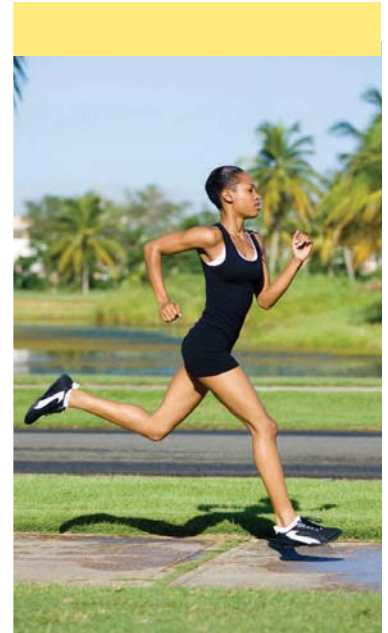


HIGHLIGHTS

Exposure Factors Handbook



HIGHLIGHTS

of the Exposure Factors Handbook

National Center for Environmental Assessment
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Preferred Citation:

U.S. Environmental Protection Agency (U.S. EPA). (2011) *Highlights of the Exposure Factors Handbook*. National Center for Environmental Assessment, Washington, DC; EPA/600/R-10/030. Available from the National Technical Information Service, Springfield, VA and online at <http://www.epa.gov/ncea>.

Authors, Contributors, and Acknowledgements

The U.S. Environmental Protection Agency (U.S. EPA), Office of Research and Development, National Center for Environmental Assessment (NCEA) was responsible for the preparation of the *Highlights of the Exposure Factors Handbook* and the *Exposure Factors Handbook: 2011 Edition*. The Highlights document was prepared by ICF International under Contract No. EP-C-09-009. Dr. Linda Phillips served as the Work Assignment Manager for this Highlights document and is a contributing author on both the Highlights document and the *Exposure Factors Handbook: 2011 Edition*. Westat, Inc., and Versar, Inc., provided technical assistance to the U.S. EPA in the development of the *Exposure Factors Handbook: 2011 Edition* under contracts with the U.S. EPA. Ms. Jacqueline Moya served as the Work Assignment Manager for the development of the *Exposure Factors Handbook: 2011 Edition* under these contracts, providing overall direction and technical assistance, and is a contributing author on both the Highlights document and the *Exposure Factors Handbook: 2011 Edition*.

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The authors wish to acknowledge the important contributions of the following U.S. EPA individuals who conducted additional analyses for the *Exposure Factors Handbook: 2011 Edition*, as summarized in this Highlights document:

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In addition, the U.S. EPA's National Exposure Research Laboratory (NERL) made an important contribution to the *Exposure Factors Handbook: 2011 Edition* by conducting additional analyses of the National Human Activity Pattern Survey (NHAPS) data. U.S. EPA input to the NHAPS data analysis came from Karen A. Hammerstrom and Jacqueline Moya from NCEA-Washington Division; William C. Nelson from NERL-Research Triangle Park; and Stephen C. Hern, Joseph V. Behar (retired), and William H. Englemann from NERL-Las Vegas.

The U.S. EPA's Office of Water and Office of Pesticide Programs made important contributions by conducting analyses of the U.S. Department of Agriculture's Continuing Survey of Food Intakes by Individuals (CSFII) data and the Centers for Disease Control and Prevention's (CDC) National Health and Nutrition Examination Survey (NHANES) data to provide general population food intake rates.

Foreword

The *Exposure Factors Handbook* was first published by the U.S. Environmental Protection Agency (U.S. EPA) in 1989. It was revised in 1997 and again in 2011 by the U.S. EPA's Office of Research and Development (ORD), National Center for Environmental Assessment (NCEA). The purpose of the Handbook is to provide exposure/risk assessors with information on behavioral and physiological factors that can be used in assessing exposures among both adults and children. The 2011 edition of the *Exposure Factors Handbook* incorporates new factors and data provided in the 2008 *Child-Specific Exposure Factors Handbook* (U.S. EPA, 2008) as well as other relevant information published through July 2011.

This Highlights document was developed to provide a brief overview of the contents of the *Exposure Factors Handbook: 2011 Edition* and to facilitate access to its exposure factors recommendations. As such, it contains a subset of the information provided in the complete Handbook. This Highlights document is a product of the U.S. EPA's Exposure Factors Program. The Program has three main goals: (1) provide updates to the *Exposure Factors Handbook*, (2) identify exposure factor 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.

NCEA invites you to visit its Web site at www.epa.gov/ncea where you can view and download chapters from the *Exposure Factors Handbook: 2011 Edition*. Each chapter in the Handbook presents recommended values for the exposure factors covered in the chapter as well as a discussion of the underlying data used in developing the recommendations. U.S. EPA intends to update its Web site periodically so that the information provided by the Exposure Factors Program is current and relevant.

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1. Introduction

1.1 Purpose

This Highlights document presents an overview of the information provided in the U.S. Environmental Protection Agency's (U.S. EPA) *Exposure Factors Handbook: 2011 Edition* (U.S. EPA, 2011). Excerpts of each chapter of the Handbook and summaries of key recommendations for each of the exposure factors are provided.

1.2 About the Handbook

The *Exposure Factors Handbook: 2011 Edition*, hereafter referred to as the *Exposure Factors Handbook* or Handbook, is the update of an earlier version prepared in 1997 (U.S. EPA, 1997). Its purpose is to (1) summarize data on human behaviors and characteristics that affect exposure to environmental contaminants, and (2) recommend 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 assessors can consider and modify as needed. Many of these factors are best quantified on a site- or situation-specific basis. 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 includes full discussions of the issues that assessors should consider in deciding how to use these data and recommendations.

The Handbook reviews and summarizes data on the various factors used in the exposure assessment. It contains 19 chapters: an introduction (Chapter 1), a discussion about the variability and uncertainty in assessing exposure factors (Chapter 2), and non-chemical specific data on exposure factors 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 (Chapter 7);
- body weight (Chapter 8);

- intake of fruits and vegetables (Chapter 9);
- intake of fish and shellfish (Chapter 10);
- intake of meats, 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);
- consumer products (Chapter 17);
- lifetime (Chapter 18); and
- building characteristics (Chapter 19).

1.3 Intended Audience

The *Exposure Factors Handbook* is intended for use by exposure assessors and risk assessors, both within and outside the U.S. EPA, as a reference tool and primary source of exposure factor information. It may be used by scientists, economists, and other interested parties as a source of data and/or U.S. EPA recommendations on numeric estimates for behavioral and physiological characteristics needed to estimate exposure to environmental agents.

1.4 Selection of Studies for the Handbook

Information in the *Exposure Factors Handbook* and in this Highlights document has been summarized from studies documented in the scientific literature and other publicly available sources. Studies were chosen that were seen as useful and appropriate for estimating exposure factors for both adults and children. The Handbook contains summaries of selected studies published through July 2011. Certain studies described in the Handbook are designated as “key,” that is, the most up-to-date and scientifically sound for deriving recommendations for exposure factors. The recommended values for most exposure factors are based on the results of the key studies (see Section 1.5 in the *Exposure Factors Handbook*). Other studies designated as “relevant,” meaning applicable or pertinent, but not necessarily the most important, are also summarized in the Handbook.

1.5 Approach Used to Develop Recommendations for Exposure Factors

U.S. EPA's procedure for developing recommendations included study review and evaluations, considering single versus multiple key studies, evaluating the variability of a factor across the population, and identifying uncertainties in the data. Based on these evaluations, U.S. EPA assigned a confidence rating to each factor. This qualitative rating is not intended to represent an uncertainty analysis; rather,

it represents U.S. EPA's judgment on the quality of the underlying data used to derive the recommendation. Table 1-1 summarizes the factors used in selecting studies for consideration in the Handbook and in evaluating data limitations. It should be noted that while U.S. EPA has developed recommendations for each exposure factor, different values may be appropriate in consideration of policy, precedent, strategy, or other factors such as site-specific information.

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

General Assessment Factors	Increasing Confidence	Decreasing Confidence
Soundness		
<i>Adequacy of Approach</i>	The studies used the best available methodology and capture the measurement of interest.	There are serious limitations with the approach used; the 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.	The sample size is 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.
<i>Minimal (or defined) Bias</i>	The study design minimizes measurement errors.	Uncertainties with the data exist due to measurement error.
Applicability and Utility		
<i>Exposure Factor of Interest</i>	The studies focused on the exposure factor of interest.	The purpose of the studies was to characterize a related factor.
<i>Representativeness</i>	The studies focused on the U.S. population.	Studies are not representative of the U.S. population.
<i>Currency</i>	The studies represent current exposure conditions.	Studies may not be representative of current exposure conditions.
<i>Data Collection Period</i>	The data collection period is sufficient to estimate long-term behaviors.	Shorter data collection periods may not represent long-term exposures.
Clarity and Completeness		
<i>Accessibility</i>	The study data could be accessed.	Access to the primary data set was limited.
<i>Reproducibility</i>	The results can be reproduced or the methodology can be followed and evaluated.	The results cannot be reproduced, the methodology is hard to follow, and the author(s) cannot be located.
<i>Quality Assurance</i>	The studies applied and documented quality assurance/quality control measures.	Information on quality assurance/quality control was limited or absent.
Variability and Uncertainty		
<i>Variability in Population</i>	The studies characterize variability in the population studied.	The characterization of variability is limited.
<i>Uncertainty</i>	The uncertainties are minimal and can be identified. Potential biases 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.

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

Evaluation and Review		
General Assessment Factors	Increasing Confidence	Decreasing Confidence
<i>Peer Review</i>	The studies received high level of peer review (e.g., they are published in peer reviewed journals).	The studies received limited peer review.
<i>Number and Agreement of Studies</i>	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.

1.6 The Use of Age Groups When Assessing Exposure

When the *Exposure Factors Handbook* was published in 1997, no specific guidance existed with regard to which age groupings should be used when assessing children’s exposure. More recently, U.S. EPA established a consistent set of age groupings and published guidance on this topic (U.S. EPA, 2005). The 2011 edition of the Handbook attempts to present data in a manner consistent with the U.S. EPA’s recommended set of age groupings for children. To this date, no specific guidance is available with regard to age groupings for presenting adult data. Therefore, adult data (i.e., >21 years of age) are presented using the age groups defined by the authors of the individual studies. No attempt was made to re-analyze the data using a consistent set of age groups for adults. In cases where data were analyzed by U.S. EPA, age categories were defined as finely as possible based on adequacy of sample size.

The selection of rates (e.g., inhalation, ingestion, dermal) to be used for exposure assessments depends on the life stage of the exposed population and the specific activity levels of this population during various exposure scenarios. The recommended values for adults and children (including infants) for use in various exposure scenarios are presented in each chapter.

1.7 Considering Life Stage When Calculating Exposure and Risk

In recent years, there has been an increased concern regarding the potential impact of environmental exposures among children and other susceptible populations such as older adults and pregnant/lactating women. As a result, U.S. EPA and others have developed policy and guidance, and undertaken research to better incorporate life-stage data into human health risk assessment (Brown et al., 2008). A framework for considering life stages in human health risk assessments was developed by U.S. EPA in the report entitled, *A Framework for Assessing Health Risks of Environmental Exposures to Children* (U.S. EPA, 2006). Although the framework discusses the importance of incorporating life stages in the evaluation of risks to children, the approach can also be applied to other life stages that may have their own unique susceptibilities, such as older individuals.

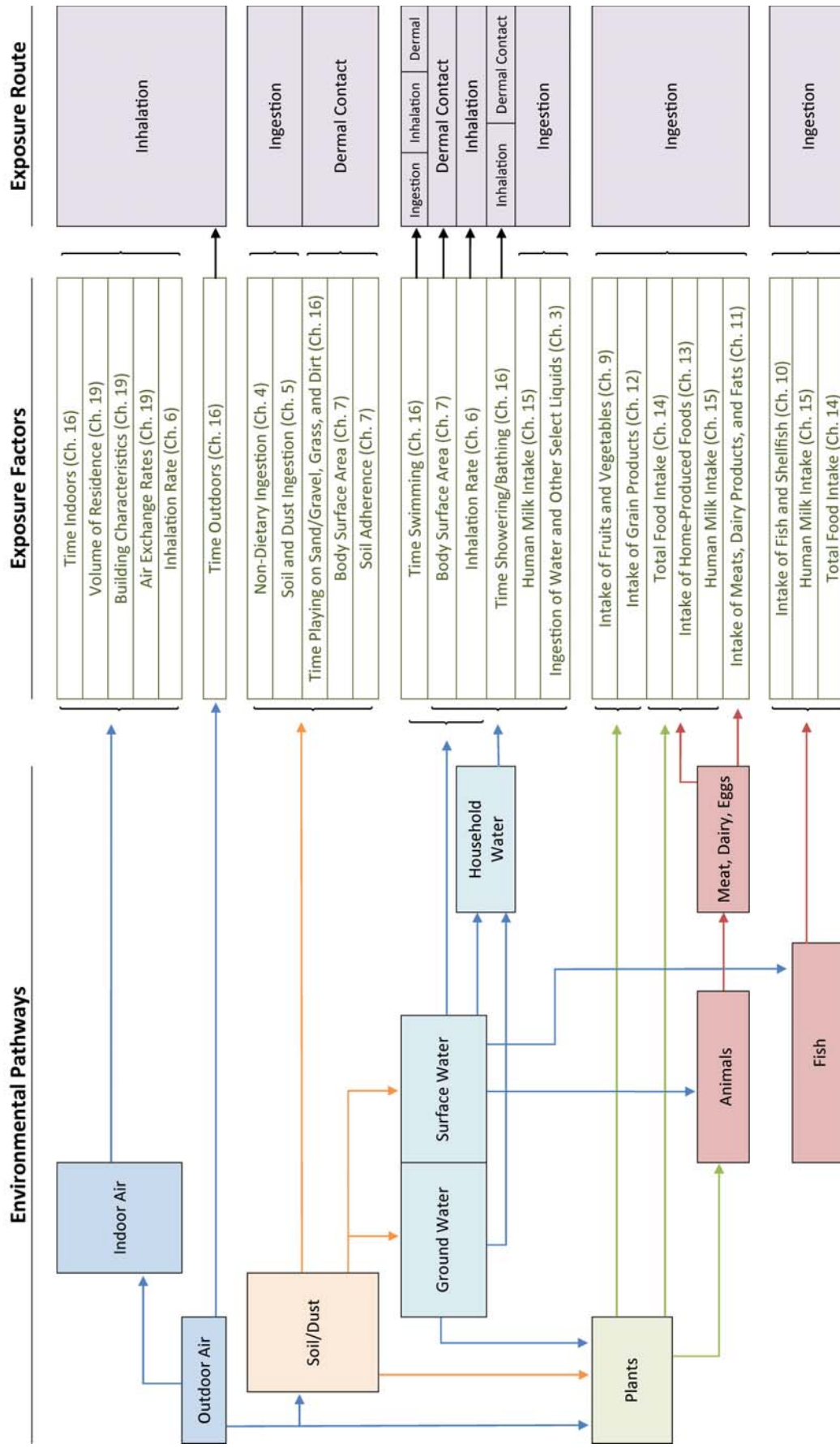
1.8 Fundamental Principles of Exposure Assessment

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 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. This approach has been used historically in exposure assessments and exposure modeling. It is usually referred to as the source-to-dose approach. In recent years, person-oriented approaches and models have gained popularity. This approach is aimed at accounting for cumulative and aggregate exposures to individuals (Georgopoulos, 2008; Price et al., 2003). The person-oriented approach can also take advantage of information about the individual’s susceptibility to environmental factors (e.g., genetic differences) (Georgopoulos, 2008).

There are three approaches to calculate exposures: (1) the point-of-contact approach, (2) the scenario evaluation approach, and (3) the dose reconstruction approach (U.S. EPA, 1992). The data presented in the Handbook are generally useful for evaluating exposures using the scenario evaluation approach. See Section 1.10 in the *Exposure Factors Handbook* for more detailed information on exposure assessment, including dose equations and the use of exposure factors in probabilistic analyses. Figure 1-1 provides a schematic diagram that shows the linkages of a select number of exposure pathways with the exposure factors presented in the Handbook and the corresponding exposure routes.

Figure 1-1. Schematic Diagram of Exposure Pathways, Factors, and Routes



Notes:
 The pathways presented are selected pathways. This diagram is not meant to be comprehensive.
 Consumer Products (Ch. 17), such as perfume, are not shown on this diagram. Humans can be exposed to consumer products through all pathways and routes.
 Body Weight (Ch. 8) and Lifetime (Ch. 18) potentially modify all exposure pathways.

2. Variability and Uncertainty

2.1 Variability versus Uncertainty

Accounting for variability and uncertainty is fundamental to exposure assessment and risk analysis. Characterizing and communicating uncertainty and variability should be done throughout all the components of the risk assessment process (NRC, 1994). Thus, careful consideration of the variabilities and uncertainties associated with the exposure factors information used in an exposure assessment is of utmost importance.

This section highlights some of the fundamental concepts of variability and uncertainty related to exposure factors data, as presented in Chapter 2 of the *Exposure Factors Handbook*.

2.2 Types of Variability

Variability in exposure potential 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 contaminant 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). Four types of variability can be distinguished: across locations (spatial), over time (temporal), within an individual (intra-individual), and among individuals (inter-individual).

2.3 Types of Uncertainty

Uncertainty in exposure analysis is related to the lack of knowledge concerning one or more components of the assessment process. U.S. EPA (1992) classified uncertainty in exposure 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), and (3) uncertainty regarding gaps in scientific theory required to make predictions on the basis of causal inferences (model uncertainty).

Because uncertainty in exposure assessment is fundamentally tied to a lack of knowledge concerning important exposure factors, strategies for reducing uncertainty necessarily involve reduction or elimination of knowledge gaps. Strategies for reducing 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.



2.4 How the *Exposure Factors Handbook* Addresses Variability and Uncertainty

The *Exposure Factors Handbook* 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 for various life stages, demographic variables, geographical regions, and sociodemographic variables where available and applicable; (2) as probability

distributions with specified parameters including confidence intervals; or (3) as a qualitative discussion.

The *Exposure Factors Handbook* addresses uncertainty by providing qualitative discussions of the limitations associated with each of the studies used to derive recommendations. Confidence ratings are also provided based on U.S. EPA's judgment of the data underlying such recommendations.

For more information about variability and uncertainty, refer to **Chapter 2 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter02.pdf>. Detailed information on variability versus uncertainty is provided in Section 2.1, types of variability in Section 2.2, addressing variability in Section 2.3, types of uncertainty in Section 2.4, reducing uncertainty in Section 2.5, analyzing variability and uncertainty in Section 2.6, literature review of variability and uncertainty analysis in Section 2.7, and presenting results of variability and uncertainty analysis in Section 2.8.



3. Ingestion of Water and Other Select Liquids

3.1 Introduction

Water ingestion can be a pathway of exposure to environmental chemicals. Contamination of water may occur at the water supply source (ground water or surface water); during treatment (e.g., toxic by-products may be formed during chlorination); or post-treatment (e.g., leaching of lead or other materials from plumbing systems). People 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 environmental contaminants from water ingestion requires information on the quantity of water consumed. Chapter 3 of the *Exposure Factors Handbook* provides information on ingestion of water consumed as a beverage, ingestion of other select liquids, and ingestion of water while swimming. Highlights of these data are provided here.

3.2 Recommended Exposure Factors

Drinking Water Ingestion Rates: The recommended drinking water ingestion rates for general population children <3 years of age are based on an analysis of data from the U.S. Department of Agriculture's 1994-1996 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) (Kahn and Stralka, 2008a; Kahn, 2008). The recommended drinking water ingestion rates for individuals ≥ 3 years of age are based on the U.S. EPA analysis of 2003-2006 data from the National Health and Nutrition Examination Survey (NHANES). The CSFII data set includes survey response data for more than 20,000 people nationwide. The NHANES data set includes survey responses from more than 18,000 people nationwide. These recommended rates represent both consumption of water as a beverage (direct intake) and water used in preparing foods and beverages (indirect intake). The recommended intake rates for pregnant and lactating women are also based on an analysis of data from CSFII (Kahn and Stralka, 2008b). The recommended data represent intake from community (site-specific) water supplies and do not include intake from bottled water or water intrinsic in purchased foods that may be widely distributed. Table 3-1 provides the recommended per capita

and consumer-only drinking water ingestion rates. Per capita rates include all survey participants whether or not they ingested any water from the source during the survey period. Consumer-only rates exclude individuals who did not ingest water from the source during the survey period. Overall, the confidence rating for the recommendations for drinking water ingestion rates is medium to high.

Water Ingestion Rates While Swimming: The recommended values for water ingestion rates during swimming for children and adults are presented in Table 3-2. These values are based on a study by Dufour et al. (2006), which estimated water ingestion of 53 swimmers (12 adults and 41 children under 18 years of age) during a 45-minute swimming period at an outdoor pool. The overall confidence in the recommendations for ingestion of water while swimming is low. Data on the amount of time spent swimming are provided in Chapter 16 of the *Exposure Factors Handbook*.



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

Age Group	Mean		95 th Percentile		Mean		95 th Percentile	
	mL/day	mL/kg-day	mL/day	mL/kg-day	mL/day	mL/kg-day	mL/day	mL/kg-day
	Per Capita^b				Consumers Only^d			
Birth to <1 month	184	52	839 ^c	232 ^c	470 ^c	137 ^c	858 ^c	238 ^c
1 to <3 months	227	48	896 ^c	205 ^c	552	119	1,053 ^c	285 ^c
3 to <6 months	362	52	1,056	159	556	80	1,171 ^c	173 ^c
6 to <12 months	360	41	1,055	126	467	53	1,147	129
1 to <2 years	271	23	837	71	308	27	893	75
2 to <3 years	317	23	877	60	356	26	912	62
3 to <6 years	327	18	959	51	382	21	999	52
6 to <11 years	414	14	1,316	43	511	17	1,404	47
11 to <16 years	520	10	1,821	32	637	12	1,976	35
16 to <18 years	573	9	1,783	28	702	10	1,883	30
18 to <21 years	681	9	2,368	35	816	11	2,818	36
≥21 years	1,043	13	2,958	40	1,227	16	3,092	42
>65 years	1,046	14	2,730	40	1,288	18	2,960	43
All ages	869	14	2,717	42	1,033	16	2,881	44
Pregnant women	819 ^c	13 ^c	2,503 ^c	43 ^c	872 ^c	14 ^c	2,589 ^c	43 ^c
Lactating women	1,379 ^c	21 ^c	3,434 ^c	55 ^c	1,665 ^c	26 ^c	3,588 ^c	55 ^c

^a Ingestion rates for combined direct and indirect water from community water supply. For multiple percentiles, see Chapter 3 of the *Exposure Factors Handbook*.

^b Per capita intake rates are generated by averaging consumer-only intakes over the entire population (including those individuals that reported no intake).

^c Estimates are less statistically reliable based on guidance published in the *Joint Policy on Variance Estimation and Statistical Reporting Standards on NHANES III and CSFII Reports: NHIS/NCHS Analytical Working Group Recommendations* (NCHS, 1993).

^d Consumer-only intake represents the quantity of water consumed only by individuals that reported consuming water during the survey period.

The source of data for children <3 years is the 1994-1996 and 1998 CSFII (Kahn and Stralka, 2008a; Kahn, 2008); for individuals ≥3 years and all ages, the source of data is the U.S. EPA analysis of 2003-2006 NHANES data. The source of data for pregnant and lactating women is the 1994-1996 and 1998 CSFII (Kahn and Stralka, 2008b).

Table 3-2. Recommended Values for Water Ingestion While Swimming

Age Group	Mean		Upper Percentile	
	mL/event ^a	mL/hour	mL/event ^a	mL/hour
Children	37	49	90 ^b	120 ^b
Adults	16	21	53 ^c	71 ^c

^a Participants swam for 45 minutes.

^b 97th percentile.

^c Maximum value.

Source: Dufour et al., 2006.

For more information about the key studies used to derive the recommended water ingestion rate values, refer to **Chapter 3 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter03.pdf>. Detailed information on water ingestion studies among the general population is included in Section 3.3, and studies regarding pregnant and lactating women can be found in Section 3.4. Section 3.5 presents relevant studies on water intake among individuals located in hot climates or engaging in high activity levels. Section 3.6 presents information on ingestion of water while swimming or diving. Limited information on the ingestion of select liquids is also provided in Section 3.3.

4. Non-Dietary Ingestion Factors

4.1 Introduction

Adults and children have the potential for exposure to toxic substances through non-dietary ingestion when these substances are transferred from treated surfaces to the hands or objects that are mouthed. 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). Adults mouth objects such as cigarettes, pens and pencils, or their hands. Young children mouth objects, surfaces, or their fingers as they explore their environment. Data on mouthing frequency (e.g., contacts per hour or contacts per minute) and/or duration of mouthing events (how long each contact lasts, expressed in units of seconds or minutes) are required in order to estimate the magnitude of exposure to toxic substances through this behavior. Chapter 4 of the *Exposure Factors Handbook* provides information on mouthing behaviors and their frequency and duration in children and adults. Highlights of these data are provided here.

4.2 Recommended Exposure Factors

Hand-to-Mouth and Object-to-Mouth Frequencies: Mouthing frequencies are 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). The recommendations for frequency of object-to-mouth contact are based on data from Xue et al. (2009). Xue et al. (2007, 2009) report a secondary analysis of data from several studies summarized in Chapter 4 of the *Exposure Factors Handbook*, as well as data from unpublished studies. Table 4.1 presents the recommended values for mouthing frequency. The overall confidence rating for hand-to-mouth and object-to-mouth contact frequency is low.

Hand-to-Mouth and Object-to-Mouth Duration: Recommendations for duration of object-to-mouth contacts are based on data from Juberg et al. (2001), Greene (2002), and Beamer et al. (2008). Recommendations for

hand-to-mouth duration are not provided because the algorithm to estimate exposures from this pathway is not time dependent. Table 4-1 presents the recommended values for mouthing duration. The overall confidence rating for hand-to-mouth and object-to-mouth duration is low.



For more information about the key studies used to derive the recommended mouthing frequency and duration values, refer to **Chapter 4 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter04.pdf>. Detailed information about studies on mouthing frequency in children is included in Section 4.3, and studies regarding mouthing duration are provided in Section 4.4. Information on mouthing prevalence (i.e., the number or percentage of children performing specific mouthing behaviors at a certain age) is provided in Section 4.5.

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

Age Group	Hand-to-Mouth ^a			
	Indoor Frequency (contacts/hour)		Outdoor Frequency (contacts/hour)	
	Mean	95 th Percentile	Mean	95 th Percentile
Birth 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	-	-	-	-
Age Group	Object-to-Mouth ^b			
	Indoor Frequency (contacts/hour)		Outdoor Frequency (contacts/hour)	
	Mean	95 th Percentile	Mean	95 th Percentile
Birth to <3 months	-	-	-	-
3 to <6 months	11	32	-	-
6 to <12 months	20	38	-	-
1 to <2 years	14	34	8.8	21
2 to <3 years	9.9	24	8.1	40
3 to <6 years	10	39	8.3	30
6 to <11 years	1.1	3.2	1.9	9.1
11 to <16 years	-	-	-	-
16 to <21 years	-	-	-	-
Age Group	Mean Duration (minutes/hour) ^c		95 th Percentile Duration (minutes/hour) ^c	
Birth to <3 months	-		-	
3 to <6 months	11 ^d		26 ^e	
6 to <12 months	9 ^f		19 ^g	
1 to <2 years	7 ^h		22 ^h	
2 to <3 years	10 ⁱ		11 ^j	
3 to <6 years	-		-	
6 to <11 years	-		-	
11 to <16 years	-		-	
16 to <21 years	-		-	

^a Source: Xue et al., 2007.

^b Source: Xue et al., 2009.

^c Source: Juberg et al., 2001; Greene, 2002; and Beamer et al., 2008.

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

^e Calculated 95th percentile from Greene, 2002 (3 to 12 months).

^f Mean calculated from Juberg et al., 2001 (0 to 18 months); Greene, 2002 (3 to 12 months); and Beamer et al., 2008 (6 to 13 months).

^g Calculated 95th percentile from Greene, 2002 (3 to 12 months) and Beamer et al., 2008 (6 to 13 months).

^h Mean and 95th percentile from Greene, 2002 (12 to 24 months).

ⁱ Mean calculated from Juberg et al., 2001 (19 to 36 months); Greene, 2002 (24 to 36 months); and Beamer et al., 2008 (20 to 26 months).

^j Calculated 95th percentile from Greene, 2002 (24 to 36 months) and Beamer et al., 2008 (20 to 26 months).

- No data.

5. Ingestion of Soil and Dust

5.1 Introduction

The ingestion of soil and dust is a potential route of exposure to environmental chemicals for both adults and children. Children, in particular, 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 ingest soil and dust through deliberate hand-to-mouth movements, or unintentionally by eating food that has dropped on the floor. Adults may also ingest soil or dust particles that adhere to food, cigarettes, or their hands. Thus, understanding soil and dust ingestion patterns is an important part of estimating overall exposures to environmental chemicals. At this point in time, knowledge of soil and dust ingestion patterns within the United States is somewhat limited. Chapter 5 of the *Exposure Factors Handbook* explains the concepts of soil ingestion, soil pica, and geophagy; defines soil, indoor and outdoor settled dust, and dust ingestion; and presents recommended values for amounts of soil and dust ingested for adults and children. This information is summarized here.

Definitions: The Centers for Disease Control and Prevention's (CDC) 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). The *Exposure Factors Handbook* 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.



In the *Exposure Factors Handbook*, soil, indoor 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 or blown 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, because outdoor settled dust generally would be present on the uppermost surface layer of soil.

For the purposes of providing recommended values in the *Exposure Factors Handbook*, soil ingestion includes both soil and outdoor settled dust, and dust ingestion includes indoor settled dust only.

5.2 Recommended Exposure Factors

Table 5-1 shows the central tendency recommendations for daily ingestion of soil, dust, or soil + dust, in mg/day. It also shows the high-end recommendations for daily ingestion of soil, in mg/day. The high-end recommendations are subdivided into a general population soil ingestion rate, an ingestion rate for “soil-pica,” and an estimate for individuals who exhibit “geophagy.” The soil pica and geophagy recommendations are likely to represent acute high soil ingestion episodes or behaviors at an unknown point on the high end of the distribution of soil ingestion.

The recommendations for children are based on various key studies presented in Chapter 5 of the *Exposure Factors Handbook* (Vermeer and Frate, 1979; Wong, 1988; Calabrese et al., 1989, 1991, 1997a,b; Barnes, 1990; Davis et al., 1990; Van Wijnen et al., 1990; Calabrese and Stanek, 1993, 1995; Stanek and Calabrese, 1995; Hogan et al., 1998; Stanek et al., 1998; Davis and Mirick, 2006; Özkaynak et al., 2010). Studies estimating adult soil ingestion are extremely limited, and only two of these are considered to be key studies (Vermeer and Frate, 1979 and Davis and Mirick, 2006). There are no available studies estimating the ingestion of dust by adults. Therefore, the assumption used by the U.S. EPA Integrated Exposure Uptake Biokinetic (IEUBK) model for lead in children (i.e., 45% soil, 55% dust contribution) was used to derive estimates for soil and dust using the soil + dust value derived from Davis and Mirick (2006).

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. The inhalation and subsequent swallowing of soil particles is accounted for in these recommended values, therefore, this pathway does not need to be considered separately. 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 setting 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 represent the mass of ingested soil or dust on a dry-weight basis. The overall confidence rating for the soil and dust recommendations is low.



Table 5-1. Recommended Values for Daily Soil, Dust, and Soil + Dust Ingestion (mg/day)

Age Group	Soil ^a				Dust ^b		Soil + Dust	
	General Population Central Tendency ^c	High End			General Population Central Tendency ^g	General Population Upper Percentile ^h	General Population Central Tendency ^c	General Population Upper Percentile ^h
		General Population Upper Percentile ^d	Soil-Pica ^e	Geophagy ^f				
6 weeks to <1 year	30	-	-	-	30	-	60	-
1 to <6 years	50	-	1,000	50,000	60	-	100 ⁱ	-
3 to <6 years	-	200	-	-	-	100	-	200
6 to <21 years	50	-	1,000	50,000	60	-	100 ^j	-
Adult	20 ^j	-	-	50,000	30 ^j	-	50	-

^a Includes soil and outdoor settled dust.

^b Includes indoor settled dust only.

^c Davis and Mirick, 2006; Hogan et al., 1998; Van Wijnen et al., 1990; Calabrese and Stanek, 1995; Davis et al., 1990.

^d Özkaynak et al., 2010; Stanek and Calabrese, 1995; rounded to one significant figure.

^e ATSDR, 2001; Calabrese and Stanek, 1993; Calabrese et al., 1989/Barnes, 1990/Calabrese et al., 1991; Calabrese et al., 1997a, b; Stanek et al., 1998; Vermeer and Frate, 1979; Wong, 1988.

^f Vermeer and Frate, 1979.

^g Hogan et al, 1998.

^h Özkaynak et al., 2010; rounded to one significant figure.

ⁱ Total soil and dust ingestion rate is 110 mg/day; rounded to one significant figure it is 100 mg/day.

^j Estimates of soil and dust were derived from the soil + dust and assuming 45% soil and 55% dust.

- No data.

For more information about the key studies used to derive the recommended ingestion of soil and dust values, refer to **Chapter 5 of the Exposure Factors Handbook** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter05.pdf>. Detailed information on methodologies and the studies on soil and dust ingestion is included in Section 5.3. Information regarding the limitations of the study methodologies is provided in Section 5.4.

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6. Inhalation Rates

6.1 Introduction

Ambient and indoor air are potential sources of exposure to toxic substances. Adults and children can be exposed to contaminated air during a variety of activities in different environments. They may be exposed to contaminants in ambient air, and may also inhale chemicals from the indoor use of various consumer products. U.S. EPA (1992) defines exposure as the chemical concentration at the boundary of the body. In the case of inhalation, the situation is complicated; 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. 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. Assessors may not always need to select and use inhalation rates when evaluating exposure to air contaminants; for example, IRIS and Superfund risk values (i.e., Reference Concentrations (RfCs) and Unit Risks) already incorporate inhalation rates. However, Chapter 6 of the *Exposure Factors Handbook* provides recommended inhalation rates for both long-term and short-term exposure scenarios where these factors are needed. The data are summarized in this Highlights document.

6.2 Recommended Exposure Factors

The recommended inhalation rates for adults and children are based on three recent studies (Brochu et al., 2006; U.S. EPA, 2009; and Stifelman, 2007), as well as an additional study of children (Arcus-Arth and Blaisdell, 2007). Long-term inhalation 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 adults and 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 adults and children (including infants) performing various activities in m^3/minute .

The *Exposure Factors Handbook* provides recommendations for both long- and short-term exposure inhalation rates. Values for short- versus long-term are necessary because the length of exposure influences the type and severity of any effects associated with the exposure.

Table 6-1 presents the long-term mean and 95th percentile data, by age group, for males and females combined. Table 6-2 presents the short-term data by activity level. The short-term 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, 2009). The overall confidence rating in the inhalation rates is medium.



Long-term exposure is repeated exposure for more than 30 days for adults and children (including infants).

Short-term exposure is repeated exposure for more than 24 hours, up to 30 days, for adults and children (including infants) performing various activities.



Table 6-1. Recommended Long-Term Exposure (More Than 30 Days) Values for Inhalation (Males and Females Combined)

Age Group ^e	Mean m ³ /day	Sources Used for Means	95 th Percentile ^{f,g} m ³ /day	Sources Used for 95 th Percentiles
Birth to <1 month	3.6	a	7.1	a
1 to <3 months	3.5	a, b	5.8	a, b
3 to <6 months	4.1	a, b	6.1	a, b
6 to <12 months	5.4	a, b	8.0	a, b
Birth to <1 year	5.4	a, b, c, d	9.2	a, b, c
1 to <2 years	8.0	a, b, c, d	12.8	a, b, c
2 to <3 years	8.9	a, b, c, d	13.7	a, b, c
3 to <6 years	10.1	a, b, c, d	13.8	a, b, c
6 to <11 years	12.0	a, b, c, d	16.6	a, b, c
11 to <16 years	15.2	a, b, c, d	21.9	a, b, c
16 to <21 years	16.3	a, b, c, d	24.6	a, b, c
21 to <31 years	15.7	b, c, d	21.3	b, c
31 to <41 years	16.0	b, c, d	21.4	b, c
41 to <51 years	16.0	b, c, d	21.2	b, c
51 to <61 years	15.7	b, c, d	21.3	b, c
61 to <71 years	14.2	b, c, d	18.1	b, c
71 to <81 years	12.9	b, c	16.6	b, c
81 years and older	12.2	b, c	15.7	b, c

^a Arcus-Arth and Blaisdell, 2007.

^b Brochu et al., 2006.

^c U.S. EPA, 2009.

^d Stifelman, 2007.

^e When age groupings in the original reference did not match the U.S. EPA's age groupings used for the Handbook, means from all age groupings in the original reference that overlapped U.S. EPA's age groupings by more than 1 year were averaged, weighted by the number of observations contributed from each age group. Similar calculations were performed for the 95th percentiles. See Table 6-25 of the *Exposure Factors Handbook* for concordance with U.S. EPA's age groupings.

^f Some 95th percentile values may be unrealistically high and not representative of the average person.

^g For multiple percentiles, see Tables 6-4, 6-6 to 6-8, 6-10, 6-14, and 6-15 in the *Exposure Factors Handbook*; none available for Stifelman, 2007.

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	95 th Percentile ^a m ³ /minute
Sleep or Nap	Birth to <1 year	3.0×10 ⁻³	4.6×10 ⁻³
	1 to <2 years	4.5×10 ⁻³	6.4×10 ⁻³
	2 to <3 years	4.6×10 ⁻³	6.4×10 ⁻³
	3 to <6 years	4.3×10 ⁻³	5.8×10 ⁻³
	6 to <11 years	4.5×10 ⁻³	6.3×10 ⁻³
	11 to <16 years	5.0×10 ⁻³	7.4×10 ⁻³
	16 to <21 years	4.9×10 ⁻³	7.1×10 ⁻³
	21 to <31	4.3×10 ⁻³	6.5×10 ⁻³
	31 to <41	4.6×10 ⁻³	6.6×10 ⁻³
	41 to <51	5.0×10 ⁻³	7.1×10 ⁻³
	51 to <61	5.2×10 ⁻³	7.5×10 ⁻³
	61 to <71	5.2×10 ⁻³	7.2×10 ⁻³
	71 to <81	5.3×10 ⁻³	7.2×10 ⁻³
	81 years and older	5.2×10 ⁻³	7.0×10 ⁻³
Sedentary/Passive	Birth to <1 year	3.1×10 ⁻³	4.7×10 ⁻³
	1 to <2 years	4.7×10 ⁻³	6.5×10 ⁻³
	2 to <3 years	4.8×10 ⁻³	6.5×10 ⁻³
	3 to <6 years	4.5×10 ⁻³	5.8×10 ⁻³
	6 to <11 years	4.8×10 ⁻³	6.4×10 ⁻³
	11 to <16 years	5.4×10 ⁻³	7.5×10 ⁻³
	16 to <21 years	5.3×10 ⁻³	7.2×10 ⁻³
	21 to <31 years	4.2×10 ⁻³	6.5×10 ⁻³
	31 to <41 years	4.3×10 ⁻³	6.6×10 ⁻³
	41 to <51 years	4.8×10 ⁻³	7.0×10 ⁻³
	51 to <61 years	5.0×10 ⁻³	7.3×10 ⁻³
	61 to <71 years	4.9×10 ⁻³	7.3×10 ⁻³
	71 to <81 years	5.0×10 ⁻³	7.2×10 ⁻³
	81 years and older	4.9×10 ⁻³	7.0×10 ⁻³
Light Intensity	Birth to <1 year	7.6×10 ⁻³	1.1×10 ⁻²
	1 to <2 years	1.2×10 ⁻²	1.6×10 ⁻²
	2 to <3 years	1.2×10 ⁻²	1.6×10 ⁻²
	3 to <6 years	1.1×10 ⁻²	1.4×10 ⁻²
	6 to <11 years	1.1×10 ⁻²	1.5×10 ⁻²
	11 to <16 years	1.3×10 ⁻²	1.7×10 ⁻²
	16 to <21 years	1.2×10 ⁻²	1.6×10 ⁻²
	21 to <31 years	1.2×10 ⁻²	1.6×10 ⁻²
	31 to <41 years	1.2×10 ⁻²	1.6×10 ⁻²
	41 to <51 years	1.3×10 ⁻²	1.6×10 ⁻²
	51 to <61 years	1.3×10 ⁻²	1.7×10 ⁻²
	61 to <71 years	1.2×10 ⁻²	1.6×10 ⁻²
	71 to <81 years	1.2×10 ⁻²	1.5×10 ⁻²
	81 years and older	1.2×10 ⁻²	1.5×10 ⁻²

Table 6-2. Recommended Short-Term Exposure (Less Than 30 Days) Values for Inhalation (Males and Females Combined) (continued)

Activity Level	Age Group years	Mean m ³ /minute	95 th Percentile ^a m ³ /minute
Moderate Intensity	Birth to <1 year	1.4×10 ⁻²	2.2×10 ⁻²
	1 to <2 years	2.1×10 ⁻²	2.9×10 ⁻²
	2 to <3 years	2.1×10 ⁻²	2.9×10 ⁻²
	3 to <6 years	2.1×10 ⁻²	2.7×10 ⁻²
	6 to <11 years	2.2×10 ⁻²	2.9×10 ⁻²
	11 to <16 years	2.5×10 ⁻²	3.4×10 ⁻²
	16 to <21 years	2.6×10 ⁻²	3.7×10 ⁻²
	21 to <31 years	2.6×10 ⁻²	3.8×10 ⁻²
	31 to <41 years	2.7×10 ⁻²	3.7×10 ⁻²
	41 to <51 years	2.8×10 ⁻²	3.9×10 ⁻²
	51 to <61 years	2.9×10 ⁻²	4.0×10 ⁻²
	61 to <71 years	2.6×10 ⁻²	3.4×10 ⁻²
	71 to <81 years	2.5×10 ⁻²	3.2×10 ⁻²
	81 years and older	2.5×10 ⁻²	3.1×10 ⁻²
High Intensity	Birth to <1 year	2.6×10 ⁻²	4.1×10 ⁻²
	1 to <2 years	3.8×10 ⁻²	5.2×10 ⁻²
	2 to <3 years	3.9×10 ⁻²	5.3×10 ⁻²
	3 to <6 years	3.7×10 ⁻²	4.8×10 ⁻²
	6 to <11 years	4.2×10 ⁻²	5.9×10 ⁻²
	11 to <16 years	4.9×10 ⁻²	7.0×10 ⁻²
	16 to <21 years	4.9×10 ⁻²	7.3×10 ⁻²
	21 to <31 years	5.0×10 ⁻²	7.6×10 ⁻²
	31 to <41 years	4.9×10 ⁻²	7.2×10 ⁻²
	41 to <51 years	5.2×10 ⁻²	7.6×10 ⁻²
	51 to <61 years	5.3×10 ⁻²	7.8×10 ⁻²
	61 to <71 years	4.7×10 ⁻²	6.6×10 ⁻²
	71 to <81 years	4.7×10 ⁻²	6.5×10 ⁻²
	81 years and older	4.8×10 ⁻²	6.8×10 ⁻²

^a For multiple percentiles, see Tables 6-17 and 6-19 in the *Exposure Factors Handbook*.

Source: U.S. EPA, 2009.

For more information about the key studies used to derive the recommended inhalation rate values, refer to **Chapter 6 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter06.pdf>. These studies are discussed in Section 6.3 and information on other relevant studies is provided in Section 6.4.

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
- solids or residues (e.g., soil/dust or chemical residues on carpets, floors, counter tops, outdoor surfaces, or clothing).

Chapter 7 of the *Exposure Factors Handbook* provides information on factors that affect dermal exposure, including body surface area, dermal adherence of solids to the skin, film thickness of liquids on the skin, transfer of chemical residues from surfaces to the skin, and other factors. However, recommended values are only provided for skin surface area and adherence of solids to the skin. Factors that influence dermal uptake (i.e., absorption) and internal dose, including chemical-specific factors, are not provided in the Handbook.

7.2 Recommended Exposure Factors

Body Surface Area: The recommended mean and 95th percentile total body surface area values are summarized in Table 7-1. These data are based on body weight and height data, used with empirical formulae, to estimate skin surface area for various age groups. For children under 21 years of age, the recommendations for total body surface area are based on the U.S. EPA analysis of NHANES 1999-2006 body weight and height data. These data are presented for the standard age groupings recommended by U.S. EPA (2005) for male and female children combined. For adults 21 years and over, the recommendations for total body surface area are based on the U.S. EPA analysis of NHANES 2005-2006 body weight and height data for males and females. The recommendations for the percentage of the total body surface area represented by individual body parts are provided in Table 7-2. The percentages are based on data

from U.S. EPA (1985) for children under 2 years of age and adults, and Boniol et al. (2007) for children over 2 years of age. Table 7-2 also provides age-specific body part surface areas (m²) that were obtained by multiplying the mean body part percentages by the total body surface areas presented in Table 7-1. Overall confidence in the body surface area factors is medium for total surface area and low for surface area of individual body parts.

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 the skin, including household dust, sediments, and commercial powders. 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.



Soil adherence values are based on field studies that considered factors such as activity, sex, age, field conditions, and clothing worn (Holmes et al., 1999; Kissel et al., 1996;

Shoaf et al., 2005). Recommended mean AF values are summarized in Table 7-3 according to common activities. Overall confidence in the soil AFs is low.

Table 7 1. Recommended Values for Total Body Surface Area, Children (Males and Females Combined) and Adults by Sex

Age Group	Mean	95 th Percentile ^a
m ²		
Males and Females Combined^b		
Birth to <1 month	0.29	0.34
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
Adult Males^c		
21 to 30 years	2.05	2.52
30 to <40 years	2.10	2.50
40 to <50 years	2.15	2.56
50 to <60 years	2.11	2.55
60 to <70 years	2.08	2.46
70 to <80 years	2.05	2.45
80 years and over	1.92	2.22
Adult Females^c		
21 to 30 years	1.81	2.25
30 to <40 years	1.85	2.31
40 to <50 years	1.88	2.36
50 to <60 years	1.89	2.38
60 to <70 years	1.88	2.34
70 to <80 years	1.77	2.13
80 years and over	1.69	1.98

^a For multiple percentiles, see Tables 7-9 (for males and females-combined data), 7-10, and 7-11 in the *Exposure Factors Handbook*.
^b Source: U.S. EPA Analysis of NHANES 1999-2006 data.
^c Source: U.S. EPA Analysis of NHANES 2005-2006 data.

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	a
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	8.4	41.0	14.4	4.7	25.3	6.3	b
3 to <6 years	8.0	41.2	14.0	4.9	25.7	6.4	
6 to <11 years	6.1	39.6	14.0	4.7	28.8	6.8	
11 to <16 years	4.6	39.6	14.3	4.5	30.4	6.6	
16 to <21 years	4.1	41.2	14.6	4.5	29.5	6.1	
Adult Males—21+ years	6.6	40.1	15.2	5.2	33.1	6.7	c
Adult Females—21+ years	6.2	35.4	12.8	4.8	32.3	6.6	
Mean Surface Area by Body Part^d m²							
Birth to <1 month	0.053	0.104	0.040	0.015	0.060	0.019	e
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	0.051	0.250	0.088	0.028	0.154	0.038	f
3 to <6 years	0.061	0.313	0.106	0.037	0.195	0.049	
6 to <11 years	0.066	0.428	0.151	0.051	0.311	0.073	
11 to <16 years	0.073	0.630	0.227	0.072	0.483	0.105	
16 to <21 years	0.075	0.759	0.269	0.083	0.543	0.112	
Adult Males—21+ years	0.136	0.827	0.314	0.107	0.682	0.137	c
Adult Females—21+ years	0.114	0.654	0.237	0.089	0.598	0.122	
95th Percentile Surface Area by Body Part^g m²							
Birth to <1 month	0.062	0.121	0.047	0.018	0.070	0.022	e
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	0.059	0.287	0.101	0.033	0.177	0.044	f
3 to <6 years	0.076	0.391	0.133	0.046	0.244	0.061	
6 to <11 years	0.090	0.586	0.207	0.070	0.426	0.100	
11 to <16 years	0.095	0.816	0.295	0.093	0.626	0.136	
16 to <21 years	0.096	0.960	0.340	0.105	0.687	0.142	
Adult Males—21+ years	0.154	1.10	0.399	0.131	0.847	0.161	c
Adult Females—21+ years	0.121	0.850	0.266	0.106	0.764	0.146	

^a Source: U.S. EPA, 1985.

^b Source: Boniol et al., 2007.

^c U.S. EPA analysis of NHANES 2005-2006 data and U.S. EPA, 1985.

^d Children's values calculated as mean percentages of body part times mean total body surface area.

^e U.S. EPA analysis of NHANES 1999-2006 data and U.S. EPA, 1985. Percentages based on small number of observations for this age group.

^f Boniol et al., 2007 and U.S. EPA Analysis of NHANES 1999-2006 data; some body parts and age groups presented by Boniol et al. (2007) were combined to be consistent with the body part categories and age groups used here.

^g Children's values calculated as mean percentage of body part times 95th percentile total body surface area.

Note: Surface area values reported in m² can be converted to cm² by multiplying by 10,000 cm²/m².

Table 7-3. Recommended Values for Mean Solids Adherence to Skin

	Face	Arms	Hands	Legs	Feet
	mg/cm ²				
Children					
Residential (indoors) ^a	-	0.0041	0.011	0.0035	0.010
Daycare (indoors & outdoors) ^b	-	0.024	0.099	0.020	0.071
Outdoor sports ^c	0.012	0.011	0.11	0.031	-
Indoor sports ^d	-	0.0019	0.0063	0.0020	0.0022
Activities with soil ^e	0.054	0.046	0.17	0.051	0.20
Playing in mud ^f	-	11	47	23	15
Playing in sediment ^g	0.040	0.17	0.49	0.70	21
Adults					
Outdoor sports ^h	0.0314	0.0872	0.1336	0.1223	-
Activities with soil ⁱ	0.0240	0.0379	0.1595	0.0189	0.1393
Construction Activities ^j	0.0982	0.1859	0.2763	0.0660	-

^a Based on weighted average of geometric mean soil loadings for 2 groups of children (ages 3 to 13 years; N = 10) playing indoors. Source: Holmes et al., 1999.

^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. Source: Holmes et al., 1999.

^c Based on geometric mean soil loadings of 8 children (ages 13 to 15 years) playing soccer. Source: Kissel et al., 1996.

^d Based on geometric mean soil loadings of 6 children (ages ≥ 8 years) and 1 adult engaging in Tae Kwon Do. Source: Kissel et al., 1996.

^e Based on weighted average of geometric mean soil loadings for gardeners and archeologists (ages 16 to 35 years). Source: Holmes et al., 1999.

^f Based on weighted average of geometric mean soil loadings of 2 groups of children (age 9 to 14 years; N = 12) playing in mud. Source: Kissel et al., 1996.

^g Based on geometric mean soil loadings of 9 children (ages 7 to 12 years) playing in tidal flats. Source: Shoaf et al., 2005.

^h Based on weighted average of geometric mean soil loadings of 3 groups of adults (ages 23 to 33 years) playing rugby and 2 groups of adults (ages 24 to 34 years) playing soccer. Source: Holmes et al., 1999; Kissel et al., 1996.

ⁱ Based on weighted average of geometric mean soil loadings for 69 gardeners, farmers, groundskeepers, landscapers, and archeologists (ages 16 to 64 years) for faces, arms, and hands; 65 gardeners, farmers, groundskeepers, and archeologists (ages 16 to 64 years) for legs; and 36 gardeners, groundskeepers, and archeologists (ages 16 to 62 years) for feet. Source: Holmes et al., 1999; Kissel et al., 1996.

^j Based on weighted average of geometric mean soil loadings for 27 construction workers, utility workers, and equipment operators (ages 21 to 54 years) for faces, arms and hands; and based on geometric mean soil loadings for 8 construction workers (ages 21 to 30 years) for legs. Source: Holmes et al., 1999.

- No data.

For more information about the key studies used to derive the dermal exposure factors, refer to **Chapter 7 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter07.pdf>. Detailed information on surface area studies is included in Section 7.3, and studies regarding adherence of solids to the skin are described in Section 7.4. Data on the film thickness of liquids on human skin is provided in Section 7.5, and information on residue transfer studies is provided in Section 7.6 of the Handbook. Information on other factors that may affect dermal exposure (e.g., frequency and duration of hand contact and thickness of the skin) is provided in Section 7.7.

For guidance on how to use skin surface area and dermal AFs, as well as other factors, 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). Additional information on consumer products use and activity factors that may affect dermal exposure is presented in Chapters 16 and 17 of the *Exposure Factors Handbook*.



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8. Body Weight

8.1 Introduction

Body weight is one of several physiological factors needed to calculate potential exposures. 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). Conversely, if adult exposures are being evaluated, an adult body weight value should be used. Chapter 8 of the *Exposure Factors Handbook* provides recommendations for body weight for the general U.S. population. These recommendations are highlighted here.

8.2 Recommended Exposure Factors

Data on body weight come from the U.S. EPA analysis of NHANES 1999-2006 data. The recommendations for body weight are summarized in Table 8-1. The recommended values represent mean body weights in kilograms for the age groups for children recommended by U.S. EPA in *Guidance for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005) and for adults. If percentile data are needed, Tables 8-3 through 8-5 in the *Exposure Factors Handbook* can be used to select the appropriate data for percentiles or mean values. However, use of upper percentile body weight values is 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. The mean recommended value for adults (80 kg) is different from the 70 kg commonly assumed in U.S. EPA risk assessments. Assessors are encouraged to use values that most accurately reflect the exposed population. When using values other than 70 kg, however, exposure assessors should consider if the dose estimate will be used to estimate risk by combining it with a dose-response relationship that was derived assuming a body weight of 70 kg. If such an inconsistency exists, the assessor may need to adjust the dose-response relationship as described in the appendix to Chapter 1 of the *Exposure Factors Handbook*. Overall confidence in the body weight recommendations is high.



For more information about the key studies used to derive the recommended body weight values, refer to **Chapter 8 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter08.pdf>. Detailed information on the key body weight study is provided in Section 8.3 and relevant body weight studies are discussed in Section 8.4. Sections 8.5 and 8.6 present relevant studies on pregnant women and fetal weight.

Table 8-1. Recommended Values for Body Weight

Age Group	Mean ^a
	kg
Birth to <1 month	4.8
1 to <3 months	5.9
3 to <6 months	7.4
6 to <11 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
Adults	80.0

^a For multiple percentile values, see available Tables 8-3 through 8-5 in the *Exposure Factors Handbook*. Body weight data for males and females are presented separately in Tables 8-4 and 8-5.

Source: U.S. EPA analysis of NHANES 1999-2006 data.



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. Chapter 9 of the *Exposure Factors Handbook* provides information on and recommendations for fruit and vegetable ingestion rates. This information is highlighted here.

9.2 Recommended Exposure Factors

Table 9-1 presents a summary of the recommended values for per capita and consumer-only intake of total fruits and total vegetables. These values are based on the U.S. EPA analysis of NHANES 2003-2006 data. NHANES collected 24-hour dietary intake data via interviews conducted on 2 non-consecutive days. U.S. EPA converted intake data on the foods people reported eating to the quantities of agricultural commodities eaten (e.g., an apple pie may contain the commodities apples, flour, fat, sugar, and spices), and estimated intake rates for fruits and vegetables. Consumer-only intake is defined as the quantity of fruits and vegetables consumed by individuals during the survey period. These data are generated by averaging intake across only the individuals in the survey who consumed these food items. Per capita intake rates are generated by averaging consumer-only intakes over the entire population (including those individuals that reported no intake). The U.S. EPA analysis was conducted using childhood 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, childhood data were placed in the standardized age categories closest to those used in the

analysis. Overall confidence in the averages is medium-high, low for some individual fruits and vegetables with small sample size, and low in the long-term upper percentiles.



Table 9-1. Recommended Values for Intake of Fruits and Vegetables, Edible Portion, Uncooked^{a, b}

Age Group	Per Capita		Consumers Only	
	Mean	95 th Percentile	Mean	95 th Percentile
	g/kg-day	g/kg-day	g/kg-day	g/kg-day
Total Fruits				
Birth to 1 year	6.2	23.0 ^c	10.1	25.8 ^c
1 to <2 years	7.8	21.3 ^c	8.1	21.4 ^c
2 to <3 years	7.8	21.3 ^c	8.1	21.4 ^c
3 to <6 years	4.6	14.9	4.7	15.1
6 to <11 years	2.3	8.7	2.5	9.2
11 to <16 years	0.9	3.5	1.1	3.8
16 to <21 years	0.9	3.5	1.1	3.8
21 to <50 years	0.9	3.7	1.1	3.8
≥50 years	1.4	4.4	1.5	4.6
Total Vegetables				
Birth to 1 year	5.0	16.2 ^c	6.8	18.1 ^c
1 to <2 years	6.7	15.6 ^c	6.7	15.6 ^c
2 to <3 years	6.7	15.6 ^c	6.7	15.6 ^c
3 to <6 years	5.4	13.4	5.4	13.4
6 to <11 years	3.7	10.4	3.7	10.4
11 to <16 years	2.3	5.5	2.3	5.5
16 to <21 years	2.3	5.5	2.3	5.5
21 to <50 years	2.5	5.9	2.5	5.9
≥50 years	2.6	6.1	2.6	6.1
Individual Fruits and Vegetables—See Tables 9-5 and 9-6 in the <i>Exposure Factors Handbook</i>				
^a Analysis was conducted using slightly different childhood age groups than those recommended in <i>Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants</i> (U.S. EPA, 2005). Data were placed in the standardized age categories closest to those used in the analysis.				
^b For multiple percentiles, see Tables 9-3 and 9-4 in the <i>Exposure Factors Handbook</i> .				
^c Estimates are less statistically reliable based on guidance published in the <i>Joint Policy on Variance Estimation and Statistical Reporting Standards on NHANES III and CSFII Reports: NHIS/NCHS Analytical Working Group Recommendations</i> (NCHS, 1993).				
Source: U.S. EPA analysis of NHANES 2003-2006 data.				

For more information about the key studies used to derive the recommended values for intake of fruits and vegetables, refer to **Chapter 9 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter09.pdf>. Detailed information on the intake studies is provided in Section 9.3. Section 9.4 presents information on the conversion between intake rates for wet weight and dry weight (i.e., the weight of the food consumed after the moisture content has been removed). For more information on consumption of individual fruits and vegetables, refer to Chapter 9 of the *Exposure Factors Handbook*.

For more information on potential contaminant loss to cooking and conversions necessary to account for such losses, refer to Chapter 13 of the *Exposure Factors Handbook*.

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. Accurately estimating exposure to toxic chemicals in fish requires information about the nature of the exposed population (i.e., general population, subsistence fishers) and their intake rates. Because 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. Chapter 10 of the *Exposure Factors Handbook* provides recommended values for fish intake for the general population and recreational marine anglers. Highlights of Chapter 10 are presented here.

10.2 Recommended Exposure Factors

General Population: Recommendations for general population intake (presented in Table 10-1) are based on the U.S. EPA analysis of NHANES 2003-2006 data. The overall confidence in the recommendations is medium-high for the mean and low for the long-term upper percentiles.

Recreational Marine Anglers: The recommended values for recreational marine anglers are presented in Table 10-2. These values are based on the surveys of the National Marine Fisheries Service (NMFS, 1993). The overall confidence in these recommendations is low-medium for adults and low for children.

Recreational Freshwater Anglers and Native American Fishers: Recommended values are not provided for recreational freshwater anglers or Native American fishers because these data are limited to certain geographic areas and cannot be readily generalized to these populations as a whole; however, data from several relevant studies are provided in the *Exposure Factors Handbook* (see Sections 10.5

and 10.6). The following general observations can be made for freshwater recreational anglers: the range of average consumption for anglers from rivers, lakes, and ponds from Alabama, Connecticut, Indiana, Maine, Michigan, Minnesota, North Dakota, and Wisconsin varies from 5 to 51 g/day (includes all survey respondents); the consumption rate of fish from rivers in Georgia and Tennessee ranges from 20 to 70 g/day; and the consumption rate of fish from three lakes in Washington averages 10 g/day for adults. A summary of intake rates for Native American anglers is provided in Table 10-6 of the *Exposure Factors Handbook*.



Table 10-1. Recommended Per Capita and Consumer-Only Values for Fish Intake (g/kg-day), Edible Portion, Uncooked^{a, b}

Age in Years	Per Capita				Consumers Only		
	N	% Consuming	Mean	95 th percentile	N	Mean	95 th percentile
Finfish							
All	16,783	23	0.16	1.1	3,204	0.73	2.2
Birth to 1 year	865	2.6	0.03	0.0 ^c	22	1.3	2.9 ^c
1 to <2 years	1,052	14	0.22	1.2 ^c	143	1.6	4.9 ^c
2 to <3 years	1,052	14	0.22	1.2 ^c	143	1.6	4.9 ^c
3 to <6 years	978	15	0.19	1.4	156	1.3	3.6 ^c
6 to <11 years	2,256	15	0.16	1.1	333	1.1	2.9 ^c
11 to <16 years	3,450	15	0.10	0.7	501	0.66	1.7
16 to <21 years	3,450	15	0.10	0.7	501	0.66	1.7
20 to <50 years	4,289	23	0.15	1.0	961	0.65	2.1
Females 13 to 49 years	4,103	22	0.14	0.9	793	0.62	1.8
50+ years	3,893	29	0.20	1.2	1,088	0.68	2.0
Shellfish							
All	16,783	11	0.06	0.4	1,563	0.57	1.9
Birth to 1 year	865	0.66	0.0	0.0 ^c	11	0.42	2.3 ^c
1 to <2 years	1,052	4.4	0.04	0.0 ^c	53	0.94	3.5 ^c
2 to <3 years	1,052	4.4	0.04	0.0 ^c	53	0.94	3.5 ^c
3 to <6 years	978	4.6	0.05	0.0	56	1.0	2.9 ^c
6 to <11 years	2,256	7.0	0.05	0.2	158	0.72	2.0 ^c
11 to <16 years	3,450	5.1	0.03	0.0	245	0.61	1.9
16 to <21 years	3,450	5.1	0.03	0.0	245	0.61	1.9
20 to <50 years	4,289	13	0.08	0.5	605	0.63	2.2
Females 13 to 49 years	4,103	11	0.06	0.3	474	0.53	1.8
50+ years	3,893	13	0.05	0.4	435	0.41	1.2
Total Finfish and Shellfish							
All	16,783	29	0.22	1.3	4,206	0.78	2.4
Birth to 1 year	865	3.1	0.04	0.0 ^c	30	1.2	2.9 ^c
1 to <2 years	1,052	17	0.26	1.6 ^c	183	1.5	5.9 ^c
2 to <3 years	1,052	17	0.26	1.6 ^c	183	1.5	5.9 ^c
3 to <6 years	978	18	0.24	1.6	196	1.3	3.6 ^c
6 to <11 years	2,256	22	0.21	1.4	461	0.99	2.7 ^c
11 to <16 years	3,450	18	0.13	1.0	685	0.69	1.8
16 to <21 years	3,450	18	0.13	1.0	685	0.69	1.8
20 to <50 years	4,289	31	0.23	1.3	1,332	0.76	2.5
Females 13 to 49 years	4,103	28	0.19	1.2	1,109	0.68	1.9
50+ years	3,893	36	0.25	1.4	1,319	0.71	2.1

^a Analysis was conducted using slightly different childhood 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.

^b For multiple percentiles, see Tables 10-7 through 10-12 in the *Exposure Factors Handbook*.

^c Estimates are less statistically reliable based on guidance published in the *Joint Policy on Variance Estimation and Statistical Reporting Standards on NHANES III and CSFII Reports: NHIS/NCHS Analytical Working Group Recommendations* (NCHS, 1993).

Source: U.S. EPA analysis of NHANES 2003-2006 data.

Table 10-2. Recommended Values for Recreational Marine Fish Intake

Age Group	Per Capita ^a	
	Mean (g/day)	95 th Percentile (g/day)
Atlantic		
3 to <6 years ^b	2.5	8.8
6 to <11 years ^b	2.5	8.6
11 to <16 years ^b	3.4	13
16 to <18 years ^b	2.8	6.6
>18 years	5.6	18
Gulf		
3 to <6 years ^b	3.2	13
6 to <11 years ^b	3.3	12
11 to <16 years ^b	4.4	18
16 to <18 years ^b	3.5	9.5
>18 years	7.2	26
Pacific		
3 to <6 years ^b	0.9	3.3
6 to <11 years ^b	0.9	3.2
11 to <16 years ^b	1.2	4.8
16 to <18 years ^b	1.0	2.5
>18 years	2.0	6.8

^a Represents per capita values for recreational fishing population only. Data from U.S. EPA analysis of NMFS (1993) assumed to represent adults >18 years. Per capita values represent both survey individuals who ate recreational fish during the survey period and those that did not, but may eat recreationally caught fish during other periods.

^b Recommendations for children were estimated based on the ratios of marine fish intake for general population children to that of adults using data from EPA's analysis of CSFII data (see Table 10-31 of the *Exposure Factors Handbook*), multiplied by the adult recreational marine fish intake rates for the Atlantic, Gulf, and Pacific regions, using data from NMFS (1993) (see Table 10-50 of the *Exposure Factors Handbook*). The ratios of each age group to adults >18 years were calculated separately for the means and 95th percentiles.

For more information about the key studies used to derive fish and shellfish intake values, refer to **Chapter 10 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter10.pdf>. Detailed information on fish intake studies among the general population is included in Section 10.3. Information on marine recreational studies is included in Section 10.4, and details of freshwater recreational studies are found in Section 10.5. Section 10.6 presents information about Native American studies of fish intake and Section 10.7 discusses other populations. Serving size studies are included in Section 10.8 and other factors to be considered for fish consumption (e.g., dry weight vs. wet weight) are discussed in Section 10.9.

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11. Intake of Meats, Dairy Products, and Fats

11.1 Introduction

Meats, dairy products, and fats may become contaminated with toxic chemicals by several pathways. These food 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 is needed. Chapter 11 of the *Exposure Factors Handbook* provides information and recommendations on ingestion rates for meats, dairy products, and fats. These data are highlighted in this document.

11.2 Recommended Exposure Factors

The recommended ingestion rates for total meat, dairy, and fats are presented in Table 11-1. The data for meats and dairy products are based on the U.S. EPA analyses of NHANES 2003-2006 data. The data for fats are based on the U.S. EPA analysis of data from the 1994-1996/1998 Continuing Survey of Food Intakes by Individuals (CSFII) (U.S. EPA, 2007). NHANES and CSFII collected 24-hour dietary intake data via interviews conducted on 2 non-consecutive days. U.S. EPA converted intake data on the foods people reported eating to the quantities of agricultural commodities eaten (e.g., beef stew may contain the commodities beef, potatoes, carrots, and other vegetables), and estimated intake rates for meats, dairy products, and fats. Both consumer-only and per capita intake recommendations are given in Table 11-1. Consumer-only intake is defined as the quantity of meats, dairy products, or fats consumed by individuals during the survey period averaged across only the individuals who consumed these food items during the survey period. Per capita intake rates are generated by averaging consumer-only intakes over the entire population. The U.S. EPA analysis of NHANES data was conducted using childhood 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, childhood data were placed in the standardized age categories closest to those used in the analysis. Overall confidence in the values for intake of meats, dairy products, and fats is medium-high for the averages and low for the long-term upper percentiles.



For more information about the key studies used to derive the recommended values for meat, dairy product, and fat intake, refer to **Chapter 11 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter11.pdf>. Detailed information on studies of meat and dairy product intake is provided in Section 11.3, and information on studies of fat intake is found in Section 11.4. For more information on the consumption of specific meats, dairy products, and fats, refer to Chapter 11 of the *Exposure Factors Handbook*. Information on the conversion between wet-weight and dry-weight intake rates is provided in Section 11.5, and information on the conversion between wet-weight and lipid-weight intake rates is provided in Section 11.6.

Table 11-1. Recommended Values for Intake of Meats, Dairy Products, and Fats, Edible Portion, Uncooked

Age Group	Per Capita		Consumers Only	
	Mean	95 th Percentile	Mean	95 th Percentile
	g/kg-day	g/kg-day	g/kg-day	g/kg-day
Total Meats^{a, b, c}				
Birth to 1 year	1.2	5.4 ^d	2.7	8.1 ^d
1 to <2 years	4.0	10.0 ^d	4.1	10.1 ^d
2 to <3 years	4.0	10.0 ^d	4.1	10.1 ^d
3 to <6 years	3.9	8.5	3.9	8.6
6 to <11 years	2.8	6.4	2.8	6.4
11 to <16 years	2.0	4.7	2.0	4.7
16 to <21 years	2.0	4.7	2.0	4.7
21 to <50 years	1.8	4.1	1.8	4.1
≥50 years	1.4	3.1	1.4	3.1
Total Dairy Products^{a, b, c}				
Birth to 1 year	10.1	43.2 ^d	11.7	44.7 ^d
1 to <2 years	43.2	94.7 ^d	43.2	94.7 ^d
2 to <3 years	43.2	94.7 ^d	43.2	94.7 ^d
3 to <6 years	24.0	51.1	24.0	51.1
6 to <11 years	12.9	31.8	12.9	31.8
11 to <16 years	5.5	16.4	5.5	16.4
16 to <21 years	5.5	16.4	5.5	16.4
21 to <50 years	3.5	10.3	3.5	10.3
≥50 years	3.3	9.6	3.3	9.6
Individual Meat and Dairy Products—See Tables 11-5 and 11-6 in the Exposure Factors Handbook				
Total Fats^{e, f}				
Birth to <1 month	5.2	16	7.8	16
1 to <3 months	4.5	12	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
21 to <31 years	1.2	2.3	1.2	2.3
31 to <41 years	1.1	2.1	1.1	2.1
41 to <51 years	1.0	1.9	1.0	1.9
51 to <61 years	0.9	1.7	0.9	1.7
61 to < 71 years	0.9	1.7	0.9	1.7
71 to <81 years	0.8	1.5	0.8	1.5
≥81 years	0.9	1.5	0.9	1.5

^a Analysis was conducted using slightly different childhood 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.

^b For multiple percentiles, see Tables 11-3 and 11-4 in the *Exposure Factors Handbook*.

^c Source: U.S. EPA analysis of NHANES 2003-2006 data.

^d Estimates are less statistically reliable based on guidance published in the *Joint Policy on Variance Estimation and Statistical Reporting Standards on NHANES III and CSFII Reports: NHIS/NCHS Analytical Working Group Recommendations* (NCHS, 1993).

^e For multiple percentiles, see Tables 11-31 and 11-33 in the *Exposure Factors Handbook*.

^f Source: U.S. EPA, 2007.

12. Intake of Grain Products

12.1 Introduction

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 is needed. Chapter 12 of the *Exposure Factors Handbook* provides information and recommendations on ingestion rates of grain products for the general population. Highlights of these data are provided here.

12.2 Recommended Exposure Factors

Table 12-1 presents a summary of the recommended values for per capita and consumer-only intake of total grain products. The U.S. EPA analysis of NHANES 2003-2006 data was used in selecting recommended intake rates. NHANES collects 24-hour dietary intake data via interviews conducted on 2 non-consecutive days. U.S. EPA converted intake data on the foods people reported eating to the quantities of agricultural commodities eaten (e.g., an apple pie may contain the commodities apples, flour, fat, sugar, and spices), and estimated intake rates for total grain products. Consumer-only intake is defined as the quantity of grain products consumed by individuals during the survey period. These data are generated by averaging intake across only the individuals in the survey who consumed these food items. Per capita intake rates are generated by averaging consumer-only intakes over the entire population (including those individuals who reported no intake). The U.S. EPA analysis was conducted using childhood 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, childhood data were placed in the standardized age categories closest to those used in the analysis. Overall confidence in the recommended values is medium-high for the averages and low for the long-term upper percentiles.



For more information about the key studies used to derive the recommended grain intake rates, refer to **Chapter 12 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter12.pdf>. Detailed information on the grain intake studies are presented in Section 12.3, and information on the conversion between dry (after the moisture content has been removed from food weight) and wet intake rate is provided in Section 12.4. For more information on consumption of specific grain products refer to Chapter 12 of the *Exposure Factors Handbook*.

Table 12-1. Recommended Values for Intake of Grains, Edible Portion, Edible Portion, Uncooked^a

Age Group	Per Capita		Consumers Only	
	Mean	95 th Percentile	Mean	95 th Percentile
	g/kg-day	g/kg-day	g/kg-day	g/kg-day
Total Grains^b				
Birth to 1 year	3.1	9.5 ^c	4.1	10.3 ^c
1 to <2 years	6.4	12.4 ^c	6.4	12.4 ^c
2 to <3 years	6.4	12.4 ^c	6.4	12.4 ^c
3 to <6 years	6.2	11.1	6.2	11.1
6 to <11 years	4.4	8.2	4.4	8.2
11 to <16 years	2.4	5.0	2.4	5.0
16 to <21 years	2.4	5.0	2.4	5.0
20 to <50 years	2.2	4.6	2.2	4.6
≥50 years	1.7	3.5	1.7	3.5
Individual Grain Products—See Tables 12-5 and 12-6 in the <i>Exposure Factors Handbook</i>				
^a Analysis was conducted using slightly different childhood age groups than those recommended in <i>Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants</i> (U.S. EPA, 2005). Data were placed in the standardized age categories closest to those used in the analysis.				
^b For multiple percentiles, see Tables 12-3 and 12-4 in the <i>Exposure Factors Handbook</i> .				
^c Estimates are less statistically reliable based on guidance published in the <i>Joint Policy on Variance Estimation and Statistical Reporting Standards on NHANES III and CSFII Reports: NHIS/NCHS Analytical Working Group Recommendations</i> (NCHS, 1993).				
Source: U.S. EPA analysis of NHANES 2003-2006 data.				

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, 1996). Assessing exposures to individuals who consume home-produced foods requires knowledge of intake rates of such foods. Chapter 13 provides recommended ingestion rates of home-produced food. The data presented may be used to assess exposure to contaminants in foods grown, raised, or caught at a specific site. These data are highlighted here.

13.2 Recommended Exposure Factors

Data from the 1987-1988 Nationwide Food Consumption Survey (NFCS) were used to generate intake rates for home-produced foods (USDA, 1987-1988). The recommended values for mean and upper percentile (i.e., 95th percentile) intake rates for the various food groups for consumers only are presented in Table 13-1. Adjustments may be made to account for preparation losses (see Section 13.3.2 of the Handbook). Table 13-1 also provides mean and 95th percentile per capita intake rates for populations that garden, farm, or raise animals based on an analysis by Phillips and Moya (2011). The per capita data have been adjusted to account for preparation losses. Overall confidence in the recommended values for intake of home-produced foods is low-medium for means and short-term distributions and low for long-term distributions.



For more information about the key studies used to derive the recommended values for intake of home-produced foods, refer to **Chapter 13 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter13.pdf>. Detailed information on the key studies for intake of home-produced food is included in Section 13.3, and detailed information on the relevant study is provided in Section 13.4. For more information on consumption of specific home-produced foods refer to Chapter 13 of the *Exposure Factors Handbook*.

Table 13-1. Summary of Recommended Values for Intake of Home-Produced Foods^a

Age Group	Consumers Only, Unadjusted ^{b,c} (g/kg-day)		Age Group	Per Capita for Populations that Garden (or Farm), Adjusted ^{d,e} (g/kg-day)	
	Mean	95 th Percentile		Mean	95 th Percentile
Home-Produced Fruits^f					
1 to 2 years	8.7	60.6	1 to <2 years	1.0 (1.4)	4.8 (9.1)
3 to 5 years	4.1	8.9	2 to <3 years	1.0 (1.4)	4.8 (9.1)
6 to 11 years	3.6	15.8	3 to <6 years	0.78 (1.0)	3.6 (6.8)
12 to 19 years	1.9	8.3	6 to <11 years	0.40 (0.52)	1.9 (3.5)
20 to 39 years	2.0	6.8	11 to <16 years	0.13 (0.17)	0.62 (1.2)
40 to 69 years	2.7	13.0	16 to <21 years	0.13 (0.17)	0.62 (1.2)
≥70 years	2.3	8.7	21 to <50 years	0.15 (0.20)	0.70 (1.3)
			50+ years	0.24 (0.31)	1.1 (2.1)
Home-Produced Vegetables^g					
1 to 2 years	5.2	19.6	1 to <2 years	1.3 (2.7)	7.1 (14)
3 to 5 years	2.5	7.7	2 to <3 years	1.3 (2.7)	7.1 (14)
6 to 11 years	2.0	6.2	3 to <6 years	1.1 (2.3)	6.1 (12)
12 to 19 years	1.5	6.0	6 to <11 years	0.80 (1.6)	4.2 (8.1)
20 to 39 years	1.5	4.9	11 to <16 years	0.56 (1.1)	3.0 (5.7)
40 to 69 years	2.1	6.9	16 to <21 years	0.56 (1.1)	3.0 (5.7)
≥70 years	2.5	8.2	21 to <50 years	0.56 (1.1)	3.0 (5.7)
			50+ years	0.60 (1.2)	3.2 (6.1)
Age Group	Consumers Only, Unadjusted ^{b,c} (g/kg-day)		Age Group	Per Capita for Populations that Farm (or Raise Animals) ^{d,e} (g/kg-day)	
	Mean	95 th Percentile		Mean	95 th Percentile
Home-Produced Meats^h					
1 to 2 years	3.7	10.0	1 to <2 years	1.4 (1.4)	5.8 (6.0)
3 to 5 years	3.6	9.1	2 to <3 years	1.4 (1.4)	5.8 (6.0)
6 to 11 years	3.7	14.0	3 to <6 years	1.4 (1.4)	5.8 (6.0)
12 to 19 years	1.7	4.3	6 to <11 years	1.0 (1.0)	4.1 (4.2)
20 to 39 years	1.8	6.2	11 to <16 years	0.71 (0.73)	3.0 (3.1)
40 to 69 years	1.7	5.2	16 to <21 years	0.71 (0.73)	3.0 (3.1)
≥70 years	1.4	3.5	21 to <50 years	0.65 (0.66)	2.7 (2.8)
			50+ years	0.51 (0.52)	2.1 (2.2)
Home-Produced Dairy					
1 to 2 years	- ⁱ	-	1 to <2 years	11 (13)	76 (92)
3 to 5 years	-	-	2 to <3 years	11 (13)	76 (92)
6 to 11 years	-	-	3 to <6 years	6.7 (8.3)	48 (58)
12 to 19 years	-	-	6 to <11 years	3.9 (4.8)	28 (34)
20 to 39 years	-	-	11 to <16 years	1.6 (2.0)	12 (14)
40 to 69 years	-	-	16 to <21 years	1.6 (2.0)	12 (14)
≥70 years	-	-	21 to <50 years	0.95 (1.2)	6.9 (8.3)
			50+ years	0.92 (1.1)	6.7 (8.0)

Table 13-1. Summary of Recommended Values for Intake of Home-Produced Foods^a (continued)

Age Group	Consumers Only, Unadjusted ^{b,c} (g/kg-day)		Age Group	Per Capita for Populations that Farm (or Raise Animals) ^{d,e} (g/kg-day)	
	Mean	95 th Percentile		Mean	95 th Percentile
Home-Caught Fish^f					
1 to 2 years	-	-	-	-	-
3 to 5 years	-	-	-	-	-
6 to 11 years	2.8	7.1	-	-	-
12 to 19 years	1.5	4.7	-	-	-
20 to 39 years	1.9	4.5	-	-	-
40 to 69 years	1.8	4.4	-	-	-
≥70 years	1.2	3.7	-	-	-

^a Analysis was conducted prior to the Agency's issuance of *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA, 2005).

^b Not adjusted to account for preparation or post-cooking losses.

^c Source: U.S. EPA Analysis of 1987–1988 NFCS.

^d Adjusted for preparation and post-cooking losses.

^e Source: Phillips and Moya, 2011.

^f For consumers only, multiple percentiles are available in Table 13-5 in the *Exposure Factors Handbook*.

^g For consumers only, multiple percentiles are available in Table 13-10 in the *Exposure Factors Handbook*.

^h For consumers only, multiple percentiles are available in Table 13-15 in the *Exposure Factors Handbook*.

ⁱ Data not presented for age groups/food groups where less than 20 observations were available or data not available for that age or food group.

^j For consumers only, multiple percentiles are available in Table 13-20 in the *Exposure Factors Handbook*.

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14. Total Food Intake

14.1 Introduction

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. To assess chemical exposure through this pathway, information on dietary composition is sometimes needed. Chapter 14 of the *Exposure Factors Handbook* provides data on total food intake and diet composition. Recommended values for total food intake are highlighted here, and information on the proportion of the total diet made up by the major food groups is provided in Section 14.3.1 of the Handbook.

14.2 Recommended Exposure Factors

The recommended values for total food intake are based on the U.S. EPA analysis of NHANES 2003-2006 data. Total food intake was defined as intake of the sum of all foods, beverages, and water ingested. A summary of recommended values for total food intake is presented in Table 14-1. Total intake recommendations are provided as per capita rates, which are generated by averaging consumer-only intakes over the entire population. Overall confidence in the recommendations for total food intake is medium.

In an earlier analysis, 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) 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 10th percentile or above the 90th percentile for fish consumption). This analysis was based on data from USDA's CSFII 1994-1996, 1998 (USDA, 2000). Data on these specific contributions to total intake are provided in Tables 14-4 through 14-11 in the *Exposure Factors Handbook*.



For more information about the key study used to derive the total food intake values, refer to **Chapter 14 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter14.pdf>. Detailed information on the key study for total intake as well as a key study on the composition of the diet are provided in Section 14.3 of the *Exposure Factors Handbook*.

Table 14-1. Recommended Values for Per Capita Total Food Intake

Age Group	Mean	95 th Percentile ^a
	g/kg-day	
Children		
Birth to <1 year	91	208 ^b
1 to <3 years	113	185 ^b
3 to <6 years	79	137
6 to <11 years ^c	47	92
11 to <16 years ^d	28	56
16 to <21 years ^d	28	56
Adults		
20 to <50 years	29	63
50 years and older	29	59

Note: Total food intake was defined as intake of the sum of all foods, beverages, and water ingested.

^a For multiple percentiles, see Table 14-12 of the *Exposure Factors Handbook*.

^b Estimates are less statistically reliable based on guidance published in the *Joint Policy on Variance Estimation and Statistical Reporting Standards on NHANES III and CSFII Reports: NHIS/NCHS Analytical Working Group Recommendations* (NCHS, 1993).

^c Based on data for ages 6 to <13 years.

^d Based on data for ages 13 to <20 years.

Source: U.S. EPA analysis of NHANES 2003-2006 data.

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 United States (Chen and Rogan, 2004). The American Academy of Pediatrics recommends exclusive breast-feeding for approximately the first six months and supports the continuation of breast-feeding 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. 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. Chapter 15 of the *Exposure Factors Handbook* provides recommendations for human milk intake rates and lipid intake rates. These data are highlighted here.

15.2 Recommended Exposure Factors

A summary of recommended values for human milk and lipid intake rates is presented in Table 15-1. These values are based on data from Pao et al. (1980), Dewey and Lönnerdal (1983), Butte et al. (1984), Neville et al. (1988), Dewey et al. (1991a, b), Butte et al. (2000), and Arcus-Arth et al. (2005). These studies presented data by month, and these month-by-month intakes were composited to yield intake rates for the standardized age groups by calculating weighted averages. Recommendations were converted to mL/day using a density of human milk of 1.03 g/mL rounded to two significant figures. The overall confidence in the recommended values for human milk and lipid intake rates is medium.



For more information about the key studies used to derive the recommended human milk intake values, refer to **Chapter 15 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter15.pdf>. Detailed information on human milk intake studies is included in Section 15.3. Key studies on lipid content and lipid intake from milk are discussed in Section 15.4, and a relevant study on lipid intake is included in Section 15.5. Section 15.6 discusses other factors that influence the initiation, continuation, and amount of human milk intake.

Table 15-1. Recommended Values for Human Milk and Lipid Intake Rates for Exclusively Breast-Fed Infants

Age Group	Mean		Upper Percentile ^a	
	mL/day	mL/kg-day	mL/day	mL/kg-day
Human Milk Intake				
Birth to <1 month ^{b, c}	510	150	950	220
1 to <3 months ^{b, c, d, e, f}	690	140	980	190
3 to <6 months ^{b, c, d, e, f, g, h}	770	110	1,000	150
6 to <12 months ^{b, c, d, f, g, h}	620	83	1,000	130
Lipid Intakeⁱ				
Birth to <1 month ^{b, c}	20	6.0	38	8.7
1 to <3 months ^{b, c, d, e, f}	27	5.5	40	8.0
3 to <6 months ^{b, c, d, e, f, g, h}	30	4.2	42	6.1
6 to <12 months ^{b, c, d, f, g, h}	25	3.3	42	5.2

^a Upper percentile is reported as mean plus two standard deviations.

^b Neville et al., 1988.

^c Arcus- Arth et al., 2005.

^d Pao et al., 1980.

^e Butte et al., 1984.

^f Dewey and Lönnerdal, 1983.

^g Butte et al., 2000.

^h Dewey et al., 1991b.

ⁱ The recommended value for the lipid content of human milk is 4.0 percent. See Section 15.4 of the *Exposure Factors Handbook*.

16. Activity Factors

16.1 Introduction

Individual or group activities are important determinants of potential exposure because toxic chemicals introduced into the environment may not cause harm to an individual until an activity is performed that subjects the individual to contact with those contaminants. The types of activities and time spent on these activities varies among individuals on the basis of, for example, culture, ethnicity, hobbies, location, sex, age, socioeconomic characteristics, and personal preferences. Chapter 16 of the *Exposure Factors Handbook* summarizes data on how much time individuals spend participating in various activities in various microenvironments and on the frequency of performing various activities. Information is also provided on occupational mobility and population mobility. Highlights of this information are provided here.

16.2 Recommended Exposure Factors

Activity Factors: The recommended values for activity 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). The recommendations for total time spent indoors and the total time spent outdoors are based on the 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 childhood age groups >1 year of age. For adults 18 years and older, the recommended values are taken directly from the source document (U.S. EPA, 1996). The overall confidence in the recommendations for activity factors is medium for the mean and low for the upper percentile.

Occupational Mobility: Table 16.2 presents the recommended values for occupational mobility for males and females. These values are derived from Carey (1988, 1990). The overall confidence in the recommendations for occupational mobility is medium.

Population Mobility: There are two key studies from which the population mobility recommendations were derived: the U.S. Bureau of the Census American Housing Survey (U.S. Bureau of the Census, 2008) and Johnson and Capel (1992). Table 16-3 presents the recommendations for population mobility. The overall confidence in these recommendations is medium.



Table 16-1. Recommended Values for Activity Patterns

Age Group	Mean	95 th Percentile	Source
Time Indoors (total) minutes/day			
Birth to <1 month	1,440	-	a
1 to <3 months	1,432	-	
3 to <6 months	1,414	-	
6 to <12 months	1,301	-	
1 to <2 years	1,353	-	b
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 year	1,248	-	c, d
18 to <65 years	1,159	-	
≥65 years	1,142	-	
Time Outdoors (total) minutes/day			
Birth to <1 month	0	-	a
1 to <3 months	8	-	
3 to <6 months	26	-	
6 to <12 months	139	-	
1 to <2 years	36	-	b
2 to <3 years	76	-	
3 to <6 years	107	-	
6 to <11 years	132	-	
11 to <16 years	100	-	
16 to <21 year	102	-	c, e
18 to <65 years	281	-	
≥65 years	298	-	
Time Indoors (at residence) minutes/day			
Birth to <1 year	1,108	1,440	b
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	
18 to <65 years	948	1,428	c
≥65 years	1,175	1,440	
Showering minutes/day			
Birth to <1 year	15	-	b
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 Patterns (continued)

Age Group	Mean	95 th Percentile	Source
Bathing minutes/day			
Birth to <1 year	19	30	b
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	
Bathing/Showering minutes/day			
18 to <65 years	17	-	c
≥65 years	17	-	
Swimming minutes/month			
Birth to <1 year	96	-	b
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	
18 to <65 years	45 ^f	181	c
≥65 years	40 ^f	181	
Playing on Sand/Gravel minutes/day			
Birth to <1 year	18	-	b
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	-	
18 to <65 years	0 ^f	121	c
≥65 years	0 ^f	-	
Playing on Grass minutes/day			
Birth to <1 year	52	-	b
1 to <2 years	68	121	
2 to <3 years	62	121	
3 to <6 years	79	121	
6 to <11 years	73	121	c
11 to <16 years	75	121	
16 to <21 years	60	-	
18 to <65 years	60 ^f	121	
≥65 years	121 ^f	-	

Table 16-1. Recommended Values for Activity Patterns (continued)

Age Group	Mean	95 th Percentile	Source
Playing on Dirt minutes/day			
Birth to <1 year	33	-	b
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	-	c
18 to <65 years	0 ^f	120	
≥65 years	0 ^f	-	

^a U.S. EPA analysis of source data from Wiley et al. (1991). Average for boys and girls, whole population.

^b U.S. EPA re-analysis of source data from U.S. EPA (1996).

^c U.S. EPA, 1996.

^d Total minutes per 24 hours (1,440) minus time outdoors, doers only.

^e Sum of minutes spent outdoors away from the residence and minutes spent outdoors at the residence. Doers only.

^f Median value, mean not available in U.S. EPA (1996).

- Percentiles were not calculated for sample sizes less than 10 or in cases where the mean was calculated by summing the means from multiple locations or activities.

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. Recommended Values for Occupational Mobility

Age Group	Median Tenure (years)	
	Men ^a	Women ^a
All ages, ≥16 years	7.9	5.4
16-24 years	2.0	1.9
25-29 years	4.6	4.1
30-34 years	7.6	6.0
35-39 years	10.4	7.0
40-44 years	13.8	8.0
45-49 years	17.5	10.0
50-54 years	20.0	10.8
55-59 years	21.9	12.4
60-64 years	23.9	14.5
65-69 years	26.9	15.6
≥70 years	30.5	18.8

Table 16-2. Recommended Values for Occupational Mobility (continued)

Age Group	Occupational Mobility Rate ^{b, c} (percent)
16-24 years	12.7
25-34 years	6.6
35-44 years	4.0
45-54 years	1.9
55-64 years	1.0
≥64 years	0.3
Total, ≥16 years	5.3

^a Source: Carey (1988).

^b Source: Carey (1990).

^c Occupational mobility rate = percentage of persons employed in an occupation who had voluntarily entered it from another occupation.

Table 16-3. Recommended Values for Population Mobility

	Mean	95 th Percentile
Residential Occupancy Period ^a	12 yrs	33 yrs
Current Residence Time ^b	13 yrs	46 yrs

^a Source: Johnson and Capel (1992).

^b Source: U.S. Bureau of the Census (2008).



For more information about the key studies used to derive the recommended activity factors, refer to **Chapter 16 of the Exposure Factors Handbook** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter16.pdf>. Detailed information on relevant studies of activity patterns is provided in Section 16.3. Studies on occupational mobility are discussed in Section 16.4, and studies on population mobility are discussed in Section 16.5.

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17. Consumer Products

17.1 Introduction

Consumer products may include cleaners, solvents, paints, pesticides, personal care products, or other types of products used in and around the home. These products may contain toxic or potentially toxic chemical constituents to which people may be exposed as a result of their use. Potential routes of exposure to consumer products or chemicals released from consumer products during use include ingestion, inhalation, and dermal contact. Non-users, including children, can be passively exposed to chemicals in these products. Because people 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).

Limited information is available on how the various 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). **Chapter 17 of the *Exposure Factors Handbook*** summarizes available information regarding the amount used, frequency of use, and duration of use for various consumer products typically found in consumer households. 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 the *Exposure Factors Handbook*. However, Table 17-1 summarizes information about the various consumer product studies described in Chapter 17 of the *Exposure Factors Handbook*. Users are encouraged to refer to the Handbook for more detailed information about these studies.



Table 17-1. Consumer Product Use Studies Included in the *Exposure Factors Handbook*

Source	Study	Description	<i>Exposure Factors Handbook</i> Section
CTFA, 1993	Summary of the Results of Surveys of the Amount and Frequency of Use of Cosmetic Products by Women	The Cosmetic, Toiletry and Fragrance Association (CTFA) conducted three surveys on frequency of use of various cosmetic products.	17.3.1
Westat, 1987a	Household Solvent Products: A National Usage Survey	A nationwide survey was conducted to determine consumer exposure to common household products believed to contain methylene chloride or its substitutes.	17.3.2
Westat, 1987b	National Usage Survey of Household Cleaning Products	A nationwide telephone survey was conducted to gather information on cleaning activities performed in the interior of homes during the previous year; some participants were re-interviewed or asked to keep diaries of activities.	17.3.3
Westat, 1987c	National Household Survey of Interior Painters	A survey of household members who had painted the interior of the home during the last 12 months prior to the survey date; participants were asked questions relating to frequency and time spent for interior painting activities, the amount of paint used, and protective measures used, (i.e., wearing gloves, hats, and masks or keeping a window open).	17.3.4
Abt, 1992	Methylene Chloride Consumer Products Use Survey Findings	A telephone survey of nearly 5,000 households was conducted to gather data on use of paint strippers, non-automotive spray paint, and adhesive removers in order to estimate the percent of the population using these products.	17.3.5
U.S. EPA, 1996	National Human Activity Pattern Survey (NHAPS)	Data were collected on the duration and frequency of selected activities and the time spent in selected microenvironments via 24-hour diaries; data were also collected on duration and frequency of use of selected consumer products such as microwave ovens and paints.	17.3.6
Bass et al., 2001	What's Being Used at Home: A Household Pesticide Survey	A survey (one-to-one interview) was conducted to assess the use of pesticide products in homes with children; the study obtained information on what pesticides were used, where they were used, and how frequently they were used.	17.3.7
Weegels and van Veen, 2001	Variation of Consumer Contact with Household Products: A Preliminary Investigation	A survey was conducted to determine consumer exposure to common household products that are used once a day or every other day (i.e., dishwashing detergent, all-purpose cleaners, and hair styling products).	17.3.8
Loretz et al., 2005	Exposure Data for Cosmetic Products: Lipstick, Body Lotion, and Face Cream	A nationwide survey was conducted to estimate the usage (i.e., frequency of application and amount used per application) of lipstick, body lotion, and face cream in women.	17.3.9
Loretz et al., 2006	Exposure Data for Personal Care Products: Hairspray, Spray Perfume, Liquid Foundation, Shampoo, Body Wash, and Solid Antiperspirant	A nationwide survey was conducted to determine the usage (i.e., frequency of use and amount used) of hair-spray, spray perfume, liquid foundation, shampoo, body wash, and solid antiperspirant in women.	17.3.10
Hall et al., 2007	European Consumer Exposure to Cosmetic Products, a Framework for Conducting Population Exposure Assessments	A probabilistic European population model of exposure for six cosmetic products (i.e., body lotion, deodorant/antiperspirant, lipstick, facial moisturizer, shampoo, and toothpaste) was developed using market information and a controlled products use study.	17.3.11
Loretz et al., 2008	Exposure Data for Cosmetic Products: Facial Cleanser, Hair Conditioner, and Eye Shadow	Data from a study conducted in 2005 were used to estimate frequency of use and usage amount for facial cleanser, hair conditioner, and eye shadow.	17.3.12
Sathyanarayana et al., 2008	Baby Care Products: Possible Sources of Infant Phthalate Exposure	This study estimated dermal exposure to phthalates in infants via the dermal application of personal care products; products studied were baby lotion, baby powder, baby shampoo, diaper cream, and baby wipes.	17.3.13

18. Lifetime

18.1 Introduction

The length of an individual's life is an important factor to consider when evaluating cancer risk because the dose estimate is averaged over an individual's lifetime. Because the averaging time is found in the denominator of the dose equation, a shorter lifetime would result in a higher potential risk estimate, and conversely, a longer life expectancy would produce a lower potential risk estimate. Chapter 18 of the *Exposure Factors Handbook* provides information and recommendations for life expectancy. These data are highlighted here.

18.2 Recommended Exposure Factors

The life expectancy values presented in Table 18-1 are based on data from Xu et al. (2010). These data are based on information compiled from death certificates. Using data for 2007, life expectancy for an average person in the United States is 78 years. If sex is a factor considered in the assessment, note that the average life expectancy value for females is higher than for males. It is recommended that the assessor use the appropriate value of 75 years for males or 80 years for females. If race is a consideration in assessing exposure for individuals, note that the life expectancy is longer for Whites than for Blacks. Therefore, assessors are encouraged to use values that most reflect the exposed population. Tables 18-4 and 18-5 in the *Exposure Factors Handbook* provide life expectancy data for Whites and Blacks separately.

The recommended value of 78 for the total population is different than the 70 years commonly assumed for the general population in U.S. EPA risk assessments. The Integrated Risk Information System (IRIS) does not use a 70-year lifetime assumption in the derivation of RfCs and RfDs, cancer slope factors, or unit risks. Therefore, using a value different than 70 years will not result in an inconsistency with the toxicity data. Overall confidence in the life expectancy recommendations is high.



Table 18-1. Recommended Values for Expectation of Life at Birth: 2005

Population	Life Expectancy (years)
Total	78
Males	75
Females	80

Source: Xu et al., 2010.

For more information about the key study used to derive the recommended lifetime values, refer to **Chapter 18 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter18.pdf>. Detailed information on the key study on lifetime is included in Section 18.3.

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19. Building Characteristics

19.1 Introduction

Unlike previous chapters in the *Exposure Factors Handbook* that focus on human behavior or characteristics that affect exposure, Chapter 19 focuses on building characteristics. Assessment of exposure in indoor settings requires information on the availability of the chemical(s) of concern at the point of exposure, characteristics of the structure and micro-environment that affect exposure, and human presence within the building. **Chapter 19 of the *Exposure Factors Handbook*** provides recommended values on residential and non-residential building characteristics that affect exposure in an indoor environment. Information from Chapter 19 is highlighted here.

19.2 Recommended Exposure Factors

Table 19-1 presents the recommendations for residential building volumes and air exchange rates. The U.S. EPA 2010 analysis of the 2005 Residential Energy Consumption Survey (RECS) is the basis of the recommended housing volumes (U.S. DOE, 2008a). The residential air exchange rate is based on the perfluorocarbon tracer (PFT) database (Koontz and Rector, 1995). Table 19-2 presents the recommendations for non-residential buildings. These data come from the Commercial Building Energy Consumption Survey (CBECS) (U.S. DOE, 2008b). The recommended

air exchange rates for non-residential buildings come from Turk et al. (1987). The overall confidence ratings are medium for residential and non-residential building volumes. The data for air exchange rates are limited. Therefore, the recommendations for this factor have been assigned low confidence ratings and these values should be used with caution. Information on several other factors for which specific recommendations are not provided, are also presented in Chapter 19 of the Handbook.



Table 19-1. Recommendations—Residential Parameters

Volume of Residence	492 m ³ (central estimate) ^a	154 m ³ (lower percentile) ^b
Air Exchange Rate	0.45 ACH ^c (central estimate) ^d	0.18 ACH (lower percentile) ^e

^a Average value presented in Table 19-6 in the *Exposure Factors Handbook* recommended for use as a central estimate for all single family homes, including mobile homes and multi-family units.

^b 10th percentile values recommended to be used as a lower percentile estimate.

^c ACH = air changes per hour.

^d Median value recommended to be used as a central estimate (Table 19-24 in the *Exposure Factors Handbook*).

^e 10th percentile value recommended to be used as a lower percentile value (Table 19-24 in the *Exposure Factors Handbook*).

Source: U.S. EPA analysis of U.S. DOE, 2008a; Koontz and Rector, 1995.

Table 19-2. Summary of Recommended Values for Non-Residential Building Parameters

Volume of Building (m ³) ^{a,b}	Mean ^c	10 th Percentile ^d
Vacant	4,789	408
Office	5,036	510
Laboratory	24,681	2,039
Non-refrigerated warehouse	9,298	1,019
Food sales	1,889	476
Public order and safety	5,253	816
Outpatient healthcare	3,537	680
Refrigerated warehouse	19,716	1,133
Religious worship	3,443	612
Public assembly	4,839	595
Education	8,694	527
Food service	1,889	442
Inpatient healthcare	82,034	17,330
Nursing	15,522	1,546
Lodging	11,559	527
Strip shopping mall	7,891	1,359
Enclosed mall	287,978	35,679
Retail other than mall	3,310	510
Service	2,213	459
Other	5,236	425
All buildings ^e	5,575	527
Air Exchange Rate ^{f,g}	Mean (SD)1.5 (0.87) ACH Range 0.3-4.1 ACH	0.60 ACH

^a U.S. EPA analysis of U.S. DOE, 2008b.

^b Volumes were calculated assuming a ceiling height of 20 feet for warehouses and enclosed malls and 12 feet for other structures (see Table 19-20 of *Exposure Factors Handbook*).

^c Mean values are recommended as central estimates for non-residential buildings (see Table 19-20 of *Exposure Factors Handbook*).

^d 10th percentile values are recommended as lower estimates for non-residential buildings (see Table 19-20 of *Exposure Factors Handbook*).

^e Weighted average assuming a ceiling height of 20 feet for warehouses and enclosed malls and 12 feet for other structures (see Table 19-20 of *Exposure Factors Handbook*).

^f Air exchange rates for commercial buildings (see Table 19-27 of *Exposure Factors Handbook*).

^g Turk et al., 1987.

SD = Standard deviation.

ACH = Air changes per hour.

Source: U.S. EPA analysis of U.S. DOE, 2008a; Koontz and Rector, 1995.



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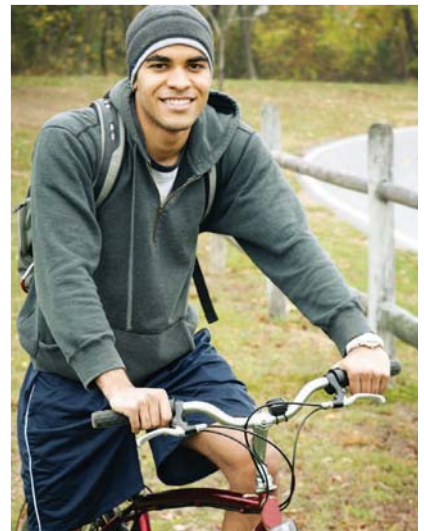
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