct additional step.

High end exposure - An estimate of individual exposure or dose for those persons at the upper end of an exposure or dose distribution, conceptually above the 90^{th} percentile, but not higher than the individual in the population who has the highest exposure or dose.

Homegrown/home produced foods - Fruits and vegetables produced by home gardeners, meat and dairy products derived form consumer-raised livestock, game meat, and home caught fish.

Human Equivalent Concentration (HEC) or Dose (HED) - The human concentration (for inhalation exposure) or dose (for other routes of exposure) of an agent that is believed to induce the same magnitude of toxic effect as the experimental animal species concentration or dose. This adjustment may incorporate toxicokinetic information on the particular agent, if available, or use a default procedure, such as assuming that daily oral doses experienced for a lifetime are proportional to body weight raised to the 0.75 power.

Indirect water ingestion - Includes water added during food preparation, but not water intrinsic to purchased foods. Indirect water includes for example, water used to prepare baby formulas, cake mix, and concentrated orange juice.

Indoor settled dust - Particles in building interiors that have settled onto objects, surfaces, floors, and carpeting. These particles may include soil particles that have been tracked into the indoor environment from outdoors.

Inhalation dosimetry - Process of measuring or estimating inhaled dose.

Inhalation unit risk - The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air for a lifetime.

Inhaled dose - The amount of an inhaled substance that is available for interaction with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism.

Insensible water loss - Evaporative water losses that occur during breastfeeding. Corrections are made to account for insensible water loss when estimating breast milk intake using the test weighing method.

Intake - The process by which a substance crosses the outer boundary of an organism without passing an absorption barrier (e.g., through ingestion or inhalation).

Intake rate - Rate of inhalation, ingestion, and dermal contact depending on the route of exposure. For ingestion, the intake rate is simply the amount of food containing the contaminant of interest that an individual ingests during some specific time period (units of mass/time). For inhalation, the intake rate is the rate at which contaminated air is inhaled. Factors that affect dermal exposure are the amount of material that comes into contact with the skin, and the rate at which the contaminant is absorbed.

Inter-individual variability - Variations between individuals in terms of human characteristics such as age or body weight, or behaviors such as location, activity patterns, and ingestion rates.

Internal dose - The amount of a substance penetrating across absorption barriers (the exchange boundaries) of an organism, via either physical or biological processes (synonymous with absorbed dose).

Intra-individual variability - Fluctuations in an individual's physiologic (e.g., body weight), or behavioral characteristics (e.g., ingestion rates or activity patterns).

Key study - A study that is useful for deriving exposure factors.

Lead isotope ratio methodology - A method that measures different lead isotopes in children's blood and/or urine, food, water, and house dust and compares the ratio of these isotopes to infer sources of lead exposure that may include dust or other environmental exposures.

Lifestage - A distinguishable time frame in an individual's life characterized by unique and relatively stable behavioral and/or physiological characteristics that are associated with development and growth.

Lifetime Average Daily Dose (LADD) - Dose rate averaged over a lifetime. The LADD is used for compounds with carcinogenic or chronic effects. The LADD is usually expressed in terms of mg/kg-day or other mass/mass-time units.

Limiting Tracer Method (LTM) - Method for evaluating soil ingestion that assumes that the maximum amount of soil ingested corresponds with the lowest estimate from various tracer elements.

Long-term exposure - Repeated exposure for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days).

Lowest-Observed-Adverse-Effect Level (LOAEL): The lowest exposure level at which there are biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group.

Margin of safety - For some experts, margin of safety has the same meaning as margin of exposure, while for others, margin of safety means the margin between the reference dose and the actual exposure.

Mass-balance/tracer techniques - Method for evaluating soil intake that accounts for both inputs and outputs of tracer elements. Tracers in soil, food, medicine and other ingested items as well as in feces and urine are accounted for.

Mean value - Simple or arithmetic average of a range of values, computed by dividing the total of all values by the number of values.

Measurement error - A systematic error arising from inaccurate measurement (or classification) of subjects on the study variables.

Measurement end-point - Measurable (ecological) characteristic that is related to the valued characteristic chosen as an assessment point.

Median value - The value in a measurement data set such that half the measured values are greater and half are less.

Metabolic Equivalent of Work (MET) - A dimensionless energy expenditure metric used to represent an activity level.

Microenvironment - Surroundings that can be treated as homogeneous or well characterized in the concentrations of an agent (e.g., home, office, automobile, kitchen, store).

Model uncertainty - Uncertainty regarding gaps in scientific theory required to make predictions on the basis of causal inferences.

Moisture content - The portion of foods made up by water. The percent water is needed for converting food intake rates and residue concentrations between whole weight and dry weight values.

Monte Carlo technique - A repeated random sampling from the distribution of values for each of the parameters in a generic (exposure or dose) equation to derive an estimate of the distribution of (exposures or doses in) the population.

Mouthing behavior - Activities in which objects, including fingers, are touched by the mouth or put into the mouth except for eating and drinking, and includes licking, sucking, chewing, and biting.

Non-dietary ingestion - Ingestion of non-food substances, typically resulting from the mouthing of hands and objects.

No-Observed-Adverse-Effect-Level (NOAEL) - The highest exposure level at which there are no biologically significant increases in the frequency or severity of adverse effect between the exposed population and its appropriate control; some effects may be produced at this level, but they are not considered adverse or precursors of adverse effects.

Outdoor settled dust - Particles that have settled onto outdoor objects and surfaces due to either wet or dry deposition.

Oxygen consumption (VO_2) - The rate at which oxygen is used by tissues.

Parameter uncertainty - Uncertainty regarding some parameter.

Pathway - The physical course a chemical or pollutant takes from the source to the organism exposed.

Per capita intake rate - The average quantity of food consumed per person in a population composed of both individuals who ate the food during a specified time period and those that did not.

Pica - Pica behavior is the repeated eating of non-nutritive substances, whereas soil-pica is a form of soil ingestion that is characterized by the recurrent ingestion of unusually high amounts of soil (i.e., on the order of 1,000 - 5,000 milligrams per day or more).

Plain tap water - Excludes tap water consumed in the form of juices and other beverages containing tap water.

Population mobility - An indicator of the frequency at which individuals move from one residential location to another.

Population risk descriptor - An assessment of the extent of harm to the population being addressed. It can be either an estimate of the number of cases of a particular effect that might occur in a population (or population segment), or a description of what fraction of the population receives exposures, doses, or risks greater than a specified value.

Potential dose - The amount of a chemical contained in material ingested, air breathed, or bulk material applied to the skin.

Poverty/income ratio - Ratio of reported family income to federal poverty level.

Precision - A measure of the reproducibility of a measured value under a given set of circumstances.

Preparation losses - Net cooking losses, which include dripping and volatile losses, post cooking losses, which involve losses from cutting, bones, excess fat, scraps and juices, and other preparation losses which include losses from paring or coring.

Primary data/analysis - Information gathered from observations or measurements of a phenomena or the surveying of respondents.

Probabilistic uncertainty analysis - Technique that assigns a probability density function to each input parameter, then randomly selects values from each of the distributions and inserts them into the exposure equation. Repeated calculations produce a distribution of predicted values, reflecting the combined impact of variability in each input to the calculation. Monte Carlo is a common type of probabilistic Uncertainty analysis.

Questionnaire/survey response - A "question and answer" data collection methodology conducted via in-person interview, mailed questionnaire, or questions administered in a test format in a school setting.

Random samples - Samples selected from a statistical population such that each sample has an equal probability of being selected.

Range - The difference between the largest and smallest values in a measurement data set.

Ready-to-feed - Infant and baby products (formula, juices, beverages, baby food), and table foods that do not need to have water added to them prior to feeding.

Reasonable maximum exposure (or worst case) - A semiquantitative term referring to the lower portion of the high end of the exposure, dose, or risk distribution. As a semiquantitative term, it should refer to a range that can conceptually be described as above the 90^{th} percentile in the distribution, but below the 98^{th} percentile.

Recreational/sport fishermen - Individuals who catch fish as part of a sporting or recreational activity and not for the purpose of providing a primary source of food for themselves or for their families.

Reference Concentration (RfC) - An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments. Durations include acute, short-term, subchronic, and chronic.

Reference Dose (RfD) - An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments. Durations include acute, short-term, subchronic, and chronic.

Relevant study - Studies that are applicable or pertinent, but not necessarily the most important to derive exposure factors.

Representativeness - The degree to which a sample is, or samples are, characteristic of the whole medium, exposure, or dose for which the samples are being used to make inferences.

Risk - The probability of an adverse effect in an organism, system, or (sub)population caused under specified circumstances by exposure to an agent.

Risk assessment - A process intended to calculate or estimate the risk to a given target organism, system, or (sub)population, including the identification of attendant uncertainties, following exposure to a particular agent, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system. The risk assessment process includes four steps: hazard identification, hazard characterization (related term: Dose-response assessment), exposure assessment, and risk characterization. It is the first component in a risk analysis process.

Risk characterization - The qualitative and, wherever possible, quantitative determination, including attendant uncertainties, of the probability of occurrence of known and potential adverse effects of an agent in a given organism, system, or (sub)population, under defined exposure conditions. Risk characterization is the fourth step in the risk assessment process.

Risk communication - Interactive exchange of information about (health or environmental) risks among risk assessors, managers, news media, interested groups, and the general public.

Route - The way a chemical or pollutant enters an organism after contact, e.g., by ingestion, inhalation, or dermal absorption.

Sample - A small part of something designed to show the nature or quality of the whole. Exposure-related measurements are usually samples of environmental or ambient media, exposures of a small subset of a population for a short time, or biological samples, all for the purpose of inferring the nature and quality of parameters important to evaluating exposure.

Scenario uncertainty - Uncertainty regarding missing or incomplete information needed to fully define exposure and dose.

Screening-level assessment - An exposure assessment that examines exposures that would fall on or beyond the high end of the expected exposure distribution.

Secondary data/analysis - The reanalysis of data collected by other individuals or group; an analysis of data for purposes other than those for which the data were originally collected.

Sensitivity analysis - Process of changing one variable while leaving the others constant to determine its effect on the output. This procedure fixes each uncertain quantity at its credible lower and upper bounds (holding all others at their nominal values, such as medians) and computes the results of each combination of values. The results help to identify the variables that have the greatest effect on exposure estimates and help focus further information-gathering efforts.

Serving sizes - The quantities of individual foods consumed per eating occasion. These estimates may be useful for assessing acute exposures.

Short-term exposure - Repeated exposure for more than 24 hours, up to 30 days.

Soil - Particles of unconsolidated mineral and/or organic matter from the earth's surface that are located outdoors, or are used indoors to support plant growth.

Soil adherence - The quantity of soil that adheres to the skin and from which chemical contaminants are available for uptake at the skin surface.

Soil ingestion - The intentional or unintentional consumption of soil, resulting from various behaviors including, but not limited to, mouthing, contacting dirty hands, eating dropped food, or consuming soil directly. Soil-pica is a form of soil ingestion that is characterized by the recurrent ingestion of unusually high amounts of soil (i.e., on the order of 1,000 - 5,000 milligrams per day or more). Geophagy is also a form of soil ingestion defined as the intentional ingestion of earths and is usually associated with cultural practices.

Spatial variability - Variability across location, whether long- or short-term.

Subsistence fishermen - Individuals who consume fresh caught fish as a major source of food.

Surface area - Coating, triangulation, and surface integration are direct measurement techniques that have been used to measure total body surface area and the surface area of specific body parts. Consideration has been given for differences due to age, gender, and race. Surface integration is performed by using a planimeter and adding the areas.

Surface integration - Method used to measure skin surface area in which a planimeter is used to measure areas of the skin, and the areas of various surfaces are summed.

Survey response methodology - Responses to survey questions are analyzed. This methodology includes questions asked of children directly, or their care givers, about behaviors affecting exposures.

Tap water from food manufacturing - Water used in industrial production of foods.

Temporal variability - Variability over time, whether long- or short-term.

Threshold - Dose or exposure concentration of an agent below which a stated effect is not observed or expected to occur.

Time-averaged exposure - The time-integrated exposure divided by the exposure duration. An example is the daily average exposure of an individual to carbon monoxide. (Also called timeweighted average exposure.)

Total tap water - Water consumed directly from the tap as a beverage or used in the preparation of foods and beverages (i.e., coffee, tea, frozen juices, soups, etc.).

Total fluid intake - Consumption of all types of fluids including tapwater, milk, soft drinks, alcoholic beverages, and water intrinsic to purchased foods.

Tracer-element studies - Soil ingestion studies that use trace elements found in soil and poorly metabolized in the human gut as indicators of soil intake.

Triangulation - Method used to measure skin surface area in which areas of the body are marked into geometric figures, then their linear dimensions are calculated.

Uncertainty - Uncertainty represents a lack of knowledge about factors affecting exposure or risk and can lead to inaccurate or biased estimates of exposure. The types of uncertainty include: scenario, parameter, and model.

Upper percentile - Values in the upper tail (i.e., between 90th and 99.9th percentile) of the distribution of values for a particular exposure factor. Values at the upper end of the distribution of values for a particular set of data.

Uptake - The process by which a substance crosses an absorption barrier and is absorbed into the body.

Variability - Variability arises from true heterogeneity across people, places or time and can affect the precision of exposure estimates and the degree to which they can be generalized. The types of variability include: spatial, temporal, and inter-individual.

Ventilation Rate (VR) - Alternative term for inhalation rate or breathing rate. Usually measured as minute volume, i.e. volume (liters) of air exhaled per minute.

Wet-weight intake rates - Intake rates that are based on the wet (or whole) weight of the food consumed. This in contrast to dry-weight intake rates.

____

Glossary entries adapted from:

International Programme on Chemical Safety (2004). IPCS Risk Assessment Terminology. Available on-line at: http://www.who.int/ipcs/methods/harmonization/areas/ipcsterminologyparts1and2.pdf

U.S. EPA (1992)Guidelines for exposure assessment. Washington, DC: Office of Research and Development, Office of Health and Environmental Assessment. EPA/600/2-92/001.

U.S. EPA. (1997) Exposure Factors Handbook Revised. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/P-95/002F.

United States
Environmental Protection
Agency

PRESORTED STANDARD
POSTAGE & FEES PAID
EPA
PERMIT NO. G-35

National Center for Environmental Assessment
Office of Research and Development
Washington, DC 20460

Official Business
Penalty for Private Use
$300