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EXPOSURE FACTORS HANDBOOK

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Office of Health and Environmental Assessment
U.S. Environmental Protection Agency
Washington, DC 20460

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CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

TABLES

Page No.

PART I

TABLES (continued)

TABLES (continued)

FOREWORD

The Exposure Assessment Group (EAG) of EPA's Office of Research and Development has three main functions: (1) to conduct exposure assessments, (2) to review assessments and related documents, and (3) to develop guidelines for exposure assessments. The activities under each of these functions are supported by and respond to the needs of the various program offices. In relation to the third function, EAG sponsors projects aimed at developing or refining techniques used in exposure assessments.

The purpose of this document is to provide statistical data on the various factors used in assessing exposure. Additionally, a number of specific exposure scenarios are identified and recommendations are provided for default parameter values to be used when appropriate site-specific data are not available. The recommended values are based solely on our interpretations of the available data. In many situations different values may be appropriate to use in consideration of policy, precedent or other factors. The document is published in the three-ring binder format so that it can be easily updated as new information on these factors becomes available.

Michael A. Callahan
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PREFACE

The Exposure Assessment Group (EAG) of the Office of Health and Environmental Assessment (OHEA) has prepared this handbook to address factors commonly used in exposure assessments. It was prepared in response to requests from many EPA program and regional offices for additional guidance on how to select values for exposure factors.

The purpose of this handbook is to provide a summary of the available data on various factors used in assessing exposure. Additionally, a number of specific exposure scenarios are identified with recommendations for default values to use when site-specific data are not available. The handbook will provide a common data base which all Agency programs can use to derive values for exposure assessment factors. Thus, it should help improve the consistency with which exposure assessments are conducted across the Agency, but still allow different approaches as may be appropriate in consideration of policy, precedent, or other factors. The document is published in a 3-ring binder format to allow convenient updates which we plan to make as new data become available.

ABSTRACT

This document provides a summary of the available data on various factors used in assessing human exposure including drinking water consumption, consumption rates of broad classes of food including fruits, vegetables, beef, dairy products, and fish; soil ingestion; inhalation rate; skin area; lifetime; activity patterns; and body weight. Additionally, a number of specific exposure scenarios are identified with recommendations for default values to use when site-specific data are not available. The basic equations using these parameters to calculate exposure levels are also presented for each scenario. Default values are presented as ranges from typical to reasonable worst case and as frequency distributions where appropriate data were available. Finally, procedures for assessing the uncertainties in exposure assessments are also presented with illustrative examples. These procedures include qualitative and quantitative methods such as Monte Carlo and sensitivity analysis.

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The Exposure Assessment Group (EAG) within EPA's Office of Health and Environmental Assessment was responsible for the preparation of this handbook. The document was prepared by Versar Inc. under EPA Contract No. 68-02-4254, Work Assignment No. 189. John Schaum, of EAG, served as the EPA task manager, providing overall direction and coordination of the production effort as well as technical assistance and guidance.

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1. INTRODUCTION

1.1 Background

The Exposure Factors Handbook is intended to serve as a support document to EPA's Guidelines for Estimating Exposures (USEPA 1986), and Proposed Guidelines for Exposure-Related Measurements (USEPA 1988) by providing data on standard factors that may be needed to calculate human exposure to toxic chemicals. The Guidelines were developed to promote consistency among the various exposure assessment activities that are carried out by the various EPA program offices. This handbook should assist in this goal by providing a consistent framework to calculate exposure.

The handbook is organized by grouping the factors into those needed for each specific route of exposure (i.e., ingestion, inhalation, or dermal) or those needed for more than one route. Standard exposure scenarios using these factors are included to facilitate the use of the data. Finally, procedures for analyzing uncertainty in exposure assessments are presented.

The Exposure Factors Handbook is an extension of earlier efforts towards standardizing the Agency's exposure assessment calculations sponsored by the Exposure Assessment Group, Office of Health and Environmental Assessment, Office of Research and Development. USEPA (1985) covered body weight, body surface area, and respiration rate in their report "Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments." The results of this study are incorporated into this handbook.

1.2 General Equation for Calculating Exposure

The Guidelines define exposure as the contact with a chemical or physical agent. The magnitude of the exposure is the amount of the agent available at human exchange boundaries (skin, lungs, gut) during some specified time. Starting with a general integral equation for exposure (USEPA 1988), several exposure equations can be derived depending upon boundary assumptions. One of the more useful of these derived equations used for dealing with lifetime exposures to agents with linear non-threshold responses (i.e., our current assumptions about many carcinogens) is the Lifetime Average Daily Exposure (LADE) discussed below. Exposure assessments are usually done to support risk assessments; only exposure calculations used to support cancer risk assessments and repeated and prolonged (chronic) exposures to noncarcinogens will be covered in this handbook. (See the Proposed Guidelines for Exposure-Related Measurements (USEPA 1988) for an expanded discussion of some of the other equations that can be used.)

For cancer risk assessments, exposure is averaged over the body weight and lifetime:

$$\text{LADE} = \frac{\text{Total Exposure}}{\text{Body Weight} \times \text{Lifetime}}$$

The total exposure can be expanded as follows:

$$\text{Total Exposure} = \begin{matrix}\text{Contaminant}\\ \text{Concentration}\end{matrix} \times \begin{matrix}\text{Contact}\\ \text{Rate}\end{matrix} \times \begin{matrix}\text{Exposure}\\ \text{Duration}\end{matrix}$$

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

The contact rate refers to the rates of inhalation, ingestion, and dermal contact depending on the route of exposure. For ingestion, the contact rate is simply the amount of food containing the contaminant of interest that an individual ingests during some specific time period (units of mass/time). Much of this handbook is devoted to standard rates of ingestion for some broad classes of food.

The exposure duration is the length of time that contaminant contact lasts. The time a person lives in an area, frequency of bathing, time spent indoors vs. outdoors, etc. all affect the exposure duration.

The Activity Patterns Section (Section 5.3) gives some examples of population behavior patterns, which may be useful for exposure calculations.

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

Exposure (sometimes called "administered dose") can be expressed as a total amount (with units of mass, e.g., mg) or as an exposure rate in terms of mass/time (e.g., mg/day), or as a rate normalized to body mass (e.g., with units of mg of chemical per kg of body weight per day (mg/kg-day). The LADE is usually expressed in terms of mg/kg-day or other mass/mass-time units.

In using the LADE, the upper-bound cancer risk is estimated by adjusting the exposure to account for absorption into the body and multiplying by the 95 percent upper confidence limit of the linear slope factor of the dose-response function. Since the slope factor is derived on the basis of administered dose, the exposure should be expressed on a comparable basis. If the absorption from the medium used in the animal studies is the same as that occurring in the human exposure scenario, no adjustment is needed.

The lifetime value used in the above equation is the period of time over which the administered dose is averaged. For carcinogens, this should represent the average life expectancy of the exposed population. According to the 1985 edition of the U.S. Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years is suggested for the lifetime of men and women. For exposure estimates to be used for assessments other than carcinogenic risk, different averaging periods are frequently used. For acute exposures, the administered doses are usually averaged over a day or single event. For chronic noncancer effects, the time period used is the actual period of exposure. The objective in selecting the averaging time is to express the exposure in a way which makes it comparable to the dose-response relationship used in conjunction with the exposure estimate to calculate risk.

The body weight used to calculate the total exposure in the above equation should reflect the average weight of the exposed population during the time when the exposure actually occurs. If the exposure occurs continuously throughout an individual's life or only during the adult ages, using an adult average weight of 70 kg should provide sufficient accuracy. However, when the exposure is limited to childhood, the weight representing those ages should be used. Body weight is covered in more detail in the section on other factors needed for exposure calculations.

1.3 Organization

All factors are organized in a loose-leaf, tabbed format for easy reference. Factors are grouped according to exposure route in Part I: ingestion, inhalation and dermal contact. Standard exposure scenarios using these factors are presented in Part II. This Part provides default values and ranges to use for specific exposure scenarios. This Part will be useful for screening assessments and for quick-response estimations. Additional scenarios will be added as data become available.

1.4 References

USEPA. 1985. U.S. Environmental Protection Agency. Development of statistical distributions or ranges of standard factors used in exposure assessments. Washington, DC: Office of Health and Environmental Assessment. EPA No. 600/8-85-010. Available from: NTIS, Springfield, VA. PB85-242667.

USEPA. 1986. U.S. Environmental Protection Agency. Guidelines for estimating exposures. Federal Register 51:34042-34054.

USEPA. 1988. U.S. Environmental Protection Agency. Proposed guidelines for exposure-related measurements. Federal Register 53:48830-48853.

2. INGESTION ROUTE

This chapter discusses consumption rates of broad classes of food including water, fruits and vegetables, beef, dairy products, and fish. Consumption of the specific food groups has been the subject of a number of studies, and the assessor should refer to other references to obtain consumption rates. For example, Pennington (1983) developed representative diets using about 200 foods for eight age-sex groups. Also, Saunders and Petersen (1987) describe the Tolerance Assessment System, which can be used to estimate dietary exposure to a pesticide.

2.1 Exposure Equation for Ingestion

The contact rate for the ingestion route is the consumption rate. The general LADE equation for ingestion exposure is:

$$\text{Lifetime Average Ingestion Exposure} = \frac{\text{Consumption Rate} \times \text{Contaminant Concentration in Food} \times \text{Exposure Duration}}{\text{Body Weight} \times \text{Lifetime}}$$

Consumption rate is determined from site-specific data or (less desirably) can be estimated from generic rates derived from relevant regional studies or national consumption surveys. The contaminant concentration refers to the concentration in food or whatever is being ingested. Exposure duration refers to the time an individual is exposed at a particular site of concern.

2.2 Drinking Water Consumption

The USEPA presently uses the quantity of 2 L per day for adults and 1 L per day for infants (individuals of 10 kg body mass or less) as the average amount of water consumed per person (USEPA 1980). This amount includes drinking water consumed in the form of juices and other beverages containing tap water (e.g., coffee). The volume of 2 L per day is a historical figure set by the U.S. Army in determining the amount of water needed for each person in the field.* Based on discussions with USEPA officials, Patrizi* stated that the Agency believes that a water consumption rate of 2 L per day is an overestimate for most people and is used to represent a long-term average consumption rate.

The National Academy of Sciences (NAS 1977) estimated that daily consumption of water may vary with levels of physical activity and fluctuations in temperature and humidity. It is reasonable to assume that some individuals in physically oriented occupations or living in warmer regions may exceed this level of water intake on an average basis. NAS (1977) estimated that most of those who consume more than 2 L of water per day are still adequately protected, since the margin of safety estimated for contaminants in drinking water is sufficient to offset the excess consumption.

NAS (1977) calculated the average per capita water (liquid) consumption per day to be 1.63 L. This figure was based on a survey of the following literature sources: Evans (1941), Bourne and Kidder (1953), Walker et al. (1957), Wolf (1958), Guyton (1968), McNall and Schlegal (1968), Randall (1973), NAS (1974), and Pike and Brown (1975). Although the calculated intake and volume of 1.63 L per day may have more of a scientific basis than the presently accepted figure of 2 L per day, NAS (1977) adopted the larger volume (i.e., 2 L per day) to represent the intake of the majority of water consumers.

Several other drinking water intake rates have been suggested. The National Cancer Institute (NCI), in a population-based, case control study investigating the possible relationship between bladder cancer and drinking water, interviewed approximately 9,000 individuals using a standardized questionnaire (Cantor et al. 1987). Based on responses from

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* K. Patrizi, Safe Drinking Water Hotline, U.S. Environmental Protection Agency, Office of Drinking Water, personal communication with K. Lisi (Versar) August 25, 1987.

the interviews (2,982 cases and 5,782 controls), average consumption rates for a "typical" week were compiled by sex, age group, and geographic region. These rates are listed in Table 2-1. The overall average tap water consumption rate was 1.39 L/day. Distribution data are presented in Table 2-2. These data suggest a 50th percentile value of approximately 1.3 L/day and a 90th percentile value of approximately 2.0 L/day.

Gillies and Paulin (1983) reported drinking water intake rates based on a survey of 109 adults in New Zealand. The mean intake rate was 1.256 (±0.39) L/day and the 90th percentile rate was 1.90 L/day. The reported range was 0.26 to 2.80 L/day.

Based on data from the Food and Drug Administration's (FDA's) Total Diet Study, Pennington (1983) reported the average daily fluid consumption rates for different age/sex groups. Using these data, the average fluid and water/water-based food consumption rates were summarized for six age groups. These consumption rates are presented in Table 2-3. Based on the consumption rates for water and water-based foods for the two adult age groups, 1.07 and 1.30 L/day, the average adult consumption rate is 1.2 L/day.

Using data collected by the U.S. Department of Agriculture (USDA) in the 1977-78 Nationwide Food Consumption Survey, EPA (1984e) determined daily beverage intake levels by age. Tap water was one of the identified subcategories of the beverage category. Daily intake rates for beverages and for tap water are presented in Table 2-4. As seen in the table, daily beverage intake levels for adults ranged from 1.24 to 1.73 L.

Data on fluid intake levels have been summarized by the International Commission on Radiological Protection (ICRP) in the Report of the Task Group on Reference Man (ICRP 1981). These intake levels for adults and children are summarized in Table 2-5. The amount of drinking water (tap water and water-based drinks) consumed by adults ranged from about 400 mL/day to about 2,200 mL/day under "normal" conditions. The levels for children ranged from 540 to 790 mL/day.

Table 2-1. Tap Water Consumption Rate by Sex, Age, and Geographic Area

Group/subgroup	No. of respondents	Average Tap water consumption, L/day
Total group	5,258	1.39
Sex		
Males	3,892	1.40
Females	1,366	1.35
Age, years		
21-44	291	1.30
45-64	1,991	1.48
65-84	2,976	1.33
Geographic area		
Atlanta	207	1.39
Connecticut	844	1.37
Detroit	429	1.33
Iowa	743	1.61
New Jersey	1,542	1.27
New Mexico	165	1.49
New Orleans	112	1.61
Seattle	316	1.44
San Francisco	621	1.36
Utah	279	1.35

Source: Cantor et al. (1987).

Table 2-2. Frequency Distribution of Tap Water Consumption Rates[a]

Consumption rate (L/day)	Cumulative frequency (%)
≤0.80	19.2
0.81-1.12	39.6
1.13-1.44	59.7
1.45-1.95	79.9
≥1.96	100.0

[a]Represents consumption in a "typical" week.

Source: Cantor et al. (1987).

Table 2-3. Average Daily Fluid Consumption Rate by Age Group from the Total Diet Study

	Total average daily consumption rate (L/day)	
Age group	Total fluids[a]	Water and water-based foods[b]
6-11 months	0.689	0.201
2 years	0.930	0.499
14-16 years	1.470	0.746
25-30 years	1.750	1.066
60-65 years	1.645	1.295

[a] Includes milk/formula/milk-based soup, carbonated soda, alcoholic beverages, canned juices, water, coffee, tea, reconstituted juices, and reconstituted soups.

[b] Includes water, coffee, tea, reconstituted juices, and reconstituted soups.

Source: Pennington (1983).

Table 2-4. Mean and Standard Error for the Daily Intake of Beverages[a] and Tap Water by Age

Age	Beverage intake (mL)	Tap water intake (mL)
All ages	1434 ± 13.7	662.5 ± 9.9
Under 1	307 ± 89.2	170.7 ± 64.5
1 to 4	743 ± 43.5	434.6 ± 31.4
5 to 9	861 ± 36.5	521.0 ± 26.4
10 to 14	1025 ± 34.2	620.2 ± 24.7
15 to 19	1241 ± 35.9	664.7 ± 26.0
20 to 24	1484 ± 46.9	656.4 ± 33.9
25 to 29	1531 ± 48.0	619.8 ± 34.6
30 to 39	1642 ± 37.7	636.5 ± 27.2
40 to 59	1732 ± 29.3	735.3 ± 21.1
60 and over	1547 ± 32.8	762.5 ± 23.7

[a] Includes tap water; water-based drinks such as coffee, tea, soups, and other drinks such as soft drinks, fruitades, alcoholic drinks.

Source: USEPA (1984e).

Table 2-5. Measured Fluid Intakes (mL/day)

Subject	Total fluids	Milk	Tap water	Water-based drinks[a]
Adults ("normal" conditions)	1000-2400	120-450	45-730	320-1450
Adults (high environmental temperature to 32°C)	2840-3410 3256 ± SD = 900			
Adults (moderately active)	3700			
Children (5-14 yr)	1000-1200 1310-1670	330-500 540-650	ca. 200 540-790	ca. 380

[a] Includes tea, coffee, soft drinks, beer, cider, wine, etc.

Source: ICRP (1981).

The drinking water consumption rates for adults, that have been reported in the literature, can be summarized as follows:

Average (L/day)	Range (L/day)	90th percentile (L/day)	Reference
1.63 (calculated)	--	--	NAS 1977
1.39	≤0.80-≥1.96	2.0 (est.)	Cantor et al. 1987
1.25	0.26-2.80	1.90	Gillies and Paulin 1983
1.20	--	--	Pennington 1983
1.53	1.24-1.73	1.68 (est.)	USEPA 1984

Average 1.4

These studies were selected as the basis for determining a recommended consumption rate since they were based on large surveys and other scientifically based data.

Based on the above data, the average adult drinking water consumption rate is 1.4 L/day and the reasonable worst-case value is 2.0 L/day. This average rate differs from the rate that is widely used as the average drinking water consumption rate of 2.0 L/day. However, the 1.4 L/day value is supported by the studies cited above and by the fact that Pennington (1983) and Cantor et al. (1987) report total fluid intake average rates of 1.7 L/day and 1.87 L/day in adults. Thus the average drinking water consumption rate would be somewhat less than the 2.0 L/day commonly used. Policy or precedent reasons may support the continued use of the 2.0 L/day as the average adult drinking water consumption rate; however, the data from the scientific literature suggest a rate of 1.4 L/day as the average.

Very little data are available upon which to recommend a reasonable worst-case rate. The 90th percentile value reported by Gillies and Paulin (1983), 1.90 L/day, suggests that a rate of 2.0 L/day may be a reasonable approximation. In addition, the approximate 90th percentile value suggested by Cantor et al. (1987) is 2.0 L/day. Based on these studies, a value of 2.0 L/day is recommended as the reasonable worst-case drinking water consumption rate for adults. Since drinking water consumption rates for sensitive subpopulations (e.g., manual laborers) are not addressed by these studies, additional data for these groups are required.

2.3 Consumption of Homegrown Fruits and Vegetables

2.3.1 Background

Homegrown fruits and vegetables may become contaminated with toxic chemicals by several different pathways. Ambient pollutants in the air may be deposited on or absorbed by the plants, or dissolved in rainfall or irrigation waters which contact the plants. Pollutants may also be absorbed through plant roots from contaminated soil and ground water. Finally, the addition of pesticides, soil additives, and fertilizers to gardens may result in food contamination (USEPA 1986).

This section provides information relevant to the assessment of exposure resulting from the consumption of homegrown fruits and vegetables. Its focus is on homegrown food crops since it is believed that any contaminated commercial foods would be widely distributed, thus reducing individual exposure potential. (Note that population risks would not be changed by this "dilution" effect. Thus, exposure assessors should also consider population risks resulting from consumption of contaminated commercial products.) The distinctions between fruits and vegetables are those commonly used, not the botanical definitions. For example, in this report, tomatoes are considered vegetables, although technically they are fruits.

Estimation of toxic chemical exposures via ingestion of homegrown fruits and vegetables requires information regarding the rates of their ingestion. These consumption rates are influenced by several factors: size of home gardening plots, yield, quality of produce, types of foods grown, length of growing season, and climate. According to the latest survey by the National Gardening Association (1987), a total of 34 million, or 38 percent, of U.S. households participated in vegetable gardening in 1986.

In recent years, the median size of the home vegetable garden has decreased from 600 square feet in 1982 to 325 square feet in 1986 (National Gardening Association 1987). The average yield from the home vegetable garden is 0.9 pounds of produce per square foot.* Table 2-6 contains demographic data on vegetable gardening in 1986. The largest numbers of vegetable gardens are in the Midwest and South. A larger percentage of rural households have gardens than do those in cities and suburbs. Families with children have more gardens than single people or married couples without children (National Gardening Association 1987).

Using information from the 1977-78 USDA Nationwide Food Consumption Survey (1983), the homegrown fraction of total fruits and vegetables consumed was calculated for rural, suburban, and city households (see Table 2-7). Generally, homegrown fruits and vegetables make up a larger portion of the average person's fruit and vegetable diet in rural areas than in cities or suburban areas. Consumption rates of some fruits and vegetables show seasonal fluctuations that follow the harvesting period and storage characteristics of that crop. In Table 2-8, for example, the difference between summer and winter consumption of melons is quite large, but nearly equal quantities of lettuce are eaten throughout the year. Seasonal fluctuations in consumption of homegrown fruits and vegetables may be even more pronounced, since consumption is influenced by the length of local growing seasons. On the other hand, preservation of homegrown produce by canning or freezing allows consumption of the garden yield throughout the year.

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* Rule-of-thumb average based on production rates of top 10 most popular vegetables as determined from USDA studies. Bruce Butterfield, Research Director, National Gardening Association. Personal Communication with J. Konz (Versar) August 12, 1988.

Table 2-6. 1986 Vegetable Gardening by Demographic Factors

	Percentage of total households that have gardens (%)	Number of households (million)
Total	38	34
Region/section		
East	33	7.3
New England	37	1.9
Mid-Atlantic	32	5.4
Midwest	50	11.0
East Central	50	6.6
West Central	50	4.5
South	33	9.0
Deep South	44	3.1
Rest of South	29	5.9
West	37	6.2
Rocky Mountain	53	2.3
Pacific	32	4.2
Size of community		
City	26	6.2
Suburb	33	10.2
Small town	32	3.4
Rural	61	14.0
Household size		
Single + divorced, widowed	54	8.5
Married, no children	35	11.9
Married, with children	44	13.2

Source: National Gardening Association (1987).

Table 2-7. Weight Ratio of Homegrown to Total Fruits and Vegetables Consumed (Unitless)

Fresh vegetables	All	Rural	City	Suburban
Total fresh potatoes	0.124	0.225	0.031	0.072
White potatoes	0.119	0.220	0.030	0.065
Sweet potatoes	0.176	0.333	0.095	0.154
Total dark green	0.333	0.500	0.133	0.233
Spinach	0.200	0.333	0.000	0.167
Broccoli	0.067	0.200	0.059	0.053
Carrots	0.159	0.268	0.073	0.143
Tomatoes	0.487	0.623	0.317	0.466
Total other green	0.226	0.336	0.096	0.173
Lima beans	0.750	0.857	0.500	0.667
Snap, wax beans	0.658	0.857	0.346	0.576
Cabbage	0.162	0.271	0.065	0.105
Lettuce	0.042	0.058	0.026	0.044
Peas	0.727	0.800	0.500	0.825
Cucumbers	0.395	0.590	0.212	0.390
Mature onions	0.100	0.195	0.018	0.080
Corn	0.448	0.667	0.195	0.344
Fresh fruits				
Citrus (all)	0.113	0.126	0.060	0.148
Total other fruit	0.154	0.233	0.076	0.150
Oranges	0.093	0.120	0.049	0.236
Cantaloupe	0.141	0.250	0.051	0.108
Strawberries	0.333	0.417	0.125	0.267
Apples	0.165	0.239	0.080	0.158
Melons except cantaloupe	0.181	0.305	0.079	0.170
Peaches	0.297	0.400	0.161	0.300
Pears	0.286	0.421	0.143	0.217
Grapes	0.118	0.154	0.053	0.053
Plums	0.200	0.375	0.182	0.250

Source: USDA (1983).

Table 2-8. Seasonal Variations in Weekly Household Consumption of Fruits and Vegetables

	High		Low		Ratio:
	Season	Quantity (lb/wk)	Season	Quantity (lb/wk)	high/low
Carrots	Winter	0.50	Spring	0.38	1.3
Corn	Summer	1.47	Winter	0.17	8.6
Cucumbers	Summer	0.78	Winter	0.17	4.6
Dark green, leafy	Fall	0.38	Summer, Winter	0.25	1.5
Lettuce	Summer	1.30	Fall	1.08	1.2
Onions	Winter	0.57	Spring	0.39	1.5
Peas	Summer	0.18	Winter	0.07	2.6
Peppers	Summer	0.26	Spring, Winter	0.14	1.9
Potatoes	Winter	3.69	Spring	3.11	1.2
Pumpkin, winter squash	Fall	0.36	Spring	0.06	6.0
Snap, wax beans	Summer	0.54	Winter	0.29	1.9
Tomatoes	Summer	2.04	Winter	0.75	2.7
Apples	Fall	2.39	Spring	1.14	2.1
Bananas	Fall	1.30	Spring	1.21	1.1
Cantaloupe	Summer	1.80	Winter	0.03	60.0
Grapefruit	Winter	1.21	Summer	0.23	5.3
Grapes	Summer	0.33	Winter	0.06	5.5
Melons except cantaloupe	Summer	2.82	Winter	0.02	141.0
Oranges	Winter	1.65	Summer	0.62	2.7
Peaches	Summer	1.01	Winter	0.07	14.4
Pears	Fall	0.29	Spring	0.11	2.6
Plums	Summer	0.29	Winter	0.01	29.0
Strawberries	Spring	0.32	Fall	0.04	8.0

Source: USDA (1983).

2.3.2 Methods

Two information sources were used to determine consumption rates of fruits and vegetables from household gardens: (1) Foods Commonly Eaten by Individuals: Amount Per Day and Per Eating Occasion (Pao et al. 1982) and (2) Food Consumption: Households in the United States, Seasons and Year 1977-1978 (USDA 1983).

Using the data gathered in the 1977-78 USDA Nationwide Food Consumption Survey, Pao et al. (1982) calculated percentiles of total fruit and vegetable consumption of the U.S. population. The data were collected during home interviews of 37,874 respondents, who were asked to recall food intake for the day preceeding the interview, and record food intake the day of the interview and the day after the interview. Therefore, if the food was eaten at least once in 3 days, the quantity consumed was recorded.

"All" and "bought" categories of consumption data for all foods are provided by the USDA Food Consumption Survey. From these data, the average percentage of total fruits and vegetables consumed that are homegrown is calculated by assuming that the difference between "all" and "bought" is the amount "homegrown." The consumption rate of a homegrown fruit or vegetable at a certain frequency, C_p, is approximated as follows:

$$C_p = C_{tp} \bullet P$$

where

C_{tp} = the total (homegrown + bought) consumption rate of a vegetable or fruit at a particular frequency, or percentile (i.e., for people whose consumption of white potatoes falls into the 95th percentile, C_{tp} is 202 g/day), and

P = the percentage of the quantity of the fruit or vegetable consumed that is homegrown. The average percentage for all types of households was used (rural, suburban, and metropolitan; Table 2-7).

The necessary assumption in this method is that the consumption behavior of home gardeners and their families follows the consumption rate frequencies of the U.S. population, which includes a majority of nongardeners. This assumption could be a major source of error.

Although Pao et al. (1982) reported distributions from the data, it was not felt that the data obtained from the 3-day diet records could be used to derive a distribution of annual consumption rates. These data actually represent the 3-day average intake of fruits and vegetables by consumers. No distributions of consumption rates for broader food categories--all vegetables or all fruits--are available. Obtaining a frequency distribution for all vegetables by summing the distributions for individual vegetables is not possible because the data represent the national average intake of each vegetable on any 1 day in the year. The sum of ingestion rates implies that the average individual's diet in 1 day included the average amount of all vegetables. In addition, similarly shaped distributions for each vegetable must be assumed. For example, the person whose consumption rate for tomatoes falls in the 90th percentile is also assumed to have a 90th percentile consumption rate of broccoli. While this assumption may be valid for consumption rates near the median, it introduces a large degree of uncertainty at the extremes of the distribution.

It is possible that people who consume large amounts of one vegetable eat large quantities of all vegetables, or that people whose diet includes a low vegetable intake, shun all vegetables equally. To avoid uncertainty, however, intakes of different vegetables or fruits should be treated as independent variables.

2.3.3 Results

The percentage of homegrown fruits and vegetables in the diet may vary according to the difficulty involved in growing them, their cost and availability at the market, the growing period, and the harvesting frequency.

The data in Table 2-7 show that homegrown dark green vegetables make up approximately one-third of the dark green vegetables consumed. This category includes mustard greens, kale, kohlrabi, spinach, and broccoli.

These greens may not always be available in the market and they are easy to grow. Consumption of homegrown corn, cucumbers, green beans, and tomatoes makes a significant contribution to the total consumption. The data for green peas and lima beans are probably not representative because they are based upon very small quantities. The proportion of homegrown fruits consumed is highest for strawberries, peaches, and pears and lowest for citrus fruits.

Table 2-9 contains information on the types of vegetables grown by home gardeners in 1986. Tomatoes, peppers, onions, cucumbers, lettuce, beans, carrots, and corn are among the vegetables grown by the largest percentage of gardeners. Comparison of Tables 2-7 and 2-8 suggest that the popularity of a vegetable with homegrowers does not necessarily lead to high consumption rates.

Percentiles of consumption of total and homegrown fruits and vegetables are presented in Table 2-10. However, any use of these data must consider that these may not be representative values for annual consumption rates since they were derived from 3-day consumption rates. Note that lettuce, tomatoes, corn, and green beans were the items identified most often in the 3-day diet recall. The homegrown vegetables consumed at the highest rate are corn, lima beans, green beans, tomatoes, cabbage, and cucumbers.

The average consumption rate of vegetables by individuals in 1 day, based on the USDA Nationwide Food Consumption Survey, was 201 g/day (USDA 1980, as cited by USEPA 1986). Assuming a diet consists of a mix of all listed vegetables, the average homegrown portion of all vegetables may be determined from Table 2-10. Based on this table, the average homegrown percentage of all vegetables is 25 percent. Thus, the total homegrown vegetable consumption rate is 50 g/day.

The most frequently recalled fruits in the dietary intake survey were orange juice and raw and cooked apples. The high proportion of homegrown peaches, pears, and strawberries is reflected in their consumption rates: 15.1, 15.7, and 12.3 g/day, respectively. The consumption of juices

Table 2-9. Percentage of Gardening Households Growing Different Vegetables

Vegetable	Percent
Artichokes	0.80
Asparagus	8.20
Beans	43.40
Beets	20.60
Broccoli	19.60
Brussel sprouts	5.70
Cabbage	29.60
Carrots	34.90
Cauliflower	14.00
Celery	5.40
Chard	3.50
Corn	34.40
Cucumbers	49.90
Dried peas	2.50
Dry beans	8.90
Eggplant	13.00
Herbs	9.80
Kale	3.10
Kohlrabi	3.00
Leeks	1.20
Lettuce	41.70
Melons	21.90
Okra	13.60
Onions	50.30
Oriental vegetables	2.10
Parsnips	2.20
Peanuts	1.90
Peas	29.00
Peppers	57.70
Potatoes	25.50
Pumpkins	10.20
Radishes	30.70
Rhubarb	12.20
Spinach	10.20
Summer squash	25.70
Sunflowers	8.20
Sweet potatoes	5.70
Tomato	85.40
Turnips	10.70
Winter squash	11.10

Source: National Gardening Association (1987).

Table 2-10. Average Daily Consumption of Total Fruits and Vegetables, from Three-Day Dietary Recall, at Specified Percentiles (g/day)

Food category		% Homegrown	Percentile[a] 5.0	25.0	50.0	75.0	90.0	95.0	99.0	Average	Std. Dev.	% Indiv. using food in 3 days
Raw vegetables												
White potatoes	Total		14.0	33.0	62.0	103.0	158.0	202.0	309.0	78.0	65.0	74.4
	Homegrown	11.9	1.7	3.9	7.4	12.3	18.8	24.0	36.8			
Cabbage and coleslaw	Total		5.0	15.0	20.0	40.0	40.0	60.0	90.0	27.0	20.0	9.7
	Homegrown	16.2	0.8	2.4	3.2	6.5	6.5	9.7	14.6			
Carrots	Total		1.0	5.0	17.0	22.0	41.0	51.0	96.0	18.0	19.0	5.0
	Homegrown	15.9	0.2	0.8	2.7	3.5	6.5	8.1	15.3			
Cucumbers	Total		3.0	12.0	23.0	47.0	79.0	105.0	220.0	37.0	45.0	5.6
	Homegrown	39.5	1.2	4.7	9.1	18.6	31.2	41.5	86.9			
Lettuce and tossed salad	Total		3.0	13.0	31.0	54.0	90.0	113.0	186.0	40.0	39.0	50.7
	Homegrown	4.2	0.1	0.5	1.3	2.3	3.8	4.7	7.8			
Mature onions	Total		1.0	6.0	7.0	15.0	24.0	37.0	73.0	13.0	16.0	8.5
	Homegrown	10.0	0.1	0.6	0.7	1.5	2.4	3.7	7.3			
Tomatoes	Total		10.0	20.0	30.0	60.0	91.0	123.0	205.0	44.0	42.0	27.8
	Homegrown	48.7	4.9	9.7	14.6	29.2	44.3	59.9	99.8			
Cooked vegetables												
Broccoli	Total		12.0	26.0	31.0	57.0	62.0	99.0	137.0	41.0	27.0	6.2
	Homegrown	6.7	0.8	1.7	2.1	3.8	4.2	6.6	9.2	2.7		
Cabbage	Total		13.0	25.0	50.0	50.0	100.0	102.0	200.0	50.0	39.0	4.7
	Homegrown	16.2	2.1	4.1	8.1	8.1	16.2	16.0	32.5	8.1		
Carrots	Total		6.0	15.0	25.0	39.0	52.0	71.0	103.0	30.0	21.0	9.8
	Homegrown	15.9	1.0	2.4	4.0	6.2	8.3	11.3	16.4	4.8		
Corn	Total		18.0	54.0	71.0	136.0	142.0	213.0	304.0	91.0		25.0
	Homegrown	44.8	8.1	31.8	60.9	63.6	95.4	136.2	40.8			
Lima beans	Total		7.0	28.0	29.0	58.0	85.0	113.0	170.0	43.0	33.0	2.8
	Homegrown	75.0	5.3	21.0	21.8	43.5	63.8	84.8	127.5	32.3		
Mixed vegetables	Total		11.0	30.0	31.0	62.0	78.0	123.0	187.0	46.0	33.0	3.4
	Homegrown											

Table 2-10. (continued)

Food category		% Homegrown	Percentile[a] 5.0	25.0	50.0	75.0	90.0	95.0	99.0	Average	Std. Dev.	% Indiv. using food in 3 days
Cowpeas, field peas,	Total		11.0	29.0	44.0	58.0	117.0	117.0	233.0	53.0	42.0	2.9
Black-eyed peas	Homegrown											
Green peas	Total		7.0	19.0	28.0	55.0	57.0	84.0	113.0	35.0	26.0	18.3
	Homegrown											
Spinach	Total		8.0	30.0	34.0	65.0	68.0	103.0	137.0	45.0	29.0	4.5
	Homegrown	20.0	1.6	6.0	6.8	13.0	13.6	20.6	27.4	9.0		
String beans	Total		6.0	23.0	23.0	47.0	69.0	93.0	140.0	35.0	29.0	27.3
	Homegrown	65.8	3.9	15.1	15.1	30.9	45.4	61.2	92.1	23.0		
Summer squash	Total		11.0	36.0	36.0	72.0	108.0	143.0	287.0	56.0	46.0	2.8
	Homegrown											
Sweet potatoes	Total		14.0	34.0	38.0	68.0	85.0	132.0	200.0	52.0	38.0	4.1
	Homegrown	17.6	2.5	6.0	6.7	12.0	15.0	23.2	35.2	9.2		
Tomato juice	Total		30.0	45.0	81.0	121.0	182.0	243.0	354.0	94.0	72.0	3.9
	Homegrown											
Cucumber pickles	Total		2.0	6.0	11.0	22.0	43.0	50.0	90.0	18.0	20.0	9.2
	Homegrown	39.5	0.8	2.4	4.3	8.7	17.0	19.8	35.6	7.1		
<u>Fruits</u>												
Grapefruit	Total		38.0	45.0	89.0	110.0	165.0	205.0	268.0	90.0	58.0	4.7
	Homegrown	11.3	4.3	5.1	10.1	12.4	18.6	23.2	30.3			
Grapefruit juice	Total		41.0	63.0	83.0	165.0	250.0	329.0	658.0	131.0	115.0	3.6
	Homegrown	11.3	4.6	7.1	9.4	18.6	28.3	37.2	74.4			
Oranges	Total		24.0	48.0	48.0	97.0	145.0	180.0	290.0	78.0	54.0	9.0
	Homegrown	9.3	2.2	4.5	4.5	9.0	13.5	16.7	27.0			
Orange juice	Total		42.0	73.0	125.0	166.0	249.0	290.0	496.0	133.0	92.0	35.5
	Homegrown	9.3	3.9	6.8	11.6	15.4	23.2	27.0	46.1			
Apples	Total		23.0	46.0	46.0	92.0	138.0	184.0	276.0	75.0	53.0	18.2
	Homegrown	16.5	3.8	7.6	7.6	15.1	22.7	30.3	45.4			
Applesauce, cooked	Total		11.0	38.0	43.0	85.0	127.0	160.0	253.0	61.0	47.0	9.8
apples	Homegrown	16.5	1.8	6.3	7.1	14.0	21.0	26.4	41.7			
Apple juice	Total		41.0	62.0	83.0	145.0	227.0	289.0	496.0	116.0	98.0	3.8
	Homegrown	16.5	6.8	10.2	13.7	23.9	37.5	47.7	81.8			

Table 2-10. (continued)

Food category		% Homegrown	Percentile[a] 5.0	25.0	50.0	75.0	90.0	95.0	99.0	Average	Std. Dev.	% Indiv. using food in 3 days
Cantaloupe	Total		21.0	45.0	68.0	91.0	181.0	181.0	272.0	81.0	61.0	3.3
	Homegrown	14.1	3.0	6.3	9.6	12.8	25.5	25.5	38.4			
Raw peaches	Total		25.0	51.0	51.0	101.0	152.0	203.0	355.0	84.0	66.0	4.5
	Homegrown	29.7	7.4	15.1	15.1	30.0	45.1	60.3	105.4			
Raw pears	Total		27.0	55.0	55.0	109.0	114.0	164.0	273.0	75.0	50.0	3.1
	Homegrown	28.6	7.7	15.7	15.7	31.2	32.6	46.9	78.1			
Raw strawberries	Total		12.0	25.0	37.0	50.0	99.0	120.0	225.0	46.0	44.0	2.1
	Homegrown	33.3	4.0	8.3	12.3	16.7	33.0	40.0	74.9			

[a] Percentiles are cumulative; for example, 50 percent of people eat 62 g white potatoes per day or less.

Source: Total consumption data from Pao et al. (1982).

made from homegrown fruits is also large because beverage consumption rates are higher per unit weight than food consumption rates. A source of uncertainty in these data is the assumption that home gardeners prepare juice from fruit that they grow, and that the "homegrown percentage" can be applied to juices as well as whole fruits. Total average daily fruit intake is 142 g/day per individual (USDA 1980, as cited by USEPA 1986). Assuming a diet consists of a mix of all listed fruits, the average homegrown portion of all fruits may be determined from Table 2-10. Based on this table, the average homegrown percentage of fruits is 20 percent. Thus, the total homegrown fruit consumption rate is 28 g/day.

The major source of uncertainty with these data is that they represent the average intake of homegrown fruits and vegetables per person on any 1 day in the year. This average daily intake contrasts with the daily intake, averaged over a year, of a person in the U.S. population, which would be used in exposure calculations. The two values may, in fact, be similar, although it is likely that intakes of people who eat fruits and vegetables infrequently were underrepresented in the 3-day diet recall study (Pao et al. 1982).

2.3.4 Exposure Calculation

The total dietary exposure, E_t, that results from eating contaminated fruits and vegetables from the home garden is calculated as follows (USEPA 1986):

$$E_t = \sum_{i=1}^{n} (C_f)_i (L)_i$$

where

C_f = the concentration (mg/kg) of the pollutant in the food at the time of consumption,

L = the amount (kg/day) of contaminated food consumed, and

subscript i = the number of different fruits and vegetables consumed.

In order to perform this calculation, C_f, or the contaminant concentration in the fruit or vegetable, i, must be known. L_i is selected from Table 2-10. If specific contaminated foods are not known, the generic amounts of total homegrown fruits and vegetables can be used (i.e., 50 g/day for vegetables and 28 g/day for fruits). The median, or 50th percentile, value is used for a national exposure estimate. If the exposure is limited to one region, different percentile values might be used. Consideration should also be given to urban vs. suburban vs. rural areas. The total exposure is then the sum of exposures from each homegrown fruit or vegetable consumed.

The frequency of consumption also affects exposure. It is likely that homegrown fruits and vegetables are not consumed by gardeners and their families throughout the year. The length of time that homegrown vegetables and fruits are consumed varies with geographic location, climate, and types of produce grown. As stated in the background section, preservation of the garden yield by freezing and canning extends the period during which homegrown fruits and vegetables are consumed. No information on the length of time that homegrown fruits and vegetables are consumed is available.

2.3.5 Conclusion

No data were available that presented the actual annual consumption rates for homegrown fruits and vegetables by gardeners. Because of this, it is recommended that the following four procedures be considered by assessors in the order presented:

(1) Conduct local survey of residents in the area of concern and determine actual annual consumption rates for homegrown fruits and vegetables.

(2) Determine productivity levels for gardeners in the area, and derive consumption rates by dividing the quantity of fruits and vegetables produced by the number of consumers of the homegrown crops.

(3) Based on national survey data (USDA 1980), the average amounts of total fruits and total vegetables consumed on any one day have been estimated as 200 g/day for vegetables and 140 g/day for fruits. It is not known how representative these estimates are of the entire year; however, it was assumed that the estimates represented long-term average daily consumption rates rather than actual meal sizes. Consumption rates also vary by region. These values assume that all the homegrown fruits and vegetables consumed by exposed individuals are derived from the contaminated source. From Table 2-10, the fraction of vegetables homegrown ranges from 0.04 to 0.75 depending on type. The overall average homegrown fraction from this table is 0.25, representing the typical portion. It was judged that the reasonable worst-case portion would be 0.40. Using these fractions, total homegrown vegetable consumption is estimated as follows:

Typical homegrown vegetable consumption = (200 g/day) (0.25) = 50 g/day
Reasonable worst case homegrown vegetable consumption = (200 g/day) (0.40) = 80 g/day.

The fraction of fruits that are homegrown, from Table 2-10, ranges from 0.09 to 0.33 depending on type. The overall average homegrown fraction from this table is 0.20, representing the typical portion. It was judged that a reasonable worst-case portion would be 0.30. Using these fractions, total homegrown fruit consumption is estimated as follows:

Typical homegrown fruit consumption = (140 g/day) (0.20) = 28 g/day
Reasonable worst-case homegrown fruit consumption = (140 g/day) (0.30) = 42 g/day.

2.4 Consumption of Homegrown Beef and Dairy Products

Consumption of homegrown beef and dairy products is a potential pathway of exposure to toxic chemicals. These food sources are contaminated as animals consume contaminated soil, water, or feed crops. This chapter focuses on homegrown food products, since any contaminated commercial products would be widely distributed, thus reducing individual exposure potential. (Note that population risks would not be changed by this "dilution" effect. Thus, exposure assessors should also consider population risks resulting from consumption of contaminated commercial products.) Data for consumption of both whole beef and dairy products and fat portions are provided, since many contaminants concentrate in the fat portion of these foods. Additional exposure scenarios could be developed using these data. Other meat groups, such as poultry and pork, are potentially of interest to exposure assessors and will be added to future editions of this handbook.

Average consumption rates and fat content data for all (homegrown and bought) beef and dairy products are presented in Table 2-11, which has been adapted from USEPA (1984b) by the addition of information from USEPA (1984c, 1984d) and Fries (1986). Much greater "resolution" actually is available in USEPA (1984c, 1984d) than is found in Table 2-11, since both (USEPA 1984c, 1984d) are based on a USDA Nationwide Food Consumption Survey (NFCS) conducted in 1977-78. The NFCS covered intake of 3,735 possible food items by 30,770 individuals characterized by age, sex, geographic locations, and season of the year. A further description of the survey design is given in USEPA (1984e).

The average beef fat consumption noted in Table 2-11 ranges from 14.9 to 26.0 g/70 kg/person-day, with a single high consumption estimate of 30.6 g/70 kg/person-day. Since this is a per capita value, it is likely that families of beef producers who home slaughter would have higher consumption rates. Milk fat consumption from all dairy products ranges from 24.1 to 43 g/70 kg/person-day, with the lower end of this range appearing best supported at present. Considering fresh milk only, milk fat consumption is reported to average 8.9 to 10.7 g/70 kg/person-day, with a single high consumption estimate of 35 g/70 kg/person-day, perhaps appropriate for dairy farm families. [Age range-specific information is available in both USEPA (1984c) and USEPA (1984d).]

According to USDA studies, in farm households where beef is homegrown, the average percent of annual consumption of beef that is homegrown is 44 percent. This is based on a survey of 900 rural farm households (USDA 1966). Since the total amount of beef consumed averages approximately 100 g/day (see Table 2-11), it can be estimated that 44 percent of this amount, 44 g/day, represents the average consumption rate for homegrown

Table 2-11. Rates of Ingestion of Beef and Dairy Products

Total consumption rate ± std. error (g/70 kg/person-day)	Percentage of fat	Fat consumption rate ± std. error (g/70 kg/person-day)	Reference
Beef			
124[a]	15	19	USEPA (1981)
110.7 ± 1.7[b]	23	26.0 ± 0.3	USEPA (1984c)
87.6 ± 1.1[c]	(23)	(20.1 ± 0.3)[d]	USEPA (1984d)
96.3[e]	(23)	(22.1)	Berglund (1984)
66.8[f]	22	14.9	Fries (1986)[c]
137.1 (high)[f]	22	30.6	Fries (1986)
Dairy products			
550	7.8	43	USEPA (1981)
308.6 ± 5.3[c]	(7.8)	(24.1 ± 0.4)[g]	USEPA (1984d)
431.6 ± 5.6[c]	(7.8)	(33.7)	USEPA (1984c)
Fresh milk (only)			
253.5 ± 4.9	(3.5)	(8.9)	USEPA (1984d)
305 (average)	3.5	10.7	Fries (1986)
1000 (high)	3.5	35.0	Fries (1986)

[a] Per capita ingestion rate for the United States from national statistics.

[b] Average consumption rate for all beef subcategories included in EPA's Tolerance Assessment System.

[c] Mean per capita ingestion rates. The categories established in USEPA (1984d) exclude beef in meat mixtures (e.g., meat loaf), meat by-products (e.g., wieners), and organ meats. The basic data set underlying both USEPA (1984c) and USEPA (1984d) was the 1977-78 USDA Nationwide Food Consumption Survey. The basis for the difference in total dairy products consumption rates noted for USEPA (1984c) and USEPA (1984d) has not yet been resolved.

[d] Beef fat consumption rates in parentheses are calculated using percentages of fat derived from USEPA (1984c).

[e] Estimate derived from National Cattleman's Association.

[f] This and succeeding values from Fries (1986) are reportedly derived from Breidenstein (1984). Values are per capita ingestion rates for "average" and "high" beef consumption populations.

[g] Dairy fat consumption rates are calculated using percentages of fat derived from USEPA (1981).

beef (in farm households). Because this value is applied to a per capita rate, it is likely to underestimate actual consumption by families who home slaughter.

Similarly, in farm households where dairy products are homegrown, the average percent of annual consumption that is of homegrown dairy products is 40 percent (USDA 1966). Since the total amount of dairy products consumed averages approximately 400 g/day (see Table 2-11), it can be estimated that 40 percent of this amount, or 160 g/day, represents the average consumption rate for homegrown dairy products.

These consumption rates represent long-term averages and are not representative of the amounts consumed for a meal. The duration of exposure to be used in conjunction with these rates is thus not the number of days on which an individual actually consumes beef and dairy products, but rather the entire period of time from the first to the last meal that included homegrown beef and dairy products.

No data were available that presented the actual annual consumption rates for homegrown beef and dairy products. Because of this, it is recommended that the following two steps be considered by assessors in the order presented:

(1) Conduct a survey of farmers in the area of concern and determine the actual annual consumption rates of homegrown beef and dairy products.

(2) Based on data presented in this section, an estimate of annual average consumption rates can be made using per capita data. This results in an estimated annual average consumption rate of 44 g/day for beef and 160 g/day for dairy products for individuals consuming homegrown beef and dairy products. No data are available to represent the 90th percentile consumption rate. It is suggested that a consumption rate of 75 g/day for beef and 300 g/day for dairy products be used as reasonable worst case rates until better data are available. These rates were derived from the assumption that the percentage of annual consumption that is homegrown is 75 percent for the 90th percentile consumer.

2.5 Consumption of Recreationally Caught Fish and Shellfish

2.5.1 Background

Currently, a consumption rate of 6.5 g/day is used to represent the average per capita nonmarine fish consumption rate. This value is the value established for setting Ambient Water Quality Criteria (USEPA 1980; PTI 1987). This value is based on one-year survey data collected during 1973 and 1974 by NPD Research, Inc. The overall fish consumption rate estimated from this survey was 14.3 g/day. Both of these values were estimated on a per capita basis and represent the average over the entire population including fish-eaters and nonfish-eaters. Thus, they underestimate actual consumption rates for recreational fisherman and are not accurate values to use when assessing exposure to recreational fishermen at a specific site.

Accurate estimation of toxic chemical exposures of people who consume fish from polluted water bodies requires an additional estimation of consumption rates for recreationally caught fish by fishermen and their families. Commercially caught fish are marketed widely, making the prediction of an individual's consumption from a particular commercial source difficult. Since the catch of sport fishermen is not "diluted" in this way, these individuals represent the population that is most vulnerable to exposure by consumption of contaminated fish from one location.

2.5.2 Methods

Three surveys are available that represent national fish consumption rates. Two additional local recreational surveys are also available that represent consumption rates for recreational fishermen. These surveys are discussed below and summarized in Tables 2-12 and 2-13.

National recreational catch data for coastal areas in 1985 was obtained by the National Marine Fisheries Service (NMFS) by direct surveys of fishermen in the field and an independent telephone survey of house-

Table 2-12. Summary of National Surveys

Parameter	Survey: NMFS	Survey: NPO/Javitz	Survey: Pao/USDA
Area studied	Coastal	National	National
No. of people	200,000	24,652	37,874
Survey time	Entire year	2/mo. for year[a]	3 days
Type of fish	Marine	Marine/fresh	Marine/fresh
Recreational/commercial	Recreational	Both	Both
Catch/diet survey	Catch	Diet	Diet
Statistics generated	Catch size	Consumption rate	Consumption rate

[a] This is twice per month for one year.

Table 2-13. Summary of Local Recreational Surveys

	Survey	
Parameter	Puffer (1981)	Pierce et al. (1981)
Area studied	Los Angeles	Commencement Bay
No. of people	1059	608
Survey time	3/month for year[a]	July-November
Type of fish	Marine/fresh	Marine/fresh
Catch/diet survey	Diet	Diet
Statistics generated	Consumption rate distribution	Consumption rate distribution

[a] This is three times per month for one year.

holds. For the Atlantic and Gulf coasts, approximately 41,000 field interviews and 58,000 telephone interviews were conducted. For the Pacific coast, approximately 38,000 field interviews and 73,000 telephone interviews were conducted. Estimates were derived for six 2-month periods in 1985. The recreational marine catch represented an estimated 30 percent of the finfish landing used for food in 1985 in the U.S. and totaled 717 million pounds (NMFS 1986a). Total catch size by marine species, seasonal variations in catch, and number of sport fishermen in Atlantic, Gulf, and Pacific Coast regions are presented in Appendix 2A. Consumption rates were not derived from these surveys.

Data on total fish consumption were obtained by a 1-year survey conducted during 1973 and 1974 by NPD Research, Inc. and funded by the Tuna Research Institute. The sample of 6,980 families represented the U.S. population, i.e., they were weighted on the basis of a number of census-defined controls, which included census region, family size, income, children, race, and age. The head of each household completed a diary of fish purchases twice monthly for 12 months (i.e., summarizing fish diet for previous 2 weeks). The families answered questionnaires concerning the date of meals containing fish, type and quantity of fish, the number of servings consumed by each family member and the amount of fish not consumed during the meal, packaging of the fish, and whether fresh fish was recreationally caught or purchased. Meals eaten away from home were also included in the survey. The total number of fish consumers was 24,652, representing, on a weighted basis, 94 percent of U.S. residents.

Using the data obtained by NPD Research, Inc., Javitz (1980) calculated means (see Table 2-14) and 95th percentiles of monthly fish consumption for fish consumers in the United States (assumed to be 94 percent of the population). The calculation of means, percentiles, and percentages, which was performed on a weighted basis, with each person contributing to the mean in proportion to his/her assigned survey weight is explained in Appendix 2B. The mean and 95th percentile consumption

Table 2-14. Mean Total Fish Consumption by Species[a]

Species	Mean consumption (g/day)	Species	Mean consumption (g/day)
Not reported	1.173	[b]Mullet	0.029
Abalone	0.014	[b]Oysters	0.291
Anchovies	0.010	[b]Perch (Freshwater)	0.062
[b]Bass	0.258	Perch (Marine)	0.773
Bluefish	0.070	[b]Pike (Marine)	0.154
[b]Bluegills	0.089	Pollock	0.266
Bonito	0.035	Pompano	0.004
[b]Buffalofish	0.022	[b]Rockfish	0.027
Butterfish	0.010	Sablefish	0.002
[b]Carp	0.016	[b]Salmon	0.533
[b]Catfish (Freshwater)	0.292	[b]Scallops	0.127
[b]Catfish (Marine)	0.014	[b]Scup	0.014
[b]Clams	0.442	Sharks	0.001
Cod	0.407	[b]Shrimp	1.464
Crab, King	0.030	[b]Smelt	0.057
[b]Crab, other than King	0.254	Snapper	0.146
[b]Crappie	0.076	[b]Snook	0.005
[b]Croaker	0.028	[b]Spot	0.046
Dolphin	0.012	Squid and Octopi	0.016
[b]Drums	0.019	[b]Sunfish	0.020
[b]Flounders	1.179	Swordfish	0.012
Groupers	0.026	Tilefish	0.003
Haddock	0.399	[b]Trout (Freshwater)	0.294
Hake	0.117	[b]Trout (Marine)	0.070
Halibut	0.170	Tuna, light	3.491
[b]Herring	0.224	Tuna, White Albacore	0.008
Kingfish	0.009	[b]Whitefish	0.141
[b]Lobster (Northern)	0.162	[b]Other finfish	0.403
Lobster (Spiny)	0.074	[b]Other shellfish	0.013
Mackerel, Jack	0.002		
Mackerel, other than Jack	0.172		

[a] The calculations in this table are based on responses to a survey conducted by NPD Research, Inc. in which respondents were asked to report the species and amount consumed during the month in which the survey was conducted. NPD Research, Inc. estimates that these respondents represent, on a weighted basis, 94.0 percent of the population of U.S. residents.

[b] Designated as freshwater or estuarine species by Stephan (1980).

Source: Javitz (1980).

rates derived by Javitz (1980) were 14.3 g/day and 41.7 g/day, respectively. Note that this is one of the few diet studies where the percentile data can be appropriately applied to long-term exposures since the data were collected over the entire year. Unfortunately, the distinction between recreationally caught and purchased fish was not maintained in the original compilation of data.

The weighted mean and 95th percentile total fish consumption rates for the U.S. population calculated by Javitz (1980) are presented by demographic variables on Table 2-15. Consumption of fish by Asian-American people is significantly higher than that of other groups, a fact that is confirmed by regional sportfishing consumption studies, which are discussed later. Other obvious differences in consumption rates are those between sexes and between age groups. While males eat slightly more fish than females, and adults eat more fish than children, the corresponding difference in body weight would compensate for the different consumption rates in exposure calculations. There appear to be no large differences in regional consumption rates, although higher rates occur in the coastal states. From Table 2-13, the overall calculated (weighted) mean fish consumption rate for fish eaters is 14.3 g/day, and the 95th percentile rate is 41.7 g/day. These data were based on both purchased fish and recreationally caught fish. Therefore, these data were not used for subsequent calculations of fish consumption rates for recreationally caught fish.

Pao et al. (1982) used consumption information obtained in the 1977-78 USDA Nationwide Food Consumption Survey to obtain frequency distributions for consumption rates of various foods. The data were collected during home interviews in which the respondent was asked to recall food intake for the day of the interview, the day preceding, and the day after the interview. Therefore, if the food was eaten at least once in 3 days, the quantity consumed was recorded. Of 37,874 individuals with 3-day diet records, 24.5 percent had eaten fish and shellfish at least once in 3 days.

Table 2-15. Total Fish Consumption by Demographic Variables[a]

Demographic category	Consumption (g/person/day) Mean	Upper 95th percentile
Race		
Caucasian	14.2	41.2
Black	16.0	45.2
Oriental	21.0	67.3
Other	13.2	29.4
Sex		
Female	13.2	38.4
Male	15.6	44.8
Age (years)		
0- 9	6.2	16.5
10-19	10.1	26.8
20-29	14.5	38.3
30-39	15.8	42.9
40-49	17.4	48.1
50-59	20.9	53.4
60-69	21.7	55.4
70+	13.3	39.8
Census Region		
New England	16.3	46.5
Middle Atlantic	16.2	47.8
East North Central	12.9	36.9
West North Central	12.0	35.2
South Atlantic	15.2	44.1
East South Central	13.0	38.4
West South Central	14.4	43.6
Mountain	12.1	32.1
Pacific	14.2	39.6

[a] The calculations in this table are based on responses to a survey conducted by NPD Research, Inc. in which respondents were asked to report the species and amount consumed during the month in which the survey was conducted. NPD Research, Inc. estimates that these respondents represent, on a weighted basis, 94.0 percent of the population of U.S. residents.

The distribution for total consumption of fish and shellfish calculated by Pao et al. (1982) from the 1977-78 USDA consumption survey is presented in Table 2-16. The median and 95th percentile fish consumption rates for persons who included fish in their 3-day dietary intake (37 and 128 g/day, respectively) are more than twice those calculated from the NPD data.

Since many individuals eat fish at a frequency of less than once every 3 days, the data obtained from the 3-day diet records cannot be used to derive distributions of annual consumption rates. However, they should provide accurate estimates of mean per capita ingestion rates since a very large population was surveyed. Because these studies present per capita consumption rates, the data are not representative of recreational fishermen who consume larger amounts of fish than the general population.

Puffer (1981) conducted 1059 interviews with sport fishermen in the Los Angeles harbor area. (The study is described in detail in Appendix 2C.) Puffer (1981) also observed higher consumption of recreationally caught fish by Asian-American people than people in other ethnic groups. Sport fishermen kept 67 to 89 percent of the finfish and 97 percent of the shellfish catch. The distribution of total fish and shellfish consumption by sport fishermen in the Los Angeles area is presented in Table 2-17. The median fish and shellfish consumption rate was reported to be 37 g/day and the 90th percentile consumption rate was 225 g/day.

Another survey of sport fishermen was performed in Commencement Bay at Tacoma, Washington, by Pierce et al. in 1981. The sample size, 304 fishermen, was smaller than in the Puffer study, and the sampling frequency was lower. Consumption rates by species, ethnic makeup of sport fishermen, and a detailed description of the study are contained in Appendix 2C. Pierce et al. found that over half of the fishermen caught and consumed fish weekly (see Table 2-17). The fishing frequencies can be used with the mean daily total sportsfish consumption to calculate the fish consumption rates on a yearly and daily basis for people in different fishing frequency categories in Table 2-18. The 50th percentile consumption rate

Table 2-16. Distribution of Fish and Shellfish Consumption Rates of Fish Eaters

Source	Percentile	C_t Total fish + shellfish consumption[a] (g/person/day)
Pao et al. (1982)	5	8.00
	25	20.00
	50	37.00
	75	57.00
	90	94.00
	95	128.00
	99	215.00
USDA (1976)	Mean	18.8

[a] Consumers who ate fish once in 3 days.

Table 2-17. Cumulative Distribution of Total Fish/Shellfish Consumption by Sport Fishermen in the Metropolitan Los Angeles Area

Percentile	Consumption rate (g/person/day)
5	2.3
10	4.0
20	8.3
30	15.5
40	23.9
50	36.9
60	53.2
70	79.8
80	120.8
90	224.8
95	338.8

Source: Puffer (1981).

Table 2-18. Yearly and Daily Fish Consumption Data by Recreational Fishing Frequencies in Commencement Bay, Washington

Fishing frequency	Percentage	Fish consumption[a] (kg/person/yr)	Fish consumption (g/person/day)	Percentile
Daily	9.40	139.14	381.19	100.65
Weekly	51.30	19.82	54.31	91.25
Monthly	18.45	4.57	12.53	39.95
Bimonthly	5.25	2.29	6.27	21.50
Biyearly	5.40	0.76	2.09	16.25
Yearly	10.85	0.38	1.04	10.85

[a] Mean daily consumption of the recreational catch x number of fishing days per year.

Source: Pierce et al. (1981).

for recreationally caught fish lies within the range of 12 to 54 g/day, which is in fair agreement with Puffer's estimate for median consumption rates of recreationally caught marine fish. Fish species that spend a portion of their lives in estuaries (and therefore fall into the freshwater category) probably constitute a portion of the total recreational catch consumption obtained in these coastal studies.

2.5.3 Conclusion

The consumption rate data from the Puffer (1981) and Pierce et al. (1981) studies are considered representative of actual annual consumption rates for recreational fishermen. Although these studies were limited to the west coast, it is recommended that these values be used to represent consumption rates for recreational fishermen in any area where there is a large water body present and widespread contamination is evident. The values to use under these conditions are the average of the 50th and 90th percentile values reported by Puffer (1981) and Pierce et al. (1981):

	50th percentile	90th percentile	Reference
	36.9 g/day	224.8 g/day	Puffer (1981)
	23.0 g/day (est)	54.0 g/day (est)	Pierce et al. (1981)
Average	30 g/day	140 g/day	

Additional factors to consider when using data derived from these studies include location, climate, and ethnic makeup of the fishing population.

Due to a lack of data, no specific values are recommended for small water bodies or for areas of localized contamination in large water bodies. For contaminated sites located in these areas, the following four procedures are recommended for consideration by assessors in the order presented:

(1) Interview local recreational fishermen in the affected area and obtain actual consumption rates. This would provide data comparable to the Puffer (1981) and Pierce et al. (1981) studies. Since consumption rates are likely to vary by region, climate, location, and the ethnic makeup of the population, local surveys would provide the most accurate data for exposure assessment purposes.

(2) Obtain productivity data for the area under consideration and divide this total catch data by the number of recreational fishermen (and family members) in the area. This will provide an average consumption rate assuming productivity data and population estimates were adequate.

(3) Estimate what portion of fish consumed in the local area is caught in the local area. This diet fraction could then be applied to the 50th and 90th percentile consumption rates recommended for large water bodies.

(4) Develop standard exposure scenarios assuming the number of fish meals eaten from the area per year and applying a meal size in the range of 100 to 200 g/meal.

2.6 Soil Ingestion and Pica

2.6.1 Background

All children mouth or ingest substances that are not considered food. This is usually a temporary behavior and is considered to be a normal phase of childhood development (Barltrop 1966, Bicknell 1974, Lourie et al. 1963). When this behavior persists beyond the age of about 18 months, the child is said to practice pica (Barltrop 1966, Robischon 1971, Ziai 1983). The extent to which a child practices pica is highly variable depending upon many factors, including nutrition, quality of care, and parental relationship (Behrman and Vaughan 1983, Bellinger et al. 1986, Bicknell 1967, Danford 1982, Danford et al. 1982, Forfar and Arneil 1984, Glickman et al. 1981). As stated by Danford (1987),* "No sharp demarcation exists between pathological states and normality, nor between the age at which some form of pica is considered normal." It is not felt that children who engage in pica are different from those who do not in any consistently predictable way (Feldman 1987).** According to Chisolm (1987),*** severe pica (i.e., abnormal ingestion of nonfood

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* D. Danford. Nutrition Coordinator Office, National Institutes of Health, Bethesda, MD. Personal communication with J. Konz (Versar) August 27, 1987.

** M.D. Feldman. Duke University Medical Center. Personal communication with J. Konz (Versar) August 7, 1987.

*** J. Chisolm. Francis Scott Key Medical Center, Baltimore, MD. Personal communication with J. Konz (Versar) July 27, 1987.

substances) is representative of grossly disturbed or mentally retarded children and will not be seen in the "normal" population.

As commonly used in the medical, behavioral, and psychological literature, however, pica refers to the ingestion of nonfood substances (see Table 2-19). This ingestion may be deliberate or may occur through the mouthing of objects or hands (Gallacher et al. 1984, Lepow et al. 1975, McAlpine and Singh 1986, Walker and Roberts 1983).

The literature reports a wide variety of substances that have been ingested including: soil, clay, sand, dust, grass, leaves, plaster, hair, starch, paint chips, string, soap, polish, cloth, insects, feces, ashes, cigarettes, matches, charcoal, plastic, crayons, wood, metal, powders, chalk, and paper (Adams and Sutker 1984, Albin 1977, Bellinger et al. 1986, Illingworth 1983, Lourie et al. 1963, Mahaffey 1981, Ziai 1983). The most common form of pica (in the study that differentiated among the objects ingested) was dirt eating, which occurred in 23 percent of the children studied (Cooper 1957). The range of substances mouthed or ingested decreases with increasing age (Barltrop 1966). Pica appears to be more common in populations of low socioeconomic status (Behrman and Vaughan 1983, Danford 1982, Glickman et al. 1981). Groups at high risk include infants, young children, and blacks--especially those who are brain-damaged, epileptic, or mentally retarded. Sources of information on pica are presented in Appendix 2D.

In conclusion, pica is defined in many ways (see Table 2-19). For purposes of this handbook, pica is defined as an abnormally high soil ingestion rate. No quantitative ingestion rates are recommended since children with known pica behavior have not been studied. The aim of this section is to discuss factors relevant to normal soil ingestion that occurs as a result of normal mouthing or unintentional hand-to-mouth activity. "Abnormal" soil ingestion (i.e., pica) is believed to be uncommon and may need to be addressed in cases involving sensitive population considerations.

Table 2-19. Definitions of Pica Used in the Research Literature

Reference	Pica definition
Adams and Sutker 1984	Persistent eating of nonnutritive substances
Albin 1977	Ingestion of nonnutritive substances
Anonymous 1975	Eating of substances usually considered inedible
Barltrop 1966	Persistent ingestion of nonedible substances after the age of 18 months
Behrman and Vaughan 1983	Repeated and chronic ingestion of inedible substances
Bicknell 1974	Eating objects not usually considered food
Bruhn and Pangborn 1971	Ingestion of nonfood items
Cooper 1957	Habit of eating clay, plastics, ashes, charcoal, etc.
Crosby 1976	Compulsive eating of anything
Feldman 1986	Repeated eating of a nonnutritive substance for at least 1 month
Forfar and Arneil 1984	Scavenging ... incessant eating
Gallacher et al. 1984	Ingestion of alien, nonfood substances
Glickman et al. 1981	Habitual ingestion of nonfood substances
Illingsworth 1983	Dirt eating
Kaplan and Sadock 1985	Persistent ingestion of nonnutritive substances
Keith et al. 1970	Denotes perversion of the appetite, ingestion of unnatural substances
Lepow et al. 1975	Ingestion or mouthing of nonfood items
Levine et al. 1983	Stubborn pursuit and ingestion of nonedible matters [sic]
Lourie et al. 1963	Craving for ingestion of a particular substance
Mace and Knight 1986	Ingestion of inedible objects
Mayer 1970	Persistent ingestion of substances commonly considered unfit as food
McAlpine and Singh 1986	Persistent eating of nonnutritive or inedible substances

Table 2-19. (continued)

Reference	Pica definition
Pueschel et al. 1978	Habitual intake of nonfood substances by young children beyond the oral stage of development
Robischon 1971	Habitual ingestion of nonedible substances
Sayetta 1986	Persistent, compulsive ingestion of any substance
Vermeer and Frate 1979	(Geophagia) the deliberate consumption of earth
Walker and Roberts 1983	Ingestion of inedible substances
Walter et al. 1980	Craving nonfood objects
Ziai 1983	Perversion of the appetite with persistent and purposeful ingestion of unsuitable substances seemingly of no nutrient value

2.6.2 Methods

Several studies have been conducted to characterize soil ingestion by children. Most of the earlier studies attempted to estimate the amount of soil ingested by measuring the amount of dirt present on children's hands and making generalizations based on behavior. Lepow et al. (1975) measured hand dirt by applying preweighed adhesive labels to the hands and weighing the amount of dirt that was removed. These researchers also observed "mouthing" behavior and reported that a child would put fingers or other "dirty" objects into his mouth about 10 times a day. The authors acknowledged, however, that the amount of hand dirt measured with this technique was an underestimate, since dirt trapped in skin folds and creases was not removed by the adhesive label.

Duggan and Williams (1977) estimated the amount of dust that would be retained on the forefinger and thumb by removing a small amount of dust from a weighed amount, rubbing the forefinger and thumb together, and reweighing to determine the amount retained on the finger and thumb. They then assumed that a child would suck his/her finger or thumb 10 times a day.

Day et al. (1975) estimated the amount of soil that might be ingested by measuring the amount of dirt that was transferred to a sticky sweet during 30 minutes of play. They then assumed that a child might eat from 2 to 20 such sweets per day.

During the past 2 years, studies have been conducted using a new methodology, that of measurement of trace elements in feces and soil which are believed to be poorly absorbed in the gut. These include studies by Binder et al. (1986) and Clausing et al. (1987). Similar studies are currently being conducted by USEPA and by the University of Massachusetts.

Binder et al. (1986) studied the ingestion of soil among children 1 to 3 years of age who wear diapers. The children studied were part of a larger study of residents living near a lead smelter in East Helena, Montana. Soiled diapers were collected over a 3-day period from

65 children (42 males and 23 females), and composited samples of soil were obtained from the children's yards. Both excreta and soil were analyzed for aluminum, silicon, and titanium, elements thought to be poorly absorbed in the gut and to have been present in the diet only in limited quantities, making them reasonable to use as tracers in a mass-balance calculation. Both soil and excreta measurements were obtained for 59 children. Using a standard assumed fecal dry weight of 15 g/day, soil ingestion by each child was estimated using each of the three tracer elements (assuming no absorption or nonsoil source of these elements). All ingestion rates were corrected to account for fecal sample losses.

Clausing et al. (1987) conducted a soil ingestion study with Dutch children using a tracer element methodology similar to that of Binder et al. (1986). Aluminum, titanium, and acid-insoluble residue (AIR) contents were determined for fecal samples from children, aged 2 to 4, attending a nursery school, and for samples of playground dirt at that school. Fecal samples were obtained daily over a 5-day period for the 18 children examined. Using the average soil concentrations present at the school, and assuming a standard fecal dry weight of 10 g/day, the authors calculated mass-balance estimates of soil ingestion for each material.

In a second sample, Clausing et al. (1987) collected fecal samples for six hospitalized, bedridden children. These children served as a control group, representing children who had very limited access to soil.

2.6.3 Results

(1) <u>Age of concern for soil ingestion</u>. Based on observational data, children are most likely to ingest soil from ages 1 to 6 (Walter et al. 1980, Cooper 1957, Charney et al. 1980, Sayre et al. 1974). Several researchers have investigated the age of occurrence of soil ingestion and the duration of the behavior. Soil ingestion is usually established by the 18th month and abnormal ingestion behavior may persist until age 6 or 7 (Walter et al. 1980, Cooper 1957, Charney et al. 1980, Sayre et al. 1974). Ingestion of nonfood substances beyond age 6 or 7 is usually the

result of inadvertent ingestion (e.g., from soil or dust present on fruits and vegetables) or developmental problems (Lourie et al. 1963, Paustenbach et al. 1986). As will be discussed subsequently, several investigators have proposed different soil ingestion rates for different age groups.

(2) Incidence of soil ingestion. All children will inadvertently ingest soil as part of a normal mouthing behavior. The incidence of abnormal soil ingestion behavior is more difficult to generalize. Statistics on the incidence of abnormal soil ingestion behavior are difficult to interpret for several reasons. Most information about abnormal soil ingestion behavior is derived from clinical data rather than research data. Because of this, the data base is not conclusive for the general population. For example, the occurrence of abnormal soil ingestion behavior is usually not a part of a child's medical history unless lead poisoning is suspected (Zamula 1986). Therefore, the actual incidence rate of abnormal soil ingestion behavior among children cannot be derived from the clinical data. The literature contains information based on several surveys of abnormal ingestion behavior; however, the groups were usually selected from a particular population (e.g., the group of children coming to a particular clinic) and are not necessarily representative of the general population. These surveys used different definitions of abnormal ingestion behavior, which resulted in inconsistencies in the evaluation of the results. There is also some evidence that the results may be biased because the subjects or the subjects' parents were reluctant to admit to abnormal ingestion behavior. The information obtained from these surveys is summarized in Table 2-20. According to these studies, the incidence rate for abnormal ingestion behavior in these selected groups of children ranges from 10 to 57 percent.

The incidence of abnormal ingestion behavior in children differs for different subpopulations. The incidence rate appears to be higher for black children than for white children. Approximately 30 percent of black children aged 1 to 6 years are reported to have abnormal ingestion behavior, compared with 10 to 18 percent of white children in the same age

Table 2-20. Incidence of Abnormal Ingestion Behavior in Selected Reports

Study area	Reference	Definition	Number of subjects	Description and/or age of group	Source of subjects	Percentage of population with abnormal ingestion behavior
Baltimore	Cooper (1957)	Habit of eating dirt, plaster, ashes, etc.	386	black, >6 months	Mental Hygiene Clinic	27
			398	white, >6 months		17
Washington, DC	Millican et al. (1962)	Ingestion of nonedible substances	486	low-income black, 1-2 years	Private patients	57
			294	middle-, upper-income white, 1-2 years		28
				low-income black, 2-3 years		39
				middle-, upper-income white, 2-3 years		20
				low-income black, 3-4 years		19
				middle-, upper-income white, 3-4 years		2
				low-income black, 4-5 years		20
				middle-, upper-income white, 4-5 years		4
				low income black, 5-6 years		17
				middle-,upper-income white, 5-6 years		2
				low income black, 1-6 years		32
				middle-, upper-income white, 1-6 years		10
Boston (interview)	Barltrop (1966)	Ingestion of nonedible substances after the age of 18 months	439	children, 1-2 years	Random sample from all children in Boston	42
(mail survey)			277	children, 1-2 years		48
				children, 2-3 years		23
				children, 2-3 years		41
				children, 3-4 years		18
				children, 3-4 years		30
				children, 4-5 years		7
				children, 4-5 years		30

Table 2-20. (continued)

Study area	Reference	Definition	Number of subjects	Description and/or age of group	Source of subjects	Percentage of population with abnormal ingestion behavior
Boston (interview)				children, 5-6 years		13
(mail survey)				children, 5-6 years		10
(continued)				children, 6+ years		15
				children, 6+ years		20
				children, 1-6 years		15
				children, 1-6 years		20
California	Bruhn and Pangborn (1971)	Ingestion of nonfood items	21	Hispanic children	Migrant families	32
Mississippi	Vermeer and Frate (1979)	Deliberate consumption of earth (geophagia)	115	rural children, 1-4 years	Random samples from rural Mississippi county	16
New York	Robischon (1971)	Habitual ingestion of nonedible substances	130	black, 19-24 months	Low income clinics	37

group (Danford 1982). There does not appear to be any sex difference in the incidence rates for males or females (Kaplan and Sadock 1985). Abnormal soil ingestion behavior appears to be more common in rural areas (Vermeer and Frate 1979); therefore, more children in these areas can be expected to practice this behavior.

Mentally retarded children have been identified as being especially prone to practice abnormal ingestion behavior. A child is considered mentally retarded if intelligence is below an IQ of 70 and behavioral development (e.g., eating, dressing, etc.) shows deficiencies (American Psychiatric Association 1980). Based on national statistics on mental retardation, approximately 9 percent of the 7 million mentally retarded people in the United States (or approximately 630,000) are children aged 1 to 6 years (Bureau of the Census 1986, Bouthilet 1987).* Of these, 89 percent are considered mildly retarded, 6 percent are moderately retarded, 3.5 percent are severely retarded, and 1.5 percent are profoundly retarded. Less than 2 percent of these children are institutionalized, predominantly those in the severely and profoundly retarded groups. The others live with their families, or in residential facilities within their communities (Bouthilet 1987).* Although it would be useful to know how the severity of abnormal ingestion behavior is distributed among the different classes of mentally retarded children (i.e., whether the problem is worse in the severely and profoundly retarded groups), these data have not been collected (Bouthilet 1987).* Data from mentally retarded adults show a 10 percent incidence in mildly retarded adults and a 33 percent incidence in severely retarded adults (Feldman 1986). However, these rates may not be relevant to children. In general, it can be assumed that abnormal ingestion behavior is more frequent and more severe in mentally retarded children than in children

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* G. Bouthilet, Research Coordinator, President's Committee on Mental Retardation, Washington, DC. Personal communication with J. Konz (Versar) August 17, 1987.

in the general population (Behrman and Vaughan 1983, Danford 1982, Forfar and Arneil 1984, Illingworth 1983, Sayetta 1986). However, the incidence rate in this subpopulation has not been reported.

As previously discussed, the incidence rate data are primarily based on abnormal ingestion behavior among selected (e.g., clinical, rural, low income) groups and are not representative of the general population. Based on the data from the four tracer studies (Binder et al. 1986, Clausing et al. 1987, USEPA, and University of Massachusetts), only one child out of the 240 involved in all of these studies ingested an amount of soil significantly greater than the range for other children.* Although these studies did not include all populations and were representative of short-term ingestions only, it will be assumed that the incidence rate of abnormal soil ingestion behavior in the general population is extremely low.

(3) Amount ingested. The normal amount of soil ingested by children has been investigated by several researchers whose work has been summarized by Paustenbach et al. (1986). These researchers have estimated different amounts ingested depending upon the age of the child. The environmental setting is also an important variable; rural areas appear to be associated with higher ingestion rates (Vermeer and Frate 1979). Estimates of the amount of soil ingested are presented in Table 2-21. The support of these estimates varies widely from judgment to experimental evidence.

Hawley (1985), using existing literature, developed scenarios for estimating exposure of young children, older children, and adults to contaminated soil. His approach to estimating levels of ingestion is presented here (see Table 2-22). Each year was divided into two activity periods, May through October, when individuals were assumed to spend much

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* J. Schaum, USEPA. Personal communication with J. Konz (Versar) March 31, 1988.

Table 2-21. Soil Ingestion According to Age

Study reference	Amount ingested at specified age (mg/day)							Type of evidence
	Children	Toddler	2.5	1-3	2-4	6	Adult clay eaters (average)	
Duggan and Williams (1977)	20							Measurement of dust on fingers
Lepow et al. (1974, 1975)	100							Measurement of dirt on hands
Barltrop (1973)		100						Not available
NRC (1980)	40							Not available
Day et al. (1975)	100							Measurement of dirt on sticky sweets
Bryce-Smith (1974)	33							Not specified
EPA (1984a)	100							Summary of others
Hawley (1985)	100		165			25		Specific scenarios using data from others
Binder et al. (1986)				180-1800				Tracer study
Clausing et al. (1987)					130-1400			Tracer study
Vermeer and Frate (1979)							50,000	Questionnaire

Source: Adapted from Paustenbach et al. (1986).

Table 2-22. Estimates of Soil Ingestion from Dermal Contact

Scenarios	Exposure (mg/day)	Days/year activity	Annual average (mg/day)
Young child (2.5 years old)			
Outdoor activities (summer)	250	130	90
Indoor activities (summer)	50	182	25
Indoor activities (winter)	100	182	50
			165
Older child (6 years old)			
Outdoor activities (summer)	50	152	21
Indoor activities (year-round)	3	365	3
			24
Adult			
Work in attic (year-round)	110	12	3.7
Living space (year-round)	0.56	365	0.56
Outdoor work (summer)	480	43	57
			61.26

Source: Hawley (1985).

time outdoors, and November through April, when weather conditions were assumed to eliminate outdoor exposure to soil. The following estimates were made by Hawley (1985):

1. <u>Young children (2.5 years old, 13.2 kg)</u>

   Outdoor activity, May through October, 5 days/week: 250 mg/day. Estimate based on analysis of data from Lepow et al. (1974, 1975), who hypothesized 250 mg ingestion after experiments showing that dirt from a 21.5 cm^2 area of a child's hand typically had a mass of 11 mg. Additionally, Roels et al. (1980) measured contamination of children's hands by metal contaminants of soil while the children were active on playgrounds. These data led to an estimate of 40 to 180 mg dirt being present on the dominant hand of an 11-year-old (said to be equivalent in area to both hands of a 2.5-year-old).

   Indoor activity, May through October: Child assumed to ingest 50 mg of household dust each day. Reference was made to the previously cited experimental data.

   Indoor activity, November through April: 100 mg/day ingestion assumed because of the longer period of indoor activity.

2. <u>Older child (6 years old, 20.8 kg)</u>

   Outdoor activity, May through October: 50 mg/day. Using the surface dust value cited from Lepow et al. (1974) of 0.51 mg/cm^2 on skin, a child is assumed to ingest dirt from an area equal to the area of the fingers on one hand.

   Indoor activity, year-round: 3 mg/day. Indoors, the child is assumed to have dermal dirt present at the reduced level of 0.056 mg/cm^2, which is the quantity of dirt estimated by the authors to be present on surfaces within the home. Dirt from inside surfaces of hands is assumed to be ingested.

3. <u>Adult (70 kg)</u>

   Work in attics or other uncleaned areas of a house, 12 days/year: 110 mg/day. Estimate based on ingestion of a 50-μm-thick dust layer from the inside surfaces of the fingers and thumb of one hand while eating food or handling cigarettes. Data from Wolfe et al. (1974) are cited to support dust intake while smoking cigarettes.

   Living space activities: 0.56 mg/day. Adults' hands are assumed to have dust contamination equal to that on indoor surfaces (0.056 mg/cm^2), and dust is ingested from a 10 cm^2 area of skin while eating or smoking.

> Outdoor activities, May through October: 480 mg/active day. The adult is assumed to be engaged in yard work or other outdoor physical activity for 8 hours/day, 2 days/week. The estimate is based on ingesting a 50 μm-thick layer of soil from the inside surfaces of the fingers and thumb of one hand twice daily. These estimates are summarized in Table 2-21.

The average quantity of soil ingested by the children in the Binder et al. (1986) study was estimated at 181 mg/day (range 25 to 1,324) (aluminum tracer); 184 mg/day (range 31 to 799) (silicon tracer); and 1,830 mg/day (range 4 to 17,000) (titanium). The overall soil ingestion estimate based on the minimum of the three individual element ingestion estimates for each child was 108 mg/day (range 4 to 708).

The authors were not able to explain the difference between the results for titanium and for the other two elements, but speculated that other dietary sources would account for the increased levels. The frequency distribution graph of soil ingestion estimates based on titanium shows that a group of 21 children had particularly high titanium values, >1,000 mg/day; the remainder of the children showed titanium ingestion estimates at lower levels, with a distribution more comparable to that for the other elements.

The average quantity of soil (based on individual tracer elements) ingested by children in the Clausing et al. (1987) study was as follows: aluminum, average 230 mg/day (range 23 to 979); AIR, average 129 mg/day (range 48 to 362); and titanium, average 1,430 mg/day (range 64 to 11,620). As in the Binder et al. (1986) study, a fraction of the children (6/19) showed titanium values of well above 1,000 mg/day, with most of the remaining children showing substantially lower values. Based on the minimum of the three chemical measurements for each child, an estimate of 105 mg/day, with a range of 23 to 362, was obtained.

A mass-balance calculation for the hospitalized children in the Clausing et al. (1987) study yielded estimates of 56 mg/day based on aluminum. For titanium, three of the children had estimates well in excess of 1,000 mg/day, with the remaining three children in the range of 28 to 58 mg/day. The data on hospitalized children suggest a major nonsoil source of titanium for some children, and may suggest a background nonsoil source of aluminum. However, conditions specific to hospitalization, e.g., medications, need to be considered. AIR measurements were not reported for the hospitalized children. Speculation as to the source of titanium includes the white coloring in (disposable) diapers and several other items, but this has not as yet been investigated.

The amount of soil ingested by children with abnormal soil ingestion behavior has not been measured. Although no values have been reported in the literature, some evidence suggests that a rate on the order of 5 to 10 g/day may not be unreasonable. The value of 5 g/day was used by USEPA in the risk assessment for TCDD (USEPA 1984b). A value of 10 g/day was used by the USDA in conducting exposure assessments in relation to the use of sludge in gardens and soils. This value is not published but is used as a general rule of thumb (Chaney 1987).*

In conducting its exposure assessment for TCDD, the Centers for Disease Control also investigated the potential for exposure through the soil ingestion route. In this study, a value of 10 g/day was suggested as the amount of soil that a child with abnormal soil ingestion behavior might ingest (Kimbrough et al. 1984).

Two additional studies may provide more recent information on the subject of the amount of soil ingested by children. One study being conducted at the University of Massachusetts involves the development of a soil ingestion profile. The other is a study being carried out in Thailand that investigates the amount of clay that is eaten by children and adults who intentionally ingest the clay. The University of Massachusetts study was completed in 1988 (Calabrese et al. 1989) but was not available for review for this report. Results from the study in Thailand should be available in 1989.

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* R.L. Chaney. U.S. Agricultural Research Service, Beltsville, MD. Personal communication with J. Konz (Versar) August 17, 1987.

Another source of data on abnormal ingestion behavior is the second National Health and Nutrition Examination Survey. This survey collected data on the medical history of 6,839 people aged 6 months to 11 years. The medical history contained information on abnormal ingestion behavior; however, the data have not yet been published.

The data from the tracer element studies, Binder et al. (1986) and Clausing et al. (1987), provide support for a preliminary estimate of average soil ingestion by children on the order of 100 to 200 mg/day, consistent with the "low" estimate reported by other researchers (see Table 2-21). These estimates are based on findings with silicon or AIR and aluminum. Estimates based on a titanium tracer are higher by a factor of 5 to 10 and were not used to derive the average value. This discrepancy has not been explained, but may be due to inadvertent sample contamination or to dietary sources other than soil. Recent unpublished data indicate that dietary contribution should be considered in calculations of soil ingestion using tracer elements (USEPA, University of Massachusetts). Hawley (1985), who estimated quantities of soil likely to be present on skin and subsequently ingested, also arrived at an estimate in the above range. It should be noted that Hawley's approach would not address children who deliberately ingest dirt or mouth soiled objects.

Binder et al. (1986) and Clausing et al. (1987) also provided some limited information on the upper range of soil ingestion in children. With the exception of the titanium data, the two studies provide evidence of an upper range of soil ingestion in children on the order of 800 mg/day or more. It should be noted that both studies had limited sample sizes and that neither specifically included children with abnormal soil ingestion behavior. Again, estimates based on titanium would be substantially higher, on the order of 20 g/day.

Calabrese et al. (1987) have recently summarized the data on soil ingestion from available studies. Based on the data and the authors' opinions, various levels of consumption have been suggested to represent the range of soil ingestion rates experienced by different categories of children. Level 1 represents the child with the lowest tendency to ingestion soil, while Levels 2 and 3 are intermediate levels. Level 4 represents the child with abnormal soil ingestion behavior. These results are presented in Table 2-23. As discussed by Calabrese et al. (1987), a high level of uncertainty is associated with all values.

The EPA is sponsoring a study of soil ingestion by children, using the tracer element methodology. Preliminary research has included a study in miniature swine to assess the assumption that the tracer elements are poorly absorbed, and to provide an experimental check on mass-balance calculations.

The study in children includes a pre-pilot study to test field methods and to address possible nonsoil sources of titanium. A randomly selected sampling of 100 children was selected to provide a population-based estimate of soil ingestion in one location (the Richland, Washington, area). Dietary contributions to tracer element intake will be measured in this study. The field work for this study is complete and the results will be available in late 1989.

Inadvertent soil ingestion occurs among adults as well as children. While actual measurements of adult soil ingestion have not been made, Hawley (1985) estimated that soil ingestion could be 61 mg/day, based largely on unsupported assumptions regarding activity patterns and corresponding ingestion amounts. Calabrese et al. (1987) have suggested a range from 1 to 100 mg/day. These ingestion rates are less than the 100 to 1,000 mg/day measured in children by Binder et al. (1986) and Clausing et al. (1987). However, the longer exposure periods for adults (ages 7 to 70) suggest that total adult soil ingestion quantities could be of the same magnitude as those for children (ages 2 to 6) even if ingestion rates are lower.

2.6.4 Conclusion

Based on this review of the limited data now available, the studies of Binder et al. (1986) and Clausing et al. (1987) appeared to be the

Table 2-23. Estimates of Soil Ingestion by Age and Degree of Ingestion

Age	Soil ingestion range (mg/day)[a]			
	Level 1	Level 2	Level 3	Level 4
0-9 months	0	0	0	0
9-18 months	5	50	50	1,000
1.5-3.5 years	10	200	1,000	10,000
3.5-5.0 years	5	50	50	1,000
5-18 years	1	10	10	100
18 years	1	10	10	100

[a] Level 1 - Represents child with low tendency to ingest soil; based in part on data from Rabinowitz and Bellinger (1986).

Levels 2 and 3 - Represent child with intermediate tendency to ingest soil; based in part on data from Binder et al. (1986) and Clausing et al. (1987).

Level 4 - Based on CDC estimates (Kimbrough et al. 1984), considered to be overestimates of normal soil ingestion behavior. May be representative of child with a high tendency to ingest soil.

Source: Calabrese et al. (1987).

most reliable. These studies suggest the following values for soil ingestion: average soil ingestion in the population of young children (under the age of 7) is estimated at approximately 0.1 to 0.2 g/day. For calculation purposes, an estimate of 0.2 g/day is suggested as an average value. An upper-range ingestion estimate among children with a higher tendency to ingest soil materials is 0.8 g/day. These estimates are based on data using silicon, aluminum, and AIR as trace elements. The reason for the higher estimates for titanium are likely to be due to non-soil factors such as other dietary factors. The upper ends of the range values for silicon, aluminum, and AIR were used for the upper bound estimate because of the small sample size used in these studies (i.e., cannot distinguish 90th percentile).

Soil ingestion rates for children who exhibit abnormal soil ingestion behavior and for people older than 6 cannot be recommended because of the lack of data.

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APPENDIX 2A

National Marine Fisheries Service
Recreational Fishing Data

Appendix 2A

National Marine Fisheries Service Recreational Fishing Data

The National Marine Fisheries Service (NMFS) estimated recreational marine catch from intercept surveys of fishermen in the field and an independent telephone survey of households. In 1985, the marine recreational finfish catch in the United States, excluding fish caught in Alaska and Hawaii and Pacific Coast salmon, was an estimated 425 million fish weighing 717.3 million pounds (NMFS 1986a). The estimated number of marine recreational fishermen, which has been relatively stable over the last few years, is 17 million. The size of the population that consumes the national recreational marine catch has not been measured.

Recreational marine fish catch data from the Atlantic and Gulf Coasts for 1985 is presented by species and region in Table 2A-1 (NMFS 1986b). Catch quantities include catch brought ashore in whole form and available for identification during the interview; fish not available for identification and those released alive, discarded dead, filleted, or used for bait are excluded. Weights (including inedible portions) and lengths of the identified fish were measured. Of the approximately 114 million kilograms of fish caught on the Atlantic and Gulf Coasts, the smallest portion of the total catch was made in the North Atlantic. Over one half of the recreational marine catch occurred within 3 miles of the shore or in inland waterways. The data in Table 2A-2 demonstrate the effect of season and local climate on the size of recreational catch. Total catch weight for the Atlantic declines significantly from November throughout February, but the Gulf Coast catch rate remains fairly stable throughout the year. Estimated total numbers of sport fishermen by state and subregion are given in Table 2A-3. These totals may include fishermen who participate but take no fish home for consumption.

Similar data for the Pacific Coast are presented in Tables 2A4 through 2A6 (NMFS 1986c). Table 2A-4 shows that over 80 percent of the 12.7 million kg total Pacific Coast recreational catch (excluding Hawaii and Alaska occurs along the California coast. As in the Atlantic, the majority of the recreational marine catch is taken within 3 miles of the shore or from inland waterways. Table 2A-5 shows seasonal fluctuations in the recreational catch; May through October are the peak recreational fishing months for the Pacific Coast. The estimated total number of participants is given according to regions in Table 2A-6.

Table 2A-1. Estimated Weight of Fish Caught (Catch Type A)[a] by Marine Recreational Fishermen by Species Group and Subregion

Species group	North Atlantic (1,000 kg)	Mid-Atlantic (1,000 kg)	South Atlantic (1,000 kg)	Gulf (1,000 kg)	All regions (1,000 kg)
01. Sharks	*[b]	2,165	1,521	1,618	5,305
02. Sharks, Dogfish	--[c]	126	--	*	148
03. Skates/Rays	--	--	--	--	110
04. Eels	22	73	*	--	95
05. Herrings	19	31	--	--	54
06. Freshwater Catfishes	*	138	--	--	142
07. Saltwater Catfishes	*	*	161	226	387
08. Toadfishes	--	18	--	--	20
09. Atlantic Cod	2,128	311	*	*	2,439
10. Atlantic Tomcod	22	--	*	*	22
11. Pollock	94	--	*	*	128
12. Silver Hake	--	21	*	*	23
13. Searobins	22	70	*	--	92
14. Sculpins	--	--	*	*	--
15. White Perch	--	82	14	*	104
16. Striped Bass	169	149	--	--	332
17. Black Sea Bass	9	1,084	1,125	843	3,061
18. Groupers	*	*	947	2,881	3,827
19. Sea Basses	--	--	29	17	47
20. Bluefish	9,283	10,733	7,108	213	27,337
21. Jack Crevalle	*	*	230	247	478
22. Blue Runner	*	*	56	42	98
23. Greater Amberjack	*	*	668	925	1,593
24. Florida Pompano	*	--	81	--	93
25. Jacks	*	--	67	257	325
26. Dolphins	*	--	1,745	262	2,040
27. Gray Snapper	*	*	347	369	716
28. Red Snapper	*	*	803	1,865	2,667
29. Lane Snapper	*	*	31	47	78
30. Vermilion Snapper	*	*	138	54	192
31. Yellowtail Snapper	*	*	36	197	232
32. Snappers	*	*	74	68	142
33. Pigfish	*	5	100	19	124
34. White Grunt	*	*	43	605	648
35. Grunts	*	--	95	149	245
36. Scup	1,441	1,537	--	*	2,977
37. Pinefish	*	--	86	46	132
38. Sheepshead	*	*	413	1,088	1,501
39. Red Porgy	*	*	107	126	233
40. Porgies	*	--	89	66	156

Table 2A-1. (continued)

Species group	North Atlantic (1,000 kg)	Mid-Atlantic (1,000 kg)	South Atlantic (1,000 kg)	Gulf (1,000 kg)	All regions (1,000 kg)
41. Spotted Seatrout	*	--	931	3,222	4,178
42. Weakfish	--	1,969	157	*	2,218
43. Sand Seatrout	*	*	*	1.392	1.392
44. Silver Perch	*	*	19	20	39
45. Spot	*	1,248	1,222	4	2,473
46. Kingfishes	*	17	485	298	800
47. Atlantic Croaker	*	527	441	821	1,788
48. Black Drum	*	--	295	785	1,311
49. Red Drum	*	*	610	2,217	2,828
50. Drums	*	--	49	196	246
51. Mullets	*	7	130	196	333
52. Barracudas	*	*	230	240	470
53. Tautog	355	1,758	--	*	2,116
54. Cunner	11	--	*	*	15
55. Little Tunny/ATL Bonito	--	208	506	321	1,062
56. Atlantic Mackerel	479	988	*	*	1,467
57. King Mackerel	*	--	4,571	684	5,258
58. Spanish Mackerel	*	*	425	528	953
59. Tunas/Mackerels	--	2,328	5,401	115	8,985
60. Summer Flounder	202	3,966	597	*	4,765
61. Gulf Flounder	*	*	--	240	245
62. Southern Flounder	*	--	210	734	948
63. Winter Flounder	2,380	5,837	*	*	8,217
64. Flounders	--	21	--	50	77
65. Triggerfishes/Filefishes	*	--	165	203	379
66. Puffers	--	30	36	--	70
67. Other Fishes	108	282	1,180	1,130	2,701
TOTALS	18,045	36,074	33,876	25,684	113,679

[a] Catch Type A is an estimate of part of the total catch based on fish brought ashore in whole form, available for interviewer identification and enumeration, from which samples of lengths and weights were obtained.

[b] An asterisk (*) denotes none reported.

[c] A dash denotes no information available.

Table 2A-2. Estimated Weight of Fish Caught (Catch Type A)[a] by Marine Recreational Fishermen by Wave and Subregion January 1985 - December 1985

Wave	Subregion	Weight
Jan/Feb	South Atlantic	2,345
	Gulf	4,355
	TOTAL	6,700
Mar/Apr	North Atlantic	1,348
	Mid Atlantic	8,063
	South Atlantic	9,884
	Gulf	2,315
	TOTAL	21,609
May/Jun	North Atlantic	3,818
	Mid Atlantic	9,339
	South Atlantic	6,325
	Gulf	5,096
	TOTAL	24,577
Jul/Aug	North Atlantic	4,928
	Mid Atlantic	6,221
	South Atlantic	4,002
	Gulf	5,403
	TOTAL	20,554
Sep/Oct	North Atlantic	7,516
	Mid Atlantic	10,259
	South Atlantic	8,731
	Guld	4,720
	TOTAL	31,227
Nov/Dec	North Atlantic	436
	Mid Atlantic	2,193
	South Atlantic	2,588
	Gulf	3,795
	TOTAL	9,012
	GRAND TOTAL	113,679

[a] Catch Type A is an estimate of part of the total catch based on fish brought ashore in whole form, available for interviewer identification and enumeration, from which samples of lengths and weights were obtained.

Table 2A-3. Estimated Number of Participants in Marine Recreational Fishing by State and Subregion for the Atlantic and Gulf Coasts January 1985 - December 1985

Subregion	State	Coastal participants (thousands)	Non-coastal participants (thousands)	Out of state (1) (thousands)	Total participants in state (1) (thousands)
North Atlantic	Connecticut	284	*[a]	78	362
	Std. Err.	203	*	42	208
	Maine	125	38	115	277
	Std. Err.	94	32	88	133
	Massachusetts	760	110	710	1,580
	Std. Err.	620	75	333	707
	New Hampshire	18	1	22	41
	Std. Err.	11	1	12	16
	Rhode Island	188	*	362	550
	Std. Err.	116	*	149	189
	TOTALS	1,374	149		
	Std. Errs.	669	81		
Mid Atlantic	Delaware	38	*	91	128
	Std. Err.	29	*	56	63
	Maryland	366	18	213	597
	Std. Err.	248	11	109	271
	New Jersey	625	4	1,170	1,799
	Std. Err.	542	5	747	923
	New York	612	20	72	704
	Std. Err.	458	32	75	465
	Virginia	528	71	310	909
	Std. Err.	347	48	163	387
	TOTALS	2,168	114		
	Std. Errs.	828	58		

[a]An asterisk denotes none reported.

(1) = not additive across states. One person can be counted as "out-of-state" for more than one state.

Table 2A-4. Estimated Weight of Fish Caught (Catch Type A)[a] by Marine Recreational Fishermen by Species Group and Subregion January 1985 to December 1985

Species group	Southern California (1,000 kg)	Northern California (1,000 kg)	Oregon (1,000 kg)	Washington (1,000 kg)	All regions (1,000 kg)
01. Spiny Dogfish	--[b]	--	*[c]	7	57
02. Sharks, Other	253	--	*	*	401
03. Sturgeons	*	--	--	--	--
04. Pacific Herring	*	7	--	0[d]	7
05. Northern Anchovy	--	--	--	*	--
06. Surf Smelt	*	46	2	1	48
07. Smelts, Other	*	*	--	--	--
08. Pacific Cod	*	*	*	78	78
09. Pacific Tomcod	*	--	--	--	--
10. Walleye Pollock	*	*	*	158	158
11. Pacific Hake	--	49	*	--	58
12. Silversides	*	*	--	*	0
13. Jacksmelt	40	7	*	*	47
14. Striped Bass	--	58	--	*	62
15. Kelp Bass	354	*	*	*	354
16. Spotted Sand Bass	29	*	*	*	29
17. Barred Sand Bass	431	*	*	*	431
19. Yellowtail	179	*	*	*	179
20. White Croaker	78	142	*	*	--
21. California Corbina	--	*	*	*	--
22. Queenfish	14	*	*	*	14
23. Croakers, Other	57	--	*	*	58
24. Opaleye	21	*	*	*	21
25. Halfmoon	10	*	*	*	10
26. Shiner Perch	--	1	--	--	1
27. Striped Seaperch	--	20	27	--	55
28. Black Perch	12	--	*	*	15
29. Walleye Surfperch	9	6	--	--	20
30. Silver Surfperch	10	9	--	--	20
31. White Seaperch	--	--	--	*	10
32. Pile Perch	--	--	21	15	60
33. Redtail Surfperch	*	29	34	53	116
34. Barred Surfperch	75	24	*	*	99
35. Surfperches, Other	15	7	--	--	22
36. Pacific Barracuda	132	*	*	*	132
37. California Sheephead	132	*	*	*	132
38. Pacific Bonito	267	--	*	*	268
39. Chub Mackerel	684	37	--	*	721

Table 2A-4. (continued)

Species group	Southern California (1,000 kg)	Northern California (1,000 kg)	Oregon (1,000 kg)	Washington (1,000 kg)	All regions (1,000 kg)
40. Tunas	612	333	*	*	945
41. Brown Rockfish	89	121	*	21	231
42. Copper Rockfish	140	134	--	78	355
43. Widow Rockfish	34	18	--	--	54
44. Yellowtail Rockfish	151	238	45	--	441
45. Chilipepper Rockfish	203	159	*	*	362
46. Quillback Rockfish	--	--	--	61	78
47. Black Rockfish	34	430	354	219	1,037
48. Blue Rockfish	138	258	43	--	451
49. Bocaccio	298	64	--	--	366
50. Canary Rockfish	33	129	60	--	229
51. Greensoptted Rockfish	159	75	*	*	235
52. Olive Rockfish	108	28	*	*	136
53. Gopher Rockfish	104	30	*	*	134
54. California Scorpionfish	63	*	*	*	63
55. Rockfishes, Other	601	280	47	--	952
56. Sablefish	--	--	*	--	34
57. Kelp Greenling	--	28	18	--	64
58. Lingcod	128	760	175	162	1,225
59. Greenlings, Other	*	--	--	--	10
60. Cabezon	29	39	--	--	106
61. Sculpins, Other	--	--	--	--	6
62. Sanddabs	11	39	--	16	65
63. California Halibut	227	--	*	*	252
64. Rock Sole	--	--	*	16	24
65. Starry Flounder	--	--	--	--	--
66. Flatfishes, Other	--	--	--	87	106
67. Other Fish	184	107	179	--	479
TOTALS	6,248	4,064	1,069	1,364	12,745

[a] Catch Type A is an estimate of part of the total catch based on fish brought ashore in whole form, available for interviewer identification and enumeration, from which samples of lengths and weights were obtained.

[b] A dash denotes no information available.

[c] An asterisk (*) denotes none reported.

[d] A zero (0) indicates less than one thousand.

Table 2A-5. Estimated Weight of Fish Caught (Catch Type A)[a] by Marine Recreational Fishermen by Wave and Subregion
January 1985 - December 1985

Wave	Subregion	Weight
Jan/Feb	Southern California	827
	Northern California	365
	Oregon	27
	Washington	75
	TOTAL	1,294
Mar/Apr	Southern California	495
	Northern California	253
	Oregon	43
	Washington	144
	TOTAL	935
May/Jun	Southern California	1,201
	Northern California	489
	Oregon	366
	Washington	617
	TOTAL	2,673
Jul/Aug	Southern California	1,757
	Northern California	1,543
	Oregon	42
	Washington	425
	TOTAL	3,768
Sep/Oct	Southern California	921
	Northern California	1,006
	Oregon	505
	Washington	67
	TOTAL	2,499
Nov/Dec	Southern California	1,047
	Northern California	408
	Oregon	86
	Washington	35
	TOTAL	1,576
	GRAND TOTAL	12,745

[a] Catch Type A is an estimate of part of the total catch based on fish brought ashore in whole form, available for interviewer identification and enumeration, from which samples of lengths and weights were obtained.

Table 2A-6. Estimated Number of Participants in Marine Recreational Fishing by Subregion for the Pacific Coast January 1985 - December 1986

Subregion	Coastal participants (thousands)	Non-coastal participants (thousands)	Out of state (1) (thousands)	Total participants in state (1) (thousands)
Southern California	994	50	344	1,389
Standard Error	1,427	44	193	1,441
Northern California	624	101	62	787
Standard Error	783	92	52	790
Oregon	188	22	35	245
Standard Error	234	18	35	237
Washington	252	34	46	333
Standard Error	352	32	43	356
GRAND TOTALS	2,058	208		
Standard Errors	1,682	108		

(1) = Not additive across states. One person can be counted as "out of state" for more than one state.

APPENDIX 2B

Method of Calculation: Weighted Means and Percentiles

Appendix 2B

Method of Calculation: Weighted Means and Percentiles

The weighted mean of N respondents from the survey having weights W_1, W_2, ... W_n and monthly fish consumption C_1, C_2, ..., C_n is computed as follows:

$$\text{Mean consumption} = \sum_{i=1}^{N} W_i C_i / \sum_{i=1}^{N} W_i .$$

The weight W_i is the number of fish consumers represented by the ith survey respondent. The sum of all the weights represents the average number of U.S. fish consumers during the survey year.

The 95th percentile of fish consumption was also computed on a weighted basis; no assumptions about the data distribution were made. Using the same parameters described above, the consumption rates of individuals in a subset can be ordered so the $C_1 \leq C_2 \leq \ldots \leq C_n$. The 95th percentile of fish consumption for N respondents is defined as the consumption of the jth individual such that:

$$\sum_{i=1}^{j-1} W_i < (0.95) \sum_{i=1}^{N} W_i .$$

The sum of the weights of the individuals in the subset with consumption less than the jth person is less than 95 percent of the total weight of the subset, or:

$$\sum_{i=1}^{j} W_i \geq (0.95) \sum_{i=1}^{N} W_i .$$

The sum of the weights of individuals in the subset with consumption equal to or less than the jth person's is 95 percent or more of the total weight of the subset.

APPENDIX 2C

Studies of Consumption of Recreationally Caught Fish

Appendix 2C

Studies of Consumption of Recreationally Caught Fish

The primary data requirements for determining consumption rates of fish and shellfish that are caught by sport fishermen are catch quantities, the number of fishermen making the catch, and the total number of people who consume the catch. The average number of people in the family or living group of the fisherman is usually assumed to be the number of people consuming the fish. For simplicity, it is assumed that each person in the family eats equal portions of the catch. The practice of giving away part or all of a catch to people outside of the family is rarely measured and is therefore generally ignored.

The following factors must also be considered in estimating consumption rates:

(1) The proportional quantity of the total catch that is taken home for consumption. All or part of the catch may be released alive, used for bait, or discarded dead.

(2) The portion of the total fish weight that is edible. This fraction may vary with species, but usually one value is applied to all species.

(3) Fishing frequency, which determines the level of consumption, shows seasonal variations; however, for simplicity, the frequency of consumption of recreationally caught fish is assumed to be constant over the year.

(4) In some studies, an average fish weight for each species may be used with the catch number to obtain the catch weight. The resulting catch estimates are accurate if the catch weight for a species follows a normal distribution. However, if, on the whole, more small fish are caught than large ones, the total catch weight may be overestimated by using an average species weight.

Perhaps the most thorough recreational survey was conducted in the Los Angeles area by Puffer (1981). The survey of 12 fishing locations in the harbor and coastal areas was conducted for the full 1980 calendar year; each site was surveyed an average of three times per month on different days and at a different time of the day. A total of 1,059 interviews with fishermen were conducted. The sample number was extrapolated to an estimated 91,606 total unique fishermen in the area. Including family/living groups, the total population estimated to consume locally caught fish was 342,606.

Puffer used the following formula to calculate the consumption of sportfishing catch in the Los Angeles area:

$$\text{Consumption} = K \times NW/E \times F/365$$

where

K = edible proportion of fish,
F = frequency of fishing/year,
E = number of fish eaters in family/living group,
W = average weight of fish in catch, and
N = number of fish in catch.

Assumptions inherent in the calculations are the following:

(1) Amount of fish and average weight of fish per catch is constant.

(2) The frequency of fishing for each fisherman is constant throughout the year.

(3) The number of family fish-eaters is constant (greater than zero), and the catch is shared evenly among family members.

(4) All of the catch is eaten, and 25 to 50 percent of the weight of the fish is edible.

Consumption rates were calculated only for those fishermen who indicated that they eat the fish they catch.

The median consumption rate for total fish and shellfish is approximately 37 g/person/day. Consumption data in Table 2C-1, organized by species, show that California halibut is consumed in the largest quantities. Table 2C-2 shows differences in the participation and consumption rates of ethnic groups. Although Caucasians make up the largest percent of fishermen interviewed, the fish consumption rate for Oriental/Samoan fishermen and their families is considerably higher than for other groups.

Table 2C-1. Description of Consumption Patterns for Primary Fish Kept by Sport Fishermen (n = 1059)

Species	Percent of fishermen who consume/give away		Median consumption (g/person/day)
White Croaker	82%	15%	14.8
Pacific Mackerel	74%	15%	35.8
Pacific Bonito	77%	18%	63.6
Queenfish	79%	13%	7.8
Jacksmelt	78%	16%	9.4
Walleye Perch	83%	7%	5.4
Shiner Perch	67%	10%	2.0
Opaleye	87%	7%	16.1
Black Perch	89%	5%	8.1
Kelp Bass	78%	2%	3.9
California Halibut	86%	8%	143.1
Shellfish[a]	97%	0%	10.0

[a] Crab, mussels, lobster, abalone.

Source: Puffer (1981).

Table 2C-2. Demographic Data of Sport Fishermen and Their Family/Living Group

Ethnic group	Percent of total interviewed	Median consumption (g/person/day)
Caucasian	42	46.0
Black	24	24.2
Mexican-American	16	33.0
Oriental/Samoan	13	70.6
Other	5	

Source: Puffer (1981).

Another local survey of sportfishing was performed in Commencement Bay, Washington, by Pierce et al. (1981). This survey was conducted by interviewing fishermen along Commencement Bay waterways in Tacoma, Washington, for 5 consecutive days in the summer and 4 consecutive days in the fall. The total number of interviews was 304 in the summer and 204 in the fall, and the total number of unique fishermen was calculated at 3,391. The ethnic makeup of the fishermen surveyed is presented in Table 2C-3.

Table 2C-4 contains catch data by species obtained from the survey. The mean daily catch (kilograms/day) was calculated from the total summer and fall catch quantities during the survey. Therefore, the mean value may not be entirely representative because winter and spring fishing were omitted.

The formula of Puffer (1981) can be used for the Commencement Bay sport catch data because the following factors were measured:

(1) Interviews with fishermen suggested that, on the average, 98 percent of the catch is eaten.

(2) The average number of fishermen per day is 53.

(3) The average size of the family or living group of the fishermen was 3.74 persons.

(4) The edible portion of all fish caught was assumed to be 49 percent of the total weight.

Thus,

mean daily fish consumption = [mean daily catch/(fishermen x family size)] x 0.98 x 0.49.

Calculated mean daily consumption of recreationally caught fish is listed by species in the fourth column in Table 2C-4. The largest proportion of the fishermen is composed of weekly fishermen. Fishing frequencies obtained in the study can be used to obtain cumulative frequencies and to calculate yearly fish consumption for each group (see Table 2-17 in this handbook).

Table 2C-3. Commencement Bay Ethnic Makeup of Fishermen Surveyed

Ethnic group	Summer	Fall
White	58.9%	60.8%
Black	22.7%	15.2%
Oriental	15.5%	23.5%
Mexican	2.6%	0.5%
Indian	0.3%	0%

Source: Pierce et al. (1981).

Table 2C-4. Catch Quantities and Consumption Rates - Commencement Bay, Washington

Species	Summer catch wt (kg/day)	Fall catch wt (kg/day)	Mean daily catch[a] (kg/day)	Mean fish consumed (g/person/day)
Pacific Hake	30.08	34.34	31.97	77.46
Walleye Pollock	30.52	108.35	61.72	180.14
Pile Perch	11.74	1.95	6.08	17.76
Pacific Cod	9.65	10.59	8.99	26.25
Pacific Tomcod	7.56	5.92	5.99	17.49
Rock Sole	2.67	1.36	1.79	5.23
Striped Seaperch	2.64	0.39	1.35	3.93
Speckled Sandab	2.53	4.65	3.19	9.32
Brown Rockfish	2.06	1.58	1.62	4.72
Sand Sole	1.96	0.77	1.22	3.55
English Sole	1.60	0.41	0.90	2.61
Big Skate	1.36	1.08	1.08	3.17
Copper Rockfish	0.07	1.53	0.71	2.08
Quillback Rockfish	0.69	1.38	0.92	2.69
Black Rockfish	0.68	5.88	2.92	8.51
Solney Dogfish	0.68	0.72	0.62	1.81
Starry Flounder	0.57	0.92	0.66	1.94
White Spotted Greenling	0.48	0.08	0.25	0.73
Shiner Perch	0.40	2.47	1.28	3.73
Canary Rockfish	0.40	1.21	0.72	2.09
Red Irish Lord	0.28	0.46	0.33	0.96
Dover Sole	0.26	0.36	0.27	0.80
Boccaccia Rockfish	0.23	0.05	0.12	0.36
Flathead Sole	0.18	0.00	0.08	0.23
Pacific Sandab	0.14	1.19	0.59	1.72
Staghorn Sculpin	0.12	0.45	0.25	0.74
Petrale Sole	0.10	0.14	0.11	0.31
Butter Sole	0.06	0.00	0.03	0.07
Red Stripe Rockfish		0.60	0.27	0.78
TOTAL				381.19

[a] Summer + Fall Catch/9 days

Assumptions:
- 98% of catch eaten.
- Average fishermen/day = 53.
- Average living group = 3.74/fishermen.
- Portion of edible tissue = 0.49 percent.

Source: Derived from Pierce et al. (1981).

APPENDIX 2D

Pica Data Sources

Appendix 2D

Pica Data Sources

The data base used to assess pica consisted of textbooks, handbooks, research literature, and personal contacts. Textbooks and handbooks covered such fields as pediatric behavior, pediatric psychology, pediatric psychiatry, and pediatric nutrition. Research literature was identified from an online literature search on DIALOG. The DIALOG data bases searched were Medline, Toxline, Embase, Eric, Agricola, PsychInfo, Social Scisearch, and NTIS. Personal contacts consisted of telephone inquiries to the following organizations and researchers:

<u>Organizations</u>

American Academy of Pediatrics
American Psychiatric Association
National Association of Anorexia Nervosa and Associated Disorders
National Center for Health Statistics
National Institute of Child Health and Human Development
National Institute of Environmental Health Sciences
National Institute on Mental Health
National Research Council
North American Society for Pediatric Gastroenterology
Society for Pediatric Research
U.S. Public Health Service, Division of Maternal and Child Health

<u>Researchers</u>

David Bellinger, M.D.	Children's Hospital (Boston)
Susan Binder, M.D.	Centers for Disease Control
Rufus Chaney, Ph.D.	Agriculture Research Service (USDA)
James Chisolm, M.D.	Johns Hopkins University
William Crosby, M.D.	George Washington University
Darla Danford, M.D.	Nutrition Coordinator (NIH)
Marc Feldman, M.D.	Duke University
James Smith, Ph.D.	Vitamin and Mineral Research Center (USDA)
Donald Vermeer, Ph.D.	Louisiana State University
Mohsen Ziai, M.D.	Georgetown University

3. INHALATION ROUTE

Humans can be exposed to toxic chemicals from the inhalation route from various sources. This chapter discusses factors associated with exposure to both vapors and particulates.

3.1 Exposure Equation for Inhalation

The general equation for calculating inhalation exposure is given by:

$$\text{Lifetime Average Inhalation Exposure} = \frac{\text{Inhalation Rate} \times \text{Contaminant Concentration in Air} \times \text{Exposure Duration}}{\text{Body Weight} \times \text{Lifetime}}$$

The inhalation rate varies according to the exertion level and other factors. Activity patterns that might indicate the exertion level for various periods of time are given in the section on other factors needed for exposure calculations (Section 5.3). Pulmonary ventilation is discussed in detail in the following section.

3.2 Pulmonary Ventilation

3.2.1 Background

Pulmonary ventilation is the mass movement of gas in and out of the lungs (Astrand 1970). This movement is generally represented by the minute volume, the volume of gas expired in L per minute at normal body temperature and ambient barometric pressure, saturated with water vapor. Minute volume is the product of tidal volume, the volume of gas moved during each respiratory cycle, and respiratory frequency (Astrand and Rodahl 1977). It will vary with an individual's age, weight, sex, activity level, and general physical condition.

Measurement of minute volumes is usually conducted through the use of a spirometer and a collection system. The spirometer, through the use of one-way valves, funnels the expired gas into a collection system (e.g., a Douglas Bag). In this manner, the expired gas volume is recorded over time. These types of spirometric measurements of minute volume have been reported by various clinical studies since the early 1930s. Today, the accuracy of this instrumentation is still considered to be very good. For this reason, experts in the field of pulmonary science regard the results of these early studies to be valid determinations of lung volume measurements.

Several formulae have been proposed in the literature to calculate minute volumes of humans at rest from anthropometric data (USEPA 1985). Most of these formulae are based upon measurements of relatively small sample sizes; all of them are applicable only to the estimation of minute ventilation at rest.

3.2.2 Methods

Review of the literature failed to identify equations that would enable the development of statistical distributions of minute ventilation at all activity levels for male and female children and adults. Therefore, ranges of measured values were compiled from the available data and estimates of minute ventilation rates were derived (USEPA 1985). Many of these measurements are from early studies. In more recent investigations, minute ventilation tends to be measured more as background information than as a research objective itself, making more current measurements difficult to locate in the literature. In addition, those recent measurements that have been located are frequently of specific subpopulations such as obese asthmatics or marathon runners.

Measurements of minute ventilation at various activity levels were compiled for each age/sex group. The activity levels at which the measurements were taken were categorized as light, moderate, or heavy according to criteria developed by the Environmental Criteria and Assessment Office of EPA for the air quality criteria document for ozone. These criteria were developed for a reference male adult with a body weight of 70 kg (USEPA 1984). Minute ventilation rates for adult males based on these activity level categories are detailed in Appendix 3A. Activity level categories for the other age/sex groups were extrapolated from the criteria for male adults on the basis of body weight (AIHA 1971). For exposure assessment purposes, minute volumes (expressed as L per minute) were converted to an inhalation rate expressed as cubic meters per hour.

3.2.3 Results

Table 3-1 presents the compilation of available inhalation rate data by age, sex, and activity level. The data presented include inhalation rates for adult males, adult females, and children during resting and during light, moderate, and heavy exertion. Values of inhalation rates presented in this table represent the mean of values reported for each activity level in USEPA (1985). Additional detailed information that would provide range data for these age/sex/activity level categories and for individual ages from infants to 18 years of age is found in Appendix 3A.

Each activity level is representative of various activities. Resting is characterized by activities such as watching television, reading, or sleeping. Light activity includes level walking, meal cleanup, care of laundry and clothes, domestic work and other miscellaneous household chores, attending to personal needs and care, photography, hobbies, and conducting minor indoor repairs and home improvements. Moderate activity includes climbing stairs, heavy indoor cleanup (e.g., scrubbing surfaces), and performing major indoor repairs and alterations (e.g., remodeling). Heavy activity consists of vigorous physical exercise, such as weight lifting, dancing, or riding an exercise bike.

Very few data are available for preschool-aged children. This is because of the difficulty of conducting clinical studies with this age group. For many of the children's age/sex groups, the sample numbers are very small. In addition, for most groups, very few measurements at light and moderate activity levels are available. Representative data have been included for a 6-year-old child and a 10-year-old child. Additional inhalation rate data for all aged children could be developed from the data in Appendix 3A.

Table 3-1. Summary of Human Inhalation Rates for Men, Women, and Children by Activity Level (m^3/hour)[a]

	Resting[b]	Light[c]	Moderate[d]	Heavy[e]
Adult male	0.7	0.8	2.5	4.8
Adult female	0.3	0.5	1.6	2.9
Average adult[f]	0.5	0.6	2.1	3.9
Child, age 6	0.4	0.8	2.0	2.4
Child, age 10	0.4	1.0	3.2	4.2

[a] Values of inhalation rates for males, females, and children presented in this table represent the mean of values reported for each activity level in USEPA (1985).

[b] Includes watching television, reading, and sleeping.

[c] Includes most domestic work, attending to personal needs and care, hobbies, and conducting minor indoor repairs and home improvements.

[d] Includes heavy indoor cleanup, performance of major indoor repairs and alterations, and climbing stairs.

[e] Includes vigorous physical exercise and climbing stairs carrying a load.

[f] Derived by taking the mean of the adult male and adult female values for each activity level.

3.2.4 Application of Pulmonary Ventilation Data

Inhalation rate is a necessary component of an assessment of inhalation exposure. The overall equation that is used to calculate inhalation exposure is:

$$IHX = IR \times ED \times C$$

where

IHX = inhalation exposure (mg/year),
IR = inhalation rate (m^3/hour),
ED = duration of exposure event (hours), and
C = average air concentration of a given constituent (mg/m^3).

The selection of the inhalation rate to be used in the equation would depend upon the age of the population exposed and the activity level of the population during exposure. For example, if the exposed population were adults conducting minor home improvements, a ventilation rate of 0.6 m^3/hour would be used. Judgment would have to be used to decide upon the activity levels represented by various forms of activity.

Various inhalation rates are commonly used to represent daily inhalation rates. Based on 16 hours of activity at the light activity level and 8 hours resting, the International Commission of Radiological Protection (ICRP) reported 23 m^3/day for adult males and 21 m^3/ day for adult females as representative inhalation rates (ICRP 1981). Using these rates an average value for an adult would be 22 m^3/day. A value of 20 m^3/day is used in the Ambient Water Quality Criteria documents (USEPA 1980). This value is derived from earlier publications on reference man values by ICRP.

For estimating inhalation rates for indoor and outdoor scenarios, USEPA (1985) report the total amount of time spent indoors and outdoors at 3 activity levels, low, medium, and high. Since these activity levels do not correspond to the resting, light, moderate, and heavy activity levels used in Table 3-1, the values cannot be used directly. However, if one assumes that the amount of time spent at the "low" activity level can be equally divided between "resting" and "light" activity, estimates of inhalation rates for indoor and outdoor activities may be made. These data are presented in Table 3-2.

3.2.5 Conclusion

Inhalation rate varies depending upon the activity levels of the exposed individual. The commonly used values, 20 to 23 m^3/day are based on data from ICRP (1981) for reference man. These values assume 16 hours of light activity and 8 hours of resting. Daily inhalation rates for individuals performing activities at levels other than resting or light are not presented. Thus, the values are not representative inhalation rates for individuals at the moderate and/or heavy activity levels.

Data presented in USEPA (1985) suggest lower inhalation rates for light and resting activity levels. Using the same assumptions as used in ICRP (1981), the daily inhalation rate would be approximately 14 m^3 (See Table 3-1). In addition, USEPA (1985) report inhalation data for moderate and heavy activity levels, making it possible to estimate total daily inhalation rate for any combination of activity levels. The data also suggest that the maximum inhalation rate is roughly twice the reported mean rates for all activity levels.

Based on the above discussion, the following recommendations are made:

(1) For continuous exposure situations, or assessments in which specific activity patterns are not known, use 20 m^3/day as the average adult daily inhalation rate and 30 m^3/day as the reasonable worst-case inhalation rate. The 20 m^3/day rate is the value reported for reference man, rounded to one significant figure, and is widely used for exposure assessments. The 30 m^3/day rate was estimated based on the observation that maximal inhalation rates reported in USEPA (1985) were roughly twice the reported mean values. Based on this, it was judged that a value 1.5 times the mean rate would represent a reasonable worst-case rate.

Table 3-2. Activity Pattern Data Aggregated for Three Microenvironments by Activity Level

Microenvironment	Activity level	Average hours in each microenvironment at each activity level
Indoors	Resting	9.82
	Light	9.82
	Moderate	0.71
	Heavy	0.098
	Total	20.4
Outdoors	Resting	0.505
	Light	0.505
	Moderate	0.65
	Heavy	0.12
	Total	1.77
In transportation vehicle	Resting	0.86
	Light	0.86
	Moderate	0.05
	Heavy	0.0012
	Total	1.77

Source: Adapted from USEPA (1985)

(2) For exposure scenarios in which the distribution of activity patterns is known, the values reported by USEPA (1985) in Table 3-1, should be used. These activity-specific rates allow a more representative daily inhalation rate to be calculated.

In calculating an average inhalation rate for an individual performing outdoor activities, data from Table 3-2 suggest that a typical activity mix would consist of the following: 37 percent of the time at a moderate activity level, 28 percent at both the resting and the light activity levels, and 7 percent at a heavy activity level. For a reasonable worst-case inhalation rate, it was assumed that an individual would spend 50 percent of the time at a heavy activity level and 50 percent of the time at a moderate activity level. Using the values in Table 3-1, the average hourly outdoor inhalation rate is 1.4 m^3/hour and the reasonable worst-case outdoor inhalation rate is 3.0 m^3/hour.

For indoor activities, inhalation rates were based on a different mix of activities. For an average case, it was assumed that an individual would spend 48 percent of the time at both the resting activity level and the light activity level, 3 percent of the time at a moderate activity level, and 1 percent of the time at a heavy activity level. A reasonable worst-case value is based on 25 percent of the time at a resting activity level, 60 percent at a light activity level, 10 percent at a moderate activity level, and 5 percent at a heavy activity level. Based on the values in Table 3-1, the average indoor inhalation rate is 0.63 m^3/hour, and the reasonable worst-case indoor inhalation rate is 0.89 m^3/hour.

If the assessment is applicable to children, a similar approach can be taken using values for specific age groups at specified activity levels as provided in Table 3-1. For assessments involving specific activities (e.g., showering, painting), inhalation rates can be selected that are judged to be representative of these activities.

3.3 References

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APPENDIX 3A

Detailed Ventilation Rate Data

Table 3A-1. Estimated Minute Ventilation Associated with Activity Level for Average Male Adult

Level of work	L/min	Representative activities
Light	13	Level walking at 2 mph; washing clothes
Light	19	Level walking at 3 mph; bowling; scrubbing floors
Light	25	Dancing; pushing wheelbarrow with 15-kg load; simple construction; stacking firewood
Moderate	30	Easy cycling; pushing wheelbarrow with 75-kg load; using sledgehammer
Moderate	35	Climbing stairs; playing tennis; digging with spade
Moderate	40	Cycling at 13 mph; walking on snow; digging trenches
Heavy Heavy Very heavy	55 63 72	Cross-country skiing; rock climbing; stair climbing with load; playing squash or handball; chopping with axe
Very heavy	85	Level running at 10 mph; competitive cycling
Severe	100+	Competitive long distance running; cross-country skiing

Source: Adapted from USEPA (1985).

Table 3A-2. Minute Ventilation Ranges by Age, Sex, and Activity Level

Age (yr)	Sex	Weight (kg)	Ventilation ranges (liters/minute) Resting	Mean	Light	Mean	Moderate	Mean	Heavy	Mean
Infants	M/F		0.25 - 2.09	0.84						
2	F	10.7	---		---		---		---	
	M	11.7	---		---		---		---	
3	F	12.8	---		---		---		---	
	M	13.4	---		---		---		---	
4	F	14.8	---		---		---		32.0 - 32.5	32.3
	M	15.5	---		---		---		39.3 - 43.3	41.2
5	F	16.8	---		---		---		31.0 - 35.0	32.8
	M	17.6	---		---		---		30.9 - 42.6	37.5
6	F	19.4	---		---		---		35.9 - 38.9	37.4
	M	19.7	5.0 - 7.0	6.5	5.0 - 32.0	13.9	28.0 - 43.0	33.3	35.5 - 43.5	40.3
7	F	21.9	---		---		---		48.2 - 51.4	49.6
	M	22.8	---		---		---		44.1 - 55.8	50.0
8	F	24.6	---		---		---		51.2 - 67.6	57.6
	M	24.9	---		---		---		59.3 - 62.2	60.7
9	F	27.5	---		---		---		55.8 - 63.4	50.9
	M	28.0	---		---		---		59.5 - 75.2	65.7
10	F	31.7	---		---		---		46.2 - 71.1	60.4
	M	30.7	5.2 - 8.3	7.1	5.2 - 35.0	17.2	41.0 - 68.0	53.4	63.9 - 74.6	70.5
11	F	35.7	---		---		---		49.7 - 80.9	63.5
	M	36.2	---		---	20.3	---	31.1	47.6 - 77.5	65.5
12	F	41.4	4.1 - 16.1	15.4	---		19.6 - 46.3	26.5	65.5 - 79.9	71.8
	M	39.7	7.2 - 16.3	15.4	---		18.5 - 46.3	34.1	58.1 - 84.7	67.7
13	F	46.1	7.2 - 15.4	9.9	---		18.5 - 46.3	30.3	67.6 - 102.6	87.7
	M	44.1	3.1 - 15.4	8.9	3.1 - 24.9	16.4	14.2 - 48.4	32.8	27.8 - 105.0	57.9
14	F	50.9	3.1 - 15.6	14.9	---		21.6 - 37.1	28.1	80.7 - 100.7	88.9
	M	49.5	3.1 - 27.8	14.2	---		24.7 - 55.0	39.7	42.2 - 121.0	86.9

Table 3A-2. (Continued)

Age (yr)	Sex	Weight (kg)	Ventilation ranges (liters/minute) Resting	Mean	Light	Mean	Moderate	Mean	Heavy	Mean
15	F	54.3	---	6.2	---		---	26.8	68.4 - 97.1	87.1
	M	56.4	3.1 - 26.8	11.1	---		27.8 - 46.3	39.3	48.4 - 140.3	110.5
16	F	55.0	---	15.2	---		---		73.6 - 119.1	93.9
	M	61.2	---	15.6	---		---		79.6 - 132.2	102.5
17	F	57.8	---		---		---		91.9 - 95.3	93.6
	M	66.5	5.8 - 9.0	7.3	---		40.0 - 63.0	48.6	89.4 - 139.3	107.7
18	F	59.6	---		---		---		---	
	M	66.7	---		---		---		99.7 - 143.0	120.9
Adults	F	65.4	4.2 - 11.66	5.7	4.2 - 29.4	8.1	20.7 - 34.2	26.5	23.4 - 114.8	47.9
Adults	M	70.0	2.3 - 18.8	12.2	2.3 - 27.6	13.8	14.4 - 78.0	40.9	34.6 - 183.4	80.0

Source: Adapted from USEPA (1985).

4. DERMAL ROUTE

4.1 Exposure Equation for Dermal

The equation for calculating dermal exposure is:

$$\text{Dermal Exposure} = \frac{\text{Contact Rate} \times \text{Contaminant Concentration on Skin} \times \text{Exposure Duration}}{\text{Body Weight} \times \text{Lifetime}}$$

For this route, the contact rate is expressed differently for liquids and solids. For dermal exposure to liquids, the contact rate should be expressed as a volumetric rate to keep the units consistent with the concentration term which is typically expressed as mass per unit volume. When exposure to solids is being assessed, the concentration of the contaminant on the skin is usually expressed in mass per mass units; thus, a contact rate consistent with these units should be used.

Dermal dose can be calculated in two ways:

$$\text{Dose} = \text{(Mass Contact Rate/Density)} \times \text{Contaminant Concentration} \times \text{Exposure Duration} \times \text{Absorption Fraction}$$

or

$$\text{Dose} = \text{Permeability Constant} \times \text{Contaminant Concentration} \times \text{Exposure Duration} \times \text{Contact Area}$$

The first equation for dose is simply the numerator of the equation above for dermal exposure adjusted for absorption and with the first term changed from a volumetric contact rate to a mass contact rate divided by density. The second equation for dose is derived from Fick's Law on diffusion and requires data on permeability. Both the contact rate and permeability constant are difficult to estimate. This lack of data makes dermal exposure calculations more uncertain than calculations for the other routes. The body surface area standard factors presented in the next section will reduce the uncertainty associated with one of the terms in the dose equation.

4.2 Surface Area of the Human Body

4.2.1 Background

Dermal exposure to contaminants is a potentially important pathway that warrants consideration in many exposure assessments. Subsequent health effects depend on the chemical characteristics of the compound and the duration and frequency of exposure. Upon determination that a contaminant can gain access to the body through topical (skin) exposure, the assessor may use estimations of total body surface area to help calculate the contact rate for the contaminant. Mean values of total surface area of body parts can be used for cases in which only a certain area of the body is at risk of exposure. A literature search of the historical development of models to estimate surface area of the human body was conducted by USEPA (1985). A review of estimation techniques and human body surface data generated by USEPA (1985) is presented below.

4.2.2 Measurement Techniques

Direct measurement techniques that have been used to measure total body surface area include direct coating, triangulation, and surface integration (Boyd 1935). The coating methods consist of coating either the whole body or specific regions with a substance of known or measured area. In some instances the pieces of coating were placed on cross-section paper and the area was measured by counting the squares covered. In others, the areas of the pieces of coating were calculated by weighing the coating or weighing duplicates cut from a substance of uniform thickness (Boyd 1935). Triangulation consists of marking the area of the body into geometric figures, then calculating the figure areas from their linear dimensions. Surface integration is performed by running a planimeter over the body in parallel strips of equal width. The surface area is calculated by adding the areas of all the strips measured.

Directly measuring body surface area by the methods described above is a difficult, time-consuming task. Gehan and George (1970) cited only three studies completed after 1935 that used methods of direct measurement to determine the surface area of the human body. Consequently, existing direct measurement data are limited and somewhat old.

Surface area of the body can also be estimated using geometric approximations by assuming that parts of the body resemble geometric solids. Calculation of the surface area of a solid results in an estimation of the surface area of the corresponding body part. Boyd (1935) cited one example in which an estimation of surface area of the trunk was performed by measuring the length from the groove of the neck to the tip of the coccyx, and the circumferences just under the arms, at the level of the umbilicus, and the level of the pubis. The surface areas of cylindrical shapes corresponding to these measurements were calculated.

A linear method has been proposed by DuBois and DuBois (1916) in which estimates are made on the principle that the surface area of the parts of the body are proportional, rather than equal, to the surface area of the solids they resemble. Estimates of surface area made from lengths and circumferences are corrected by constants obtained from direct measurements of surface area. A table was developed with definitions of linear dimensions and constants for each body part, derived from direct measurement (Boyd 1935).

More recently, Popendorf and Leffinwell (1976) and Haycock et al. (1978) used their own geometric methods for estimating body surface area. Both methods made use of the assumption that body parts correspond to geometric solids, such as the sphere and cylinder. Haycock et al. (1978) calculated surface area of the body from 34 body measurements.

4.2.3 Formulae for Total Body Surface Area

Several formulae have been proposed for estimating body surface area from measurements of other major body dimensions. Generally, the formulae are based on the principles that body density and shape are roughly the same and that the relationship of surface area to any dimension may be represented by the curve of central tendency of their plotted values or by the algebraic expression for the curve (Boyd 1935). A discussion and comparison of formulae to determine total body surface area is presented in Appendix 4A. Analysis of the formulae reveal that the model proposed by Gehan and George (1970) will produce the most accurate estimations of total body surface area. Description and use of the model will be discussed in the Methods section of this chapter.

4.2.4 Surface Area of Body Parts

Several investigators who have worked in determining body surface area have reported their results in terms of surface areas of different parts of the body as well as total surface area. The literature contains surface area of body parts both as direct measurements and as estimates. Data on surface area of body parts have been reported for both sexes, for several ethnic groups, and for ages ranging from newborn to elderly.

Boyd (1935) summarized direct measurements of surface area made by various investigators who reported results in varying degrees of detail. Boyd measured a female child at three different ages and another female child at five different ages over a period of 8 months. The result is a record of the growth of the surface area of the body and the change in the percentage of total body surface area associated with each part. Another investigator (Lissauer 1903, as cited in USEPA 1985) reported the body surface area of 12 infants ranging in age from 17 days to 15 months. Measurements of body parts recorded surface area in terms of head, trunk, upper extremities, and lower extremities. DuBois and DuBois (1916) reported the surface area of various body parts for four adult males and one adult female. Another research team (Sawyer et al.

no date, as cited in USEPA 1985) reported body part surface area for a 29-month-old female, a 12-year-old, 10-month-old male, an 18-year-old male, a 21-year-old male or female, 6-month-old male, and a 26-year-old female. Both research efforts measured surface area for head, trunk, arms, hand, thighs, legs, and feet.

A study by Fujimoto and Watanabe (1969) presented the results of direct measurements of 201 Japanese of both sexes ranging in age from less than 1 year to 76 years. The subjects were prescreened by an obesity index so that all individuals had a "standard Japanese physique by sex and age," or were categorized as slender or obese after adolescence. The authors reported the average percentage of total body surface area for a large number of different body regions, including the area covered by head hair, the forehead, face, ear, neck, upper front trunk, lower front trunk, upper back trunk, lower back trunk, hip, upper arm, lower arm, hand, thigh, leg, and foot. Upon analyzing the data according to sex and age, the authors made the following generalizations:

- The percentage of total surface area of the head, face, and neck decreases with increasing age;
- The percentage of total surface area of the lower extremities, such as thighs, increases with age; and
- The differences in percentages of different body regions between sexes become significant after adolescence, the thigh having a higher percentage in the female.

While there are some physical differences between Japanese and Americans that might limit the applicability of the data from this study to the U.S. population, it is possible that these generalizations may pertain to all humans. This study represents the largest single group of direct measurements made by any surface area investigator and presents a balanced sample of individuals according to sex and age.

Two additional methods have been used extensively to estimate the surface area of body parts: linear methods and geometric methods. Linear methods are based on actual measurement data, and generally involve multiplying a linear dimension of a body part (length, circumference, etc.) by a constant derived from previous direct measurements. Geometric methods divide the body into parts that are assigned a simple geometric shape; e.g., a forearm is treated like a cylinder, the head like a sphere, etc. The dimensions of the body parts are measured; then the surface area is computed from the formula for the particular geometric solid. Both of these methods provide only a rough estimation of the surface area of body parts.

4.2.5 Methods

Available direct measurement data were analyzed using the Statistical Processing System (SPS) software package (Buhyoff et al. 1982) to generate equations that calculate surface area as a function of height and weight. These equations were then used to calculate surface area distributions of the U.S. population using the National Health and Nutrition Examination Survey (NHANES) II height and weight data and the computer program QNTLS (Rochon and Kalsbeek 1983). A description of this program is provided in Appendix B of the final report by USEPA (1985).

4.2.6 Total Body Surface Area

A review of the literature identified the equation proposed by Gehan and George (1970) as the best choice for estimating surface area. However, their paper gave insufficient information to estimate the standard error about the regression. Therefore, the 401 direct measurements of children and adults used by the authors were reanalyzed using the SPS to obtain the standard error. These data are presented in Appendix B, Table B-1 of USEPA (1985). Summary data are presented in Appendix 4B of this chapter.

The model uses weight and height as independent variables to predict total body surface area (SA), and can be written as:

$$SA_i = a_0 \, H_i^{a_1} \, W_i^{a_2} \, e_i$$

data. The data for adults were used to develop equations for estimating body part surface area from height and weight. Insufficient data for children, however, precluded the development of equations to estimate their body part surface area.

For adults, regression equations relating weight and height to the surface area of the body part were developed using the SPS for the head, trunk, upper extremities and lower extremities. Upper extremities comprise arms and hands; arms are further divided into upper arms and forearms. Lower extremities include legs and feet, with legs further divided into thighs and lower legs. The trunk includes the neck. Only data reflecting similar demarcation between parts were used in the analyses.

The same model used to estimate total body surface area with the independent variables height and weight was used for the surface area of body parts (surface areaP):

$$SAP = a_0 H^{a_1} W^{a_2}.$$

Three regressions were run on each body part for which data were available: observations on females, observations on males, and the pooled observations. For each body part an F-test was conducted to test whether two different regression models (male and female) were necessary. When indicated by the F-test, the null hypothesis that there was no difference between the two regressions (i.e., that the data should be pooled) was rejected and two equations were listed. The equations are summarized in Table 3-5 of USEPA (1985). The data and statistical summaries are presented in Appendix B of USEPA (1985).

4.2.8 Results

(1) Adults. Percentile estimates of total surface area and surface area of body parts calculated with regression equations and NHANES II height and weight data using QNTLS are presented in Appendix 4B for adult

males and adult females. The calculated mean surface areas of body parts for men and women are presented in Table 4-1. The standard deviation, the minimum value, and the maximum value for each body part are included. The median total body surface area for men and women and the corresponding standard errors about the regressions are also given for the 106 individuals upon which the data in Table 4-1 are based. It has been assumed that errors associated with height and weight are negligible. The data in Table 4-2 present the percentage of total body surface by body part for men and women.

(2) <u>Children</u>. Available measurements of the surface area of children's body parts are summarized as percentage of total surface area in Table 4-3. Because of the small sample size (21 children), the data cannot be assumed to represent the average percentage of surface area by body part for all children.

Percentile estimates of total surface area of children calculated with the total surface area regression equation and NHANES II height and weight data using QNTLS for males and females are presented in Appendix 4B (Tables 4B-3 and 4B-4). Estimates are not included for children younger than 2 years old because there are no NHANES height data for this age group. For children, the error associated with height and weight cannot be assumed to be zero because of their relatively small sizes. Therefore, the standard errors of the percentile estimates cannot be estimated, since it cannot be assumed that the errors associated with the exogenous variables (height and weight) are independent of that associated with the model; there are insufficient data to determine the relationship between these errors. A summary of total body surface area for male and female children from Appendix 4B is presented below.

<u>Median Total Body Surface Area (m^2)</u>

Age (year)	Male	Female
3<6	0.728	0.711
6<9	0.931	0.919
9<12	1.16	1.16
12<15	1.49	1.48
15<18	1.75	1.60

Table 4-1. Surface Area by Body Part for Adults (m^2)

Body part	Men			Women		
	Mean (s.d.)	Min. - Max.	n	Mean (s.d.)	Min. - Max.	n
Head	0.118 (0.0160)	0.090 - 0.161	29	0.110 (0.00625)	0.0953 - 0.127	54
Trunk	0.569 (0.0140)	0.306 - 0.893	29	0.542 (0.0712)	0.437 - 0.867	54
Upper extremities	0.319 (0.0461)	0.169 - 0.429	48	0.276 (0.0241)	0.215 - 0.333	57
Arms	0.228 (0.0374)	0.109 - 0.292	32	0.210 (0.0129)	0.193 - 0.235	13
Upper arms	0.143 (0.0143)	0.122 - 0.156	6	-	-	-
Forearms	0.114 (0.0127)	0.0945 - 0.136	6	-	-	-
Hands	0.084 (0.0127)	0.0596 - 0.113	32	0.0746 (0.00510)	0.0639 - 0.0824	12
Lower extremities	0.636 (0.0994)	0.283 - 0.868	48	0.626 (0.0675)	0.492 - 0.809	57
Legs	0.505 (0.0885)	0.221 - 0.856	32	0.488 (0.0515)	0.423 - 0.585	13
Thighs	0.198 (0.1470)	0.128 - 0.403	32	0.258 (0.0333)	0.258 - 0.360	13
Lower legs	0.207 (0.0379)	0.093 - 0.296	32	0.194 (0.0240)	0.165 - 0.229	13
Feet	0.112 (0.0177)	0.0611 - 0.158	32	0.0975 (0.00903)	0.0834 - 0.115	13
TOTAL	1.94 (0.00374)[a]	1.66 - 2.28[b]	48	1.69 (0.00374)[a]	1.45 - 2.09[b]	58

[a] median (standard error).
[b] percentiles (5th - 95th).

s.d. = standard deviation.
s.e. = standard error for the 5th to 95th percentile of each body part.
n = number of observations.

Source: Adapted from USEPA (1985).

Table 4-2. Percentage of Total Body Surface Area by Part for Adults

	Men			Women		
Body part	Mean (s.d.)	Min. - Max.	n	Mean (s.d.)	Min. - Max.	n
Head	7.8 (1.0)	6.1-10.6	48	7.1 (0.6)	5.6- 8.1	57
Trunk	35.9 (2.1)	30.5-41.4	48	34.8 (1.9)	32.8-41.7	57
Upper Extremities	18.8 (1.1)	16.4-21.0	48	17.9 (0.9)	15.6-19.9	57
Arms	14.1 (0.9)	12.5-15.5	32	14.0 (0.6)	12.4-14.8	13
Upper Arms	7.4 (0.5)	6.7- 8.1	6	-	-	-
Forearms	5.9 (0.3)	5.4- 6.3	6	-	-	-
Hands	5.2 (0.5)	4.6- 7.0	32	5.1 (0.3)	4.4- 5.4	13
Lower Extremities	37.5 (1.9)	33.3-41.2	48	40.3 (1.6)	36.0-43.2	57
Legs	31.2 (1.6)	26.1-33.4	32	32.4 (1.6)	29.8-35.3	13
Thighs	18.4 (1.2)	15.2-20.2	32	19.5 (1.1)	18.0-21.7	13
Lower Legs	12.8 (1.0)	11.0-15.8	32	12.8 (1.0)	11.4-14.9	13
Feet	7.0 (0.5)	6.0- 7.9	32	6.5 (0.3)	6.0- 7.0	13

s.d. = standard deviation.
n = number of observations.

Source: USEPA (1985).

Table 4-3. Percentage of Total Body Surface Area by Part for Children

		Percent of total											
		Head		Trunk		Arms		Hands		Legs		Feet	
Age	N M:F	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.
<1	2:0	18.2 (0.098)	18.2-18.3	35.7 (1.3)	34.8-36.6	13.7 (1.9)	12.4-15.1	5.3 (0.13)	5.21-5.39	20.6 (3.3)	18.2-22.9	6.54 (0.07)	6.49-6.59
1<2	1:1	16.5 (0.019)	16.5-16.5	35.5 (1.6)	34.5-36.6	13.0 (0.23)	12.8-13.1	5.68 (0.15)	5.57-5.78	23.1 (1.36)	22.1-24.0	6.27 (0.61)	5.84-6.70
2<3	1:0	14.2		38.5		11.8		5.30		23.2		7.07	
3<4	0:5	13.6 (0.28)	13.3-14.0	31.9 (1.2)	29.9-32.8	14.4 (0.19)	14.2-14.7	6.07 (0.23)	5.83-6.32	26.8 (1.0)	26.0-28.6	7.21 (0.42)	6.80-7.86
4<5	1:3	13.8 (1.3)	12.1-15.3	31.5 (0.87)	30.5-32.4	14.0 (1.1)	13.0-15.5	5.70 (0.70)	5.15-6.62	27.8 (1.5)	26.0-29.3	7.29 (0.55)	6.91-8.10
5<6													
6<7	1:0	13.1		35.1		13.1		4.71		27.1		6.90	
7<8													
8<9													
9<10	0:2	12.0 (0.61)	11.6-12.5	34.2 (1.1)	33.4-34.9	12.3 (0.76)	11.7-12.8	5.30 (0.27)	5.15-5.44	28.7 (0.21)	28.5-28.8	7.58 (0.27)	7.38-7.77
10<11													
11<12													

Table 4-3. (continued)

		Percent of total											
		Head		Trunk		Arms		Hands		Legs		Feet	
Age	N M:F	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.	Mean (s.d.)	Min.-Max.
12<13	1:0	8.74		34.7		13.7		5.39		30.5		7.03	
13<14	1:0	9.97		32.7		12.1		5.11		32.0		8.02	
14<15													
15<16													
16<17	1:0	7.96		32.7		13.1		5.68		33.6		6.93	
17<18	1:0	7.58		31.7		17.5		5.13		30.8		7.28	

s.d. = standard deviation.
N = number of subjects.

4.2.9 Application of Body Surface Area Data

For cases of dermal exposure to contaminants, the assessor may estimate the median total body surface area of an adult male or female from the data presented in Table 4-1. There is a greater likelihood that only certain areas of the body, as opposed to the total body, are at risk of exposure, and the assessor may also use the data in Table 4-1 to estimate the surface area of a particular body part(s). For example, if an individual is using a household cleaning product that contains a contaminant of interest, the hands and arms have the greater risk of exposure. The assessor may determine the mean surface area of these body parts for men and women as follows:

	Surface Area (m^2)	
	Men	Women
Arms	0.228	0.210
Hands	0.0840	0.0746
Total area	0.312	0.285

Therefore, the total body part surface area that may be in contact with the contaminant contained in the cleaning product is 0.312 m^2 for men and 0.285 m^2 for women. For some cleaning products, only the hands may be exposed. The assessor must determine all body parts that may come in contact with a contaminant to estimate the total surface area of the body dermally exposed to the contaminant.

4.2.10 Conclusion

For most dermal exposure scenarios, it is recommended that the body surface areas presented in Table 4-1 be used following a determination of which body parts will be exposed. For most scenarios this will be a straightforward determination; however, for some scenarios additional considerations may need to be addressed. For example, the type of clothing worn will have a significant effect on the surface area exposed. An individual may wear gloves while contacting contaminated soil, which would reduce dermal exposure, or may wear shorts, short-sleeve shirt, and no gloves, which would increase exposure potential. Climatic conditions will also affect the type of clothing worn and, thus, the skin surface area exposed.

For outdoor activities, the following "clothing" scenarios are suggested:

Typical case:	Individual will wear long-sleeve shirt, pants, and shoes. Exposed areas will be head and hands (0.20 m^2).
Reasonable worst case:	Individual will wear short-sleeve shirt, shorts, and shoes. Exposed areas will be head, hands, forearms, and lower legs (0.53 m^2).

For these activities, the amount of clothing worn will differentiate between typical and reasonable worst-case exposure conditions. Therefore, mean values from Table 4-1 can be used to determine exposed surface area.

For activities in which the entire body is exposed (e.g., swimming, bathing), the range of typical to reasonable worst-case exposure conditions may be accounted for by using percentile data from Appendix Table 4B-1. The 50th percentile would represent typical exposure conditions (i.e., 1.94 m^2 for adult males, 1.69 m^2 for adult females), and the 90th percentile would represent reasonable worst-case exposure (i.e., 2.20 m^2 for adult males, 1.98 m^2 for adult females).

The body surface area data for children presented in Appendix 4B (Tables 4B-3 and 4B-4) and Table 4-3 provide only rough estimations of the surface area of body parts. We recommend that the data not be used to represent all children within age groups presented unless the assessor is particularly interested in the exposures of children and no other data exist at that time.

Typical scenarios involving dermal exposure will include dermal contact with contaminated water and dermal contact with contaminated soil. Since standard scenarios for dermal exposure have not yet been developed, more detailed recommendations regarding selection of standard dermal factors will be included in a later draft of this handbook.

4.3 References

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APPENDIX 4A

Formulae for Total Body Surface Area

APPENDIX 4A

Formulae for Total Body Surface Area

Most formulae for estimating surface area (SA) relate height to weight. The first such equation can be expressed by:

$$SA = KW^{2/3}$$

where

SA = surface area in square meters,
W = weight in kg, and
K is a constant (Gehan and George 1970).

While the above equation has been criticized because the specific gravity of human bodies is not equal and because the surface area per unit volume differs for individuals with different body builds, it gives a reasonably good estimate of surface area.

A formula published in 1916 that still has found wide acceptance and use even to the present is that of DuBois and DuBois. Their model can be written:

$$SA = a_0 H^{a_1} W^{a_2}$$

where

SA = surface area in square meters,
H = height in centimeters, and
W = weight in kg.

The values of a_0 (0.007182), a_1 (0.725), and a_2 (0.425) were estimated from a sample of only nine individuals for which surface area was directly measured. Boyd (1935) stated that the DuBois and DuBois formula was used more extensively than any other for estimating surface area. Nomograms for determining surface area from height and mass presented in Volume I of the Geigy Scientific Tables (1981) are based on the DuBois and DuBois formula. In addition, a computerized literature search conducted for this report identified several articles written in the last 10 years in which the DuBois and DuBois formula was used to estimate body surface area.

Boyd (1935) developed new constants for the DuBois and DuBois model based on 231 direct measurements of body surface area she found in her review of the literature. These data were limited to measurements of surface area by coating methods (122 cases), surface integration (93 cases), and triangulation (16 cases) made of Caucasians of normal body build for whom data on weight, height, and age (except for exact age of adults) were complete. Resulting values for the constants in the DuBois and DuBois model were $a_0 = 0.01787$, $a_1 = 0.500$, and $a_2 = 0.4838$. Boyd also developed a formula based on weight alone, but this was inferior to the DuBois and DuBois formula based on height and weight.

In 1970 Gehan and George proposed another set of constants for the DuBois and DuBois model. The constants were based on a total of 401 direct measurements of surface area, height, and weight of all postnatal subjects listed in Boyd (1935). Included were data for some Japanese and Chinese individuals, as well as for some individuals with unusual body types. The methods used to measure these subjects were coating (163 cases), surface integration (222 cases), and triangulation (16 cases).

A least-squares method was used to identify the values of the constants. The values of the constants chosen are those that minimize the sum of the squared percentage errors of the predicted values of surface area. This approach, rather than minimizing the sum of squared absolute error, was used because the importance of an error of 0.1 square meter depends on the surface area of the individual. Using the least-squares method on the 401 observations summarized in Boyd (1935), Gehan and George (1970) obtained the following estimates of the constants: $a_0 = 0.02350$, $a_1 = 0.42246$, and $a_2 = 0.51456$. Hence, their equation for predicting surface area (SA) is:

$$SA = 0.02350\ H^{0.42246}\ W^{0.51456}$$

or in logarithmic form:

$$\ln SA = -3.75080 + 0.42246 \ln H + 0.51456 \ln W$$

where

H = height in centimeters,
W = weight in kg, and
SA = surface area in square meters.

This prediction explains more than 99 percent of the variations in surface area among the 401 individuals measured (Gehan and George 1970).

When natural logarithms of the measured surface areas are plotted against natural logarithms of the surface predicted by the equation, the observed surface areas are symmetrically distributed around a line of perfect fit, with only a few large percentage deviations. Only five individuals differed from the measured value by 25 percent or more. Because each of the five individuals weighed less than 13 pounds, the amount of difference was small. Eighteen estimates differed from measurements by 15 to 24 percent. Of these, 12 weighed less than 15 pounds each, 1 was overweight (5 feet 7 inches, 172 pounds), 1 was very thin (4 feet 11 inches, 78 pounds), and 4 were of average build. Since the same observer measured surface area for these 4 individuals, the possibility of some bias in measured values cannot be discounted (Gehan and George 1970).

Gehan and George (1970) also considered separate constants for different age groups: less than 5 years old, 5 years old to less than 20 years old, and greater than 20 years old. The different values for the constants are presented below:

Estimated Parameter Values for Different Age Intervals

Age group	Number of persons	a_0	a_1	a_2
All ages	401	0.02350	0.42246	0.51456
<5 years old	229	0.02667	0.38217	0.53937
≥ 5 - <20 years old	42	0.03050	0.35129	0.54375
≥ 20 years old	130	0.01545	0.54468	0.46336

The surface areas estimated by the values for all ages were compared to surface areas estimated by the values for each age group for individuals at the 3rd, 50th, and 97th percentiles of weight and height. Nearly all differences in surface area estimates were less than 0.01 square meter, and the largest difference was 0.03 m^2 for an 18-year-old at the 97th percentile. The authors concluded that there is no advantage in using separate values of a_0, a_1, and a_2 by age interval.

Haycock et al. (1978) without knowledge of the work by Gehan and George (1970), developed values for the parameters a_0, a_1, and a_2 for the DuBois and DuBois model. Their interest in making the DuBois and DuBois model more accurate arose from their work in pediatrics and the fact that DuBois and DuBois (1916) included only one child in their study group, a severely undernourished girl who weighed only 13.8 pounds at age 21 months. Haycock et al. (1978) used their own geometric method for estimating surface area from 34 body measurements for 81 individuals. Their study included newborn infants (10 cases), infants (12 cases), children (40 cases), and adult members of the medical and secretarial staffs of 2 hospitals (19 cases). The subjects all had grossly normal body structure, but the sample included individuals of widely varying physique ranging from thin to obese. Black, Hispanic, and white children were included in their sample.

The values of the model parameters were solved for the relationship between surface area and height and weight by multiple regression analysis. The least squares best fit for this equation yielded the following values for the three coefficients: $a_0 = 0.024265$, $a_1 = 0.3964$, and $a_2 = 0.5378$. The result was the following equation for estimating surface area:

$$SA = 0.024265\ H^{0.3964}\ W^{0.5378}$$

expressed logarithmically as:

$$\ln SA = \ln 0.024265 + 0.3964 \ln H + 0.5378 \ln W.$$

The coefficients for this equation agree remarkably with those obtained by Gehan and George (1970) for 401 measurements.

George et al. (1979) agree that a more complex model than the DuBois and DuBois model for estimating surface area is unnecessary. Based on samples of direct measurements by Boyd (1935) and Gehan and George (1970), and samples of geometric estimates by Haycock et al. (1978), these authors have obtained parameters for the DuBois and DuBois model that are different than those originally postulated in 1916. The DuBois and DuBois model can be written logarithmically as:

$$\ln SA = \ln a_0 + a_1 \ln H + a_2 \ln W.$$

The values for a_0, a_1, and a_2 obtained by the various authors discussed in this section are presented below.

Summary of Surface Area Prediction Formulae for the DuBois and DuBois Model

Author (year)	Number of persons	a_0	a_1	a_2
DuBois and DuBois (1916)	9	0.007184	0.725	0.425
Boyd (1935)	231	0.01787	0.500	0.4838
Gehan and George (1970)	401	0.02350	0.42246	0.51456
Haycock et al. (1978)	81	0.024265	0.3964	0.5378

The agreement between the model parameters estimated by Gehan and George (1970) and Haycock et al. (1978) is remarkable in view of the fact that Haycock et al. were unaware of the previous work. They used an entirely different set of subjects, and they used geometric estimates of surface area rather than direct measurements. It has been determined that the Gehan and George model is the formula of choice for estimating total surface area of the body since it is based on the largest number of direct measurements.

Nomograms

Sendroy and Cecchini (1954) proposed a graphical method whereby surface area could be read from a diagram relating height and weight to surface area. However, they do not give an explicit model for calculating surface area. The graph was developed empirically based on 252 cases, 127 of which were from the 401 direct measurements reported by Boyd (1935). In the other 125 cases the surface area was estimated using the linear method of DuBois and DuBois (1916). Because the Sendroy and Cecchini method is graphical, it is inherently less precise and less accurate than the formulae of other authors discussed above.

APPENDIX 4B

Percentile Estimates of Total Body Surface Area and Surface Area of Body Parts for Adult Males, Adult Females, Male Children, and Female Children

Table 48-1. Surface Area of Adult Males in Square Meters

Body part	Percentile 5	10	15	25	50	75	85	90	95	s.e.
Total	1.66	1.72	1.76	1.82	1.94	2.07	2.14	2.20	2.28	0.00374
Head	0.119	0.121	0.123	0.124	0.130	0.135	0.138	0.140	0.143	0.0202
Trunk[a]	0.591	0.622	0.643	0.674	0.739	0.807	0.851	0.883	0.935*	0.0118
Upper extremities	0.321	0.332	0.340	0.350	0.372	0.395	0.408	0.418	0.432*	0.00101
Arms	0.241	0.252	0.259	0.270	0.291	0.314*	0.328*	0.339*	0.354*	0.00387
Forearms	0.106	0.111	0.115	0.121	0.131	0.144*	0.151*	0.157*	0.166*	0.0207
Hands	0.085	0.088	0.090	0.093	0.099	0.105	0.109	0.112	0.117	0.0187
Lower extremities	0.653	0.676	0.692	0.715	0.761	0.810	0.838	0.858	0.888*	0.00633
Legs	0.539	0.561	0.576	0.597	0.640	0.686*	0.714*	0.734*	0.762*	0.0130
Thighs	0.318	0.331	0.341	0.354	0.382	0.411*	0.429*	0.443*	0.463*	0.0149
Lower legs	0.218	0.226	0.232	0.240	0.256	0.272	0.282	0.288	0.299*	0.0149
Feet	0.114	0.118	0.120	0.124	0.131	0.138	0.142	0.145	0.149	0.0147

[a] Trunk includes neck.

*These percentile estimates exceed the maximum measured values upon which the equations are based.

s.e. = standard error for the 5-95 percentile of each body part.

Table 4B-2. Surface Area of Adult Females in Square Meters

Body part	Percentile 5	10	15	25	50	75	85	90	95	s.e.
Total	1.45	1.49	1.53	1.58	1.69	1.82	1.91	1.98	2.09	0.0037
Head	0.106	0.107	0.108	0.109	0.111	0.113	0.114	0.115	0.117	0.0067
Trunk[a]	0.490	0.507	0.518	0.538	0.579	0.636	0.677	0.704	0.752	0.0056
Upper extremities	0.260	0.265	0.269	0.274	0.287	0.301	0.311	0.318	0.329	0.0083
Arms	0.210	0.214	0.217	0.221	0.230	0.238*	0.243*	0.247*	0.253*	0.0099
Hands	0.0730	0.0746	0.0757	0.0777	0.0817	0.868*	0.0903*	0.0927*	0.0966*	0.0172
Lower extremities	0.564	0.582	0.595	0.615	0.657	0.704	0.736	0.757	0.796	0.0063
Legs	0.460	0.477	0.488	0.507	0.546	0.592	0.623	0.645	0.683*	0.0130
Thighs	0.271	0.281	0.289	0.300	0.326	0.357	0.379	0.394	0.421*	0.0149
Lower legs	0.186	0.192	0.197	0.204	0.218	0.233	0.243	0.249	0.261	0.0149
Feet	0.100	0.103	0.105	0.108	0.114	0.121	0.126	0.129	0.134	0.0147

[a] Trunk includes neck.

*These percentile estimates exceed the maximum measured values upon which the equations are based.

s.e. = standard error for the 5-95 percentile of each body part.

Table 4B-3. Total Body Surface Area of Male Children in Square Meters

Age (yr)[a]	Percentile 5	10	15	25	50	75	85	90	95
2 < 3	0.527	0.544	0.552	0.569	0.603	0.629	0.643	0.661	0.682
3 < 4	0.585	0.606	0.620	0.636	0.664	0.700	0.719	0.729	0.764
4 < 5	0.633	0.658	0.673	0.689	0.731	0.771	0.796	0.809	0.845
5 < 6	0.692	0.721	0.732	0.746	0.793	0.840	0.864	0.895	0.918
6 < 7	0.757	0.788	0.809	0.821	0.866	0.915	0.957	1.01	1.06
7 < 8	0.794	0.832	0.848	0.877	0.936	0.993	1.01	1.06	1.11
8 < 9	0.836	0.897	0.914	0.932	1.00	1.06	1.12	1.17	1.24
9 < 10	0.932	0.966	0.988	1.00	1.07	1.13	1.16	1.25	1.29
10 < 11	1.01	1.04	1.06	1.10	1.18	1.28	1.35	1.40	1.48
11 < 12	1.00	1.06	1.12	1.16	1.23	1.40	1.47	1.53	1.60
12 < 13	1.11	1.13	1.20	1.25	1.34	1.47	1.52	1.62	1.76
13 < 14	1.20	1.24	1.27	1.30	1.47	1.62	1.67	1.75	1.81
14 < 15	1.33	1.39	1.45	1.51	1.61	1.73	1.78	1.84	1.91
15 < 16	1.45	1.49	1.52	1.60	1.70	1.79	1.84	1.90	2.02
16 < 17	1.55	1.59	1.61	1.66	1.76	1.87	1.98	2.03	2.16
17 < 18	1.54	1.56	1.62	1.69	1.80	1.91	1.96	2.03	2.09
3 < 6	0.616	0.636	0.649	0.673	0.728	0.785	0.817	0.842	0.876
6 < 9	0.787	0.814	0.834	0.866	0.931	1.01	1.05	1.09	1.14
9 < 12	0.972	1.00	1.02	1.07	1.16	1.28	1.36	1.42	1.52
12 < 15	1.19	1.24	1.27	1.32	1.49	1.64	1.73	1.77	1.85
15 < 18	1.50	1.55	1.59	1.65	1.75	1.86	1.94	2.01	2.11

[a] Lack of height measurements for children <2 years in NHANES II precluded calculation of surface areas for this age group.

Table 4B-4. Total Body Surface Area of Female Children in Square Meters

Age (yr)[a]	Percentile 5	10	15	25	50	75	85	90	95
2 < 3	0.516	0.532	0.544	0.557	0.579	0.610	0.623	0.637	0.653
3 < 4	0.555	0.570	0.589	0.607	0.649	0.688	0.707	0.721	0.737
4 < 5	0.627	0.639	0.649	0.666	0.706	0.758	0.777	0.794	0.820
5 < 6	0.675	0.700	0.714	0.735	0.779	0.830	0.870	0.902	0.952
6 < 7	0.723	0.748	0.770	0.791	0.843	0.914	0.961	0.989	1.03
7 < 8	0.792	0.808	0.819	0.854	0.917	0.977	1.02	1.06	1.13
8 < 9	0.863	0.888	0.913	0.932	1.00	1.05	1.08	1.11	1.18
9 < 10	0.897	0.948	0.969	1.01	1.06	1.14	1.22	1.31	1.41
10 < 11	0.981	1.01	1.05	1.10	1.17	1.29	1.34	1.37	1.43
11 < 12	1.06	1.09	1.12	1.16	1.30	1.40	1.50	1.56	1.62
12 < 13	1.13	1.19	1.24	1.27	1.40	1.51	1.62	1.64	1.70
13 < 14	1.21	1.28	1.32	1.38	1.48	1.59	1.67	1.75	1.86
14 < 15	1.31	1.34	1.39	1.45	1.55	1.66	1.74	1.76	1.88
15 < 16	1.38	1.42	1.43	1.47	1.57	1.67	1.72	1.76	1.83
16 < 17	1.40	1.46	1.48	1.53	1.60	1.69	1.79	1.84	1.91
17 < 18	1.42	1.49	1.51	1.56	1.63	1.73	1.80	1.84	1.94
3 < 6	0.585	0.610	0.630	0.654	0.711	0.770	0.808	0.831	0.879
6 < 9	0.754	0.790	0.804	0.845	0.919	1.00	1.04	1.07	1.13
9 < 12	0.957	0.990	1.03	1.06	1.16	1.31	1.38	1.43	1.56
12 < 15	1.21	1.27	1.30	1.37	1.48	1.61	1.68	1.74	1.82
15 < 18	1.40	1.44	1.47	1.51	1.60	1.70	1.76	1.82	1.92

[a] Lack of height measurements for children <2 years in NHANES II precluded calculation of surface areas for this age group.

5. OTHER FACTORS FOR EXPOSURE CALCULATIONS

5.1 Lifetime

Statistical data on life expectancy are published annually by the U.S. Department of Commerce. The latest year for which statistics are available is 1985. Preliminary data for 1985 show that life expectancy for the total population is 74.7 years, for males 71.2 years, and for females 78.2 years (Bureau of the Census 1986). Life expectancies for various subpopulations from 1920 to 1950 are presented in Table 5-1. Although 70 years has been widely used in the past, current data suggest that 75 years would now be a more appropriate average value.

5.2 Body Weight

5.2.1 Background

Published percentile distributions for body weight for men and women (Abraham et al. 1979) and male and female children (Hamill et al. 1979) are based primarily on data gathered in the first National Health and Nutrition Examination Survey conducted during 1970 to 1974. The source of the data used in this study is the more recent, second National Health and Nutrition Examination Survey, NHANES II.

NHANES II was conducted on a nationwide probability sample of approximately 28,000 persons, aged 6 months to 74 years, from the civilian, non-institutionalized population of the United States. The survey began in February 1976 and was completed in February 1980. The sample was selected so that certain population groups thought to be at high risk of malnutrition (persons with low incomes, preschool children, and the elderly) were oversampled. Adjusted sampling weights were then computed for 76 age, sex, and race categories in order to reflect the estimated civilian non-institutionalized U.S. population aged 6 months to 74 years on March 1, 1978, the midpoint of the survey (National Center for Health Statistics 1983).

NHANES II provides information on 20,322 interviewed and examined individuals. Selected sample persons for whom appointments could be made were brought into examination centers. There, examinees changed from

Table 5-1. Expectation of Life at Birth: 1920 to 1985

Year	Total			White			Black and other			Black		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
1920	54.1	53.6	54.6	54.9	54.4	55.6	45.3	45.5	45.2	NA	NA	NA
1930	59.7	58.1	61.6	61.4	59.7	63.5	48.1	47.3	49.2	NA	NA	NA
1940	62.9	60.8	65.2	64.2	62.1	66.6	53.1	51.5	54.9	NA	NA	NA
1950	68.2	65.6	71.1	69.1	66.5	72.2	60.8	59.1	62.9	NA	NA	NA
1955	69.6	66.7	72.8	70.5	67.4	73.7	63.7	61.4	66.1	NA	NA	NA
1960	69.7	66.6	73.1	70.6	67.4	74.1	63.6	61.1	66.3	NA	NA	NA
1965	70.2	66.8	73.7	71.0	67.6	74.7	64.1	61.1	67.4	NA	NA	NA
1970	70.8	67.1	74.7	71.7	68.0	75.6	65.3	61.3	69.4	64.1	60.0	68.3
1971	71.1	67.4	75.0	72.0	68.3	75.8	65.6	61.6	69.8	64.6	60.5	68.9
1972	71.2	67.4	75.1	72.0	68.3	75.9	65.7	61.5	70.1	64.7	60.4	69.1
1973	71.4	67.6	75.3	72.2	68.5	76.1	66.1	62.0	70.3	65.0	60.9	69.3
1974	72.0	68.2	75.9	72.8	69.0	76.7	67.1	62.9	71.3	66.0	61.7	70.3
1975	72.6	68.8	76.6	73.4	69.5	77.3	68.0	63.7	72.4	66.8	62.4	71.3
1976	72.9	69.1	76.8	73.6	69.9	77.5	68.4	64.2	72.7	67.2	62.9	71.6
1977	73.3	69.5	77.2	74.0	70.2	77.9	68.9	64.7	73.2	67.7	63.4	72.0
1978	73.5	69.6	77.3	74.1	70.4	78.0	69.3	65.0	73.5	68.1	63.7	72.4
1979	73.9	70.0	77.8	74.6	70.8	78.4	69.8	65.4	74.1	68.5	64.0	72.9
1980	73.7	70.0	77.4	74.4	70.7	78.1	69.5	65.3	73.6	68.1	63.8	72.5
1981	74.2	70.4	77.8	74.8	71.1	78.4	70.3	66.1	74.4	68.9	64.5	73.2
1982	74.5	70.9	78.1	75.1	71.5	78.7	71.0	66.8	75.0	69.4	65.1	73.7
1983	74.6	71.0	78.1	75.2	71.7	78.7	71.1	67.2	74.9	69.6	65.4	73.6
1984	74.7	71.2	78.2	75.3	71.8	78.8	71.3	67.3	75.2	69.7	65.5	73.7
1985, prel	74.7	71.2	78.2	75.3	71.8	78.7	71.2	67.2	75.2	69.5	65.3	73.7

NA = not available.

Source: Bureau of the Census (1986).

their street clothing into disposable paper examination uniforms and foam rubber slippers designed to facilitate and standardize various elements of the examination. Body measurements, including height and weight, were made at various times of the day and in different seasons of the year; thus, diurnal and seasonal variations in body measurements were not standardized. This approach takes into account the fact that one's weight may vary between winter and summer and may fluctuate with recency of food and water intake and other daily activities (National Center for Health Statistics 1983).

Weight was measured with a Toledo self-balancing scale that mechanically prints weight to quarter-pound intervals directly onto the permanent record. Direct printing was used to minimize observer and recording errors. The scale was calibrated with a set of known weights, and any necessary fine adjustments were made at each new examination location (National Center for Health Statistics 1983).

5.2.2 Methods

NHANES II uses a multistage sample designed to represent the civilian noninstitutionalized population of the United States, 6 months to 74 years of age. Since the sample is not a simple random one, it is necessary to incorporate the person's sample weight for proper analysis of the data. The sample weight is a composite of the individual selection probability, adjustments for nonresponse, and poststratification adjustments (National Center for Health Statistics 1983).

The current methodologies appropriate for the analysis of data from complex surveys such as NHANES II have not been made readily available in the standard statistical software packages. In this study, percentiles (and their standards errors) of the distribution of body weight have been computed from the NHANES II data using the computer program QNTLS. QNTLS is a SAS macro written in PROC MATRIX that performs variance estimation of multistage sample survey data using the Jackknife Repeated Replicate Approach (Rochon and Kalsbeek 1983). A more detailed discussion of this program is presented in a paper by its authors found in Appendix A of the final report by USEPA (1985). Weighted mean body weights have been determined from the NHANES II data using the SAS procedure UNIVARIATE (SAS Institute, Inc. 1982).

5.2.3 Results

Mean body weights of adults, by age, and their standard errors are presented in Table 5-2 for men, women, and men and women combined. Mean body weights of children, by age, and their standard errors are presented in Table 5-3 for boys, girls, and boys and girls combined. Percentile distributions of the body weights of adults and children are included in Appendix 5A.

5.2.4 Application of Body Weight Data

A standard factor in exposure assessments is the average body weight of individuals. The data in Table 5-2 present the mean body weights of men and women, by age groups. The mean body weights for men and women between the ages of 18 and 75 are also included. If the assessor has an age and sex distribution of the exposed population, the mean body weight values of the age groups can be used to better characterize body weights within the population. If the number of individuals in the specific age groups is not known, the average body weights for men and women (18 to 75) can be used as an estimation of body weights within the population. The average body weights of adults, under the column headed "Men and Women," were derived by adding the body weight values for men and the body weight values for women, and dividing by two. The figures in this column can be used if the assessor does not distinguish sex differences within the population.

The data in Table 5-3 present the mean body weights of boys and girls, by age group. The mean body weights for all children between the ages of 0 and 18 were not included by USEPA (1985), presumably because body weights change relatively rapidly during these years. The assessor will need an estimation of the age distribution within the exposed population of children to determine the standard factor of body weight to be used in exposure assessment. The average body weights of children, under

Table 5-2. Body Weights of Adults (kilograms)

Age	Men		Women		Men and women	
	Mean	Std. error of mean	Mean	Std. error of mean	Mean	Std. error of mean
18 < 25	73.7	0.0035	60.6	0.0032	67.2	---
25 < 35	78.7	0.0034	64.2	0.0037	71.5	---
35 < 45	80.8	0.0040	67.1	0.0043	74.0	---
45 < 55	81.0	0.0041	67.9	0.0044	74.5	---
55 < 65	78.8	0.0041	67.9	0.0045	73.4	---
65 < 75	74.8	0.0051	66.6	0.0048	70.7	---
18 < 75	78.1	0.0016	65.4	0.0017	71.8	---

Source: Adapted from USEPA (1985).

Table 5-3. Body Weights of Children (kilograms)

Age	Boys		Girls		Boys and girls	
	Mean	Std. error of mean	Mean	Std. error of mean	Mean	Std. error of mean
< 3	11.9	0.0016	11.2	0.0011	11.6	---
3 < 6	17.6	0.0014	17.1	0.0015	17.4	---
6 < 9	25.3	0.0023	24.6	0.0024	25.0	---
9 < 12	35.7	0.0038	36.2	0.0043	36.0	---
12 < 15	50.5	0.0051	50.7	0.0049	50.6	---
15 < 18	64.9	0.0047	57.4	0.0042	61.2	---

Source: Adapted from USEPA (1985).

the column headed "Boys and Girls," were derived by adding the body weight values for boys and the body weight values for girls, and dividing by two. The figures in this column can be used if the assessor does not distinguish between sexes of children.

5.2.5 Conclusion

Based on data from Table 5-2 for men and women combined, the value of 71.8 kg was rounded to 70 kg. Thus, 70 kg is recommended as the body weight to use for adults. For younger ages, appropriate weights may be selected from Table 5-3.

5.3 Activity Patterns

5.3.1 Background

Time use studies reveal human activity patterns within the population and provide a means by which to estimate the duration of exposure to contaminants in a particular setting or in a variety of settings over a lifetime. A broad range of time use studies have been conducted to determine the amount of time spent in specific activities, such as television viewing and commuting to and from work. On a larger scale, four national studies of time use have been conducted to collect data on how groups of people of different ages, sex, marital status, and employment status use time, with one day (24 hours) as the sampling unit. Different time use patterns depending on the day of the week (i.e., weekdays, Saturdays, and Sundays) were also assessed to give properly weighted weekly averages of time use.

The University of Michigan Institute for Social Research has compiled information and created data bases for three of the national studies. The earliest survey was conducted in 1965-66 as part of a multinational study of daily activities in 12 countries (Szalai 1972). To meet the study design criteria, the portion of the population sampled was limited by age, occupation, and geographic location. The following groups of people were excluded: (1) those over age 65, (2) those in farm-related occupations, (3) those in households where no adult members were in the labor force for at least 10 hours per week, and (4) those who resided in a town with a population of less than 30,000 (Robinson 1977). According to Juster and Stafford (1985), these limitations eliminated approximately 40 percent of the 1965-66 U.S. population over 18 years of age.

The second study, conducted from fall 1975 to fall 1976, was completely nationally representative (Robinson 1977). The entire noninstitutional population 18 years of age and older served as the sampling base, regardless of occupation. Excluded were individuals in college dormitories, nursing homes, and other institutional settings. The Sampling Department within the University of Michigan's Institute for Social Research maintains national lists of sampling units based on U.S. census information about residential locations. A probability sample of households and individuals was obtained from this information. The data for the 1975-76 study were collected from the sample of Americans who were first interviewed in October through November of 1975 as part of the Institute's 1975 Fall Omnibus Study. The study covered time use plus a number of other types of behavior that were of interest to other research programs (Kalton 1985). The respondents in the 1975 general purpose survey were chosen to form a representative sample of American adults living in the continental United States. As part of the time use measurement effort, spouses of respondents, when present, were also interviewed. The original respondents and spouses were reinterviewed three times during 1976, in the months of February, May, and September. The result was an annual representation of time use. Juster and Stafford (1985) discussed the response rates and sample sizes in the four waves of the 1975-76 study. The first wave of the survey had 1,519 respondents, produced by a response rate of 72 percent. The response rates for subsequent interviews ranged from 75 percent in the first (February) reinterview to approximately 94 percent in the last (September) reinterview. The total number of respondents who completed four time diaries with proper distribution between weekdays and weekend days was 975.

The third study, conducted in 1981-82, was a longitudinal panel follow-up survey of respondents who participated in all four waves of the 1975-76 study. Since no new respondents were added to the sample, no time diaries were obtained from individuals aged 18 to 24. The survey had a relatively low response rate and was not intended to be a representative cross-section of the American population (Juster 1985a).

The fourth, and most recent, national study was conducted from January through December of 1985 by Dr. John Robinson of the University of Maryland Survey Research Center. Dr. Robinson was also a key figure in the 1965-66 University of Michigan survey. The data from the 1985 study have undergone preliminary analysis but are not currently available for citation.

5.3.2 Estimations of Exposure Duration

Much of the following discussion of human time use patterns in the United States and their subsequent use in estimating exposure durations is based on the 1975-76 University of Michigan study. As previously mentioned, the 1975-76 data were obtained through use of a time diary. Respondents were asked to reconstruct the activities of the preceding day, from midnight to midnight, in four separate interviews spaced approximately 3 months apart. Time diary dates were selected to include two weekdays, one Saturday, and one Sunday. Each time diary consisted of a sequential list of activities and the time allotted to each activity, with all minutes of the 24-hour period accounted for. The diaries were then subjected to uniform coding procedures by a trained staff.

Data from each separate diary were weighted to adjust for the fact that a week contains 5 weekdays, and all observations were weighted to adjust for differential nonresponse (Hill 1985). In creating the weights, researchers were attempting to produce a weighted sample with a sex and age distribution close to the 1970 census distributions. Some groups of respondents tended to have a lower response rate resulting in a higher level of uncertainty. Reported values for these low response groups required heavier weights to give an accurate representation of time use by these individuals. For example, single men between the ages of 18 and 25 may have a response rate of only 10 percent, whereas the response rate of men in the age group 25 to 44 may be as high as 60 percent. Since respondents should represent the entire male population within a particular age group according to census information, the resulting values of time use obtained from the time diaries of single men (18 to 25) must have proportionately heavier weights. For a more detailed discussion of weighting procedures, refer to Juster et al. (1983).

One inherent deficiency in the time diary method used for the 1975-76 study is the possible misrepresentation of time spent in activities that take place rarely. Activities that take place every day or on a regular basis for most individuals (e.g., sleeping, eating, and working) will be sufficiently represented by the four diaries collected during the sampling period. In contrast, a very large sample of days would be needed to give an accurate representation of activities that take place rarely, such as visiting museums, medical appointments, and attending sporting events. Additionally, if an activity is frequent but highly variable in the amount of time spent, small samples of days will have large sampling errors (Juster 1985b).

Table 5-4 shows the ten major time use categories that formed the basis of the aforementioned national studies. The data from all the studies were coded in the same manner to allow comparisons of human activity patterns through time. The categorization first divides activities into non-free activities (01-49), and free time activities (50-99). Non-free activities are subdivided as follows: paid work codes (00-09), family care (10-39), and personal care (40-49). The categories and corresponding groups of activity codes are further broken down into the 87 activities presented in Table 5-5. A detailed explanation of the coding scheme and activities is presented in Appendix 5B. The time use data in Table 5-5 represent the activity patterns of all respondents of the 1975-76 survey who completed acceptable time diaries for the four-wave study. The data are given in units of mean hours per week spent in

Table 5-4. Major Time Use Activity Categories

Activity code	Activity
01-09	Market work
10-19	House/yard work
20-29	Child care
30-39	Services/shopping
40-49	Personal care
50-59	Education
60-69	Organizations
70-79	Social entertainment
80-89	Active leisure
90-99	Passive leisure

Table 5-5. Weighted Mean Hours Per Week by Sex:
87 Activities and 10 Subtotals

Activity	Men N = 410		Women N = 561		Men and women N = 971	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
01 - Normal work	29.78	20.41	14.99	17.62	21.82	20.33
02 - Unemployment acts	0.14	1.06	0.08	0.75	0.11	0.90
05 - Second job	0.73	3.20	0.17	1.62	0.43	2.49
06 - Lunch at work	1.08	1.43	0.65	1.21	0.85	1.33
07 - Before/after work	0.51	1.27	0.23	0.69	0.36	1.01
08 - Coffee breaks	0.57	1.05	0.36	1.03	0.46	1.04
09 - Travel: to/from work	2.98	2.87	1.45	2.17	2.16	2.63
10 - Meal preparation	1.57	2.61	7.25	5.04	4.63	4.98
11 - Meal cleanup	0.33	0.83	2.30	2.19	1.39	1.97
12 - Indoor cleaning	0.85	2.01	5.03	5.05	3.10	4.46
13 - Outdoor cleaning	1.59	3.59	0.56	1.59	1.03	2.75
14 - Laundry	0.13	0.72	2.44	3.34	1.38	2.75
16 - Repairs/maintenance	2.14	4.29	0.68	3.43	1.35	3.92
17 - Gardening/pet care	0.94	2.78	1.00	2.19	0.97	2.48
19 - Other household	0.92	2.42	0.72	1.84	0.81	2.13
20 - Baby care	0.24	1.20	0.90	3.04	0.60	2.40
21 - Child care	0.24	0.78	0.99	2.11	0.64	1.68
22 - Helping/teaching	0.07	0.61	0.15	0.76	0.11	0.70
23 - Reading/talking	0.07	0.35	0.30	0.86	0.19	0.68
24 - Indoor playing	0.13	0.69	0.18	0.82	0.16	0.76
25 - Outdoor playing	0.06	0.37	0.12	0.72	0.09	0.58
26 - Medical care - child	0.01	0.09	0.09	0.67	0.05	0.50
27 - Babysitting/other	0.14	0.78	0.64	2.58	0.41	1.98
29 - Travel: child care	0.23	0.67	0.50	1.21	0.38	1.00
30 - Everyday shopping	1.45	2.18	2.78	3.25	2.17	2.89
31 - Durables/house shopping	0.19	1.39	0.08	0.51	0.13	1.01
32 - Personal care services	0.06	0.42	0.35	1.14	0.22	0.90
33 - Medical appointments	0.15	0.75	0.37	1.63	0.27	1.31
34 - Govt/financial services	0.15	0.44	0.19	0.61	0.17	0.54
35 - Repair services	0.11	0.45	0.17	0.78	0.14	0.65
37 - Other services	0.11	0.61	0.13	0.61	0.12	0.61
38 - Errands	0.04	0.41	0.06	0.68	0.05	0.57
39 - Travel: goods/services	1.60	2.02	2.14	2.17	1.89	2.12

Table 5-5. (continued)

Activity	Men N = 410		Women N = 561		Men and women N = 971	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
40 - Washing/dressing	4.33	2.39	5.43	3.24	4.92	2.93
41 - Medical care - adults	0.09	0.67	0.18	1.00	0.14	0.86
42 - Help and care	1.02	2.84	1.30	3.04	1.17	2.95
43 - Meals at home	6.59	3.87	6.32	3.53	6.44	3.69
44 - Meals out	2.72	3.48	2.24	2.73	2.46	3.10
45 - Night sleep	55.76	8.43	56.74	8.49	56.29	8.47
46 - Naps/resting	2.94	5.18	3.19	4.70	3.08	4.93
48 - N.A. activities	1.77	6.12	1.99	5.70	1.89	5.89
49 - Travel: personal	2.06	2.59	1.61	2.51	1.82	2.56
50 - Students' classes	0.92	4.00	0.38	2.51	0.63	3.29
51 - Other classes	0.23	1.68	0.15	1.05	0.18	1.38
54 - Homework	0.76	3.48	0.38	1.87	0.56	2.74
56 - Other education	0.11	0.86	0.02	0.22	0.06	0.61
59 - Travel: education	0.29	1.07	0.16	1.06	0.22	1.07
60 - Professional/union organizations	0.04	0.46	0.04	0.62	0.04	0.55
61 - Identity organizations	0.14	0.97	0.18	1.55	0.16	1.31
62 - Political/citizen organizations	0.01	0.08	0.02	0.15	0.01	0.12
63 - Volunteer/helping organizations	0.02	0.32	0.14	1.05	0.09	0.80
64 - Religious groups	0.38	1.82	0.41	1.61	0.40	1.71
65 - Religious practice	0.89	2.05	1.31	2.97	1.12	1.60
66 - Fraternal organizations	0.16	1.17	0.05	0.66	0.10	0.93
67 - Child/family organizations	0.10	0.88	0.21	1.33	0.16	1.15
68 - Other organizations	0.34	2.40	0.32	1.53	0.32	1.98
69 - Travel: organizations	0.43	1.04	0.52	1.02	0.48	1.03
70 - Sports events	0.30	1.31	0.26	1.28	0.28	1.29
71 - Miscellaneous events	0.07	0.52	0.08	0.59	0.07	0.56
72 - Movies	0.31	1.25	0.26	1.13	0.28	1.19
73 - Theatre	0.13	0.93	0.06	0.48	0.09	0.72
74 - Museums	0.04	0.37	0.03	0.35	0.03	0.36
75 - Visiting with others	4.24	5.72	5.84	6.42	5.10	6.16
76 - Parties	0.64	2.05	0.44	1.65	0.53	1.84
77 - Bars/lounges	0.71	2.21	0.46	2.09	0.57	2.15
78 - Other events	0.12	0.72	0.18	1.18	0.15	0.99
79 - Travel: events/social	1.40	1.82	1.26	1.67	1.32	1.74

Table 5-5. (continued)

Activity	Men N = 410 Mean	Men N = 410 Std. dev.	Women N = 561 Mean	Women N = 561 Std. dev.	Men and women N = 971 Mean	Men and women N = 971 Std. dev.
80 - Active sports	1.05	2.62	0.50	1.68	0.76	2.18
81 - Outdoors	1.49	4.59	0.48	1.67	0.94	3.39
82 - Walking/biking	0.52	1.31	0.23	0.98	0.36	1.16
83 - Hobbies	0.69	3.88	0.06	0.43	0.35	2.67
84 - Domestic crafts	0.30	1.59	2.00	4.72	1.21	3.93
85 - Art/literature	0.05	0.45	0.13	1.03	0.09	0.81
86 - Music/drama/dance	0.06	0.49	0.07	0.47	0.07	0.48
87 - Games	0.60	2.00	0.99	3.16	0.81	2.69
88 - Classes/other	0.41	1.75	0.28	1.50	0.34	1.62
89 - Travel: active leisure	0.76	1.91	0.43	1.43	0.58	1.68
90 - Radio	0.39	1.40	0.39	1.55	0.39	1.49
91 - TV	14.75	12.14	13.95	10.67	14.32	11.38
92 - Records/tapes	0.46	2.35	0.33	2.13	0.39	2.23
93 - Reading books	0.37	1.52	0.56	1.83	0.47	1.70
94 - Reading magazines/N.A.	1.32	2.81	1.97	3.67	1.67	3.32
95 - Reading newspapers	1.86	2.72	1.47	2.27	1.65	2.49
96 - Conversations	1.61	2.19	2.18	2.74	1.91	2.52
97 - Letters	0.20	1.06	0.31	1.12	0.26	1.10
98 - Other passive leisure	1.68	3.53	1.41	3.32	1.53	3.42
99 - Travel: passive leisure	0.18	0.49	0.13	0.49	0.15	0.49
Totals by category:						
Hr/wk market work	35.78	23.63	17.94	20.74	26.18	23.83
Hr/wk house/yard	8.47	9.03	19.99	11.88	14.67	12.11
Hr/wk child care	1.18	2.52	3.86	6.36	2.62	5.15
Hr/wk services/shop	3.85	4.48	6.28	5.87	5.16	5.41
Hr/wk personal care	77.28	13.02	79.00	12.35	78.21	12.68
Hr/wk education	2.31	7.73	1.10	4.79	1.66	6.35
Hr/wk organizations	2.50	5.47	3.20	5.33	2.88	5.40
Hr/wk social entertainment	7.95	8.34	8.86	8.01	8.44	8.17
Hr/wk active leisure	5.93	8.23	5.15	7.43	5.51	7.81
Hr/wk passive leisure	22.81	14.11	22.71	12.65	22.75	13.34
Total time	168.07	0.11	168.08	0.08	168.08	0.09

Source: Hill (1985).

each of the 87 activities by men, women, and men and women combined. The standard deviation for each value is included. Tables 5-6 and 5-7 provide additional time use data by age for men and women, respectively. The time value shown for each activity in the column headed "Men" (Table 5-5) is the weighted mean of the activity values for all four age groups shown in Table 5-6. The time value shown for each activity in the column headed "Women" (Table 5-5) is the weighted mean of the activity values for all four age groups shown in Table 5-7. A percentile distribution (10th through 90th percentile) and minimum and maximum time values for all activities, men and women combined, are provided in Appendix 5C. However, since these percentiles are based on only 4-day diaries of activities, it is uncertain how representative they are for long-term exposure assessments. The reported mean values provide an appropriate estimate of long-term behavior averaged over the population; however, the percentiles can be appropriately applied to short term exposures (i.e., lengths comparable to the length of the time-use study) such as acute exposure scenarios.

Tables 5-5, 5-6, and 5-7 allow varying degrees of specificity in the application of time use data to the estimation of exposure duration. It can be seen from these tables that mean hours per week spent in Market (or paid) work activities (01-09) vary greatly by sex and age. Therefore, the assessor may wish to estimate exposure duration based on time use in these activities for all individuals (men and women, Table 5-5), men only (Table 5-5), women only (Table 5-5), men of a specific age group (Table 5-6), or women of a specific age group (Table 5-7). The amount of time allotted to other groups of activities, such as Child care (20-29), Personal care (40-49), and Education (50-59), show less pronounced differences between sexes but large variations by age. In order to estimate the exposure duration of individuals or a population to a specific contaminant, all possible exposure pathways should be identified. An examination of the 87 activities listed in Table 5-5 will enable the assessor to identify human activities associated with the exposure pathways under consideration.

Table 5-6. Weighted Mean Hours Per Week by Age:
87 Activities and 10 Subtotals
Respondents: Males

Activity	Men 18-24 N = 47 Mean	Std. Dev.	Men 25-44 N = 195 Mean	Std. Dev.	Men 45-64 N = 106 Mean	Std. Dev.	Men 65-97 N = 62 Mean	Std. Dev.
01 - Normal work	26.59	19.06	40.50	14.49	28.39	19.50	3.59	10.92
02 - Unemployment acts	0.45	1.74	0.09	0.84	0.12	1.15	0.00	0.00
05 - Second job	0.12	0.51	1.04	3.76	0.54	2.23	0.73	4.21
06 - Lunch at work	0.76	1.00	1.50	1.59	1.14	1.41	0.03	0.18
07 - Before/After work	0.42	1.76	0.72	1.33	0.47	1.09	0.05	0.35
08 - Coffee breaks	0.57	1.07	0.75	1.17	0.59	1.02	0.01	0.02
09 - Travel: to/from work	2.87	3.31	3.82	2.39	3.03	3.20	0.49	1.29
10 - Meal preparation	0.71	0.98	1.08	1.50	2.16	3.27	2.88	3.99
11 - Meal cleanup	0.07	0.25	0.15	0.38	0.49	0.98	0.81	1.45
12 - Indoor cleaning	0.59	1.37	0.81	2.00	1.07	2.44	0.82	1.67
13 - Outdoor cleaning	0.42	1.02	0.96	2.24	1.85	3.27	4.20	6.57
14 - Laundry	0.07	0.30	0.06	0.30	0.26	1.19	0.15	0.74
16 - Repairs/maintenance	1.66	3.12	2.15	4.03	2.42	5.03	2.05	4.64
17 - Gardening/pet care	0.72	2.15	0.41	1.06	1.03	2.50	2.58	5.50
19 - Other household	0.60	1.19	0.58	1.38	1.38	3.56	1.42	3.03
20 - Baby care	0.23	1.21	0.47	1.64	0.01	0.13	0.00	0.00
21 - Child care	0.00	0.00	0.38	0.98	0.22	0.68	0.09	0.53
22 - Helping/teaching	0.00	0.00	0.16	0.92	0.00	0.00	0.00	0.00
23 - Reading/talking	0.00	0.00	0.12	0.48	0.03	0.25	0.04	0.20
24 - Indoor playing	0.01	0.05	0.24	0.87	0.08	0.71	0.00	0.00
25 - Outdoor playing	0.00	0.00	0.12	0.54	0.01	0.05	0.00	0.00
26 - Medical care-child	0.00	0.00	0.01	0.14	0.00	0.00	0.01	0.04
27 - Babysitting/other	0.00	0.00	0.07	0.44	0.20	0.93	0.36	1.39
29 - Travel: child care	0.04	0.17	0.27	0.70	0.33	0.84	0.14	0.47
30 - Everyday shopping	1.01	1.57	1.39	2.11	1.42	2.02	2.09	2.96
31 - Durable/house shopping	0.31	1.81	0.14	0.65	0.30	2.18	0.04	0.27
32 - Personal care services	0.19	0.94	0.02	0.17	0.02	0.11	0.10	0.45

Table 5-6. (continued)

Activity	Men 18-24 N = 47 Mean	Std. Dev.	Men 25-44 N = 195 Mean	Std. Dev.	Men 45-64 N = 106 Mean	Std. Dev.	Men 65-97 N = 62 Mean	Std. Dev.
33 - Medical appointments	0.27	1.24	0.05	0.33	0.09	0.39	0.47	1.27
34 - Govt/Financial services	0.22	0.54	0.14	0.44	0.12	0.34	0.18	0.50
35 - Repair services	0.13	0.49	0.06	0.27	0.19	0.64	0.10	0.37
37 - Other services	0.07	0.19	0.15	0.58	0.12	0.90	0.03	0.14
38 - Errands	0.09	0.87	0.03	0.21	0.01	0.08	0.06	0.51
39 - Travel: goods/services	1.70	1.98	1.50	2.14	1.51	1.80	1.91	2.05
40 - Washing/dressing	3.97	1.94	4.49	2.30	4.51	2.49	3.88	2.79
41 - Medical care r/hh adults[a]	0.01	0.01	0.07	0.53	0.16	1.06	0.11	0.36
42 - Help and care	1.03	2.11	1.29	3.46	0.82	2.65	0.57	1.29
43 - Meals at home	4.46	2.83	5.74	3.55	7.95	3.79	8.81	3.99
44 - Meals out	2.39	2.21	3.15	3.87	2.64	3.47	1.93	3.21
45 - Night sleep	54.83	7.65	53.80	7.55	56.37	7.72	61.45	10.23
46 - Naps/resting	2.21	3.74	2.08	4.55	2.70	4.55	6.68	7.32
48 - N.A. activities	1.63	4.51	0.94	2.97	2.01	6.81	3.97	10.92
49 - Travel: personal	2.60	2.57	1.93	1.92	2.06	3.05	1.89	3.35
50 - Students' classes	4.75	8.54	0.47	2.51	0.00	0.00	0.07	0.75
51 - Other classes	0.64	3.51	0.28	1.43	0.04	0.60	0.00	0.00
54 - Homework	3.50	7.47	0.44	2.37	0.13	0.68	0.11	0.67
56 - Other education	0.61	2.09	0.04	0.36	0.00	0.00	0.00	0.00
59 - Travel: education	1.24	2.10	0.21	0.81	0.04	0.43	0.04	0.26
60 - Professional/union orgs	0.00	0.00	0.08	0.69	0.01	0.04	0.00	0.00
61 - Identity orgs	0.26	1.65	0.09	0.69	0.05	0.52	0.32	1.31
62 - Political/citizen org	0.02	0.15	0.01	0.05	0.00	0.00	0.01	0.10
63 - Volunt/helping org	0.00	0.00	0.02	0.17	0.04	0.59	0.00	0.00
64 - Religious groups	0.14	0.82	0.30	1.61	0.61	2.53	0.42	1.56
65 - Religious practice	0.61	2.10	0.83	2.10	1.05	2.13	1.09	1.71
66 - Fraternal orgs	0.15	0.99	0.17	1.25	0.18	1.34	0.12	0.72
67 - Child/family orgs	0.00	0.00	0.13	0.95	0.15	1.20	0.00	0.00
68 - Other orgs	0.95	5.26	0.11	0.78	0.32	1.82	0.43	1.88
69 - Travel: orgs	0.20	0.47	0.38	1.10	0.50	0.94	0.71	1.35

Table 5-6. (continued)

Activity	Men 18-24 N = 47		Men 25-44 N = 195		Men 45-64 N = 106		Men 65-97 N = 62	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
70 - Sport events	0.33	1.48	0.39	1.47	0.25	1.18	0.11	0.67
71 - Misc. events	0.17	1.11	0.05	0.31	0.07	0.42	0.01	0.10
72 - Movies	1.19	2.45	0.24	0.98	0.09	0.71	0.00	0.00
73 - Theatre	0.33	1.54	0.12	0.91	0.04	0.60	0.11	0.57
74 - Museums	0.04	0.37	0.04	0.31	0.03	0.36	0.08	0.53
75 - Visiting with others	6.07	6.57	3.50	4.62	3.51	5.27	5.91	7.65
76 - Parties	1.54	3.53	0.55	1.76	0.49	1.54	0.29	1.30
77 - Bars/lounges	1.09	2.22	0.91	2.63	0.44	1.84	0.20	1.06
78 - Other events	0.07	0.38	0.15	0.91	0.12	0.69	0.06	0.32
79 - Travel: events/social	2.01	1.89	1.48	1.98	0.97	1.40	1.29	1.73
80 - Active sports	1.82	2.71	1.11	2.60	0.81	2.53	0.52	2.60
81 - Outdoors	2.62	6.34	0.94	2.70	1.79	5.65	1.46	4.76
82 - Walking/biking	0.81	1.77	0.43	1.27	0.48	1.14	0.56	1.18
83 - Hobbies	0.53	1.77	0.60	1.90	0.31	1.48	1.78	9.14
84 - Domestic crafts	0.00	0.00	0.14	0.57	0.26	1.04	1.15	3.67
85 - Art/literature	0.14	0.67	0.02	0.30	0.08	0.60	0.00	0.00
86 - Music/drama/dance	0.05	0.25	0.06	0.50	0.10	0.67	0.01	0.10
87 - Games	0.87	2.34	0.41	1.63	0.56	2.01	0.94	2.52
88 - Classes/other	0.66	2.33	0.30	1.35	0.47	2.00	0.38	1.70
89 - Travel: active leisure	1.49	2.75	0.64	1.66	0.75	1.87	0.43	1.48
90 - Radio	0.33	0.85	0.25	0.92	0.53	1.90	0.62	1:89
91 - TV	12.68	9.34	12.65	9.81	15.93	13.80	20.93	15.27
92 - Records/tapes	1.63	3.52	0.40	2.75	0.17	0.81	0.01	0.12
93 - Reading books	0.15	0.64	0.33	1.40	0.47	1.97	0.48	1.55
94 - Reading mags/n.a.	0.69	1.70	1.17	2.57	1.23	2.25	2.58	4.50
95 - Reading newspapers	0.81	1.41	1.28	1.94	2.37	2.91	3.68	4.04
96 - Conversations	1.10	1.52	1.58	2.16	1.70	2.42	2.00	2.36
97 - Letters	0.32	1.68	0.11	0.49	0.21	1.28	0.36	1.11
98 - Other passive leisure	1.04	2.51	1.07	2.06	1.75	3.46	3.98	6.13
99 - Travel: passive leisure	0.47	0.66	0.14	0.47	0.12	0.39	0.12	0.45

Table 5-6. (continued)

Activity	Men 18-24 N = 47 Mean	Std. Dev.	Men 25-44 N = 195 Mean	Std. Dev.	Men 45-64 N = 106 Mean	Std. Dev.	Men 65-97 N = 62 Mean	Std. Dev.
Totals by category:								
Hr/wk market work	31.77	22.87	48.43	15.66	34.30	22.79	4.89	12.69
Hr/wk house/yard work	4.83	5.38	6.21	6.01	10.66	9.17	14.92	13.79
Hr/wk child care	0.28	1.28	1.89	3.09	0.88	2.04	0.64	1.77
Hr/wk services/shop	3.98	4.39	3.46	4.20	3.78	4.62	4.97	5.02
Hr/wk personal care	73.12	9.71	73.49	11.24	79.21	11.69	89.26	15.09
Hr/wk education	10.75	15.61	1.44	5.02	0.21	1.25	0.22	1.21
Hr/wk organizations	2.33	6.74	2.11	4.17	2.91	6.71	3.09	5.03
Hr/wk social entertainment	12.82	10.98	7.44	7.16	6.03	6.72	8.07	9.45
Hr/wk active leisure	8.99	10.70	4.65	5.66	5.61	7.80	7.23	11.30
Hr/wk passive leisure	19.21	8.48	18.99	11.09	24.48	15.04	34.77	17.57
Total time	168.07	0.03	168.07	0.04	168.07	0.04	168.09	0.26

[a]r/hh = respondent's household.

Source: University of Michigan (1976).

Table 5-7. Weighted Mean Hours Per Week by Age:
87 Activities and 10 Subtotals
Respondents: Females

Activity	Women 18-24 N = 80		Women 25-44 N = 230		Women 45-64 N = 156		Women 65-97 N = 95	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
01 - Normal work	18.22	16.53	18.24	18.10	16.71	18.53	1.73	6.57
02 - Unemployment acts	0.29	1.66	0.06	0.43	0.04	0.36	0.00	0.00
05 - Second job	0.16	1.16	0.15	1.42	0.06	0.47	0.44	3.09
06 - Lunch at work	0.86	1.37	0.87	1.40	0.63	1.09	0.04	0.29
07 - Before/after work	0.28	0.72	0.31	0.85	0.23	0.62	0.02	0.12
08 - Coffee breaks	0.40	0.88	0.47	1.24	0.40	1.07	0.02	0.21
09 - Travel: to/from work	2.01	2.39	1.61	1.94	1.64	2.49	0.20	1.04
10 - Meal preparation	4.63	3.66	7.57	5.01	7.87	5.04	8.00	5.50
11 - Meal cleanup	1.54	1.45	2.31	2.00	2.44	2.51	2.74	2.37
12 - Indoor cleaning	3.72	4.77	5.52	4.90	5.23	5.15	4.93	5.30
13 - Outdoor cleaning	0.21	0.97	0.46	1.36	0.67	1.63	0.88	2.26
14 - Laundry	1.13	1.81	2.53	3.01	3.32	4.10	1.91	3.07
16 - Repairs/maintenance	0.78	2.04	0.48	1.60	0.72	2.95	0.96	6.70
17 - Gardening/pet care	0.48	1.35	0.72	1.37	1.24	2.58	1.67	3.09
19 - Other household	0.15	0.40	0.61	1.51	0.88	1.92	1.22	2.78
20 - Baby care	1.79	3.95	1.64	4.09	0.05	0.41	0.06	0.64
21 - Child care	0.45	1.48	2.24	2.75	0.37	1.32	0.00	0.00
22 - Helping/teaching	0.01	0.05	0.29	0.80	0.13	1.05	0.00	0.00
23 - Reading/talking	0.12	0.40	0.56	1.10	0.25	0.87	0.00	0.00
24 - Indoor playing	0.37	1.21	0.22	0.80	0.12	0.66	0.07	0.59
25 - Outdoor playing	0.09	0.47	0.21	0.96	0.10	0.69	0.00	0.00
26 - Medical care-child	0.03	0.30	0.18	1.01	0.06	0.46	0.00	0.00
27 - Babysitting/other	1.00	4.77	0.29	1.03	1.00	2.60	0.36	1.53
29 - Travel: child care	0.44	1.07	0.96	1.62	0.28	0.82	0.01	0.10
30 - Everyday shopping	2.99	3.32	2.96	3.39	2.82	3.26	2.14	2.83
31 - Durable/house shopping	0.14	0.72	0.08	0.55	0.06	0.43	0.04	0.28
32 - Personal care services	0.04	0.36	0.35	1.16	0.54	1.39	0.31	1.02

Table 5-7. (continued)

Activity	Women 18-24 N = 80 Mean	Std. Dev.	Women 25-44 N = 230 Mean	Std. Dev.	Women 45-64 N = 156 Mean	Std. Dev.	Women 65-97 N = 95 Mean	Std. Dev.
33 - Medical appointments	0.16	0.66	0.42	2.14	0.31	1.02	0.59	1.94
34 - Govt/financial services	0.15	0.88	0.21	0.64	0.17	0.40	0.20	0.54
35 - Repair services	0.17	0.61	0.19	0.85	0.20	0.87	0.10	0.54
37 - Other services	0.09	0.28	0.13	0.45	0.12	0.56	0.18	1.07
38 - Errands	0.01	0.07	0.03	0.20	0.07	0.51	0.15	1.49
39 - Travel: goods/services	1.82	1.79	2.30	2.00	2.31	2.28	1.79	2.57
40 - Washing/dressing	6.17	3.71	5.53	2.53	5.25	3.09	4.84	4.13
41 - Medical care r/hh adults[a]	0.01	0.04	0.09	0.63	0.23	1.07	0.42	1.70
42 - Help and care	0.99	2.57	1.28	3.17	1.47	2.99	1.31	3.30
43 - Meals at home	4.26	2.51	5.51	3.09	7.26	3.63	8.28	3.54
44 - Meals out	2.88	2.68	2.27	2.43	1.98	2.76	2.05	3.20
45 - Night sleep	57.53	9.15	55.50	7.53	55.95	8.95	60.07	8.04
46 - Naps/resting	2.04	2.86	2.59	3.85	3.25	5.22	5.51	5.88
48 - N.A. activities	0.88	2.99	1.56	3.54	1.75	5.23	4.44	10.03
49 - Travel: personal	1.84	2.32	1.68	2.66	1.31	1.87	1.78	3.28
50 - Students' classes	1.62	4.68	0.33	2.61	0.00	0.00	0.00	0.00
51 - Other classes	0.09	0.72	0.28	1.50	0.10	0.83	0.00	0.00
54 - Homework	1.25	3.65	0.34	1.54	0.15	1.01	0.07	0.34
56 - Other education	0.05	0.18	0.01	0.12	0.02	0.32	0.02	0.21
59 - Travel: education	0.65	2.37	0.14	0.68	0.02	0.11	0.01	0.03
60 - Professional/union orgs	0.00	0.00	0.06	0.65	0.07	0.86	0.00	0.00
61 - Identity orgs	0.00	0.00	0.03	0.51	0.38	2.26	0.30	2.04
62 - Political/citizen org	0.01	0.07	0.02	0.14	0.03	0.23	0.00	0.00
63 - Volunt/helping org	0.28	1.41	0.06	0.52	0.13	1.14	0.22	1.29
64 - Religious groups	0.19	1.36	0.38	1.48	0.48	1.81	0.58	1.69
65 - Religious practice	1.29	3.54	0.98	2.85	1.31	2.65	2.04	3.12
66 - Fraternal orgs	0.00	0.00	0.01	0.05	0.06	0.66	0.17	1.32
67 - Child/family orgs	0.00	0.00	0.53	2.17	0.05	0.39	0.00	0.00
68 - Other orgs	0.13	0.68	0.32	1.64	0.22	1.21	0.67	2.22
69 - Travel: orgs	0.35	0.73	0.49	1.19	0.53	0.92	0.73	1.00

Table 5-7. (continued)

Activity	Women 18-24 N = 80 Mean	Std. Dev.	Women 25-44 N = 230 Mean	Std. Dev.	Women 45-64 N = 156 Mean	Std. Dev.	Women 65-97 N = 95 Mean	Std. Dev.
70 - Sport events	0.18	1.12	0.46	1.69	0.17	0.90	0.10	0.92
71 - Misc. events	0.06	0.59	0.18	0.88	0.02	0.20	0.00	0.00
72 - Movies	0.59	1.68	0.21	1.13	0.21	0.89	0.12	0.78
73 - Theatre	0.10	0.62	0.05	0.39	0.10	0.61	0.01	0.09
74 - Museums	0.03	0.23	0.03	0.38	0.04	0.44	0.00	0.00
75 - Visiting with others	8.37	6.26	5.64	7.32	4.86	5.48	5.59	5.57
76 - Parties	0.49	1.74	0.71	2.16	0.28	1.16	0.12	0.75
77 - Bars/lounges	1.59	4.07	0.50	1.93	0.05	0.40	0.04	0.29
78 - Other events	0.25	1.74	0.14	0.60	0.23	1.51	0.06	0.55
79 - Travel: events/social	2.13	2.05	1.37	1.58	1.00	1.41	0.64	1.55
80 - Active sports	0.83	1.59	0.66	1.88	0.35	1.81	0.14	0.74
81 - Outdoors	1.33	3.09	0.36	1.25	0.25	0.93	0.31	1.28
82 - Walking/biking	0.16	0.61	0.19	0.76	0.21	0.92	0.38	1.61
83 - Hobbies	0.18	0.88	0.03	0.22	0.05	0.33	0.02	0.15
84 - Domestic crafts	1.06	3.41	1.01	2.34	2.26	5.28	4.53	7.03
85 - Art/literature	0.12	0.58	0.12	0.86	0.08	0.86	0.25	1.75
86 - Music/drama/dance	0.09	0.42	0.09	0.63	0.06	0.40	0.03	0.17
87 - Games	0.70	2.41	0.46	1.57	1.45	4.17	1.54	3.90
88 - Classes/other	0.50	1.48	0.27	1.65	0.19	1.11	0.22	1.78
89 - Travel: active leisure	0.56	1.31	0.43	1.57	0.42	1.42	0.30	1.23
90 - Radio	0.63	2.66	0.13	0.77	0.25	1.05	0.97	1.93
91 - TV	14.00	10.85	12.55	9.54	14.22	10.47	16.36	12.67
92 - Records/tapes	0.88	3.47	0.44	2.60	0.07	0.44	0.05	0.42
93 - Reading books	0.43	1.11	0.50	1.38	0.62	2.21	0.68	2.39
94 - Reading mags/n.a.	1.15	2.35	1.68	3.29	1.85	2.99	3.59	5.68
95 - Reading newspapers	0.40	0.80	1.07	1.80	1.89	2.49	2.59	2.95
96 - Conversations	2.30	2.27	2.51	3.07	2.11	2.81	1.49	2.13
97 - Letters	0.16	0.87	0.09	0.44	0.34	0.85	0.87	2.15
98 - Other passive leisure	1.26	1.88	0.93	1.60	1.32	2.10	2.76	6.85
99 - Travel: passive leisure	0.27	0.59	0.14	0.61	0.08	0.29	0.07	0.36

Table 5-7. (continued)

Activity	Women 18-24 N = 80		Women 25-44 N = 230		Women 45-64 N = 156		Women 65-97 N = 95	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Totals by category:								
Hr/wk market work	22.23	19.73	21.71	21.24	19.71	21.77	2.45	7.86
Hr/wk house/yard work	12.64	8.95	20.18	11.22	22.38	11.73	22.31	13.25
Hr/wk child care	4.28	7.70	6.58	7.11	2.35	4.77	0.49	1.75
Hr/wk services/shop	5.59	5.11	6.66	5.70	6.61	5.80	5.50	5.90
Hr/wk personal care	76.60	10.80	76.51	11.00	78.44	12.07	88.70	12.31
Hr/wk education	3.66	9.06	1.11	4.52	0.29	1.67	0.10	0.41
Hr/wk organizations	2.25	4.78	2.88	5.09	3.27	5.61	4.71	5.55
Hr/wk social entertnmt	13.79	8.29	9.29	8.84	6.96	6.46	6.67	6.18
Hr/wk active leisure	5.55	6.87	3.61	4.63	5.33	7.88	7.70	10.60
Hr/wk passive leisure	21.48	12.17	20.05	11.45	22.75	11.16	29.44	15.57
Total time	168.07	0.05	168.09	0.05	168.08	0.04	168.07	0.16

[a] r/hh = respondent's household.

Source: University of Michigan (1976).

Time use data for children are extremely limited. As part of the 1981-82 panel follow-up of the 1975-76 study, time use diaries and questionnaires were administered to children of respondents. A total of up to three children between the ages of 3 and 17 were interviewed per household. Table 5-8 is a summary of children's time use data for 18 primary activities obtained in the 1981-82 study. Data were collected from children in two waves. Two time diaries were obtained from each child and sample days were chosen to represent one school day and one nonschool day. Therefore, the weekly averages of time use in Table 5-8 only represent time when children are in school. Since vacation time is not accounted for, the data do not provide an annual estimation of children's time use. Other constraints of the 1981-82 study have been discussed. The values for mean hours per week spent in the various activities in Table 5-8 are the sum of five school days and two nonschool days. Standard deviations and weighted means for boys and girls of all ages combined were not available in the data supplied by Timmer et al. (1985). Although there are many deficiencies in the data, the time activity patterns representing 389 children in Table 5-8 provide the only estimate of children's time use that is currently available.

5.3.3 Application of Time Use Data

The time use data from the 1975-76 study provide a data base of human activity information. Once the exposure pathways of the contaminant of concern are identified, an assessment of all activities associated with the pathways can be performed. The total time allotted to the identified activities can provide an estimate of exposure duration to the contaminant. The following examples illustrate how one can apply the data in Tables 5-5, 5-6, and 5-7 to an estimation of time spent in three exposure scenarios: (1) total time spent in the yard or outdoors at home; (2) time at home vs. time away from home; and (3) and total time indoors vs. outdoors. The data in Tables 5-6 and 5-7 have the same application as the data in Table 5-5 and should be used for cases in which the assessor is interested in determining exposure to a specific age group of men or

Table 5-8. Mean Hours Per Week Spent by Children in Primary Activities by Age and Sex[a]

Activity	Boys 3-11 N = 118	Boys 12-17 N = 77	Girls 3-11 N = 111	Girls 12-17 N = 83
Market work	1.56	3.85	0.13	2.58
Household work	2.49	2.86	3.18	6.30
Personal care	4.98	5.17	5.34	8.45
Eating	9.35	8.01	9.30	7.92
Sleeping	69.50	60.41	69.80	60.23
School	21.00	26.17	21.58	28.50
Studying	1.30	3.25	1.88	3.91
Church	3.52	1.58	2.36	1.78
Visiting	2.10	2.95	1.98	3.85
Sports	3.18	6.50	1.77	3.95
Outdoors	1.83	2.03	1.35	1.46
Hobbies	0.35	0.71	0.21	0.56
Art activities	0.46	1.37	0.46	0.80
Playing and games	17.32	4.25	15.11	1.88
TV	15.78	18.15	14.73	13.67
Reading	1.15	1.23	0.91	1.71
Household conversations	1.30	2.55	1.21	3.50
Other passive leisure	1.28	3.18	1.74	1.33
NA	2.50	0.56	3.05	1.55
Percent of time accounted for by above activities	94.3	91.8	91.1	90.7

[a] This is applicable only for the time of year when children attend school.

Source: Adapted from Timmer et al. (1985).

women. For simplicity, Table 5-5 will be the reference data set in the following examples. Note that several activities are not specifically defined in the tables and the assessor must use judgment and the descriptive information included in Appendix 5B to determine the activities that are associated with a particular exposure pathway or set of pathways. It is assumed that there is no overlap or double-counting of time spent in each of the 87 activities. As discussed in Section 5.3.2, all time diaries were uniformly coded by a trained staff. Respondent diaries contained a sequential list of primary activities throughout the 24-hour sampling period. Refer to Appendix 5B for a listing of all activities included under each activity code.

(1) Example 1. In the case of the presence of a contaminant in the yards of households, the assessor may estimate the time spent in the yard by identifying activities in Table 5-5 that take place outdoors at home. Adding the mean time values for the identified activities results in a figure that is an estimation of exposure duration to the contaminant present in the yard. Activities that take place outdoors at home include:

13 - Outdoor cleaning;
16 - Outdoor repair/maintenance;
17 - Gardening/pet care;
19 - Other household;
25 - Outdoor playing; and
80 - Active sports.

Activities 16, 17, and 19 may include indoor and outdoor activities, while Activity 80 may include time outdoors away from home as well as time spent in the yard. Based on the characteristics of the pollutant and the extent of contamination, the assessor may choose to include all or only a percentage of the time given for Activities 16, 17, 19, and 80 in an estimation of time spent in the yard. For example, adding the mean hours per week spent in Activities 13 and 25, and assuming that 50 percent of the time coded to Activities 16, 17, 19, and 80 is spent in the yard, the results are as follows:

Time Spent Outdoors at Home (weighted mean hours per week)	
Men	4.17
Women	2.13
Men and Women	3.07

(2) Example 2. A comparison of importance, in terms of exposure to contaminants in and around the residence, is the amount of time spent at home vs. away from home. A review of literature relating to the coding scheme for the 87 activities in Table 5-5 resulted in the following breakdown of activity codes by number (refer to Table 5-5 for activity descriptions):

	Activity Code Numbers
Time spent at home:	10-27, 40-43, 45-48, 54, 75-76 (50%), 83-85, 87 (50%), 90-98 (50%)
Time spent away from home:	01-09, 29-39, 44, 49-51, 56-74, 75-76 (50%), 77-82, 86, 87 (50%), 88-89, 90-98 (50%), 99.

Although many codes involve a mix of at-home and away-from-home activities, most codes were assigned to one category only. For codes where this would obviously be incorrect, a 50-50 split was assumed. A more detailed analysis was not considered necessary for this example.

Adding the mean time values for the activities in each of the above two categorical breakdowns results in the following time use estimates:

	Weighted Mean Hours Per Week		
	Men	Women	Men and Women
Time spent at home	97.80	115.98	107.59
Time spent away from home	70.27	52.10	60.49

These figures indicate that, on average, men spend roughly 58 percent of their time at home, women spend approximately 69 percent of their time at home, and the average adult spends 64 percent of his/her time at home.

(3) Example 3. Another time use comparison that is useful in the estimation of exposure duration to indoor and outdoor pollutants is the

amount of time spent indoors vs. outdoors. A summary of earlier time use studies by Chapin (1974) and Szalai (1972) is provided in Table 5-9. The data from the Chapin (1974) study were collected from residents of Washington, D.C. Time use data from urban and suburban populations in 12 countries, including the United States, were collected in the Szalai (1972) study. The data in Table 5-9 indicate that adults spend approximately 93 percent of their time indoors, 2 percent outdoors, and 5 percent in transit (e.g., car, train, bus).

In order to determine the amount of time spent indoors, outdoors, and in transit from the time use data in Table 5-5, all outdoor and transit activities were identified. The remaining activities take place indoors. Refer to Table 5-5 for activity descriptions.

	Activity Code Numbers
Time spent outdoors:	13, 16*, 17, 19* 25, 70*, 80*, 81, 82
Time spent in transit:	09, 29, 39, 49, 59, 69, 79, 89, 99.

*Assuming 50 percent of the time allotted to these activities is spent outdoors.

Although some codes involve a mix of indoor and outdoor activities, most codes were assigned to one category only. For codes where this would obviously be incorrect, a 50-50 split was assumed. A more detailed analysis was not considered necessary for this example.

Mean time values were added and percent of daily time in each location was calculated for the amount of time spent outdoors and in transit. All remaining time was assumed to be spent indoors. The results are as follows:

	Time (weighted mean hours per week)			Percent of Daily Time		
	Outdoors	In transit	Indoors	Outdoors	In transit	Indoors
Men	5.28	9.93	152.87	3.1	5.9	91.0
Women	2.77	8.20	157.11	1.6	4.9	93.5
Men and Women	3.91	9.00	155.17	2.3	5.4	92.4

Table 5-9. Summary of Average Time-Activity Patterns for a 24-Hour Period from Studies by Chapin (1974) and Szalai (1972)[a]

Location	Hours in each location	
	Chapin (1974)	Szalai (1972)
Indoors		
Home	16.03	16.75
Work	4.61	4.03
Other	1.31	1.63
Subtotal	21.95	22.41
Outdoors		
Home	0.27	0.23
Work	--	--
Other	0.27	0.12
Subtotal	0.54	0.35
In transit		
All modes	1.16	1.25
TOTAL	23.65[b]	24.01

[a] Adapted from Sexton and Ryan (1987).
[b] Shortfall from 24 hours not explained by the author.

The estimates of time spent indoors, outdoors, and in transit from the time use data in Table 5-5 for men and women combined are virtually the same as the estimates from the earlier studies (Table 5-9).

Comparisons of the data in Table 5-9 to the previously calculated values in Examples 1 and 2 were also performed. According to the studies summarized in Table 5-9, the average adult spends 0.23 to 0.27 hour per day, or 1.6 to 1.9 hours per week, outdoors at home. These figures are slightly lower than the previous estimates of time spent outdoors at home using the activity data in Table 5-5. By the method proposed in this section it was determined that men, women, and men and women combined spend 4.17, 2.13, and 3.07 mean hours per week outdoors at home, respectively. One source of discrepancy lies in the fact that Table 5-9 reports time-activity patterns for a 24-hour period. The time values in Table 5-5 are mean hours per week weighted to reflect time use on weekdays and weekend days combined. Therefore, the additional time that respondents of the 1975-76 study spent outdoors on weekends (Hill 1985) is accounted for in Table 5-5. This distinction is not necessarily reflected in the data from studies by Chapin (1974) and Szalai (1972).

Table 5-9 also provides an estimation of time spent at home. The studies indicate that adults spend an average of 68 to 71 percent of their total daily time at home. These figures roughly correspond to the time use estimates calculated in Example 2, where it was determined that average adults spend 73 percent of their time at home.

These examples demonstrate the use of time-activity data in determining the average amount of time a population spends in specific or broad groups of activities. The amount of time allotted to an activity represents the duration of exposure to a contaminant associated with the activity. Exposure scenarios will vary among different contaminants and judgment is required when identifying all activities related to exposure pathways.

5.3.4 Regional Variations

Other factors that may affect exposure duration are regional variations in time use patterns and mobility of the population. Analysis of the 1975-76 survey data revealed very small regional differences in time use. Hill (1985) discussed a few notable variations. In southern regions respondents averaged somewhat larger amounts of time in outdoor activities and recreation, such as gardening/pet care, fishing, boating, camping, etc. Hill (1985) also noted that the ratio of time spent playing outdoors with children to time spent playing indoors with children was much higher for adults in the South than for those in other parts of the country. Adults in the West also averaged somewhat more time in outdoor activities than did adults in the North Central or Northeast regions. These variations in time use are presumably due to climatic differences between regions. Other regional differences were present in the activity areas of personal care and leisure. Adults in the South tended to spend larger amounts of time sleeping and less time eating (meals out and at home plus lunch at work) than adults in other areas. However, adults in the South spent a larger proportion of their time eating at home. Respondents from the South averaged more leisure time in domestic crafts than adults in the Northeast, and they spent more time watching television than adults in the West or North Central regions. Overall, regional differences in time use are relatively small. The trends discussed above may warrant consideration in contamination problems in the South and West. A listing of states that correspond to these geographic areas was not included in the discussion.

5.3.5 Population Mobility

An assessment of population mobility can aid in determining the length of exposure of a household in a particular location. For example, the duration of exposure to site-specific contamination, such as a polluted stream from which a family fishes or contaminated soil on which children play or vegetables are grown, will be directly related to the period of time residents live near the contaminated site. The Bureau of the

Census provides information about population mobility; however, this information is difficult to use to determine the average residence time of a homeowner or apartment dweller. Census data provide representations of a cross-section of the population at specific points in time, but the surveys are not designed to follow individual families through time. Appendix 5D summarizes the most current Bureau of the Census information about population mobility.

Other organizations that use residence history information include banks, insurance companies, and credit card companies. Several companies and banks were contacted, and it was determined that residence history information is not compiled statistically or the information is considered confidential and is not available for release to the public. Several real estate and housing associations throughout the country were also contacted. Again, the majority of associations do not follow families or individuals through time. The available information is provided below.

According to Oxford Development Corporation, a property management firm, the average residence time for an apartment dweller has been estimated to range from 18 to 24 months.* A survey of recent home buyers was conducted in 1986 by the National Association of Realtors. The survey provides an overall residence history of 1,200 respondents. The results of the survey were as follows:**

Percent of respondents	Years lived in previous house
5	1 year or less
25	2-3
36	4-7
10	8-9
24	10 years or more

* J. Hendricks, Sales Department, Oxford Development Corporation, personal communication with K. Lisi (Versar) September 10, 1987.

** J. Beckord, Economist, National Association of Realtors, Washington, D.C., personal communication with K. Lisi (Versar) September 14, 1987.

The average length of residence in respondents' previous house was 7 years and the median length was 6 years. Note that the sample includes only recent buyers of houses and not people living in their first house; therefore, the above figures are biased estimates. Because of uncertainty in these estimates, the values were not used in exposure scenarios.

In a survey representing all occupied housing units, conducted in 1983 by the Bureau of the Census, it was determined that 93 percent of householders moved into their present unit between 1950 and 1983 (Bureau of Census 1983). The householders owned the unit they occupied at the time of the survey. The information pertaining to residence time of owner-occupied housing units is as follows:

Year householder moved into unit	Percent of total householders
1982-1983	7.5
1980-1983	24.4
1970-1983	64.6
1965-1983	75.6
1960-1983	83.5
1950-1983	93.0

Using these data, the percent of householders living in houses for specified ranges of time can be determined as follows:

Years lived in current home	Percent of total householders
0 - 1	7.5
1 - 3	16.9
3 - 13	40.2
13 - 18	11.0
18 - 23	7.9
23 - 33	9.5
>33	7.0

Based on these statistics, the 50th percentile and the 90th percentile values were calculated for the number of years lived in the householder's current house. These values were calculated by apportioning the total sample size (18,825 households) to the indicated percentile associated with the applicable range of years lived in current home. Assuming an even distribution within the appropriate range, the 50th and 90th percentile values for years living in current home were determined to be 9.37 and 29.84 years, respectively. These were then rounded to 9 and 30 years. The 50th percentile represents the average length of time a typical homeowner will live in the same house, while the 90th percentile is assumed to represent a reasonable worst case. Therefore, based on the above surveys, the range of 9 to 30 years will be used in the final section of this report to represent the average length of residence and reasonable upper bound of residence time, respectively. Additional aspects such as regional variability, as well as differences among rural, suburban, and urban areas, will be investigated in future editions of this handbook.

5.3.6 Showering

Another current concern is the possibility of exposure to contaminants during the time individuals spend showering. Contaminants may include trihalomethanes and a variety of other volatile organic compounds that can be released to the air from heated water used in the shower. According to Tarshis (1981), 90 percent of the American population takes some sort of bath every day and 5 percent average more than one bath per day. Of these, 75 percent of men and 50 percent of women use showering as a primary means of bathing.

The amount of time spent showering may vary. No information could be found that specifically referred to differences in the time men, women, and children spend showering. Shower flow rates range from 5 to 15 gallons per minute. For a shower length of 5 minutes, the average amount of water used is 40 gallons.*

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* C. Cameron, Customer Service Office, Washington Surburban Sanitary Commission, personal communication with K. Lisi (Versar) August 26, 1987.

A recent study conducted in Australia provided a distribution of the amount of time spent showering (James and Knuiman 1987). This distribution was based on diary records of 2,500 households. Using these data, a cumulative frequency distribution was derived and is presented in Table 5-10. Based on these results, the median shower length is approximately 7 minutes and the 90th percentile is approximately 12 minutes.

In addition to inhalation of volatilized organics from showering, Andelman et al. (1986) pointed out that volatilization from other indoor water uses may also be significant. Andelman et al. (1986) suggest that releases from other sources (e.g., dishwasher, cooking, washing machine) also add to the overall indoor air levels of volatile organics. Releases from showering and these other sources will disperse throughout the house, leading to longer exposure times.

Table 5-10. Cumulative Frequency Distribution of Average Shower Duration for 2,500 Households

Shower duration (minutes)	Cumulative frequency (percentage)
1	0.20
2	0.80
3	3.20
4	9.80
5	22.60
6	38.20
7	52.60
8	63.80
9	73.40
10	81.00
11	86.20
12	90.20
13	92.40
14	94.20
15	95.60
16	96.80
17	97.60
18	98.60
19	99.40
20	100.00

Source: James and Knuiman (1987).

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APPENDIX 5A

Percentile Distribution of the Body Weights of Adults and Children

Table 5A-1. Body Weight of Adult Males in Kilograms

Age	Mean (s.e.)[a]	Percentile (s.e.) 5	10	15	25	50	75	85	90	95
18 < 25	73.7 (0.0035)	55.5 (0.66)	59.3 (0.48)	60.9 (0.41)	63.8 (0.47)	70.9 (0.56)	79.1 (0.65)	83.9 (1.17)	89.4 (0.98)	98.3 (1.85)
25 < 35	78.7 (0.0034)	58.4 (0.35)	61.9 (0.69)	64.6 (0.31)	68.4 (0.43)	76.7 (0.50)	84.6 (0.53)	90.2 (1.00)	94.2 (0.90)	101.7 (0.90)
35 < 45	80.8 (0.0040)	58.8 (1.00)	63.9 (0.80)	66.6 (0.70)	71.2 (0.62)	78.9 (0.58)	87.3 (0.91)	93.6 (0.52)	97.7 (1.04)	103.5 (1.04)
45 < 55	81.0 (0.0041)	59.7 (1.74)	64.4 (0.94)	66.3 (0.44)	70.9 (0.88)	78.1 (0.50)	88.7 (0.56)	94.0 (0.97)	98.3 (0.78)	104.3 (1.20)
55 < 65	78.8 (0.0041)	59.0 (0.84)	63.0 (0.92)	65.4 (0.30)	69.4 (0.31)	76.8 (0.57)	84.8 (0.44)	89.8 (0.47)	93.7 (0.77)	101.4 (0.69)
65 < 75	74.8 (0.0051)	53.5 (0.79)	57.8 (0.58)	60.4 (0.80)	65.2 (0.66)	73.2 (0.50)	81.7 (0.56)	86.9 (0.66)	90.5 (0.81)	96.0 (1.14)
18 < 35	76.4 (0.0025)	57.4 (0.31)	60.2 (0.37)	62.3 (0.45)	66.1 (0.31)	73.8 (0.42)	82.6 (0.52)	87.9 (0.63)	92.6 (0.54)	100.6 (1.14)
35 < 55	80.9 (0.0028)	59.3 (1.34)	64.2 (0.63)	66.4 (0.41)	71.0 (0.45)	78.5 (0.32)	88.0 (0.53)	93.8 (0.42)	98.0 (0.66)	103.8 (1.00)
55 < 75	77.2 (0.0032)	56.5 (0.81)	60.4 (0.63)	63.7 (0.68)	67.5 (0.58)	75.6 (0.40)	83.8 (0.50)	88.9 (0.42)	92.4 (0.58)	99.4 (1.17)
18 < 75	78.1 (0.0016)	57.7 (0.32)	61.2 (0.23)	64.0 (0.30)	67.8 (0.30)	75.9 (0.24)	84.6 (0.28)	90.4 (0.38)	94.7 (0.54)	101.7 (0.56)

[a] s.e. = standard error.

Table 5A-2. Body Weight of Adult Females in Kilograms

Age	Mean (s.e.)[a]	Percentile (s.e.) 5	10	15	25	50	75	85	90	95
18 < 25	60.6 (0.0032)	45.6 (0.62)	48.1 (0.33)	49.6 (0.35)	52.2 (0.29)	57.1 (0.48)	64.1 (0.54)	69.6 (0.83)	74.2 (0.76)	82.1 (1.39)
25 < 35	64.2 (0.0037)	46.4 (0.55)	48.7 (0.35)	50.2 (0.40)	53.2 (0.47)	59.9 (0.32)	68.7 (1.00)	77.3 (1.57)	83.2 (1.31)	92.7 (2.17)
35 < 45	67.1 (0.0043)	48.4 (0.66)	51.0 (0.53)	52.3 (0.66)	55.9 (0.53)	62.4 (0.45)	72.9 (0.87)	80.8 (1.00)	86.7 (1.12)	97.8 (1.94)
45 < 55	67.9 (0.0044)	47.3 (0.62)	50.2 (0.60)	52.5 (0.61)	56.2 (0.73)	64.4 (0.80)	74.8 (0.91)	81.5 (0.99)	86.5 (1.64)	95.0 (2.78)
55 < 65	67.9 (0.0045)	47.6 (0.87)	50.2 (0.79)	53.3 (0.39)	56.5 (0.59)	64.4 (0.47)	74.5 (0.62)	81.3 (0.51)	86.4 (0.71)	94.1 (2.53)
65 < 75	66.6 (0.0048)	46.2 (0.84)	49.8 (0.59)	52.3 (0.52)	56.3 (0.50)	63.8 (0.50)	72.8 (0.99)	79.1 (0.94)	83.6 (0.53)	90.3 (0.90)
18 < 35	62.6 (0.0025)	46.1 (0.34)	48.4 (0.23)	49.9 (0.27)	52.7 (0.24)	58.7 (0.23)	66.6 (0.64)	73.6 (1.07)	78.9 (1.07)	88.0 (1.32)
35 < 55	67.5 (0.0031)	47.8 (0.69)	50.6 (0.39)	52.4 (0.36)	56.0 (0.31)	63.3 (0.44)	73.8 (0.59)	81.1 (0.85)	86.6 (1.01)	96.7 (1.78)
55 < 75	67.3 (0.0033)	47.1 (0.69)	50.0 (0.44)	52.9 (0.49)	56.4 (0.39)	64.2 (0.30)	73.8 (0.43)	80.5 (0.63)	85.1 (0.94)	91.9 (1.83)
18 < 75	65.4 (0.0017)	46.8 (0.33)	49.3 (0.20)	51.2 (0.20)	54.4 (0.20)	61.5 (0.23)	71.1 (0.46)	78.3 (0.53)	83.4 (0.55)	92.3 (1.23)

[a] s.e. = standard error.

Table 5A-3. Body Weight of Male Children in Kilograms

Age	Mean (s.e.)[a]	Percentile (s.e.) 5	10	15	25	50	75	85	90	95
<1	9.3 (0.0015)	7.3 (0.35)	7.6 (0.05)	7.9 (0.25)	8.4 (0.27)	9.2 (0.16)	10.0 (0.09)	10.3 (0.21)	10.8 (0.14)	11.3 (0.13)
1 < 2	11.7 (0.0015)	9.4 (0.08)	9.8 (0.13)	10.0 (0.09)	10.6 (0.09)	11.5 (0.12)	12.4 (0.10)	12.9 (0.22)	13.4 (0.25)	14.3 (0.16)
2 < 3	13.4 (0.0014)	10.9 (0.06)	11.3 (0.07)	11.6 (0.13)	12.3 (0.42)	13.4 (0.07)	14.3 (0.08)	14.9 (0.22)	15.4 (0.38)	16.2 (0.24)
3 < 4	15.5 (0.0016)	12.7 (0.15)	13.3 (0.13)	13.6 (0.13)	14.3 (0.09)	15.3 (0.10)	16.5 (0.34)	17.1 (0.15)	17.7 (0.31)	18.8 (0.60)
4 < 5	17.6 (0.0020)	14.0 (0.23)	14.9 (0.22)	15.3 (0.07)	15.9 (0.12)	17.4 (0.10)	18.8 (0.07)	19.7 (0.24)	20.3 (0.40)	21.6 (0.68)
5 < 6	19.7 (0.0023)	16.0 (0.28)	16.7 (0.09)	17.0 (0.10)	17.7 (0.08)	19.3 (0.12)	21.1 (0.15)	22.2 (0.16)	23.4 (0.19)	24.7 (0.32)
6 < 7	22.8 (0.0030)	17.8 (0.68)	18.9 (0.47)	19.6 (0.52)	20.2 (0.19)	21.9 (0.10)	24.0 (0.06)	26.2 (2.02)	27.8 (1.85)	30.0 (2.18)
7 < 8	24.9 (0.0030)	19.2 (0.18)	20.3 (0.89)	21.1 (0.12)	22.0 (0.46)	24.4 (0.30)	26.5 (0.68)	27.9 (0.29)	29.5 (1.94)	33.4 (1.46)
8 < 9	28.0 (0.0046)	20.4 (0.77)	22.6 (0.48)	23.4 (0.68)	24.3 (0.67)	27.3 (0.69)	29.6 (0.36)	32.8 (1.87)	35.4 (1.84)	38.0 (2.31)
9 < 10	30.7 (0.0048)	23.5 (1.30)	25.3 (0.77)	25.7 (0.48)	26.6 (0.74)	29.7 (0.88)	32.6 (0.64)	34.1 (2.57)	38.3 (1.38)	42.2 (1.63)
10 < 11	36.2 (0.0056)	26.9 (0.88)	27.9 (0.31)	29.4 (0.27)	31.3 (0.84)	34.5 (0.44)	39.1 (1.46)	43.2 (1.48)	45.8 (1.97)	52.7 (4.35)
11 < 12	39.7 (0.0073)	26.8 (0.84)	28.8 (0.73)	31.5 (0.57)	33.2 (0.25)	36.4 (1.42)	45.2 (1.99)	50.3 (2.18)	54.4 (3.91)	59.7 (2.62)
12 < 13	44.1 (0.0078)	30.5 (0.69)	32.1 (0.97)	35.4 (1.94)	37.3 (1.33)	42.1 (1.44)	48.8 (0.86)	52.2 (3.47)	56.5 (5.28)	67.3 (2.48)
13 < 14	49.5 (0.0090)	34.4 (0.70)	36.2 (0.40)	37.7 (0.57)	39.3 (1.00)	47.7 (1.07)	56.4 (1.63)	59.6 (1.50)	64.1 (4.45)	70.9 (3.09)
14 < 15	56.4 (0.0071)	39.9 (1.95)	43.1 (2.35)	46.3 (1.79)	49.3 (0.80)	55.5 (0.99)	62.7 (1.47)	64.7 (1.10)	68.7 (1.72)	71.9 (3.33)
15 < 16	61.2 (0.0078)	46.0 (1.02)	48.7 (0.54)	50.3 (1.39)	54.3 (0.60)	60.2 (0.80)	65.4 (1.10)	68.6 (0.68)	71.8 (3.69)	80.3 (6.70)
16 < 17	66.5 (0.0084)	52.2 (2.33)	53.9 (0.40)	55.0 (0.39)	57.8 (0.53)	63.6 (0.58)	71.7 (3.37)	77.7 (2.33)	81.2 (3.68)	91.1 (7.27)
17 < 18	66.7 (0.0077)	50.4 (0.43)	53.1 (0.80)	54.6 (1.78)	58.8 (0.71)	65.7 (0.67)	72.2 (0.67)	76.5 (4.02)	82.3 (1.22)	87.9 (1.31)
<3	11.9 (0.0016)	8.4 (0.21)	9.1 (0.19)	9.6 (0.17)	10.3 (0.15)	11.8 (0.10)	13.3 (0.05)	14.1 (0.13)	14.4 (0.11)	15.2 (0.12)
3 < 6	17.6 (0.0014)	13.5 (0.08)	14.2 (0.12)	14.6 (0.08)	15.4 (0.08)	17.2 (0.16)	19.2 (0.07)	20.4 (0.14)	21.3 (0.22)	23.0 (0.40)
6 < 9	25.3 (0.0023)	18.8 (0.21)	20.0 (0.29)	20.5 (0.26)	21.8 (0.27)	24.3 (0.23)	27.7 (0.57)	29.4 (0.70)	31.3 (1.40)	34.7 (0.78)
9 < 12	35.7 (0.0038)	25.6 (0.33)	26.4 (0.15)	27.7 (0.18)	29.5 (0.58)	33.5 (0.35)	39.2 (1.02)	43.8 (1.36)	47.2 (2.58)	54.5 (1.97)
12 < 15	50.5 (0.0051)	34.0 (0.52)	36.6 (0.65)	38.3 (0.43)	40.8 (0.99)	49.1 (0.41)	57.7 (1.31)	62.9 (1.24)	65.8 (2.18)	70.9 (2.27)
15 < 18	64.9 (0.0047)	48.9 (0.50)	51.4 (0.32)	53.9 (0.77)	57.0 (0.62)	63.1 (0.85)	70.2 (1.30)	74.8 (0.55)	80.3 (1.33)	88.0 (2.53)

[a] s.e. = standard error.

Table 5A-4. Body Weight of Female Children in Kilograms

Age	Mean (s.e.)[a]	Percentile (s.e.) 5	10	15	25	50	75	85	90	95
<1	8.6 (0.0015)	6.5 (0.20)	7.0 (0.24)	7.3 (0.08)	7.7 (0.13)	8.5 (0.09)	9.2 (0.12)	9.6 (0.29)	9.9 (0.27)	10.4 (0.23)
1 < 2	10.7 (0.0011)	8.7 (0.09)	9.0 (0.13)	9.2 (0.07)	9.7 (0.25)	10.5 (0.08)	11.5 (0.17)	12.1 (0.18)	12.5 (0.16)	13.3 (0.26)
2 < 3	12.8 (0.0013)	10.4 (0.24)	10.9 (0.15)	11.4 (0.39)	11.8 (0.10)	12.6 (0.03)	13.7 (0.07)	14.3 (0.12)	14.7 (0.12)	15.5 (0.27)
3 < 4	14.8 (0.0017)	11.6 (0.07)	12.0 (0.35)	12.7 (0.18)	13.3 (0.10)	14.6 (0.15)	16.0 (0.15)	16.9 (0.25)	17.4 (0.20)	18.1 (0.32)
4 < 5	16.8 (0.0020)	13.6 (0.08)	14.2 (0.11)	14.4 (0.13)	15.1 (0.08)	16.4 (0.27)	18.3 (0.18)	19.2 (0.10)	19.9 (0.73)	21.1 (0.17)
5 < 6	19.4 (0.0026)	15.1 (0.12)	15.9 (0.27)	16.6 (0.31)	17.1 (0.12)	18.8 (0.17)	20.7 (0.81)	22.5 (0.66)	24.2 (1.21)	26.1 (1.19)
6 < 7	21.9 (0.0031)	16.8 (0.48)	17.5 (0.17)	18.3 (0.43)	19.0 (0.27)	21.0 (0.83)	23.7 (0.34)	26.0 (1.22)	27.7 (0.89)	29.2 (0.56)
7 < 8	24.6 (0.0039)	18.8 (0.87)	19.4 (0.20)	19.7 (0.18)	21.3 (0.10)	23.5 (0.43)	26.4 (0.53)	28.7 (0.97)	30.0 (0.76)	33.5 (2.07)
8 < 9	27.5 (0.0045)	21.1 (0.56)	22.3 (0.62)	23.1 (0.48)	24.1 (0.54)	27.3 (0.81)	29.6 (1.11)	30.8 (0.86)	32.5 (0.83)	36.1 (1.89)
9 < 10	31.7 (0.0059)	22.8 (0.31)	24.9 (0.61)	25.6 (0.36)	26.9 (0.39)	29.6 (0.45)	33.2 (0.54)	37.0 (3.34)	43.1 (2.93)	47.9 (3.91)
10 < 11	35.7 (0.0062)	25.6 (0.26)	27.0 (2.34)	28.9 (0.37)	30.3 (1.44)	34.3 (0.80)	39.2 (0.80)	43.6 (0.44)	45.4 (1.01)	48.8 (1.17)
11 < 12	41.4 (0.0078)	29.5 (1.80)	30.3 (0.26)	31.3 (0.42)	33.7 (1.29)	40.0 (1.74)	45.3 (0.42)	50.8 (1.57)	53.0 (2.94)	59.9 (0.35)
12 < 13	46.1 (0.0078)	31.2 (1.06)	34.3 (1.32)	36.3 (1.00)	38.7 (0.73)	45.2 (2.01)	51.6 (2.20)	57.7 (3.46)	60.2 (1.78)	63.4 (2.67)
13 < 14	50.9 (0.0091)	35.3 (1.37)	37.5 (2.63)	39.8 (0.87)	43.8 (0.81)	48.6 (0.96)	55.6 (1.19)	61.9 (2.41)	66.3 (3.62)	73.6 (8.71)
14 < 15	54.3 (0.0076)	39.9 (0.48)	41.7 (1.95)	43.6 (0.67)	46.8 (1.46)	52.8 (0.51)	60.1 (0.89)	64.4 (2.85)	67.4 (0.33)	73.8 (3.13)
15 < 16	55.0 (0.0065)	43.2 (1.26)	44.9 (0.55)	46.4 (0.45)	48.1 (0.27)	53.9 (0.77)	59.5 (0.63)	62.0 (0.89)	64.8 (2.26)	71.6 (2.91)
16 < 17	57.8 (0.0068)	44.1 (2.98)	47.2 (1.25)	48.6 (0.96)	51.1 (0.62)	55.3 (0.51)	61.1 (3.39)	67.4 (2.39)	73.2 (2.03)	77.7 (6.85)
17 < 18	59.6 (0.0082)	45.3 (2.43)	48.8 (1.36)	50.3 (1.03)	51.9 (1.44)	58.3 (1.08)	63.6 (1.60)	69.2 (2.35)	71.5 (1.13)	79.7 (5.28)
<3	11.2 (0.0011)	7.7 (0.09)	8.5 (0.12)	8.9 (0.09)	9.6 (0.22)	11.1 (0.08)	12.6 (0.05)	13.4 (0.07)	13.7 (0.09)	14.5 (0.12)
3 < 6	17.1 (0.0015)	12.6 (0.13)	13.4 (0.12)	14.0 (0.25)	14.8 (0.30)	16.6 (0.11)	18.8 (0.15)	20.1 (0.16)	21.0 (0.24)	23.0 (0.98)
6 < 9	24.6 (0.0024)	17.7 (0.19)	18.9 (0.29)	19.4 (0.14)	20.9 (0.66)	23.7 (0.15)	27.5 (0.37)	29.1 (0.52)	30.3 (0.23)	33.1 (1.36)
9 < 12	36.2 (0.0043)	25.1 (0.35)	26.1 (0.17)	27.5 (0.62)	29.4 (0.33)	33.7 (0.58)	41.4 (1.59)	45.3 (0.37)	48.6 (1.48)	56.0 (5.61)
12 < 15	50.7 (0.0049)	34.9 (0.54)	37.4 (0.94)	39.5 (0.36)	43.0 (0.17)	49.3 (0.58)	56.4 (1.40)	60.8 (1.79)	65.9 (2.69)	70.9 (4.50)
15 < 18	57.4 (0.0042)	44.1 (0.46)	46.6 (0.42)	48.0 (0.29)	50.8 (0.52)	55.5 (0.58)	61.6 (0.87)	66.3 (1.54)	70.3 (1.66)	76.4 (1.57)

[a] s.e. = standard error.

APPENDIX 5B

Activity Codes and Descriptors Used for Adult Time Diaries

WORK AND OTHER INCOME-PRODUCING ACTIVITIES

Paid Work

01 - Normal work: activities at the main job including work brought home, travel that is part of the job, and overtime; "working," "at work"
- Work at home; work activities for pay done in the home when home is the main workplace (include travel as above)

02 - Job search; looking for work, including visits to employment agencies, phone calls to prospective employers, answering want ads
- Unemployment benefits; applying for or collecting unemployment compensation
- Welfare, food stamps; applying for or collecting welfare, food stamps

05 - Second job; paid work activities that are not part of the main job (use this code only when R* clearly indicates a second job or "other" job); paid work for those not having main job; garage sales, rental property

06 - Lunch at the workplace; lunch eaten at work, cafeteria, lunchroom when "where" = work (lunch at a restaurant, code 44; lunch at home, code 43)
- Eating, smoking, drinking coffee as a secondary activity while working (at workplace)

07 - Before and/or after work at the workplace; activities at the workplace before starting or after stopping work; include "conversations," other work. Do not code secondary activities with this primary activity
- Other work-related

08 - Coffee breaks and other breaks at the workplace; unscheduled breaks and other nonwork during work hours at the workplace; "took a break"; "had coffee" (as a primary activity). Do not code secondary activities with this primary activity

09 - Travel; to and from the workplace when R's travel to and from work were both interrupted by stops; waiting for related travel
- Travel to and from the workplace, including time spent awaiting transportation

HOUSEHOLD ACTIVITIES

Indoor

10 - Meal preparation: cooking, fixing lunches
- Serving food, setting table, putting groceries away, unloading car after grocery shopping

11 - Doing dishes, rinsing dishes, loading dishwasher
- Meal cleanup, clearing table, unloading dishwasher

HOUSEHOLD ACTIVITIES (continued)

Indoor (continued)

12 - Miscellaneous, "worked around house," NA if indoor or outdoor
- Routine indoor cleaning and chores, picking up, dusting, making beds, washing windows, vacuuming, "cleaning," "fall/spring cleaning," "housework"

14 - Laundry and clothes care - wash
- Laundry and clothes care - iron, fold, mending, putting away clothes ("Sewing" code 84)

16 - Repairs indoors; fixing, repairing appliances
- Repairs indoors; fixing, repairing furniture
- Repairs indoors; fixing, repairing furnace, plumbing, painting a room

17 - Care of houseplants

19 - Other indoor, NA whether cleaning or repair; "did things in house"

Outdoor

13 - Routine outdoor cleaning and chores; yard work, raking leaves, mowing grass, garbage removal, snow shoveling, putting on storm windows, cleaning garage, cutting wood

16 - Repair, maintenance, exterior; fixing repairs outdoors, painting the house, fixing the roof, repairing the driveway (patching)
- Home improvements: additions to and remodeling done to the house, garage; new roof
- Improvement to grounds around house; repaved driveway

17 - Gardening; flower or vegetable gardening; spading, weeding, composting, picking, "worked in garden"

19 - Other outdoor; "worked outside," "puttering in garage"

MISCELLANEOUS HOUSEHOLD CHORES

16 - Car care; necessary repairs and routine care to cars; tune up
- Car maintenance; changed oil, changed tires, washed cars; "worked on car" except when clearly as a hobby - (code 83)

17 - Pet care; care of household pets including activities with pets; playing with the dog; walking the dog; (caring for pets of relatives, friends, code 42)

19 - Household paperwork; paying bills, balancing the checkbook, making lists, getting the mail, working on the budget
- Other household chores; (no travel), picking up things at home, e.g., "picked up deposit slips" (relate travel to purpose)

CHILD CARE

Child Care for Children of Household

20 - Baby care; care to children aged 4 and under

21 - Child care; care to children aged 5-17
- Child care; mixed ages or NA ages of children

22 - Helping/teaching children learn, fix, make things; helping son bake cookies; helping daughter fix bike
- Help with homework or supervising homework

23 - Giving children orders or instructions; asking them to help; telling them to behave
- Disciplining child; yelling at kids, spanking children; correcting children's behavior
- Reading to child
- Conversations with household children only; listening to children

24 - Indoor playing; other indoor activities with children (including games ("playing") unless obviously outdoor games)

25 - Outdoor playing; outdoor activities with children including sports, walks, biking with, other outdoor games
- Coaching/leading outdoor, nonorganizational activities

26 - Medical care at home or outside home; activities associated with children's health; "took son to doctor," "gave daughter medicine"

Other Child Care

27 - Babysitting (unpaid) or child care outside R's home or for children not residing in HH
- Coordinating or facilitating child's social or instructional nonschool activities; (travel related, code 29)
- Other child care, including phone conversations relating to child care other than medical

29 - Travel related to child's social and instructional nonschool activities
- Other travel related to child care activities; waiting for related travel

OBTAINING GOODS AND SERVICES

Goods (include phone calls to obtain goods)

30 - Groceries; supermarket, shopping for food
- All other shopping for goods; including for clothing, small appliances; at drug stores, hardware stores, department stores, "downtown" or "uptown," "shopping," "shopping center," buying gas, "window shopping"

OBTAINING GOODS AND SERVICES (continued)

Goods (continued)

31 - Durable household goods; shopping for large appliances, cars, furniture
- House, apartment; activities connected to buying, selling, renting, looking for house, apartment, including phone calls; showing house, including traveling around looking at real estate property (for own use)

Services (include phone conversations to obtain services)

32 - Personal care; beauty, barber shop; hairdressers

33 - Medical care for self; visits to doctor, dentist, optometrist, including making appointments

34 - Financial services; activities related to taking care of financial business; going to the bank, paying utility bills (not by mail), going to accountant, tax office, loan agency, insurance office
- Other government services: post office, driver's license, sporting licenses, marriage licenses, police station

35 - Auto services; repair and other auto services including waiting for such services
- Clothes repair and cleaning; cleaners, laundromat, tailor
- Appliance repair: including furnace, water heater, electric or battery operated appliances; including watching repair person
- Household repair services: including furniture; other repair services NA type; including watching repair person

37 - Other professional services; lawyer, counseling (therapy)
- Picking up food at a takeout place - no travel
- Other services, "going to the dump"

38 - Errands; "running errands," NA whether for goods or services; borrowing goods

39 - Related travel; travel related to obtaining goods and services and/or household activities except 31; waiting for related travel

PERSONAL NEEDS AND CARE

Care to Self

40 - Washing, showering, bathing
- Dressing; getting ready, packing and unpacking clothes, personal hygiene, going to the bathroom

41 - Medical care at home to self

PERSONAL NEEDS AND CARE (continued)

Care to Self (continued)

43 - Meals at home; including coffee, drinking, smoking, food from a restaurant eaten at home, "breakfast," "lunch"

44 - Meals away from home; eaten at a friend's home (including coffee, drinking, smoking)
- Meals away from home, except at workplace (06) or at friend's home (44); eating at restaurants, out for coffee

45 - Night sleep; longest sleep for day; (may occur during day for night shift workers) including "in bed," but not asleep

46 - Naps and resting; rest periods, "dozing," "laying down" (relaxing code 98)

48 - Sex, making out
- Personal, private; "none of your business"
- Affection between household members; giving and getting hugs, kisses, sitting on laps

Help and Care to Others

41 - Medical care to adults in household (HH)

42 - Nonmedical care to adults in HH; routine nonmedical care to adults in household; "got my wife up," "ran a bath for my husband"
- Help and care to relatives not living in HH; helping care for, providing for needs of relatives; (except travel) helping move, bringing food, assisting in emergencies, doing housework for relatives; visiting when sick
- Help and care to neighbors, friends
- Help and care to others, NA relationship to respondent

Other Personal and Helping

48 - Other personal; watching personal care activities

49 - Travel (helping); travel related to code 42, including travel that is the helping activity; waiting for related travel
- Other personal travel; travel related to other personal care activities; waiting for related travel; travel, NA purpose of trip - e.g., "went to Memphis" (no further explanation given)

EDUCATION AND PROFESSIONAL TRAINING

50 - Student (full-time); attending classes, school if full-time student; includes daycare, nursery school for children not in school

EDUCATION AND PROFESSIONAL TRAINING (continued)

51 - Other classes, courses, lectures, academic or professional; R not a full-time student or NA whether a student; being tutored

54 - Homework, studying, research, reading, related to classes or profession, except for current job (code 07); "went to the library"

56 - Other education

59 - Other school-related travel; travel related to education coded above; waiting for related travel; travel to school not originating from home

ORGANIZATIONAL ACTIVITIES

Volunteer, Helping Organizations: hospital volunteer group, United Fund, Red Cross, Big Brother/Sister

63 - Attending meetings of volunteer, helping organizations
- Officer work; work as an officer of volunteer, helping organizations; R must indicate he/she is an officer to be coded here
- Fund raising activities as a member of volunteer helping organization, collecting money, planning a collection drive
- Direct help to individuals or groups as a member of volunteer helping organizations; visiting, bringing food, driving
- Other activities as a member of volunteer helping organizations, including social events and meals

Religious Practice

65 - Attending services of a church or synagogue, including participating in the service; ushering, singing in choir, leading youth group, going to church, funerals
- Individual practice; religious practice carried out as an individual or in a small group; praying, meditating, Bible study group (not a church), visiting graves

Religious Groups

64 - Meetings: religious helping groups; attending meetings of helping - oriented church groups -ladies aid circle, missionary society, Knights of Columbus
- Other activities; religious helping groups; other activities as a member of groups listed above, including social activities and meals
- Meetings: other church groups; attending meetings of church group, not primarily helping-oriented, or NA if helping-oriented
- Other activities, other church groups; other activities as a member of church groups that are not helping-oriented or NA if helping, including social activities and meals; choir practice; Bible class

ORGANIZATIONAL ACTIVITIES (continued)

Professional/Union Organizations: State Education Association; AFL-CIO; Teamsters

60 - Meetings; professional/union; attending meetings of professional or union groups
- Other activities, professional/union; other activities as a member of professional or union group including social activities and meals

Child/Youth/Family Organizations: PTA, PTO; Boy/Girl Scouts; Little Leagues; YMCA/YWCA; school volunteer

67 - Meetings, family organizations; attending meetings of child/youth/family-oriented organizations
- Other activities, family organizations; other activities as a member of child/youth/family-oriented organizations including social activities and meals

Fraternal Organizations: Moose, VFW, Kiwanis, Lions, Civitan, Chamber of Commerce, Shriners, American Legion

66 - Meetings, fraternal organizations; attending meetings of fraternal organizations
- Other activities, fraternal organizations; other activities as a member of fraternal organizations including social activities and helping activities and meals

Political Party and Civic Participation: Citizens' groups, Young Democrats, Young Republicans, radical political groups, civic duties

62 - Meetings, political/citizen organizations; attending meetings of a political party or citizen group, including city council
- Other activities, political/citizen organizations; other participation in political party and citizens' groups, including social activities, voting, jury duty, helping with elections, and meals

Special Interest/Identity Organizations (including groups based on sex, race, national origin); NOW; NAACP; Polish-American Society; neighborhood, block organizations; CR groups; senior citizens; Weight Watchers

61 - Meetings: identify organizations; attending meetings of special interest, identity organizations
- Other activities, identity organizations; other activities as a member of a special interest, identity organization, including social activities and meals

Other Miscellaneous Organizations, do not fit above

68 - Other organizations; any activities as a member of an organization not fitting into above categories; (meetings and other activities included here)

ORGANIZATIONAL ACTIVITIES (continued)

Travel Related to Organizational Activities

69 - Travel related to organizational activities as a member of a volunteer (helping) organization (code 63); including travel that is the helping activity, waiting for related travel
- Travel (other organization-related); travel related to all other organization activities; waiting for related travel

ENTERTAINMENT/SOCIAL ACTIVITIES

Attending Spectacles, Events

70 - Sports; attending sports events - football, basketball, hockey, etc.

71 - Miscellaneous spectacles, events: circus, fairs, rock concerts, accidents

72 - Movies; "went to the show"

73 - Theatre, opera, concert, ballet

74 - Museums, art galleries, exhibitions, zoos

Socializing

75 - Visiting with others; socializing with people other than R's own HH members either at R's home or another home (visiting on the phone, code 96); talking/chatting in the context of receiving a visit or paying a visit

76 - Party; reception, weddings

77 - At bar; cocktail lounge, nightclub; socializing or hoping to socialize at bar, lounge
- Dancing

78 - Other events; other events or socializing, do not fit above

79 - Related travel; waiting for related travel

SPORTS AND ACTIVE LEISURE

Active Sports

80 - Football, basketball, baseball, volleyball, hockey, soccer, field hockey
- Tennis, squash, racketball, paddleball
- Golf, miniature golf
-

SPORTS AND ACTIVE LEISURE (continued)

Active Sports (continued)

80 - Swimming, waterskiing
- Skiing, ice skating, sledding, roller skating
- Bowling; pool, ping-pong, pinball
- Frisbee, catch
- Exercises, yoga (gymnastics - code 86)
- Judo, boxing, wrestling

Out of Doors

81 - Hunting
- Fishing
- Boating, sailing, canoeing
- Camping, at the beach
- Snowmobiling, dune-buggies
- Gliding, ballooning, flying
- Excursions, pleasure drives (no destination), rides with the family
- Picnicking

Walking, Biking

82 - Walking for pleasure
- Hiking
- Jogging, running
- Bicycling
- Motorcycling
- Horseback riding

Hobbies

83 - Photography
- Working on cars - not necessarily related to their running; customizing, painting
- Working on or repairing leisure time equipment (repairing the boat, "sorting out fishing tackle")
- Collections, scrapbooks
- Carpentry and woodworking (as a hobby)

Domestic Crafts

84 - Preserving foodstuffs (canning, pickling)
- Knitting, needlework, weaving, crocheting (including classes), crewel, embroidery, quilting, quilling, macrame
- Sewing
- Care of animals/livestock when R is not a farmer (pets, code 17; "farmer", code 01, work)

SPORTS AND ACTIVE LEISURE (continued)

Art and Literature

85 - Sculpture, painting, potting, drawing
- Literature, poetry, writing (not letters), writing a diary

Music/Theatre/Dance

86 - Playing a musical instrument (include practicing), whistling
- Singing
- Acting (rehearsal for play)
- Nonsocial dancing (ballet, modern dance, body movement)
- Gymnastics (lessons - code 88)

Games

87 - Playing card games (bridge, poker)
- Playing board games (Monopoly, Yahtzee, etc.), bingo, dominoes
- Playing social games (scavenger hunts), "played games" - NA kind
- Puzzles

Classes/Lessons for Active Leisure Activity

88 - Lessons in sports activities: swimming, golf, tennis, skating, roller skating
- Lessons in gymnastics, dance, judo, body movement
- Lessons in music, singing, instruments
- Other lessons, not listed above

Travel

89 - Related travel; travel related to sports and active leisure; waiting for related travel; vacation travel

PASSIVE LEISURE

90 - Radio

91 - TV

92 - Records, tapes, "listening to music," listening to others playing a musical instrument

93 - Reading books (current job related, code 07; professionally or class-related, code 54)

94 - Reading magazines, reviews, pamphlets
- Reading NA what; or other

EXAMPLES OF ACTIVITIES IN "OTHER" CATEGORIES (continued)

Other Child Care

27 - Waited for son to get hair cut
- Picked up nephew at sister's house
- "Played with kids" (R's children from previous marriage not living with R)
- Called babysitter

Other Services

37 - Left clothing at Goodwill
- Unloaded furniture (just purchased)
- Returned books (at library)
- Brought clothes in from car (after laundromat)
- Delivered some stuff to a friend
- Waited for father to pick up meat
- Waited for stores to open
- Put away things from swap meet
- Sat in car waiting for rain to stop before shopping
- Waiting for others while they are shopping
- Showing mom what I bought

Other Personal

48 - Waiting to hear from daughter
- Stopped at home, NA what for
- Getting hysterical
- Breaking up a fight (not child care related)
- Waited for wife to get up
- Waiting for dinner at brother's house
- Waiting for plane (meeting someone at airport)
- Laughing
- Crying
- Moaning - head hurt
- Watching personal care activities ("watched dad shave")

Other Education

56 - Watched a film
- In discussion group

EXAMPLES OF ACTIVITIES IN "OTHER" CATEGORIES (continued)

Other Organization

68 - Attending "Club House coffee klatch"
- Waited for church activities to begin
- "Meeting" NA kind
- Cleanup after banquet
- Checked into swap meet - selling and looking

Other Social, Entertainment

78 - Waiting for movies, other events
- Opening presents (at a party)
- Looking at gifts
- Decorating for party
- Tour of a home (friends or otherwise)
- Waiting for date
- Preparing for a shower (baby shower)
- Unloaded uniforms (for parade)

Other Active Leisure

88 - Fed birds, bird watching
- Astrology
- Swinging
- At park
- Showing slides
- Showing sketches

Other Active Leisure (continued)

- Recording music
- Hung around airport (NA reason)
- Picked up fishing gear
- Inspecting motorcycle
- Arranging flowers
- Work on model airplane
- Picked asparagus
- Picked up softball equipment
- Registered to play golf
- Toured a village or lodge (coded 81)

EXAMPLES OF ACTIVITIES IN "OTHER" CATEGORIES (continued)

Other Passive Leisure

98 - Lying in sun
- Listening to birds
- Looking at slides
- Stopped at excavating place
- Looking at pictures
- Walked around outside
- Waiting for a call
- Watched plane leave
- Girl watching/boy watching
- Watching boats
- Wasted time
- In and out of house
- Home movies

* R = Respondent
HH = Household.

Source: Juster et al. (1983).

APPENDIX 5C

Percentile Distributions of Weighted Mean Hours Per Week for Men and Women

Appendix 5C. Percentile Distributions of Weighted Mean Hours Per Week for Men and Women Combined: 87 Activities and 10 Subtotals

Activity	Percentile 10	20	30	40	50	60	70	80	90	Min.	Max.
01-Normal work	0.00	0.06	0.34	8.31	20.22	32.08	37.68	41.33	46.88	0	107
02-Unemployment acts	0.00	0.00	0.00	0.00	0.01	0.11	0.22	0.32	0.42	0	13
05-Second job	0.00	0.00	0.00	0.00	0.03	0.13	0.24	0.35	0.45	0	29
06-Lunch at work	0.00	0.00	0.00	0.14	0.30	0.46	1.07	2.41	3.16	0	9
07-Before/after work	0.00	0.00	0.00	0.00	0.11	0.23	0.35	0.48	1.23	0	11
08-Coffee breaks	0.00	0.00	0.00	0.03	0.16	0.29	0.43	0.83	1.74	0	12
09-Travel: to/from work	0.00	0.00	0.25	0.49	1.35	2.22	3.07	4.07	5.47	0	18
10-Meal preparation	0.00	0.40	0.99	1.72	2.98	4.41	6.12	8.75	12.30	0	27
11-Meal cleanup	0.00	0.00	0.13	0.34	0.62	1.12	1.70	2.58	4.31	0	14
12-Indoor cleaning	0.00	0.00	0.22	0.46	1.21	2.38	3.84	5.85	8.93	0	32
13-Outdoor cleaning	0.00	0.00	0.00	0.04	0.18	0.31	0.46	1.27	3.56	0	29
14-Laundry	0.00	0.00	0.00	0.11	0.27	0.42	1.07	2.40	4.96	0	21
16-Repairs/maintenance	0.00	0.00	0.00	0.03	0.16	0.30	0.43	1.32	4.40	0	58
17-Gardening/pet care	0.00	0.00	0.00	0.07	0.21	0.35	0.49	1.35	3.30	0	35
19-Other household	0.00	0.00	0.00	0.04	0.18	0.32	0.45	1.09	2.68	0	21
20-Baby care	0.00	0.00	0.00	0.00	0.07	0.18	0.29	0.41	1.03	0	30
21-Child care	0.00	0.00	0.00	0.00	0.19	0.24	0.37	0.49	2.60	0	12
22-Helping/teaching	0.00	0.00	0.00	0.00	0.03	0.13	0.24	0.34	0.45	0	11
23-Reading/talking	0.00	0.00	0.00	0.00	0.06	0.17	0.28	0.39	0.58	0	8
24-Indoor playing	0.00	0.00	0.00	0.00	0.04	0.14	0.25	0.36	0.46	0	9
25-Outdoor playing	0.00	0.00	0.00	0.00	0.02	0.12	0.23	0.33	0.44	0	11
26-Medical care-child	0.00	0.00	0.00	0.00	0.01	0.11	0.21	0.32	0.42	0	12
27-Babysitting/other	0.00	0.00	0.00	0.00	0.05	0.16	0.26	0.39	0.50	0	27
29-Travel: child care	0.00	0.00	0.00	0.00	0.12	0.24	0.36	0.48	1.39	0	10
30-Everyday shopping	0.00	0.06	0.35	0.72	1.20	1.81	2.63	3.73	5.92	0	23
31-Durables/house shopping	0.00	0.00	0.00	0.00	0.02	0.12	0.23	0.33	0.43	0	6
32-Personal care services	0.00	0.00	0.00	0.00	0.04	0.15	0.26	0.37	0.48	0	9
33-Medical appointments	0.00	0.00	0.00	0.00	0.05	0.16	0.27	0.37	0.48	0	19
34-Govt/financial services	0.00	0.00	0.00	0.00	0.07	0.18	0.29	0.41	0.69	0	11
35-Repair services	0.00	0.00	0.00	0.00	0.04	0.15	0.26	0.37	0.48	0	10
37-Other services	0.00	0.00	0.00	0.00	0.03	0.14	0.25	0.36	0.47	0	8
38-Errands	0.00	0.00	0.00	0.00	0.01	0.11	0.21	0.32	0.42	0	15
39-Travel: goods/services	0.00	0.22	0.58	0.95	1.32	1.77	2.34	3.23	4.69	0	21
40-Washing/dressing	1.73	2.57	3.27	3.91	4.52	5.19	5.96	6.98	8.48	0	29
41-Medical care - adults	0.00	0.00	0.00	0.00	0.03	0.13	0.24	0.34	0.45	0	14
42-Help and care	0.00	0.00	0.00	0.07	0.22	0.36	0.52	1.43	3.49	0	22

Appendix 5C. (continued)

Activity	Percentile 10	20	30	40	50	60	70	80	90	Min.	Max.
43-Meals at home	2.28	3.43	4.22	5.01	5.85	6.79	7.83	9.23	11.69	0	23
44-Meals out	0.00	0.11	0.42	0.92	1.50	2.34	3.15	4.26	6.43	0	24
45-Night sleep	46.23	50.11	52.24	54.01	56.10	58.38	60.34	62.69	66.63	13	88
46-Naps/resting	0.00	0.00	0.17	0.39	0.98	2.01	3.43	5.74	9.13	0	38
48-N.A. activities	0.00	0.00	0.00	0.14	0.30	0.46	0.97	1.81	4.31	0	67
49-Travel: personal	0.00	0.05	0.33	0.65	1.04	1.42	2.13	3.09	4.97	0	26
50-Students' classes	0.00	0.00	0.00	0.00	0.03	0.13	0.24	0.34	0.45	0	35
51-Other classes	0.00	0.00	0.00	0.00	0.01	0.12	0.22	0.32	0.42	0	27
54-Homework	0.00	0.00	0.00	0.00	0.05	0.16	0.27	0.38	0.49	0	33
56-Other education	0.00	0.00	0.00	0.00	0.01	0.11	0.22	0.32	0.42	0	10
59-Travel: education	0.00	0.00	0.00	0.00	0.04	0.15	0.26	0.36	0.47	0	14
60-Professional/union org.	0.00	0.00	0.00	0.00	0.01	0.11	0.21	0.31	0.41	0	13
61-Identity organizations	0.00	0.00	0.00	0.00	0.01	0.11	0.22	0.32	0.42	0	25
62-Political/citizen org.	0.00	0.00	0.00	0.00	0.01	0.11	0.21	0.31	0.41	0	3
63-Volunteer/helping org.	0.00	0.00	0.00	0.00	0.01	0.11	0.21	0.31	0.42	0	13
64-Religious groups	0.00	0.00	0.00	0.00	0.06	0.18	0.29	0.40	0.76	0	21
65-Religious practice	0.00	0.00	0.00	0.13	0.29	0.45	0.93	1.57	3.36	0	28
66-Fraternal organizations	0.00	0.00	0.00	0.00	0.01	0.11	0.21	0.32	0.42	0	13
67-Child/family org.	0.00	0.00	0.00	0.00	0.01	0.12	0.22	0.32	0.43	0	17
68-Other organizations	0.00	0.00	0.00	0.00	0.03	0.14	0.24	0.35	0.45	0	29
69-Travel: organizations	0.00	0.00	0.00	0.04	0.18	0.32	0.45	0.89	1.48	0	14
70-Sports events	0.00	0.00	0.00	0.00	0.03	0.14	0.25	0.35	0.46	0	12
71-Miscellaneous events	0.00	0.00	0.00	0.00	0.01	0.12	0.22	0.32	0.42	0	10
72-Movies	0.00	0.00	0.00	0.00	0.04	0.15	0.26	0.36	0.47	0	15
73-Theatre	0.00	0.00	0.00	0.00	0.01	0.12	0.22	0.32	0.42	0	9
74-Museums	0.00	0.00	0.00	0.00	0.01	0.11	0.21	0.31	0.41	0	6
75-Visiting with others	0.00	0.32	1.10	2.26	3.39	4.74	6.32	8.60	12.37	0	51
76-Parties	0.00	0.00	0.00	0.00	0.08	0.19	0.31	0.42	1.48	0	16
77-Bars/lounges	0.00	0.00	0.00	0.00	0.07	0.18	0.30	0.41	1.55	0	22
78-Other events	0.00	0.00	0.00	0.00	0.02	0.13	0.23	0.34	0.44	0	16
79-Travel: events/social	0.00	0.00	0.22	0.46	0.82	1.21	1.66	2.37	3.67	0	14
80-Active sports	0.00	0.00	0.00	0.00	0.10	0.22	0.34	0.46	2.73	0	20
81-Outdoors	0.00	0.00	0.00	0.00	0.11	0.23	0.36	0.48	2.70	0	47
82-Walking/biking	0.00	0.00	0.00	0.00	0.08	0.20	0.32	0.43	1.21	0	12
83-Hobbies	0.00	0.00	0.00	0.00	0.04	0.14	0.25	0.36	0.47	0	62
84-Domestic crafts	0.00	0.00	0.00	0.01	0.13	0.26	0.39	0.69	3.50	0	34
85-Art/literature	0.00	0.00	0.00	0.00	0.01	0.11	0.22	0.32	0.42	0	18

Appendix 5C. (continued)

Activity	Percentile 10	20	30	40	50	60	70	80	90	Min.	Max.
86-Music/drama/dance	0.00	0.00	0.00	0.00	0.02	0.12	0.22	0.32	0.42	0	6
87-Games	0.00	0.00	0.00	0.00	0.09	0.21	0.33	0.44	2.81	0	33
88-Classes/other	0.00	0.00	0.00	0.00	0.05	0.16	0.27	0.38	0.48	0	18
89-Travel: active leisure	0.00	0.00	0.00	0.01	0.14	0.27	0.39	0.66	1.78	0	19
90-Radio	0.00	0.00	0.00	0.00	0.08	0.19	0.31	0.42	1.11	0	15
91-Television	1.99	4.66	7.47	9.80	12.25	15.08	18.45	21.97	29.00	0	79
92-Records/tapes	0.00	0.00	0.00	0.00	0.05	0.15	0.26	0.37	0.48	0	30
93-Reading books	0.00	0.00	0.00	0.00	0.08	0.19	0.31	0.43	1.31	0	16
94-Reading magazines/N.A.	0.00	0.00	0.02	0.20	0.37	0.73	1.58	2.85	5.34	0	29
95-Reading newspapers	0.00	0.00	0.16	0.38	0.73	1.26	2.02	3.05	4.91	0	23
96-Conversations	0.00	0.02	0.28	0.58	1.06	1.57	2.48	3.45	5.35	0	18
97-Letters	0.00	0.00	0.00	0.00	0.06	0.18	0.29	0.40	0.69	0	16
98-Other passive leisure	0.00	0.00	0.06	0.25	0.43	0.83	1.35	2.45	4.37	0	45
99-Travel: passive leisure	0.00	0.00	0.00	0.00	0.05	0.17	0.28	0.39	0.50	0	8
Hr/wk - total work	0.00	0.09	0.38	11.22	25.45	37.80	44.80	49.24	55.95	0	110
Hr/wk - house/yard	1.68	3.80	5.90	8.49	11.71	16.05	19.61	24.52	31.67	0	67
Hr/wk - child care	0.00	0.00	0.01	0.19	0.36	0.71	2.15	4.56	9.06	0	44
Hr/wk - services/shop	0.04	0.66	1.61	2.59	3.60	4.69	6.58	9.02	12.10	0	48
Hr/wk - personal care	63.66	68.38	70.93	74.15	76.79	79.55	83.09	87.90	94.28	32	127
Hr/wk - education	0.00	0.00	0.00	0.00	0.07	0.19	0.30	0.41	2.10	0	57
Hr/wk - organizations	0.00	0.00	0.07	0.26	0.45	1.31	2.50	4.71	8.98	0	54
Hr/wk - social/entertainment	0.14	1.31	3.00	4.72	6.43	8.54	10.89	13.96	20.01	0	55
Hr/wk - active leisure	0.00	0.14	0.45	1.45	2.71	4.42	6.66	9.55	14.11	0	63
Hr/wk - passive leisure	7.99	11.70	14.95	17.92	20.44	23.76	27.08	32.28	40.17	0	92

Appendix 50. Mobility of the Resident Population by State: 1980

Region, division, and state	Persons 5 years old, and over[b] 1980 (1,000)	Percent distribution - residence in 1975[a]: Same house in 1980 as 1975	Different house, same county	Different county, same state	Different county, different state
United States	210,323	53.6	25.1	9.8	9.7
Northeast	46,052	61.7	22.3	8.0	6.1
New England	11,594	59.1	23.4	6.7	9.2
Maine	1,047	56.9	24.0	7.5	10.8
New Hampshire	857	51.6	22.8	6.2	18.5
Vermont	476	54.4	23.9	6.5	14.3
Massachusetts	5,398	61.0	22.7	7.6	7.0
Rhode Island	891	60.5	23.9	5.0	8.7
Connecticut	2,925	59.0	24.4	5.5	9.3
Middle Atlantic	34,458	62.6	21.9	8.4	5.0
New York	16,432	61.5	22.6	9.3	3.8
New Jersey	6,904	61.5	20.0	8.8	7.8
Pennsylvania	11,122	65.0	22.0	7.1	5.2
Midwest	54,513	55.4	26.4	10.2	7.0
East North Central	38,623	56.0	27.4	9.6	6.0
Ohio	10,015	56.7	27.9	9.0	5.7
Indiana	5,074	54.8	27.5	9.6	7.6
Illinois	10,593	55.5	28.5	8.1	6.1
Michigan	8,582	56.4	26.2	11.3	5.1
Wisconsin	4,360	56.2	25.5	11.0	6.7
West North Central	15,890	53.9	24.0	11.8	9.4
Minnesota	3,770	55.6	22.8	13.3	7.3
Iowa	2,693	55.6	25.0	10.9	7.9
Missouri	4,564	54.0	24.1	11.8	9.4
North Dakota	598	51.7	23.1	11.4	12.7
South Dakota	633	52.9	23.2	12.1	11.1
Nebraska	1,448	53.1	24.4	11.0	10.5
Kansas	2,184	50.2	25.1	10.7	12.6

Appendix 5D. (continued)

Region, division, and state	Persons 5 years old, and over[b] 1980 (1,000)	Percent distribution - residence in 1975[a]: Same house in 1980 as 1975	Different house, same county	Different county, same state	Different county, different state
South	69,880	52.4	24.1	10.0	12.0
South Atlantic	34,498	52.7	22.4	9.7	13.6
Delaware	555	57.0	26.3	2.0	13.3
Maryland	3,947	55.5	21.9	10.3	10.4
District of Columbia	603	58.2	22.7	(x)	16.3
Virginia	4,991	51.0	17.9	15.0	13.9
West Virginia	1,806	60.9	23.4	6.6	8.6
North Carolina	5,476	56.9	23.5	8.9	9.8
South Carolina	2,884	57.5	22.3	7.7	11.5
Georgia	5,052	52.5	22.8	12.2	11.5
Florida	9,183	46.2	23.7	7.8	19.6
East South Central	13,556	56.0	25.9	7.9	9.5
Kentucky	3,379	54.4	27.2	8.6	9.0
Tennessee	4,269	54.2	27.2	7.4	10.6
Alabama	3,601	57.6	25.3	7.4	8.9
Mississippi	2,307	59.0	22.5	8.6	9.2
West South Central	21,826	49.6	25.6	11.8	11.0
Arkansas	2,113	53.1	24.8	9.1	12.4
Louisiana	3,847	57.0	24.3	9.2	8.4
Oklahoma	2,793	47.6	24.9	12.3	13.7
Texas	13,074	47.3	26.2	12.8	11.0
West	39,879	43.8	28.3	11.0	13.4
Mountain	10,386	42.7	25.1	9.1	21.1
Montana	722	47.3	24.5	12.3	15.0
Idaho	852	44.4	24.7	9.5	20.0
Wyoming	425	38.4	23.6	8.6	28.3
Colorado	2,676	39.8	22.7	14.8	20.6
New Mexico	1,188	50.3	23.2	7.2	17.4
Arizona	2,506	41.9	27.1	5.0	23.9
Utah	1,272	45.8	27.8	8.4	16.0
Nevada	745	34.8	27.4	3.6	31.5

Appendix 5D. (continued)

Region, division, and state	Persons 5 years old, and over[b] 1980 (1,000)	Percent distribution - residence in 1975[a]: Same house in 1980 as 1975	Different house, same county	Different county, same state	Different county, different state
Pacific	29,493	44.2	29.4	11.6	10.7
Washington	3,825	43.7	27.7	10.1	16.2
Oregon	2,437	41.4	26.8	13.4	16.9
California	21,980	44.6	30.2	12.1	8.5
Alaska	363	32.2	27.6	8.7	29.1
Hawaii	888	49.3	25.2	2.8	16.9

[a] Survey assessed changes in residence between 1975 and 1980.
[b] Includes persons residing abroad in 1975.
x = not applicable.

Source: Bureau of the Census, Statistical Abstract (1984).

PART II

1. STANDARD EXPOSURE SCENARIOS

1.1 Approach

The purpose of this section is to demonstrate how to apply the standard factor statistics summarized in the previous sections to specific exposure scenarios. The following scenarios are currently included:

For each scenario, the following information is provided:

- The basic equation for estimating exposure. This equation estimates exposure as the amount of contaminant an individual contacts averaged over lifetime and body weight. Expressed as a lifetime average, the exposure estimate is appropriate for computing cancer risk. If sufficient data are available to determine how the absorption of the chemical into the body differs between the human exposure scenario and the animal experiment used to derive the 95th percent upper confidence limit of the linear slope factor of the dose-response function, the risk estimate can be further refined on this basis. For noncancer effects, the exposure levels are typically compared to Reference Doses (RfDs). In such cases, the equation is modified slightly by substituting exposure duration for lifetime. The EPA intends to add more detailed information on absorption considerations and estimation of noncancer chronic effects to this report in later editions.

- Recommended default values for each parameter in the exposure equation. These values are defaults in the sense that they are intended to be used only when site-specific data are not available to make more accurate estimates. Prior sections of this report provide data and procedures for estimating parameter values and should be used in lieu of these default values if feasible. These default values are presented in three ways: averages, ranges, and distributions. The recommended parameter values were derived solely from our interpretation of the available data. In many situations, different values may be appropriate to use in consideration of policy, precedent, strategy, or other factors.

- Justifications for each recommended parameter value. To the extent possible, these values were derived directly from the preceding sections. In many cases, however, no appropriate data were available and the recommendations were based on the best judgments of the authors in conjunction with EPA. Users are encouraged to modify these assumptions based on site-specific information.

The three types of default values and how they are used are described below:

- The average values are intended to represent typical values and should be used when time allows calculation of only one best estimate. Mean values were used when available; median values were used when means were not reported. Generally, users are encouraged to estimate a range of exposure values to represent the uncertainty.

- A range of values is also provided for each parameter. Where possible these ranges were derived from distributions, basing the lower end on the mean or 50th percentile and the upper end on the 90th or 95th percentile. These values were selected to help create a range of scenarios from typical to reasonable worst-case. Expressing exposures over this range provides an indication of the uncertainty and provides more information to the risk manager for making public health decisions. Typical scenarios were constructed by combining all lower ends (i.e., mean or 50th percentile) of the ranges for each parameter. The EPA does not have an official position on how to define a reasonable worst-case scenario, but we recommend using a combination of some lower values and some upper values. While not producing any firm percentile estimate, this procedure would provide an upper estimate and reduce the possibility of creating an <u>overly worst-case scenario</u>. It is difficult to prescribe a more precise procedure since "reasonable" is a largely subjective term. The best approach for deriving a 90th percentile (or other percentile judged to represent reasonable worst-case) exposure level is by using Monte Carlo techniques. Unfortunately this requires reliable distribution data for each parameter, which is rarely available. It is further recommended that assessors not limit their analysis to only these two scenarios. A variety of parameter combinations can be evaluated as a sensitivity analysis to identify the most influential parameter (see Chapter 2 in Part II). Additionally, an absolute worst-case scenario (made up of absolute upper bounds of each parameter) is useful for purposes of demonstrating that the risk is not of concern.

- The most ideal exposure estimates can be obtained using frequency distributions for the parameter values. Where these distributions are available, the scenario descriptions provide page references to the preceding sections. These parameter distributions can be used in conjunction with Monte Carlo techniques to obtain frequency distributions for exposure levels (see Chapter 2 in Part II).

Some of the parameters used in estimating exposure (primarily concentrations) are exclusively site specific, and therefore default recommendations could not be made.

Note that only the average body weight value is recommended under the set of values for the parameter ranges. Since the body weight appears in the denominator of the exposure equation, a smaller value would lead to larger exposures. This would make the combination of values used in the reasonable worst-case scenario less likely, since the combination of low body weight and high consumption (or inhalation) rates is not likely to occur.

Similarly, only the average lifetime value is recommended under the set of values for the parameter ranges. Use of a short lifetime estimate in the reasonable worst-case scenario could be unlikely in conjunction with a long exposure duration assumption. Additionally, certain lifetime assumptions are made in derivation of the cancer potency factor. Sorting out how to maintain consistency between the exposure and potency values while adjusting lifetime over a relatively narrow range implies more precision than is appropriate in risk assessment.

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

- The contact rate can be based on an individual event, such as 100 g of fish eaten per meal. The duration should be based on the number of events or, in this case, meals.
- The contact rate can also be based on a long-term average, such as 10 g/day. In this case the duration should be based on the total time interval over which the exposure occurs.

The objective is to define the terms so that when multiplied together they give the appropriate estimate of mass of contaminant contacted. This can be accomplished by basing the contact rate on either a long-term average (chronic exposure) or an event (acute exposure) basis, as long as the duration value is selected appropriately. Consider the case in which a person eats a 100-g fish meal every 10 days (long-term average is 10 g/day) for 40 years:

$$(100\ \text{g/day})\ (36.5\ \text{days/year})\ (40\ \text{years}) = 146{,}000\ \text{g}$$

$$(10\ \text{g/day})\ (365\ \text{days/year})\ (40\ \text{years}) = 146{,}000\ \text{g}$$

Thus, a duration of either 36.5 days/year or 365 days/year could be used as long as it is matched with the appropriate contact rate. As shown later in this chapter, both approaches were used depending on the data available.

Normally, exposure scenarios such as those presented in this chapter are used to estimate individual risks. If the scenario is considered representative of a population, then the population risk is estimated by multiplying the individual risk by the population size. Note that exposure durations less than an individual's lifetime were typically recommended. In these cases, the population risk must be computed using the total population exposed over a 70-year period. For example, if the exposure duration is assumed to last 10 years for an individual, the exposed population over 70 years could be 7 people since a different person could be exposed during each 10-year period.

1.2 Ingestion of Drinking Water at Residence

SCENARIO: An individual ingests tap water and beverages made from tap water at his residence. All tap water consumed at the residence is from one contaminated source.

$$\text{Lifetime Average Daily Exposure} = \frac{(CR)\ (C)\ (ED)\ (DF)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

CR = water consumption rate (L/day)
C = concentration of contaminant in water (mg/L)
ED = exposure duration (day)
DF[1] = diet fraction
BW = body weight (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
CR	1.4	1.4-2.0	p. 2-5
C	Site specific		
ED[3]	3,285	3,285-10,950	Not available
DF	0.75	0.75-1.0	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Diet fraction refers to the proportion of drinking water an individual consumes at home from one contaminated source.
2. Range represents the assumed typical value and the assumed reasonable worst-case value.
3. Exposure duration refers to the actual number of days exposed at a given residence.

RATIONALE FOR RECOMMENDED VALUES FOR CONSUMPTION OF DRINKING WATER AT RESIDENCE

Consumption Rate

The water consumption rate of 2 L/day is a historical figure set by the U.S. Army and used extensively throughout the EPA and other agencies. As discussed in Section 2.2, Part I, the scientific literature suggests an average adult drinking water consumption rate of 1.4 L/day. These data can be summarized as follows:

Average (L/day)	Range (L/day)	90th percentile (L/day)	Reference
1.63 (calculated)	--	--	NAS 1977
1.39	0.80-1.96	2.0	Cantor et al. 1987
1.25	0.26-2.80	1.90	Gillies and Paulin 1983
1.20	--	--	Pennington 1983

Average 1.4

For the reasonable worst-case value, the 90th percentile rate reported by Gillies and Paulin (1983), 1.90 L/day, suggests that a rate of 2.0 L/day may be a reasonable approximation. The 90th percentile value suggested by Cantor et al. (1987) is also approximately 2.0 L/day. This value, 2.0 L/day, is recommended as the reasonable worst-case consumption rate.

Exposure Duration

It is assumed that an individual is exposed every day at the same consumption rate. Assuming that an individual spends an average of 9 years at each residence, total exposure would be for 3,285 days. Using a reasonable worst-case assumption of 30 years at any one residence, total exposure would be 10,950 days. These 9- and 30-year values represent a judgment of how long a person will live in one area (see Section 5.3.5).

Diet Fraction

Based on survey data on time spent at home (see Section 5.3.3), the average individual would consume 75 percent of the total amount of water consumed per day at home and 25 percent would be consumed away from home. For the reasonable worst-case value, it was assumed that the individual would consume 100 percent of the total amount at home.

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the consensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 U.S. National Center for Health Statistics survey.

1.3 Ingestion of Homegrown Fruits and Vegetables

SCENARIO: Individuals ingest fruits and vegetables grown in the contaminated soil at their residence.

$$\text{Lifetime Average Daily Exposure} = \frac{(CR)\ (C)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

CR = consumption rate (g/day)
C = concentration of contaminant in food (mg/g)
ED[1] = exposure duration (day)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
CR (vegetables)	50	50-80	pp. 2-19, 2-20
CR (fruits)	28	28-42	pp. 2-20, 2-21
C	Site specific		
ED	650	650-5,500	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the actual number of days in which exposure occurs at a given residence.
2. Range values represent typical and reasonable worst-case values.

RATIONALE FOR RECOMMENDED VALUES FOR INGESTION OF HOMEGROWN FRUITS AND VEGETABLES

Consumption Rate

Based on national survey data (USDA 1980), the average amounts of total fruits and total vegetables consumed on any one day have been estimated as 200 g/day for vegetables and 140 g/day for fruits (see discussion in Section 2.3, Part I). These values assume that all the homegrown fruits and vegetables consumed by exposed individuals are derived from the contaminated source. From Table 2-10, the fraction of vegetables homegrown ranges from 0.04 to 0.75, depending on type. The overall average homegrown fraction from this table is 0.25, representing the typical portion. It was judged that the reasonable worst-case portion would be 0.40. Using these fractions, total homegrown vegetable consumption is estimated as follows:

Typical vegetable consumption = (200 g/day) (0.25) = 50 g/day
Reasonable worst-case vegetable consumption = (200 g/day) (0.40) = 80 g/day.

The fraction of fruits that are homegrown, as shown on Table 2-10, ranges from 0.09 to 0.33 depending on type. The overall average homegrown fraction from this table is 0.20, representing the typical portion. It was judged that a reasonable worst-case portion would be 0.30. Using these fractions, total homegrown fruit consumption is estimated as follows:

Typical fruit consumption = (140 g/day) (0.20) = 28 g/day
Reasonable worst-case fruit consumption = (140 g/day) (0.30) = 42 g/day.

Exposure Duration

The number of days homegrown fruits and vegetables are consumed will depend on the seasonal characteristics of the fruits and vegetables and on factors such as whether they are canned, personal taste, etc.

Additionally, the overall time contaminated food is obtained from a particular source is limited by how long a person lives in an area. No precise data are available on this issue. Thus, it was judged that homegrown fruits and vegetables are eaten primarily during the late summer and fall months when they are harvested, or about 20 percent of the year. For the reasonable worst-case in areas that have longer harvest periods or for people who preserve their food, this exposure duration was judged to be 50 percent of the time. Assuming that an individual spends an average 9 years at each residence, total residence time would be for 3,285 days. Using a reasonable worst-case assumption of 30 years at any one residence, total residence time would be 10,950 days. These 9- and 30-year values represent an estimate of how long a person will live in one area (see Section 5.3.5). Combining residence time and consumption time for homegrown fruits and vegetables results in the following estimates:

Typical exposure duration = (3,285 days) (0.20) = 657 days
Reasonable worst-case exposure duration = (10,950 days) (0.50) = 5,475 days.

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the consensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.4 Ingestion of Homegrown Meat and Dairy Products

SCENARIO: Individuals ingest homegrown meat and dairy products that were either grown on contaminated soil or obtained from animals fed contaminated feed that was grown in contaminated soil.

$$\text{Lifetime Average Daily Exposure} = \frac{(CR)\ (C)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

CR = consumption rate (g/day)
C = concentration of contaminant in food (mg/g)
ED[1] = exposure duration (day)
BW = body weight (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
CR (Beef)	44	44-75	Not available
CR (Dairy)	160	160-300	Not available
C	Site specific		———
ED	7,300	7,300-14,600	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the overall time period in which exposure occurs at a given residence.
2. Range values represent typical and reasonable worst-case values for rural farm households.

RATIONALE FOR RECOMMENDED VALUES FOR CONSUMPTION OF HOMEGROWN MEAT AND DAIRY PRODUCTS

Consumption Rate

Consumption rates for the average amount of homegrown beef and dairy products consumed were derived by averaging the following values from Table 2-11:

Beef (g/day)	Dairy Products (g/day)
124	500
111	308
88	431
96	~400 avg. total
67	40 %
~100 avg. total	160 avg. homegrown
44 %	
44 avg. homegrown	

According to USDA studies (USDA 1966), homegrown beef consumption for rural farm households is 44 percent of total beef consumption, and the consumption of homegrown dairy products for rural farm households is 40 percent of the total consumed. For the average case, it can be assumed that an individual will consume 44 g/day of homegrown beef and 160 g/day of homegrown dairy products. For a reasonable worst-case, it was assumed by judgment that 75 percent of an individual's daily intake would be homegrown. This would amount to 75 g/day of homegrown beef and 300 g/day of homegrown dairy products.

Exposure Duration

Since the consumption rate estimates are long-term averages rather than the actual amount eaten per day, the exposure duration value should represent the overall time period in which exposure occurs instead of the actual number of days that the food is consumed. Farm families are likely to live at one residence longer than the general population, thus the census data suggesting 9 to 30 years for the general population is probably low for farmers. It was judged that a typical farm family would live in one location for 20 years and that 40 years would represent a reasonable worst case exposure duration. Using these values, exposure for a typical case would be 7,300 days and for a reasonable worst-case would be 14,600 days.

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the concensus value of 70 kg traditionally used to exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.5 Ingestion of Recreationally Caught Fish/Shellfish from Large Water Bodies

SCENARIO: A recreational fisherman and his/her family consume fish/shellfish derived from one contaminated large water body while residing at one location.

$$\text{Lifetime Average Daily Exposure} = \frac{(CR)\ (C)\ (ED)\ (DF)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

CR = fish consumption rate (g/day)
C = concentration of contaminant in fish (mg/g)
ED[1] = exposure duration (day)
DF[2] = diet fraction
BW = body weight (kg)
LT = lifetime (yr)

Parameter	Average	Range[3]	Distribution
CR	30	30-140	pp. 2-37, 2-38
C	Site-specific		
ED	3,285	3,285-10,950	Not available
DF	0.2	0.2-0.75	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the overall time period that an individual is exposed at a given residence.
2. Diet fraction represents the portion of a person's fish diet derived from the contaminated source.
3. Range represents typical (~50th percentile or mean) values for total recreational fish catch to reasonable worst-case (~50th percentile) values for populations with high fish consumption rates.

RATIONALE FOR RECOMMENDED VALUES FOR CONSUMPTION OF RECREATIONALLY CAUGHT FISH/SHELLFISH FROM LARGE WATER BODIES

Consumption Rate

The consumption rate data for recreationally caught fish/shellfish from large water bodies can be summarized as follows:

Reasonable Worst Case:

	50th percentile	90th percentile	Reference
	37 g/day	224.8 g/day	Puffer 1981
	23 g/day	54.0 g/day (est)	Pierce et al. 1981
Average	30 g/day	140 g/day	

Although these values were derived from local surveys on the west coast, they are recommended as the consumption rates to be used to estimate fish/shellfish ingestion by recreational fishermen in any area with large water bodies. No consumption rate values are recommended for small water body areas. Guidance for estimating site-specific consumption rates is provided in Section 2.5.3, Part I.

Exposure Duration

The consumption rate estimates are based on long-term averages. Thus, in order to estimate the total amount of fish ingested, these values must be multiplied by an exposure duration equal to the total amount of time spent in one location. Thus, the exposure duration was assumed to equal 9 years or 3,285 days on average, and 30 years or 10,950 days for reasonable worst-case estimates, where 9 and 30 years, respectively, represent judgments of how long a person will live in one area (see Section 5.3.5).

Diet Fraction

An individual is unlikely to obtain all of his/her recreationally caught fish from the same source. The diet fraction term represents this phenomenon. This fraction is best estimated on the basis of site-specific data or judgments. For example, the diet fraction is likely to be higher for large water bodies than for small water bodies. Lacking such information, it was judged that a typical value for this parameter could be 20 percent; for a reasonable worst-case, the value would be 75 percent.

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the concensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.6 Ingestion of Soil - Residential Setting - Children

SCENARIO: A child inadvertently ingests contaminated soil/dust from hands or food while playing in and around his/her residence.

$$\text{Lifetime Average Daily Exposure} = \frac{(CR)\ (C)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

CR = soil consumption rate (g/day)
C = concentration of contaminant in soil (mg/g)
ED[1] = exposure duration (day)
BW = body weight (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
CR	0.2	0.2-0.8	____________
C	Site specific		____________
ED	800	800-2,200	Not available
BW	16	16	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the actual number of days that exposure occurs.
2. Range represents typical (~50th percentile or mean) to reasonable worst-case (~90th percentile) values.

RATIONALE FOR RECOMMENDED VALUES FOR INGESTION OF SOIL

Consumption Rate

As explained in Section 2.6, Part I, the most reliable soil ingestion studies are the tracer studies done by Binder et al. (1986) and by Clausing et al. (1987). The data from these studies can be summarized as follows:

	Element	Soil ingestion rate Avg. (mg/day)	Range (mg/day)
Binder et al. (1986)	Al	181	25 - 1324
	Si	184	31 - 799
Clausing et al. (1987)	Al	230	21 - 878
	AIR	127	48 - 362
		Avg. 180	31 - 841

These studies suggest that soil ingestion among children varies from 0.2 to 0.8 g/day. This range was adopted for the consumption rate estimates. The lower limit, or 0.2 g/days was assumed to represent typical exposure, while the upper range value of 0.8 g/day was selected as the reasonable worst-case value. The upper ends of the range values were used for the reasonable worst-case value because of the small sample size used in these studies (i.e., cannot distinguish 90th percentile).

These values should not be considered long-term average values. The studies from which these values were derived were short-duration studies conducted in warm weather. Because of this, the values are for an exposure "event" rather than for a long-term daily average rate. The rate is also for "warm" month exposure for both indoor (dust) and outdoor (dirt) contact, and assumes equal contamination levels in dirt and dust during "warm" weather months.

Exposure Duration

Since the soil consumption rate estimates represent the actual amount consumed per day, exposure duration must be based on the actual number of days that a child ingests soil. For this scenario, the assumption is that a child only contacts contaminated soil at his/her residence. Time spent in "nearby" uncontaminated areas would reduce exposure. The literature (see Section 2.6.3) suggested that soil ingestion is most prevalent among children aged 1 to 6. During this period, the actual number of days that a child ingests soil will depend on climate and individual behavior patterns. Ingestion may occur outside with direct soil contact or inside from house dust derived from outside soil. Climatic factors, such as how long the soil is frozen, can affect how often children play in the soil and ingest it. It was judged that ingestion of contaminated soil could occur typically 75 percent of the time over a 3-year period. In a reasonable worst case, this would occur 100 percent of the time over a 6-year period. Thus, the range of values was derived as follows:

Typical case: (3 years)(365 days/year)(0.75) = 820 days

Reasonable worst case: (6 years)(365 days/year)(1.00) = 2,200 day

No data were available for deriving distributions.

<u>Body Weight</u>

The 50th percentile body weight of children aged 1 to 6 averages 16 kg. This weight was selected as the typical value. Distribution data are presented in Tables 5A-3 through 5A-4.

<u>Lifetime</u>

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the average lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

Even for exposures limited to childhood ages, the averaging period used in cancer risk assessments should represent the entire life of an individual. Thus, an average of 75 years was assumed to apply.

1.7 Inhalation of Vapors Outside Residence

SCENARIO: An individual is engaged in various activities outside his/her residence and is inhaling contaminant vapors present in ambient air.

$$\text{Lifetime Average Daily Exposure} = \frac{(IR)\ (C)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

IR = inhalation rate (m^3/hr)
C = concentration of contaminant in air ($\mu g/m^3$)
ED[1] = exposure duration (hr)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
IR	1.4	1.4-3.0	Not available
C	Site specific		
ED	1,440	1,440-4,800	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the actual number of hours an individual is exposed outside a given residence.
2. Range values represent typical and reasonable worst-case values.

RATIONALE FOR RECOMMENDED VALUES FOR INHALATION OF VAPORS OUTSIDE RESIDENCE

Inhalation Rate

This parameter varies depending upon the activity levels of the exposed individual. Because activities vary widely depending upon the individual and the environmental setting, a generic mix of activity levels was assumed. More accurate, site-specific activity level data should be used when available. For the average case of an individual performing activities outside the residence, data from Table 3-2 suggest that 37 percent of the time would be spent at a moderate activity level, 28 percent at both the resting and light activity levels, and 27 percent at a heavy activity level. Using the values in Table 3-1, the average inhalation rate for this mix of outdoor activities is 1.4 m^3/hour. For a reasonable worst-case exposure, it was judged that an individual would spend 50 percent of the time at a heavy activity level and 50 percent of the time at a moderate activity level. The reasonable worst-case inhalation rate estimated using these assumptions is 3.0 m^3/hour. The above estimates are based on adults, but assessments applicable to children can be done similarly, using values for specific age groups at specified activity levels as provided in Table 3-1.

Exposure Duration

Exposure duration is determined by multiplying the number of hours exposed per week, the number of weeks exposed per year, and the number of years exposed at a residence. For this route, the number of hours exposed per week must be determined for each specific scenario. A generic value for the number of hours spent outside one's residence has been estimated at 3.07 hours per week. Refer to Section 5.3.3 for an explanation of the derivation of this generic value. This value may be used as a default value for the time spent outside one's residence on a weekly basis. It is also assumed that this value represents an annual average of the amount of time adults spend outdoors at home. Time-use data were collected during the months of October, November, February, May, and September, providing an annual representation of human activity patterns (Hill 1985). It is assumed that an individual is exposed every week of the year. The average number of years an individual lives in any given residence is assumed to be 9. For a reasonable worst-case estimate, a value of 30 years may be used. Thus, the number of hours an individual is exposed outside a given residence is as follows:

$$\text{Typical outdoor exposure} = (9\ \text{yr})\left(\frac{52\ \text{wk}}{\text{yr}}\right)\left(3.07\ \frac{\text{hr}}{\text{wk}}\right) = \sim 1{,}440\ \text{hr}$$

$$\text{Reasonable worst-case outdoor exposure} = (30\ \text{yr})\left(\frac{52\ \text{wk}}{\text{yr}}\right)\left(3.07\ \frac{\text{hr}}{\text{wk}}\right) = \sim 4800\ \text{hr.}$$

These values should only be used when site-specific considerations do not allow estimation of more precise time values. For specific activities that produce exposures of shorter duration, the lower activity-specific values should be used.

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the consensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.8 Inhalation of Vapors Inside Residence

SCENARIO: An individual is engaged in various activities inside his/her residence and is inhaling contaminant vapors present in indoor air.

$$\text{Lifetime Average Daily Exposure} = \frac{(IR)\ (C)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

IR = inhalation rate (m^3/hr)
C = concentration of contaminant in air ($\mu g/m^3$)
ED[1] = exposure duration (hr)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
IR	0.63	0.63-0.89	Not available
C	Site specific		
ED	54,000	54,000-180,000	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the actual number of hours an individual is exposed inside a given residence.
2. Range values represent typical and reasonable worst-case values.

RATIONALE FOR RECOMMENDED VALUES FOR INHALATION OF VAPORS INSIDE RESIDENCE

Inhalation Rate

This parameter varies depending upon the activity levels of the exposed individual. Since activity levels vary widely, a typical mix of activity levels was assumed. More accurate, site-specific activity level data should be used when available. An average inhalation rate for time spent indoors at home was assumed to be 0.63 m^3/hour. This was calculated using the average inhalation rates in Table 3-1 and activity levels from Table 3-2: approximately 48 percent of time at both the resting and the light activity levels, 3 percent at the moderate activity level, and 1 percent at the heavy activity level. A reasonable worst-case value of 0.89 m^3/hour may be used. This value was 25 percent of time at the resting activity level, 60 percent at the light level, 10 percent at the moderate activity level and 5 percent at the heavy activity level. If the assessment is applicable to children, a similar approach can be taken using values for specific age groups at specified activity levels as provided in Table 3-1.

Exposure Duration

Exposure duration is determined by multiplying the number of hours exposed per week, the number of weeks exposed per year, and the number of years exposed at a residence. For this route, the number of hours exposed per week must be determined for each specific scenario. As explained below, a generic value for the number of hours spent inside one's residence has been estimated at 115 hours per week. In a determination of the amount of time adults spend indoors at home, it was assumed, based on activity descriptions in Appendix 5B, that 50 percent of the time allotted to the following activities (Table 5-5) was spent inside the home: 02, 05, 16, 19, 27, 54, 75, 83, 85.

The remaining activity codes describe all other activities taking place indoors at home: 10-12, 14, 20-24, 26, 40-43, 45-48, 84, 90-98.

By adding the time values associated with the above activities, it is estimated that the average adult spends approximately 115 hours per week inside the home. This value may be used as a default value for the time spent inside one's residence on a weekly basis. The average number of years an individual lives in any given residence is assumed to be 9. For a reasonable worst-case estimate, a value of 30 years may be used. Thus, the average number of hours an individual is exposed inside a given residence is 54,000. For the reasonable worst-case estimate, a total of 180,000 hours of exposure can be used. These values should only be used when more precise time values are not available. For specific activities that produce exposures of a shorter duration, the lower activity-specific values should be used (see Section 5.3).

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the consensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.9 Inhalation of Vapors While Showering at Residence[1]

SCENARIO: An individual showers at his/her residence daily and is exposed to contaminants volatilizing from the water.

$$\text{Lifetime Average Daily Exposure} = \frac{(IR)\ (C)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

IR = inhalation rate (m^3/hr)
C = concentration of contaminant in air ($\mu g/m^3$)
ED[2] = exposure duration (hr)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range[3]	Distribution
IR	0.6	0.6	Not available
C	Site specific		————
ED	375	375-2,200	p. 5-36
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

---

1. The contaminants released during showering are likely to be found throughout a house because of the exchange with the bathroom air and releases from other sources within the house (i.e., dishwasher, cooking, washing machine). Recent work by Andelman et al. (1986) suggests that exposure while showering is less than exposure occurring throughout the house because of the longer exposure time.
2. Exposure duration refers to the actual number of hours an individual is exposed while showering at a given residence.
3. No range value is given for inhalation rate since it was felt that 0.6 m^3/hr was representative of the entire exposed population.

RATIONALE FOR RECOMMENDED VALUES FOR INHALATION OF VAPORS WHILE SHOWERING AT RESIDENCE

Inhalation Rate

The value recommended for this parameter assumes that showering represents light activity. The recommended value for this activity is 0.6 m^3/hour (see Table 3-1). No reasonable worst-case value is recommended since it is felt that the light activity level is representative of showering for the entire exposed population.

Exposure Duration

Exposure duration is determined by multiplying the number of hours exposed per week, the number of weeks exposed per year, and the number of years exposed at a residence. The number of hours exposed per week is 0.8 (7 minutes/day) for the average case (see Section 5.3.6), and 1.4 (12 minutes/day) for the reasonable worst-case exposure (James and Knuiman 1987). It was assumed that individuals were exposed daily. The average number of years an individual spends in one residence is assumed to be 9. For a reasonable worst case estimate, a value of 30 years may be used. Thus, the average number of hours an individual is exposed while showering is 375. For the reasonable worst-case estimate, a total of 2,200 hours of exposure can be assumed.

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the consensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.10 Inhalation of Particulates Outside Residence

SCENARIO: An individual is engaged in various activities outside his/her residence and is exposed to contaminated particulates present in ambient air.

$$\text{Lifetime Average Daily Exposure} = \frac{(IR)\ (PC)\ (RF)\ (C)\ (ED)\ (10^{-6}\ g/\mu g)}{(BW)\ (LT)\ (365\ days/yr)}$$

IR = inhalation rate (m^3/hr)
PC = particulate concentration in air ($\mu g/m^3$)
RF = respirable fraction of particulates
C = concentration of contaminant on particulate ($\mu g/g$)
ED[1] = exposure duration (hr)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
IR	1.4	1.4-3.0	Not available
PC	Site specific		________
RF	Site specific		________
C	Site specific		________
ED	1,440	1,440-4,800	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the actual number of hours an individual is exposed outside a given residence.
2. Range values represent typical and reasonable worst-case values.

RATIONALE FOR RECOMMENDED VALUES FOR INHALATION OF PARTICULATES OUTSIDE RESIDENCE

Inhalation Rate

For exposure screening purposes, it can be assumed that the inhalation of particulates takes place at a constant rate. This parameter varies depending upon the activity levels of the exposed individual. Because activities vary widely depending upon the individual and the environmental setting, a generic mix of activity levels was assumed. More accurate, site-specific activity data should be used when available. For the average case of an individual performing activities outside the residence, data from Table 3-2 suggest that 37 percent of the time would be spent at a moderate activity level, 28 percent at both the resting and the light activity levels, and 7 percent at a heavy activity level. The average inhalation rate for this mix of outdoor activities is 1.4 m^3/hour. For a reasonable worst-case exposure, it was assumed that an individual would spend 50 percent of the time at a heavy activity level and 50 percent of the time at a moderate activity level. The reasonable worst-case inhalation rate estimated using these assumptions is 3.0 m^3/hour. The above estimates are based on adults, but assessments applicable to children can be done similarly using values for specific age groups at specified activity levels as provided in Table 3-1.

Exposure Duration

Exposure duration is determined by multiplying the number of hours exposed per week, the number of weeks exposed per year, and the number of years exposed at a residence. For this route, the number of hours exposed per week must be determined for each specific scenario. A generic value for the number of hours spent outside one's residence has been estimated at 3.07 hours per week. Refer to Section 5.3.3 for an explanation of the derivation of this generic value. This value may be used as a default value for the time spent outside one's residence on a weekly basis. It is also assumed that this value represents an annual average of the amount of time adults spend outdoors at home. Time use data were collected for the months of October, November, February, May, and September, providing an annual representation of human activity patterns (Hill 1985). It is assumed that an individual is exposed every week of the year. The average number of years an individual lives in any given residence is assumed to be 9. For a reasonable worst-case estimate, a value of 30 years may be used. Thus, the number of hours an individual is exposed outside a given residence is as follows:

$$\text{Typical outdoor exposure} = (9\ \text{yr})\left(\frac{52\ \text{wk}}{\text{yr}}\right)\left(\frac{3.07\ \text{hr}}{\text{wk}}\right) = \sim 1{,}440\ \text{hr}$$

$$\text{Reasonable worst-case outdoor exposure} = (30\ \text{yr})\left(\frac{52\ \text{wk}}{\text{yr}}\right)\left(\frac{3.07\ \text{hr}}{\text{wk}}\right) = \sim 4{,}800\ \text{hr}$$

These values should only be used when site-specific considerations do not allow estimation of more precise time values. For specific activities that produce exposures of shorter duration, the lower activity-specific values should be used.

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the consensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.11 Inhalation of Particulates Inside Residence

SCENARIO: An individual is engaged in various activities inside his/her residence and is inhaling contaminated particulates present in indoor air.

$$\text{Lifetime Average Daily Exposure} = \frac{(IR)\ (PC)\ (RF)\ (C)\ (ED)\ (10^{-6}\ g/\mu g)}{(BW)\ (LT)\ (365\ days/yr)}$$

IR = inhalation rate (m^3/hr)
PC = particulate concentration in air ($\mu g/m^3$)
RF = respirable fraction of particulates
C = concentration of contaminant on particulate ($\mu g/g$)
ED[1] = exposure duration (hr)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]	Distribution
IR	0.63	0.63-0.89	Not available
PC	Site specific		________
RF	Site specific		________
C	Chemical specific		________
ED	54,000	54,000-180,000	Not available
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

1. Exposure duration refers to the actual number of hours an individual is exposed at a given residence.
2. Range values represent typical and reasonable worst-case values.

RATIONALE FOR RECOMMENDED VALUES FOR INHALATION OF PARTICULATES INSIDE RESIDENCE

Inhalation Rate

For exposure screening purposes, it can be assumed that the inhalation of particulates takes place at a constant rate. This parameter varies depending upon the activity levels of the exposed individual. Since activity levels vary widely, a typical mix of activity levels was assumed. More accurate, site-specific activity data should be used when available. The average inhalation rate for time spent indoors at home was assumed to be 0.63 m^3/hour. This was calculated using the average adult inhalation rates in Table 3-1 and activity levels from Table 3-2: approximately 48 percent of the time at both the resting and the light activity levels, 3 percent at the moderate activity level, and 1 percent at the heavy activity level. A reasonable worst-case value of 0.89 m^3/hour may be used. This value was calculated assuming 25 percent of time at the resting activity level, 60 percent at the light activity level, 10 percent at the moderate activity level, and 5 percent at the heavy activity level. If the assessment is applicable to children, a similar approach can be taken, using values for specific age groups at specified activity levels as provided in Table 3-1.

Exposure Duration

Exposure duration is determined by multiplying the number of hours exposed per week, the number of weeks exposed per year, and the number of years exposed at a residence. For this route, the number of hours exposed per week must be determined for each specific scenario. As explained below, a generic value for the number of hours spent inside one's residence has been estimated at 115 hours per week. In a determination of the amount of time adults spend indoors at home, it was assumed, based on activity descriptions in Appendix 5B, that 50 percent of the time allotted to the following activities (Table 5-5) was spent inside the home: 02, 05, 16, 19, 27, 54, 75, 83, 85.

The remaining activity codes describe all other activities taking place indoors at home: 10-12, 14, 20-24, 26, 40-43, 45-48, 84, 90-98.

By adding the time values associated with the above activities, it is estimated that the average adult spends approximately 115 hours per week inside the home. This value may be used as a default value for the time spent inside a house on a weekly basis. The average number of years an individual lives in any given residence is assumed to be 9. For a reasonable worst-case estimate, a value of 30 years may be used. Thus, the average number of hours an individual is exposed inside a given residence is 54,000. For the reasonable worst-case estimate, a total of 180,000 hours of exposure can be used. These values should only be used when more precise time values are not available. For specific activities that produce exposures of a shorter duration, the lower activity-specific values should be used (see Section 5.3).

Body Weight

The average body weight for an adult (men and women combined) was calculated to be 71.8 kg (USEPA 1985). Since this approximates the consensus value of 70 kg traditionally used for exposure/risk assessments, the value of 70 kg should be used to represent average body weight.

Lifetime

According to the 1985 edition of the Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.6 years, and the figures have shown a steady increase in life span through time. Therefore, an average figure of 75 years was used for the lifetime of men and women. The source of the data is a 1982 National Center for Health Statistics survey.

1.12 Dermal Contact with Water at Residence

$$\text{Lifetime Average Daily Dose*} = \frac{(C)\ (Kp)\ (A)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

C = contaminant concentration in water (mg/cm^3)
Kp = dermal permeability constant for contaminant (cm/hr)
A = skin surface area contacted (cm^2)
ED = exposure duration (hr)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range	Distribution
C	Site specific		________
Kp	Chemical specific		________
A	To be developed		________
ED	To be developed		________
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

*This equation computes the absorbed dermal dose. Dose is presented here instead of exposure (amount of contaminant in water contacting body) because it is more useful in dermal risk assessments.

1.13 Dermal Contact with Soil While Gardening

$$\text{Lifetime Average Daily Exposure} = \frac{(C)\ (CR)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

C = contaminant concentration in soil (mg/g)
CR = contact rate (g/day)
ED = exposure duration (day)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range	Distribution
C	Site specific		________
CR	To be developed		________
ED	To be developed		________
BW	70	70	pp. 5-40 - 5-43
LT	75	75	To be developed

2. ANALYSIS OF UNCERTAINTIES

The previous section presented standard exposure scenarios, algorithms for estimating exposure in each scenario, and the exposure factor values recommended for use. The exposure factor values recommended can be used to obtain average exposure estimates, reasonable worst-case estimates, and estimates that realistically "bound" the range of possible exposures. This section discusses methods that can be used to qualitatively and quantitatively evaluate and present the uncertainty associated with exposure scenario estimates.

The goal of an analysis of uncertainties is to provide decision makers with the complete spectrum of information concerning the quality of an assessment, including the potential variability in the estimated exposures (because of the inherent variability in the exposure scenario input factors), the major data gaps, and the effect these data gaps have on the accuracy or reasonableness of the exposure estimates developed. Analysis and presentation of the uncertainties allow the user(s) or decision maker(s) to better evaluate the assessment results in the context of other factors being considered. This, in turn, leads to a more sound and open decision-making process. The following subsections briefly describe procedures for qualitatively and quantitatively analyzing and presenting the uncertainties in exposure scenario estimates. Detailed information on the analysis of uncertainties in exposure assessments is presented in EPA's Guidelines for Estimating Exposures (USEPA 1986) and EPA (1985).

2.1 Qualitative Analysis

Qualitative analysis of uncertainties involves determination of the general quality and reasonableness of exposure data and exposure assessment results. Qualitative analysis should be performed on all exposure assessments and exposure-related data. Qualitative analysis is paramount to screening, preliminary, and intermediate level assessments. In addition to a qualitative analysis, however, detailed assessments may also require quantitative uncertainty analysis techniques.

As part of the qualitative analysis, the cause of uncertainty is initially determined. The basic cause of uncertainty is a lack of knowledge on the part of the analyst because of inadequate, or even nonexistent, experimental and operational data on processes and parameters. Specific causes of uncertainty include or can be categorized as follows:

- Measurement error - uncertainty in this case arises from random and systematic error in the measurement technique.
- Sampling error - uncertainty arises from the representativeness of the data of the actual population being sampled.
- Variability - the natural variability in environmental and exposure-related parameters can frequently be a major cause of uncertainty. For example, the exposure factors discussed in this handbook are all subject to variability, which in turn causes variability in the exposure estimates developed using them.
- Limitations in model form - how close to reality is the model function and output (e.g., the water quality model for estimating pollutant concentrations in the aquatic environment)?
- Application and quality of generic or indirect empirical data - uncertainty arises from both the applicability of the indirect data and the measurement or sampling error in the data.
- Professional judgment - frequently, data gaps must be filled based on engineering or scientific assumptions, which have inherent uncertainty.

Identification of the causes of uncertainty, therefore, is an outcome of the determination of the extent, consistency, completeness, and quality of the available exposure data.

Once the causes of the uncertainties are identified, the impact these uncertainties have on the assessment results should be determined. Where uncertainty exists, data or estimates of a range of plausible values should be gathered. The effects of the range of assessment input values on the assessment results (or output value) can be determined numerically through the substitution of plausible alternative values for each input parameter. This procedure is similar to a sensitivity analysis, which is discussed in the next subsection. The variation in output attributable to variations in input values or parameters can thus be evaluated. A table should be constructed to correspond to the parameters in the assessment, including a listing of possible variations in each parameter that would encompass a reasonable range of actual expected exposure conditions. The text or footnotes accompanying this table should explain the basis of each assumption.

This review of uncertainties should include a qualitative evaluation of the significance of pertinent assumptions in light of reasonable variations that could be encountered for actual exposure conditions. If possible, special emphasis should be placed on evaluating extremes in each assumption. For example, have parameters been chosen to evaluate extreme or average exposure conditions? Are the exposure estimates likely to be overestimates or underestimates? Explicit presentation of the qualitative analysis results will transmit the level of confidence in the results to the future data user or decision maker and will aid in determining future actions.

2.2 Quantitative Analysis

In detailed exposure assessments or when initial worst-case exposure estimates indicate significant exposure or risk, uncertainty can be characterized via (1) sensitivity analysis and/or (2) probability analysis (e.g., Monte Carlo simulation) techniques. The technique selected depends on the availability of input data statistics. Performance of sensitivity testing requires data on the range of values for each exposure factor in the scenario. Probabilistic analysis requires data on the range and probability function (or distribution) of each exposure factor in the scenario. Each of these procedures is subsequently discussed.

2.2.1 Sensitivity Analysis

Sensitivity analysis is a technique that tests the sensitivity of an output variable to the possible variation in the input variables of a given model. The purpose of the sensitivity analysis is to identify the influential input variables and develop bounds on the model output. By identifying the influential input variables, more resources can be directed to reduce their uncertainties and hence reduce the output uncertainty.

The sensitivity of the output variable of a given mathematical model depends on the nature of the mathematical relationship of the model (and plausible values of its input variables). For a given model, the sensitivity of the output variable with respect to each input variable is computed and the sensitivities of all input variables are compared. When computing the sensitivity with respect to a given input variable, all other input variables are held fixed at their nominal values.

The sensitivity analysis is to be performed when limited information (data) is available about the input variables. This information can be in the form of best estimates of the centralities of the input variable (mean, median, mode) or estimates of the ranges (minimum and maximum) of the input variables. Accordingly, two types of sensitivity analysis can be classified: point sensitivity and range sensitivity.

Range sensitivity analysis estimates the range of output values that would result as individual input variables are varied from their minimum to their maximum possible value with other input variables held at fixed values, e.g., their midranges. Point sensitivity is the sensitivity of the output to the centrality variability (mean, median, mode) of a given input variable at a given value of that input variable with the other input variables held at best estimates of their centralities. Point sensitivity analysis is applicable only to skewed models with distinct values for the mean, median, and mode.

Once the most influential model input variables are identified, collection of additional data for these variables would be warranted. Less effort also might be directed toward collecting data on the less sensitive input factors. It might be reasonable to treat the less sensitive factor or factors as fixed at the estimate of their centralities. A demonstration of a sensitivity analysis on an example exposure scenario algorithm is presented in Section 2.4.

2.2.2 Monte Carlo Simulation

The Monte Carlo simulation is a technique that can be used to provide a probability function of estimated exposure using random values of exposure factors in an exposure scenario. The Monte Carlo simulation involves assigning a joint probability distribution to the input variables (i.e., exposure factors) of an exposure scenario. Next, a large number of independent samples from the assigned joint distribution are taken and the corresponding outputs calculated (i.e., ≥1,000 iterations). This is accomplished by repeated computer runs through the problem using random numbers to assign values to the exposure factors. The simulated output represents a sample from the true output distribution. Methods of statistical inference are used to estimate, from the exposure output sample, some parameters of the exposure distribution, such as percentiles, mean, variance, and confidence intervals. The Monte Carlo simulation can also be used to test the effect a hypothesized probability distribution for an input parameter has on the output distribution.

When a specific probability distribution is used to express uncertainty in one or more input factors of an exposure model, a distribution of exposure is generated. The exposure assessor may investigate the effects of using different probability distributions for an input variable and/or the effects of using different functional forms of the exposure model on the type of exposure distribution output. The Monte Carlo simulation procedure yields an exposure distribution that is strictly a consequence of the assumed distributions of the model inputs and the assumed functional form of the model.

In general, the selection of a probability distribution to represent an input factor in the exposure models should be based upon any gathered information about that factor, theoretical arguments, and/or expert opinions. A probability distribution can be ascertained from such information as the following: general shape of the distribution, minimum, maximum, mode, mean, median, midrange, and other percentiles. Available data on the probability distributions for each of the exposure factors discussed in this handbook have been presented in previous sections. When distribution data are not available, distributions can be assigned using professional judgment. The following considerations are relevant to the process of selection:

- A uniform distribution would be used to represent a factor when nothing is known about the factor except its finite range. The use of a uniform distribution assumes that all possible values within the range are equally likely.

- If the range of the factor and its mode are known, then a triangular distribution would be used.

- If the factor has a finite range of possible values and a smooth probability function is desired, a Beta distribution (scaled to the desired range) may be most appropriate. The Beta distribution can be fit from the mode and the range that defines a middle specific percent (e.g., 95 percent) of the distribution.

- If the factor only assumes positive values, then a Gamma, Lognormal, or Weibull distribution may be an appropriate choice. The Gamma distribution is probably the most flexible; its probability function can assume a variety of shapes by varying its parameters and it is mathematically tractable. These distributions also can be fit from the knowledge of the mode and the percentiles that capture the middle 95 percent of the distribution.

- If the factor has an unrestricted range of possible values and is symmetrically distributed around its mode, then a normal distribution may be an appropriate distribution.

- Unless specific information on the relationships between exposure parameters is available, assume values for the required input parameters are independent.

Once the probability distributions of all exposure factors are developed or assigned, the Monte Carlo simulation can be performed. Normally, this simulation is time-consuming and requires the use of a computer. Numerous commercial personal computer (PC) based programs are available to perform the simulation. One in particular, designed specifically for use in exposure assessment, was recently developed (Versar 1987). The program, called PC-MC, can simulate algorithms with up to nine input and three output functions. A simulation can be performed in little more than the time required to enter the algorithm, range, and probability distribution of each input value. The output of the simulation is a frequency distribution and cumulative frequency distribution from which the mean, median, variance, and percentile exposure levels can be extracted. (Note: percentile exposure levels reflect the real statistical distribution only if all input assumptions (i.e., variable distributions and their independence) are known to be correct). If the input distributions were arrived at using judgment instead of actual data, the output of the simulation is useful only in terms of discussing a likely range of exposure). A demonstration of a probabilistic analysis on an example exposure scenario problem using the PC-MC program is presented in Section 2.4.

2.3 Presentation of Uncertainty Analysis Results

Comprehensive qualitative analysis and rigorous quantitative analysis are of little value if the analysis results are not clearly presented for use in the decision-making process. The following procedures can be used to present the results of the uncertainty analysis:

- Exposure estimates should clearly identify the input parameters to which they are most sensitive, including a quantitative statement of the magnitude of sensitivity (e.g., percent variability of the output across the range of possible input values). Where Monte Carlo simulations are performed, exposure estimates could be presented as percentile intervals (or cumulative probability percentile intervals). For each interval, the associated exposure conditions should be described.

- Each exposure scenario should conclude with statements of qualitative and quantitative uncertainties, including the major data gaps or other causes of uncertainty. This information can be presented in tabular format.

- Uncertainties for the overall exposure assessment could be summarized and presented as a section that precedes all other report sections or, alternatively, the results could be incorporated into an Executive Summary.

2.4 Example Problems

Performance of sensitivity analysis and probabilistic analysis techniques on exposure scenario problems is demonstrated in the following subsections. Completion of the two example problems that follow was facilitated by the use of the PC-MC program previously described. Numerous other programs are available or can be developed for specific exposure assessment problems. The example problems presented use the scenarios and exposure factors previously presented in this handbook. As has been discussed in all the scenarios presented, the concentration values used are site or issue specific. For the following sample problems, the concentration values used were assumed for demonstration purposes only. Furthermore, the values assumed are fixed values (i.e., a range and probability function for the concentration factor was not developed). This approach permits the evaluation of the significance of the other exposure factors on the estimated exposure output.

Example 1: Analysis of the Sensitivity of Estimated Inhalation Exposure to Exposure Factors Variability (Scenario presented in Section 1-9, Part II)

Scenario: Estimate the range of lifetime inhalation exposure (mass/kg body wt/day) to chemical X that volatilizes from water while showering at residence. Calculate the range sensitivity of the estimated exposure to variations in the range of values for each input parameter.

$$\text{Lifetime Average Daily Exposure} = \frac{(IR)\ (C)\ (ED)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

IR = inhalation rate (m^3/hr)
C = concentration of contaminant in air ($\mu g/m^3$)
ED[1] = exposure duration (hr)
BW = body weight of average adult (kg)
LT = lifetime (yr)

Parameter	Average	Range[2]
IR	0.6	0.6-2.0
C	Site specific[3]	
ED	220	220-1,520
BW	70	46.8-70
LT	75	75

Notes for Example 1:

[1] Exposure duration refers to the actual number of days an individual is exposed at a given residence.

[2] Except for body weight, the range of values listed is the average value to the 95th percentile value. The ranges of body weight values are the 5th to 50th percentile values for adult females and males. (These values may differ from those used in Chapter 1, Part II because a sensitively analysis requires the use of a range of values rather than a single constant value.)

[3] For purposes of this example problem, the concentration of chemical X is assumed to have a mean value of 100 $\mu g/m^3$. For most exposure estimates, a range of values should be available. For this example problem, however, use of a fixed value for the concentration permits evaluation of the sensitivity of the exposure estimate to variations of the exposure factors.

Summary of Results for Example 1:

Table 2-1 summarizes the estimated exposure range, as each parameter value is varied from its minimum to maximum while all other parameters are fixed at their nominal value. For this example problem, the estimated inhalation exposure can range from 0.00689 μg/kg/day (i.e., when average or minimum input values are used) to 0.23729 μg/kg/day (i.e., when 95th percentile or maximum input values are used). Examination of the sensitivity analysis results indicates that the estimated exposure is most sensitive to variation in the exposure duration (ED) values. Variation in values for body weight (BW) have minimal impact on the estimated exposure.

Example 2: Analysis of the Probability Distribution of Estimated Ingestion Exposure (Scenario presented in Section 1.5, Part II)

Scenario: Estimate the average to 95th percentile probability distribution of lifetime ingestion exposure (mass/kg of body wt/day) to chemical X from recreationally caught fish.

$$\text{Exposure} = \frac{(CR)\ (C)\ (ED)\ (DF)}{(BW)\ (LT)\ (365\ \text{days/yr})}$$

CR = fish consumption rate (g/day)
C = concentration of contaminant in fish (mg/g)
ED[1] = exposure duration (day)
DF[2] = diet fraction
BW = body weight (kg)
LT = lifetime (yr)

Parameter	Average	Range[3]	Distribution[4]
CR	30	30-140	Lognormal (skewed right)
C	10	10	Fixed value[5]
ED	3,285	3,285-10,950	Lognormal
DF	0.2	0.2-0.75	Lognormal
BW	70	46.8-70	Normal
LT	75	75	Fixed value

Table 2-1. Summary of Sensitivity Analysis Results for Example 1

Input parameter	Input range	Estimated exposure range (ug/kg/day)	Range difference
IR	0.6 - 2.0	0.00689 - 0.02296	0.01607
C	100	* * * FIXED VALUE * * *	
ED	220 - 1520	0.00689 - 0.04760	0.04071
BW	46.8 - 70	0.00689 - 0.01031	0.00341
LT	75	* * * FIXED VALUE * * *	

Notes for Example 2:

[1] Exposure duration refers to the actual number of days an individual is exposed.
[2] Diet fraction represents the portion of a person's fish diet derived from the contaminated source.
[3] Except for body weight, the range of values listed is the average value to the 90th or 95th percentile value. The ranges of body weight values are the 5th to 50th percentile values for both males and females. (These values may differ from those used in Chapter 1, Part II since a probabilistic simulation requires the use of a distribution rather than a single constant value.)
[4] Distributions listed are assumed for demonstration purposes only.
[5] For purposes of this example problem, the concentration of chemical X is assumed to have a mean value of 10 mg/g. For most exposure estimates, a range of values should be available. For this example problem, however, use of a fixed value for the concentration permits evaluation of the sensitivity of the exposure estimate to variations of the exposure factors.

Summary of Results for Example 2:

Statistics for the probability distribution of the estimated exposure are provided in Table 2-2. Table 2-3 presents results of a sensitivity analysis. Based on the simulation results, the estimated mean exposure is 0.604 mg/kg/day, with a median (50th percentile) value of 0.324 mg/kg/day. The 5th percentile value is 0.131 mg/kg/day, and the 95th percentile value is 1.95 mg/kg/day. The sensitivity analysis results indicate that each of the parameters has approximately equal significance to variation in the estimated exposure. Performance of the probabilistic analysis, as demonstrated, allows for the presentation of data that provide a clearer characterization of the potential variability of an output as opposed to single-value best estimates. The results are further enhanced when a qualitative analysis is also performed, describing the analyst's confidence in the algorithm input data (e.g., reasonableness of the scenario) and the overall estimated exposure.

Table 2-2. Summary of Probabilistic Analysis Results for Example 2

Statistic	Value (mg/kg/day)
Mean	0.604
Median	0.324
Minimum	0.104
Maximum	10.149
Range	10.045
Percent:	
5	0.131
10	0.144
15	0.160
20	0.178
25	0.193
30	0.213
35	0.228
40	0.251
45	0.287
50	0.324
55	0.368
60	0.416
65	0.495
70	0.556
75	0.650
80	0.810
85	1.023
90	1.319
95	1.950

Table 2-3. Summary of Sensitivity Analysis Results for Example 2

Input parameter	Input range	Estimated exposure range (mg/kg/day)	Range difference
CR	30 - 140	0.1028 - 0.48	0.3772
C	10	* * * FIXED VALUE * * *	
ED	3285 - 10950	0.1028 - 0.3427	0.2399
DF	0.2 - 0.75	0.1028 - 0.3855	0.2827
BW	46.8 - 70	0.1028 - 0.1538	0.0510
LT	75	* * * FIXED VALUE * * *	

2.5 References

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