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1. INTRODUCTION

1.1. PURPOSE

The purpose of the Exposure Factors Handbook is to: (1) summarize data on human behaviors and characteristics which affect exposure to environmental contaminants, and (2) recommend values to use for these factors. These recommendations are not legally binding on any EPA program and should be interpreted as suggestions which program offices or individual exposure assessors can consider and modify as needed. Most of these factors are best quantified on a site or situation-specific basis. The handbook has strived to include full discussions of the issues which assessors should consider in deciding how to use these data and recommendations. The handbook is intended to serve as a support document to EPA's Guidelines for Exposure Assessment (U.S. EPA, 1992a). 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 assists in this goal by providing a consistent set of exposure factors to calculate dose.

Purpose

- Summarize data on human behaviors and characteristics affecting exposure
- Recommend exposure factor values

1.2. INTENDED AUDIENCE

The Exposure Factors Handbook is addressed to exposure assessors inside the Agency as well as outside, who need to obtain data on standard factors needed to calculate human exposure to toxic chemicals.

1.3. BACKGROUND

This handbook is the update of an earlier version prepared in 1989. Revisions have been made in the following areas:

- addition of drinking water rates for children;
- changes in soil ingestion rates for children;
- addition of soil ingestion rates for adults;
- addition of tapwater consumption for adults and children;

- addition of mean daily intake of food class and subclass by region, age and per capita rates;
- addition of mean moisture content of selected fruits, vegetables, grains, fish, meat, and dairy products;
- addition of food intake by class in dry weight per kg of body weight per day;
- update of homegrown food intake;
- expansion of data in the dermal chapter;
- update of fish intake data;
- expansion of data for time spent at residence;
- update of body weight data;
- addition of body weight data for infants;
- update of population mobility data;
- addition of new data for average time spent in different locations and various microenviron-ments;
- addition of data for occupational mobility;
- addition of breast milk ingestion;
- addition of consumer product use; and
- addition of reference residence factors.

Variation Among Studies

This handbook is a compilation of available data from a variety of different sources. With very few exceptions, the data presented are the analyses of the individual study authors. Since the studies included in this handbook varied in terms of their objectives, design, scope, presentation of results, etc., the level of detail, statistics, and terminology may vary from study to study and from factor to factor. For example, some authors used geometric means to present their results, while others used arithmetic means or distributions. Authors have sometimes used different terms to describe the same racial populations. Within the constraint of presenting the original material as accurately as possible, EPA has made an effort to present discussions and results in a consistent manner. Further, the strengths and limitations of each study are discussed to provide the reader with a better understanding of the uncertainties associated with the values derived from the study.

1.3.1. Selection of Studies for the Handbook

Information in this handbook has been summarized from studies documented in the scientific literature and other available sources. Studies were chosen that were seen as useful and appropriate for estimating exposure factors. The handbook contains summaries of selected studies published through August 30, 1997.

General Considerations

Many scientific studies were reviewed for possible inclusion in this handbook. Studies were selected based on the following considerations:

- Level of peer review: Studies were selected predominantly from the peer-reviewed literature and final government reports. Internal or interim reports were therefore avoided.

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

- Reproducibility: Studies were sought that contained sufficient information so that methods could be reproduced, or at least so the details of the author's work could be accessed and evaluated.

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

- Data pertinent to the U.S.: Studies were selected that addressed the U.S. population. Data from populations outside the U.S. were sometimes included if behavioral patterns and other characteristics of exposure were similar.

- Primary data: Studies were deemed preferable if based on primary data, but studies based on secondary sources were also included where they offered an original analysis. For example, the handbook cites studies of food consumption based on original data collected by the USDA National Food Consumption Survey.

- Current information: Studies were chosen only if they were sufficiently recent to represent current exposure conditions. This is an important consideration for those factors that change with time.

- Adequacy of data collection period: Because most users of the handbook are primarily addressing chronic exposures, studies were sought that utilized the most appropriate techniques for collecting data to characterize long-term behavior.

- Validity of approach: Studies utilizing experimental procedures or approaches that more likely or closely capture the desired measurement were selected. In

general, direct exposure data collection techniques, such as direct observation, personal monitoring devices, or other known methods were preferred where available. If studies utilizing direct measurement were not available, studies were selected that rely on validated indirect measurement methods such as surrogate measures (such as heart rate for inhalation rate), and use of questionnaires. If questionnaires or surveys were used, proper design and procedures include an adequate sample size for the population under consideration, a response rate large enough to avoid biases, and avoidance of bias in the design of the instrument and interpretation of the results.

- Representativeness of the population: Studies seeking to characterize the national population, a particular region, or sub-population were selected, if appropriately representative of that population. In cases where data were limited, studies with limitations in this area were included and limitations were noted in the handbook.

- Variability in the population: Studies were sought that characterized any variability within populations.

- Minimal (or defined) bias in study design: Studies were sought that were designed with minimal bias, or at least if biases were suspected to be present, the direction of the bias (i.e., an over or under estimate of the parameter) was either stated or apparent from the study design.

- Minimal (or defined) uncertainty in the data: Studies were sought with minimal uncertainty in the data, which was judged by evaluating all the considerations listed above. At least, studies were preferred that identified uncertainties, such as those due to inherent variability in environmental and exposure-related parameters or possible measurement error. Studies that documented Quality Assurance/Quality Control measures were preferable.

Key versus relevant studies

Certain studies described in this handbook are designated as "key," that is, the most useful for deriving exposure factors. The recommended values for most exposure factors are based on the results of the key studies. Other studies are designated "relevant," meaning applicable or pertinent, but not necessarily the most important. This distinction was made on the strength of the attributes listed in the "General Considerations." For example, in Chapter 14 of Volume III, one set of studies is deemed to best address the attributes listed and is designated as "key." Other applicable studies, including foreign data, believed to have value to handbook users, but having fewer attributes, are designated "relevant."

Key vs. Relevant Studies

- Key studies used to derive recommendations
- Relevant studies included to provide additional perspective

1.3.2. Using the Handbook in an Exposure Assessment

Some of the steps for performing an exposure assessment are (1) determining the pathways of exposure, (2) identifying the environmental media which transports the contaminant, (3) determining the contaminant concentration, (4) determining the exposure time, frequency, and duration, and (5) identifying the exposed population. Many of the issues related to characterizing exposure from selected exposure pathways have been addressed in a number of existing EPA guidance documents. These include, but are not limited to the following:

- Guidelines for Exposure Assessment (U.S. EPA 1992a);
- Dermal Exposure Assessment: Principles and Applications (U.S. EPA 1992b);
- Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions (U.S. EPA, 1990);
- Risk Assessment Guidance for Superfund (U.S. EPA, 1989);
- Estimating Exposures to Dioxin-Like Compounds (U.S. EPA, 1994);
- Superfund Exposure Assessment Manual (U.S. EPA, 1988a);
- Selection Criteria for Mathematical Models Used in Exposure Assessments (U.S. EPA 1988b);
- Selection Criteria for Mathematical Models Used in Exposure Assessments (U.S. EPA 1987);
- Standard Scenarios for Estimating Exposure to Chemical Substances During Use of Consumer Products (U.S. EPA 1986a);
- Pesticide Assessment Guidelines, Subdivisions K and U (U.S. EPA, 1984, 1986b); and
- Methods for Assessing Exposure to Chemical Substances, Volumes 1-13 (U.S. EPA, 1983-1989).

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

In addition to the references listed above, this handbook discusses the recommendations provided by the American Industrial Health Council (AIHC) - Exposure Factors Sourcebook (May 1994) for some of the major exposure factors. The AIHC Sourcebook summarizes and evaluates statistical data for various exposure factors used in risk assessments. Probability distributions for specific exposure factors were derived from the available scientific literature using @Risk simulation software. Each factor is described by a specific term, such as lognormal, normal, cumulative type, or triangular. Other distributions included Weibull, beta logistic, and gamma. Unlike this handbook, however, the Sourcebook does not provide a description and evaluation of every study available on each exposure factor.

Most of the data presented in this handbook are derived from studies that targeted (1) the general population (e.g., USDA food consumptin surveys); and (2) a sample population from a specific area or group (e.g., Calabrese's et al. (1989) soil ingestion study using children from the Amherst, Massachusetts, area). Due to unique activity patterns, preferences, practices and biological differences, various segments of the population may experience exposures that are different from those of the general population, which, in many cases, may be greater. It is necessary for risk or exposure assessors characterizing a diverse population, to identify and enumerate certain groups within the general population who are at risk for greater contaminant exposures or exhibit a heightened sensitivity to particular chemicals. For further guidance on addressing susceptible populations, it is recommended to consult the EPA, National Center for Environmental Assessment document *Socio-demographic Data Used for Identifying Potentially Highly Exposed Subpopulations* (to be released as a final document in the Fall of 1997).

Most users of the handbook will be preparing estimates of exposure which are to be combined with dose-response factors to estimate risk. Some of the exposure factors (e.g., life time, body weight) presented in this document are also used in generating dose-response relationships. In order to develop risk estimates properly, assessors must use dose-response relationships in a manner consistent with exposure conditions. Although, it is beyond the scope of this document to explain in detail how assessors should address this issue, a discussion (see Appendix A of this chapter) has been included which describes how dose-response factors can be modified to be consistent with the exposure factors for a population of interest. This should serve as a guide for when this issue is a concern.

1.3.3. Approach Used to Develop Recommendations for Exposure Factors

As discussed above, EPA first reviewed all literature pertaining to a factor and determined relevant and key studies. The key studies were used to derive recommendations for the values of each factor. The recommended values were derived solely from EPA's interpretation of the available data. Different values may be appropriate

for the user to select in consideration of policy, precedent, strategy, or other factors such as site-specific information. EPA's procedure for developing recommendations was as follows:

Recommendations and Confidence Ratings

- Recommendations based on data from single or multiple key studies
- Variability and limitation of the data evaluated
- Recommendations rated as low, medium, and high confidence

1. Key studies were evaluated in terms of both quality and relevance to specific populations (general U. S. population, age groups, gender, etc.). The criteria for assessing the quality of studies is described in Section 1.3.1.

2. If only one study was classified as key for a particular factor, the mean value from that study was selected as the recommended central value for that population. If there were multiple key studies, all with reasonably equal quality, relevance, and study design information were available, a weighted mean (if appropriate, considering sample size and other statistical factors) of the studies were chosen as the recommended mean value. If the key studies were judged to be unequal in quality, relevance, or study design, the range of means were presented and the user of this handbook must employ judgment in selecting the most appropriate value for the population of interest. In cases where the national population was of interest, the mid-point of the range was usually judged to be the most appropriate value.

3. The variability of the factor across the population was discussed. If adequate data were available, the variability was described as either a series of percentiles or a distribution.

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

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

the recommendation. This judgment was made using the guidelines shown in Table 1-1. Table 1-1 is an adaptation of the General Considerations discussed earlier in Section 1.3.1. Clearly this is a continuum from low to high and judgment was used to determine these ratings. Recommendations given in this handbook are accompanied by a discussion of the rationale for their rating.

Table 1-2 summarizes EPA's recommendations and confidence ratings for the various exposure factors.

It is important to note that the study elements listed in Table 1-1 do not have the same weight when arriving at the overall confidence rating for the various exposure factors. The relative weight of each of these elements depend on the exposure factor of interest. Also, the relative weights given to the elements for the various factors were subjective and based on the professional judgement of the authors of this handbook. In general, most studies would rank high with regard to "level of peer review," "accessibility," "focus on the factor of interest," and "data pertinent to the U.S." These elements are important for the study to be included in this handbook. However, a high score of these elements does not necessarily translate into a high overall score. Other elements in Table 1-1 were also examined to determine the overall score. For example, the adequacy of data collection period may be more important when determining usual intake of foods in a population. On the other hand, it is not as important for factors where long-term variability may be small such as tapwater intake. In the case of tapwater intake, the currency of the data was a critical element in determining the final rating. In addition, some exposure factors are more easily measured than others. For example, soil ingestion by children is estimated by measuring, in the feces, the levels of certain elements found in soil. Body weight, however, can be measured directly and it is, therefore, a more reliable measurement. This is reflected in the confidence rating given to both of these factors. In general, the better the methodology used to measure the exposure factor, the higher the confidence in the value.

1.3.4. Characterizing Variability

This document attempts to characterize variability of each of the factors. Variability is characterized in one or more of three ways: (1) as tables with various percentiles or ranges of values; (2) as analytical distributions with specified parameters; and/or (3) as a qualitative discussion. Analyses to fit standard or parametric distributions (e.g., normal, lognormal) to the exposure data have not been performed by the authors of this handbook, but have been reproduced in this document wherever they were found in the literature. Recommendations on the use of these distributions are made where appropriate based on the adequacy of the supporting data. The list of exposure factors and the way that variability has been characterized (i.e., average, upper percentiles, multiple percentiles, fitted distribution) are presented in Table 1-3. The term upper percentile is used

throughout this handbook and it is intended to represent values in the upper tail (i.e., between 90th and 99.9th percentile) of the distribution of values for a particular exposure factor.

An attempt was made to present percentile values in the recommendations that are consistent with the exposure estimators defined in the Exposure Guidelines (i.e., mean, 50th, 90th, 95th, 98th, and 99.9th percentile). This was not, however, always possible because either the data available were limited for some factors, or the authors of the study did not provide such information. It is important to note, however, that these percentiles were discussed in the Exposure Guidelines within the context of risk descriptors and not individual exopusure factors. For example, the Guidelines stated that the assessor may derive a high-end estimate of exposure by using maximum or near maximum values for one or more sensitive exposure factors, leaving others at their mean value.

The use of Monte Carlo or other probabilistic analysis require a selection of distributions or histograms for the input parameters. Although this handbook is not intended to provide a complete guidance on the use of Monte Carlo and other probabilistic analyses, the following should be considered when using such techniques:

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

- It is important to note that the selection of distributions can be highly site specific and will always involve some degree of judgment. Distributions derived from national data may not represent local conditions. To the extent possible, an assessor should use distributions or frequency histograms derived from local surveys to assess risks locally. When distributional data are drawn from national or other surrogate population, it is important that the assessor address the extent to which local conditions may differ from the surrogate data.

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

- Distribution functions to be used in Monte Carlo analysis may be derived by fitting an appropriate function to empirical data. In doing this, it should be recognized

that in the lower and upper tails of the distribution the data are scarce, so that several functions, with radically different shapes in the extreme tails, may be consistent with the data. To avoid introducing errors into the analysis by the arbitrary choice of an inappropriate function, several techniques can be used. One way is to avoid the problem by using the empirical data itself rather than an analytic function. Another is to do separate analyses with several functions which have adequate fit but form upper and lower bounds to the empirical data. A third way is to use truncated analytical distributions. Judgment must be used in choosing the appropriate goodness of fit test. Information on the theoretical basis for fitting distributions can be found in a standard statistics text such as Statistical Methods for Environmental Pollution Monitoring, Gilbert, R.O., 1987, Van Nostrand Reinhold; off-the-shelf computer software such as Best-Fit by Palisade Corporation can be used to statistically determine the distributions that fit the data.

- If only a range of values is known for an exposure factor, the assessor has several options.

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

1.4. GENERAL EQUATION FOR CALCULATING DOSE

The definition of exposure as used in the Exposure Guidelines (U.S. EPA, 1992a) is "condition of a chemical contacting the outer boundary of a human." This means contact with the visible exterior of a person such as the skin, and openings such as the mouth,

nostrils, and lesions. The process of a chemical entering the body can be described in two steps: contact (exposure), followed by entry (crossing the boundary). The magnitude of exposure (dose) is the amount of agent available at human exchange boundaries (skin, lungs, gut) where absorption takes place during some specified time. An example of exposure and dose for the oral route as presented in the the EPA Exposure Guidelines is shown in Figure 1-1. Starting with a general integral equation for exposure (U.S. EPA 1992a), several dose equations can be derived depending upon boundary assumptions. One of the more useful of these derived equations is the Average Daily Dose (ADD). The ADD, which is used for many noncancer effects, averages exposures or doses over the period of time over which exposure occurred. The ADD can be calculated by averaging the potential dose (D_{pot}) over body weight and an averaging time.

$$ADD_{pot} = \frac{\text{Total Potential Dose}}{\text{Body Weight x Averaging Time}} \qquad \text{(Eqn. 1-1)}$$

For cancer effects, where the biological response is usually described in terms of lifetime probabilities, even though exposure does not occur over the entire lifetime, doses are often presented as lifetime average daily doses (LADDs). The LADD takes the form of the Equation 1-1 with lifetime replacing averaging time. The LADD is a very common term used in carcinogen risk assessment where linear non-threshold models are employed.

The total exposure can be expressed as follows:

$$\text{Total Potential Dose} = C \times IR \times ED \qquad \text{(Eqn. 1-2)}$$

Where:

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

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

The intake rate refers to the rates of inhalation, ingestion, and dermal contact depending on the route of exposure. For ingestion, the intake rate is simply the amount

of food containing the contaminant of interest that an individual ingests during some specific time period (units of mass/time). Much of this handbook is devoted to rates of ingestion for some broad classes of food. For inhalation, the intake rate is the rate at which contaminated air is inhaled. Factors that affect dermal exposure are the amount of material that comes into contact with the skin, and the rate at which the contaminant is absorbed.

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 versus outdoors, etc. all affect the exposure duration. The Activity Factors Chapter (Volume III, Chapter 15) gives some examples of population behavior patterns, which may be useful for estimating exposure durations to be used in the exposure calculations.

When the above parameter values 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 intake rate specified by the other parameters in the equation.

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

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

The lifetime value used in the LADD version of Equation 1-1 is the period of time over which the dose is averaged. For carcinogens, the derivation of the dose-response parameters usually assumes no explicit number of years as the duration of a lifetime, and the nominal value of 75 years is considered a reasonable approximation. For exposure estimates to be used for assessments other than carcinogenic risk, various averaging periods have been used. For acute exposures, the administered doses are usually averaged over a day or a single event. For nonchronic noncancer effects, the time period used is the actual period of exposure. The objective in selecting the exposure averaging time is to express the exposure in a way which can be combined with the dose-response relationship to calculate risk.

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

The units of intake in this handbook for the ingestion of fish, breast milk, and the inhalation of air are not normalized to body weight. In this case, the exposure assessor needs to use (in Equation 1-1) 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 weight of 71.8 kg should provide sufficient accuracy. If the body weight of the individuals in the population whose risk is being evaluated is non-standard in some way, such as for children or for first-generation immigrants who may be smaller than the national population, and if reasonable values are not available in the literature, then a model of intake as a function of body weight must be used. One such model is discussed in Appendix 1A of this chapter. Some of the parameters (primarily concentrations) used in estimating exposure are exclusively site specific, and therefore default recommendations could not be used.

The food ingestion rate values provided in this handbook are generally expressed as "as consumed" since this is the fashion in which data are reported by survey respondents. This is of importance because concentration data to be used in the dose equation are generally measured in uncooked food samples. In most situations, the only practical choice is to use the "as consumed" ingestion rate and the uncooked concentration. However, it should be recognized that cooking generally results in some reductions in weight (e.g., loss of moisture), and that if the mass of the contaminant in the food remains constant, then the concentration of the contaminant in the cooked food item will increase. Therefore, if the "as consumed" ingestion rate and the uncooked concentration are used in the dose equation, dose may be underestimated. On the other hand, cooking may cause a reduction in mass of contaminant and other ingredients such that the overall concentration of contaminant does not change significantly. In this case, combining cooked ingestion rates and uncooked concentration will provide an appropriate estimate of dose. Ideally, food concentration data should be adjusted to account for changes after cooking, then the "as consumed" intake rates are appropriate. In the absence of data, it is reasonable to assume that no change in contaminant concentration occurs after cooking. Except for general population fish consumption and home produced foods, uncooked intake rate data were not available for presention in this handbook. Data on the general population fish consumption have been presented in this handbook (Section 10.2) in both "as consumed" and uncooked basis. It is important for the assessor to be aware

of these issues and choose intake rate data that best matches the concentration data that is being used.

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

- The intake rate can be based on an individual event, such as 129 g of fish eaten per meal (U.S. EPA, 1996). The duration should be based on the number of events or, in this case, meals.

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

The objective is to define the terms so that when multiplied, they give the appropriate estimate of mass of contaminant contacted. This can be accomplished by basing the intake rate on either a long-term average (chronic exposure) or an event (acute exposure) basis, as long as the duration value is selected appropriately. Consider the case in which a person eats a 129-g fish meal approximately five times per month (long-term average is 21.5 g/day) for 30 years; or 21.5 g/day of fish every day for 30 years.

(129 g/meal)(5 meals/mo)(mo/30 d)(365 d/yr)(30 yrs) = 235,425 g

(21.5 g/day)(365 d/yr)(30 yrs) = 235,425 g

Thus, a frequency of either 60 meals/year or a duration of 365 days/year could be used as long as it is matched with the appropriate intake rate.

1.5. RESEARCH NEEDS

In an earlier draft of this handbook, reviewers were asked to identify factors or areas where further research is needed. The following list is a compilation of areas for future research identified by the peer reviewers and authors of this document:

- The data and information available with respect to occupational exposures are quite limited. Efforts need to be directed to identify data or references on occupational exposure.

- Further research is necessary to refine estimates of fish consumption, particularly by subpopulations of subsistence fishermen.

- Research is needed to better estimate soil intake rates, particularly how to extrapolate short-term data to chronic exposures. Data on soil intake rates by adults are very limited. Research in this area is also recommended. Research is also needed to refine methods to calculate soil intake rate (i.e., inconsistencies among tracers and input/output misalignment errors indicate a fundamental problem with the methods). Research is also needed to obtain more data to better estimate soil adherence.

- In cases where several studies of equal quality and data collection procedures are available for an exposure factor, procedures need to be developed to combine the data in order to create a single distribution of likely values for that factor.

- Reviewers recommended that the handbook be made available in CD ROM and that the data presented be made available in a format that will allow the users to conduct their own analysis. The intent is to provide a comprehensive factors tool with interactive menu to guide users to areas of interest, word searching features, and data base files.

- Reviewers recommended that EPA derive distribution functions using the empirical data for the various exposure factors to be used in Monte Carlo or other probabilistic analysis.

- Research is needed to derive a methodology to extrapolate from short-term data to long-term or chronic exposures.

- Reviewers recommended that the consumer products chapter be expanded to include more products. A comprehensive literature search needs to be conducted to investigate other sources of data.

- Breastmilk intake.

- More recent data on tapwater intake.

- SAB recommended analysis of 1994 and 1995 CSFII data.

1.6. ORGANIZATION

The handbook is organized into three volumes as follows:

Volume I - General Factors

Chapter 1	Provides the overall introduction to the handbook.
Chapter 2	Presents an analysis of uncertainty and discusses methods that can be used to evaluate and present the uncertainty associated with exposure scenario estimates.
Chapter 3	Provides factors for estimating human exposure through ingestion of water.
Chapter 4	Provides factors for estimating exposure through ingestion of soil.
Chapter 5	Provides factors for estimating exposure as a result of inhalation of vapors and particulates.
Chapter 6	Presents factors for estimating dermal exposure to environmental contaminants that come in contact with the skin.
Chapter 7	Provides data on body weight.
Chapter 8	Provides data on life expectancy.

Volume II - Ingestion Factors

Chapter 9	Provides factors for estimating exposure through ingestion of fruits and vegetables.
Chapter 10	Provides factors for estimating exposure through ingestion of fish.
Chapter 11	Provides factors for estimating exposure through ingestion of meats and dairy products.

Chapter 12	Presents data for estimating exposure through ingestion of grain products.
Chapter 13	Presents factors for estimating exposure through ingestion of home produced food.
Chapter 14	Presents data for estimating exposure through ingestion of breast milk.

Volume III - Activity Factors

Chapter 15	Presents data on activity factors (activity patterns, population mobility, and occupational mobility).
Chapter 16	Presents data on consumer product use.
Chapter 17	Presents factors used in estimating residential exposures.

Figure 1-2 provides a roadmap to assist users of this handbook in locating recommended values and confidence ratings for the various exposure factors presented in these chapters. A glossary is provided at the end of Volume III.

APPENDIX 1A

RISK CALCULATIONS USING EXPOSURE FACTORS HANDBOOK DATA AND DOSE-RESPONSE INFORMATION FROM THE INTEGRATED RISK INFORMATION SYSTEM (IRIS)

APPENDIX 1A
RISK CALCULATIONS USING EXPOSURE FACTORS HANDBOOK DATA AND DOSE-RESPONSE INFORMATION FROM IRIS

1. INTRODUCTION

When calculating risk estimates for a specific population, whether the entire national population or some sub-population, the exposure information (either from this handbook or from other data) must be combined with dose-response information. The latter typically comes from the IRIS data base, which summarizes toxicity data for each agent separately. Care must be taken that the assumptions about population parameters in the dose-response analysis are consistent with the population parameters used in the exposure analysis. This Appendix discusses procedures for insuring this consistency.

In the IRIS derivation of threshold based dose-response relationships (U.S. EPA, 1996), such as the RfD and the RfCs based on adverse systemic effects, there has generally been no explicit use of human exposure factors. In these cases the numerical value of the RfD and RfC comes directly from animal dosing experiments (and occasionally from human studies) and from the application of uncertainty factors to reflect issues such as the duration of the experiment, the fact that animals are being used to represent humans and the quality of the study. However in developing cancer dose-response (D-R) assessments, a standard exposure scenario is assumed in calculating the slope factor (i.e., human cancer risk per unit dose) on the basis of either animal bioassay data or human data. This standard scenario has traditionally been assumed to be typical of the U.S. population: 1) body weight = 70 kg; 2) air intake rate = 20 m^3/day; 3) drinking water intake = 2 liters/day; 4) lifetime = 70 years. In RfC derivations for cases involving an adverse effect on the respiratory tract, the air intake rate of 20 m^3/day is assumed. The use of these specific values has depended on whether the slope factor was derived from animal or human epidemiologic data:

- Animal Data: For dose-resopnse (D-R) studies based on animal data, scale animal doses to human equivalent doses using a human body weight assumption of 70 kg. No explicit lifetime adjustment is necessary because the assumption is made that events occurring in the lifetime animal bioassay will occur with equal probability in a human lifetime, whatever that might happen to be.

- Human Data - In the analysis of human studies (either occupational or general population), the Agency has usually made no explicit assumption of body weight or human lifetime. For both of these parameters there is an implicit assumption

that the population usually of interest has the same descriptive parameters as the population analyzed by the Agency. In the rare situation where this assumption is known to be wrong, the Agency has made appropriate corrections so that the dose-response parameters represent the national average population.

When the population of interest is different than the national average (standard) population, the dose-response parameter needs to be adjusted. In addition, when the population of interest is different than the population from which the exposure factors in this handbook were derived, the exposure factor needs to be adjusted. Two generic examples of situations where these adjustments are needed are as follows:

A) Detailed study of recent data, such as are presented in this handbook, show that EPA's standard assumptions (i.e., 70 kg body weight, 20 m^3/day air inhaled, and 2 L/day water intake) are inaccurate for the national population and may be inappropriate for sub-populations under consideration. The handbook addresses most of these situations by providing gender- and age-specific values and by normalizing the intake values to body weight when the data are available, but it may not have covered all possible situations. An example of a sub-population with a different mean body weight would be females, with an average body weight of 60 kg or children with a body weight dependent on age. Another example of a non-standard sub-population would be a sedentary hospital population with lower than 20 m^3/day air intake rates.

B) The population variability of these parameters is of interest and it is desired to estimate percentile limits of the population variation. Although the detailed methods for estimating percentile limits of exposure and risk in a population are beyond the scope of this document, one would treat the body weight and the intake rates discussed in Sections 2 to 4 of this appendix as distributions, rather than constants.

2. CORRECTIONS FOR DOSE-RESPONSE PARAMETERS

The correction factors for the dose-response values tabulated in the IRIS data base for carcinogens are summarized in Table 1A-1. Use of these correction parameters is necessary to avoid introducing errors into the risk analysis. The second column of Table 1A-1 shows the dependencies that have been assumed in the typical situation where the human dose-response factors have been derived from the administered dose in animal studies. This table is applicable in most cases that will be encountered, but it is not applicable when: a) the effective dose has been derived with a pharmacokinetic model and b) the dose-response data has been derived from human data. In the former case, the subpopulation parameters need to be incorporated into the model. In the latter case, the correction factor for the dose-response parameter must be evaluated on a case-by case basis by examining the specific data and assumptions in the derivation of the parameter.

As one example of the use of Table 1A-1, the recommended value for the average consumption of tapwater for adults in the U. S. population derived in this document (Chapter 3), is 1.4 liters per day. The drinking water unit risk for dichlorvos, as given in the IRIS information data base is 8.3 x 10^{-6} per µg/l, and was calculated from the slope factor assuming the standard intake, I_W^S, of 2 liters per day. For the United States population drinking 1.4 liters of tap water per day the corrected drinking water unit risk should be 8.3 x 10^{-6} x (1.4/2) = 5.8 x 10^{-6} per μg/l. The risk to the average individual is then estimated by multiplying this by the average concentration in units of μg/l.

Another example is when the risk for women drinking water contaminated with dichlorvos is to be estimated. If the women have an average body weight of 60 kg, the correction factor for the drinking water unit risk is (disregarding the correction discussed in the above paragraph), from Table 1A-1, is $(70/60)^{2/3}$ = 1.11. Here the ratio of 70 to 60 is raised to the power of 2/3. The corrected water unit risk for dichlorvos is 8.3 x 10^{-6} x 1.11 = 9.2 x 10^{-6} per μg/l. As before, the risk to the average individual is estimated by multiplying this by the water concentration.

When human data are used to derive the risk measure, there is a large variation in the different data sets encountered in IRIS, so no generalizations can be made about global corrections. However, the typical default exposure values used for the air intake of an air pollutant over an occupational lifetime are: air intake is 10 m^3/day for an 8-hour shift, 240 days per year with 40 years on the job. If there is continuous exposure to an ambient air pollutant, the lifetime dose is usually calculated assuming a 70-year lifetime.

3. CORRECTIONS FOR INTAKE DATA

When the body weight, W^P, of the population of interest differs from the body weight, W^E, of the population from which the exposure values in this handbook were derived, the following model furnishes a reasonable basis for estimating the intake of food and air (and probably water also) in the population of interest. Such a model is needed in the absence of data on the dependency of intake on body size. This occurs for inhalation data, where the intake data are not normalized to body weight, whereas the model is not needed for food and tap water intakes if they are given in units of intake per kg body weight.

The model is based on the dependency of metabolic oxygen consumption on body size. Oxygen consumption is directly related to food (calorie) consumption and air intake and indirectly to water intake. For mammals of a wide range of species sizes (Prosser and Brown, 1961), and also for individuals of various sizes within a species, the oxygen consumption and calorie (food) intake varies as the body weight raised to a power between 0.65 and 0.75. A value of 0.667 = 2/3 has been used in EPA as the default value for

adjusting cross-species intakes, and the same factor has been used for intra-species intake adjustments.

[NOTE: Following discussions by an interagency task force (Federal Register, 1992), the agreement was that a more accurate and defensible default value would be to choose the power to 3/4 rather than 2/3. A recent article (West et al., 1997) has provided a theoretical basis for the 3/4 power scaling. This will be the standard value to be used in future assessments, and all equations in this Appendix will be modified in future risk assessments. However, because risk assessors now use the current IRIS information, this discussion is presented with the previous default assumption of 2/3].

With this model, the relation between the daily air intake in the population of interest, $I_A^P = (m^3/day)^P$, and the intake in the population described in this handbook, $I_A^E = (m^3/day)^E$ is:

$$I_A^P = I_A^E \times (W^P/W^E)^{2/3}.$$

4. CALCULATION OF RISKS FOR AIR CONTAMINANTS

The risk is calculated by multiplying the IRIS air unit risk, corrected as described in Table 1A-1, by the air concentration. But since the correction factor involves the intake in the population of interest (I_A^P), that quantity must be included in the equation, as follows:

$$\begin{aligned}(\text{Risk})^P &= (\text{air unit risk})^P \times (\text{air concentration})\\ &= (\text{air unit risk})^S \times (I_A^P/20) \times (70/W^P)^{2/3} \times (\text{air concentration})\\ &= (\text{air unit risk})^S \times [(I_A^E \times (W^P/W^E)^{2/3}/20)] \times (70/W^P)^{2/3} \times (\text{air concentration})\\ &= (\text{air unit risk})^S \times (I_A^E/20) \times (70/W^E)^{2/3} \times (\text{air concentration})\end{aligned}$$

In this equation the air unit risk from the IRIS data base $(\text{air unit risk})^S$, the air intake data in the handbook for the populations where it is available (I_A^E) and the body weight of that population (W^E) are included along with the standard IRIS values of the air intake (20 m^3/day) and body weight (70 kg).

For food ingestion and tap water intake, if body weight-normalized intake values from this handbook are used, the intake data do not have to be corrected as in Section 3 above. In these cases, corrections to the dose-response parameters in Table 1A-1 are sufficient.

5. REFERENCES

Federal Register. (1992) Cross-species scaling factor for carcinogen risk assessments based on equivalence of (mg/kg-day)$^{3/4}$. Draft report. Federal Register, 57(109): 24152-24173, June 5, 1992.

Prosser, C.L.; Brown, F.A. (1961) Comparative Animal physiology, 2nd edition. WB Saunders Co. p. 161.

U.S. EPA. (1996) Background Documentation. Integrated Risk Information System (IRIS). Online. National Center for Environmental Assessment, Cincinnati, Ohio. Background Documentation available from: Risk Information Hotline, National Center for Environmental Assessment, U.S. EPA, 26 W. Martin Luther King Dr. Cincinnati, OH 45268. (513) 569-7254

West, G.B.; Brown, J.H.; Enquist, B.J. (1997) A general model of the origin of allometric scaling laws in biology. Science 276:122-126.

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

CONSIDERATIONS	HIGH CONFIDENCE	LOW CONFIDENCE
Study Elements		
Level of peer review	The studies received high level of peer review (e.g., they appear in peer review journals).	The studies received limited peer review.
Accessibility	The studies are widely available to the public.	The studies are difficult to obtain (e.g., draft reports, unpublished data).
Reproducibility	The results can be reproduced or methodology can be followed and evaluated.	The results cannot be reproduced, the methodology is hard to follow, and the author(s) cannot be located.
Focus on factor of interest	The studies focused on the exposure factor of interest.	The purpose of the studies was to characterize a related factor.
Data pertinent to U.S.	The studies focused on the U.S. population.	The studies focused on populations outside the U.S.
Primary data	The studies analyzed primary data.	The studies are based on secondary sources.
Currency	The data were published after 1990.	The data were published before 1980.
Adequacy of data collection period	The study design captures the measurement of interest (e.g., usual consumption patterns of a population).	The study design does not very accurately capture the measurement of interest.
Validity of approach	The studies used the best methodology available to capture the measurement of interest.	There are serious limitations with the approach used.
Study sizes	The sample size is greater than 100 samples.	The sample size is less than 20 samples.
	The sample size depends on how the target population is defined. As the size of a sample relative to the total size of the target population increases, estimates are made with greater statistical assurance that the sample results reflect actual characteristics of the target population.	
Representativeness of the population	The study population is the same as population of interest.	The study population is very different from the population of interest.[a]
Variability in the population	The studies characterized variability in the population studied.	The characterization of variability is limited.
Lack of bias in study design (a high rating is desirable)	Potential bias in the studies are stated or can be determined from the study design.	The study design introduces biases in the results.
Response rates		
In-person interviews	The response rate is greater than 80 percent.	The response rate is less than 40 percent.
Telephone interviews	The response rate is greater than 80 percent.	The response rate is less than 40 percent.
Mail surveys	The respnose rate is greater than 70 percent.	The response rate is less than 40 percent.
Measurement error	The study design minimizes measurement errors.	Uncertainties with the data exist due to measurement error.
Other Elements		
Number of studies	The number of studies is greater than 3.	The number of studies is 1.
Agreement between researchers	The results of studies from different researchers are in agreement.	The results of studies from different researchers are in disagreement.

[a] Differences include age, sex, race, income, or other demographic parameters.

Table 1-2. Summary of Exposure Factor Recommendations and Confidence Ratings

EXPOSURE FACTOR	RECOMMENDATION	CONFIDENCE RATING
Drinking water intake rate	21 ml/kg-day/1.4 L/day (average)	Medium
	34 ml/kg-day/2.3 L/day (90th percentile)	Medium
	Percentiles and distribution also included	
	Means and percentiles also included for pregnant and lactating women	
Total fruit intake rate	3.4 g/kg-day (per capita average)	Medium
	12.4 g/kg-day (per capita 95th percentile)	Low
	Percentiles also included	
	Means presented for individual fruits	
Total vegetable intake rate	4.3 g/kg-day (per capita average)	Medium
	10 g/kg-day (per capita 95th percentile)	Low
	Percentiles also included	
	Means presented for individual vegetables	
Total meat intake rate	2.1 g/kg-day (per capita average)	Medium
	5.1 g/kg-day (per capita 95th percentile)	Low
	Percentiles also included	
	Percentiles also presented for individual meats	
Total dairy intake rate	8.0 g/kg-day (per capita average)	Medium
	29.7 g/kg-day (per capita 95th percentile)	Low
	Percentiles also included	
	Means presented for individual dairy products	
Grain intake	4.1 g/kg-day (per capita average)	High
	10.8 g/kg-day (per capita 95th percentile)	Low in long-term upper percentiles
	Percentiles also included	
Breast milk intake rate	742 ml/day (average)	Medium
	1,033 ml/day (upper percentile)	Medium
Fish intake rate	General Population	
	20.1 g/day (total fish) average	High
	14.1 g/day (marine) average	High
	6.0 g/day (freshwater/estuarine)average	High
	53 g/day (total fish) 95th percentile long-term	Medium
	Percentiles also included	
	Serving size	High
	129 g (average)	High
	326 g (95th percentile)	
	Recreational marine anglers	Medium
	2 - 7 g/day (finfish only)	
	Recreational freshwater	Medium
	8 g/day (average)	Medium
	25 g/day (95th percentile)	
	Native American Subsistence Population	Medium
	70 g/day (average)	Low
	170 g/day (95th percentile)	

Table 1-2. Summary of Exposure Factor Recommendations and Confidence Ratings (continued)

EXPOSURE FACTOR	RECOMMENDATION	CONFIDENCE RATING
Home produced food intake	Total Fruits 2.7 g/kg-day (consumer only average) 11.1 g/kg-day (consumer only 95th percentile) Percentiles also included Total vegetables 2.1 g/kg-day (consumer only average) 7.5 g/kg-day (consumer only 95th percentile) Percentiles also included Total meats 2.2 g/kg-day (consumer only average) 6.8 g/kg-day (consumer only 95th percentile) Percentiles also included Total dairy products 14 g/kg-day (consumer only average) 44 g/kg-day (consumer only 95th percentile) Percentiles also included	Medium (for means and short-term distributions) Low (for long-term distributions)
Inhalation rate	Children (<1 year) 4.5 m^3/day (average) Children (1-12 years) 8.7 m^3/day (average) Adult Females 11.3 m^3/day (average) Adult Males 15.2 m^3/day (average)	High High High High
Surface area	Water contact (bathing and swimming) Use total body surface area for children in Tables 6-6 through 6-8; for adults use Tables 6-2 through 6-4 (percentiles are included) Soil contact (outdoor activities) Use whole body part area based on Table 6-6 through 6-8 for children and 6-2 through 6-4 for adults (percentiles are included)	High High
Soil adherence	Use values presented in Table 6-16 depending on activity and body part (central estimates only)	Low
Soil ingestion rate	Children 100 mg/day (average) 400 mg/day (upper percentile) Adults 50 mg/day (average) Pica child 10 g/day	Medium Low Low
Life expectancy	75 years	High
Body weight for adults	71.8 kg Percentiles also presented in tables 7-4 and 7-5	High
Body weights for children	Use values presented in Tables 7-6 and 7-7 (mean and percentiles)	High
Body weights for infants (birth to 6 months)	Use values presented in Table 7-1 (percentiles)	High

Table 1-2. Summary of Exposure Factor Recommendations and Confidence Ratings (continued)

EXPOSURE FACTOR	RECOMMENDATION	CONFIDENCE RATING
Showering/Bathing	Showering time 10 min/day (average) 35 min/day (95th percentile) (percentiles are also included)	High
	Bathing time 20 min/event (median) 45 min/event (90th percentile)	High
	Bathing/showering frequency 1 shower event/day	High
Swimming	Frequency 1 event/month	High
	Duration 60 min/event (median) 180 min/event (90th percentile)	High
Time indoors	Children (ages 3-11) 19 hr/day (weekdays) 17 hr/day (weekends)	Medium
	Adults (ages 12 and older) 21 hr/day	Medium
	Residential 16.4 hrs/day	High
Time outdoors	Children (ages 3-11) 5 hr/day (weekdays) 7 hr/day (weekends)	Medium
	Adults 1.5 hr/day	Medium
	Residential 2 hrs/day	High
Time spent inside vehicle	Adults 1 hr 20 min/day	Medium
Occupational tenure	6.6 years (16 years old and older)	High
Population mobility	9 years (average) 30 years (95th percentile)	Medium Medium
Residence volume	369 m^3 (average) 217 m^3 (conservative)	Medium Medium
Residential air exchange	0.45 (median) 0.18 (conservative)	Low Low

Table 1-3. Characterization of Variability in Exposure Factors				
Exposure Factors	Average	Upper percentile	Multiple Percentiles	Fitted Distributions
Drinking water intake rate	**T**	**T**	**T**	**T**
Total fruits and total vegetables intake rate	**T**	**T** Qualitative discussion for long-term	**T**	
Individual fruits and individual vegetables intake rate	**T**			
Total meats and dairy products intake rate	**T**	**T** Qualitative discussion for long-term	**T**	
Individual meats and dairy products intake rate	**T**			
Grains intake	**T**	**T**	**T**	
Breast milk intake rate	**T**	**T**		
Fish intake rate for general population, recreational marine, recreational freshwater, and native american	**T**	**T**		
Serving size for fish	**T**	**T**	**T**	
Homeproduced food intake rates	**T**	**T**	**T**	
Soil intake rate	**T**	Qualitative discussion for long-term		
Inhalation rate	**T**	**T**		
Surface area	**T**	**T**	**T**	
Soil adherence	**T**			
Life expectancy	**T**			
Body weight	**T**	**T**	**T**	
Time indoors	**T**			
Time outdoors	**T**			
Showering time	**T**	**T**	**T**	
Occupational tenure	**T**			
Population mobility	**T**	**T**	**T**	
Residence volume	**T**			
Residential air exchange	**T**			

Table 1A-1. Procedures for Modifying IRIS Risk Values for Non-standard Populations[a,b]

IRIS Risk Measure [Units]	IRIS Risk Measure is Proportional to:[b]	Correction Factor (CF) for modifying IRIS Risk Measures:[c]
Slope Factor [per mg/(kg/day)]	$(W^S)^{1/3} = (70)^{1/3}$	$(W^P/70)^{1/3}$
Water Unit Risk [per µg/l]	$I_W^S/[(W^S)^{2/3}] = 2/[(70)^{2/3}]$	$(I_W^P)/2 \times [70/(W^P)]^{2/3}$
Air Unit Risk: A. Particles or aerosols [per µg/m^3], air concentration by weight	$I_A^S/[(W^S)^{2/3}] = 20/[(70)^{2/3}]$	$(I_A^P)/20 \times [70/(W^P)]^{2/3}$
Air Unit Risk: B. Gases [per parts per million], air concentration by volume,	No explicit proportionality to body weight or air intake is assumed.	1.0 ppm by volume is assumed to be the effective dose in both animals and humans.

[a] W = Body weight (kg)
I_W = Drinking water intake (liters per day)
I_A = Air intake (cubic meters per day)

[b] W^S, I_W^S, I_A^S denote standard parameters assumed by IRIS

[c] Modified risk measure = (CF) x IRIS value
W^P, I_W^P, I_A^P denote non-standard parameters of the actual population

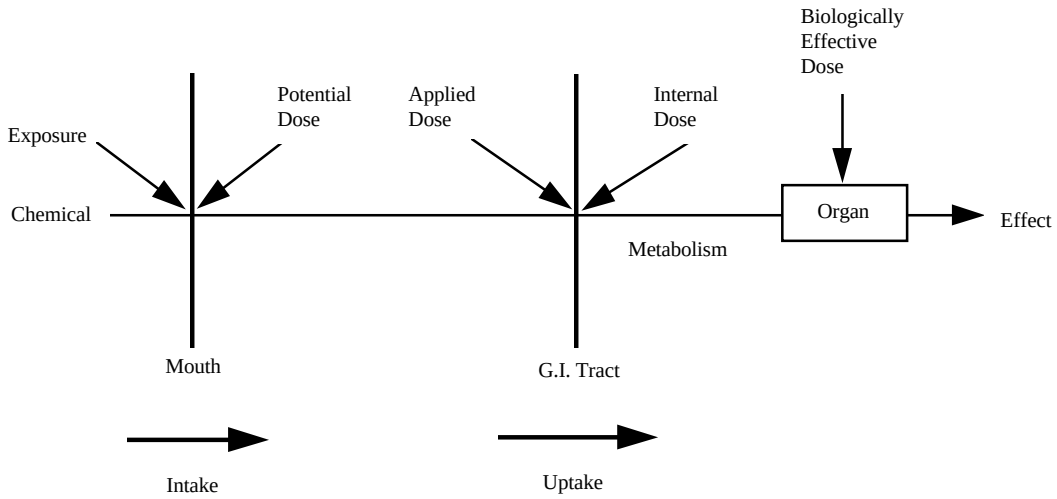

Figure 1-1. Schematic of Dose and Exposure: Oral Route

Source: U.S. EPA, 1992a

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate				
	Meat and Dairy Intake Rate				
	Homegrown Foods				
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate				
	Soil Intake Rate				
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate	Adults Children Pregnant Women High Activity	I	3	3.6/3-35
	Fruit and Vegetable Intake Rate				
	Meat and Dairy Intake Rate				
	Homegrown Foods				
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate				
	Soil Intake Rate				
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate	Various Demographic Groups — Age, Region, Season, Urbanization, Race	II	9	9.3/9-30
	Meat and Dairy Intake Rate				
	Homegrown Foods				
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate				
	Soil Intake Rate				
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate				
	Meat and Dairy Intake Rate	Various Demographic Groups — Age, Region, Season, Urbanization, Race	II	11	11.4/11-31
	Homegrown Foods				
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate				
	Soil Intake Rate				
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate	Various Demographic Groups — Age, Region, Season, Urbanization, Race			
	Meat and Dairy Intake Rate				
	Homegrown Foods		II	13	13.5/13-72
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate				
	Soil Intake Rate				
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate				
	Meat and Dairy Intake Rate				
	Homegrown Foods				
	Breast milk Intake Rate	Nursing Infants	II	14	14.6/14-14
	Fish and Shellfish Intake Rate				
	Soil Intake Rate				
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate				
	Meat and Dairy Intake Rate				
	Homegrown Foods				
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate	General Population	II	10	10.10.1/10-87
		Freshwater Recreational	II	10	10.10.3/10-89
		Marine Recreational	II	10	10.10.2/10-88
		Subsistence	II	10	10.10.4/10-90
	Soil Intake Rate				
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

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EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate				
	Meat and Dairy Intake Rate				
	Homegrown Foods				
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate				
	Soil Intake Rate	Typical Children Adults Pica Children Various Demographic Groups — Age, Region, Season, Urbanization, Race	I	4	4.7/4-21
	Grain Intake				
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

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EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion	Drinking Water Intake Rate				
	Fruit and Vegetable Intake Rate				
	Meat and Dairy Intake Rate				
	Homegrown Foods				
	Breast milk Intake Rate				
	Fish and Shellfish Intake Rate				
	Soil Intake Rate				
	Grain Intake	Typical Children Adults Pica Children Various Demographic Groups — Age, Region, Season, Urbanization, Race	II	12	12.3/12-24
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation	Inhalation Rate	Adults Children High Activity	I	5.	5.2.4/5-23
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS/ RATINGS TABLE PAGE NOS.
Ingestion					
Inhalation					
Dermal	Skin Surface Area	Adults Children	I	6.	6-8/6-25
	Soil Adherence	General Populationn	I	6.	6-8/6-27
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation					
Dermal					
(All Routes) Human Characteristics	Body Weight Lifetime				
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation					
Dermal					
(All Routes) Human Characteristics	Body Weight Lifetime	Adults Children	I	7	7.3/7-12
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation					
Dermal					
(All Routes) Human Characteristics	Body Weight Lifetime	Adults Children	I	8	8.2/8-3
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors	Activity Patterns	Adults Children	III	15	15.4.1/15-172
	Occupational Mobility	Adults	III	15	15.4.2/15-173
	Population Mobility	Adults Children	III	15	15.4.3/15-175
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use	Frequency of Use Amount Used	Adults Adults	III	16	16.4
(All Routes) Residential Building Characteristics					

Figure 1-2. Road Map to Exposure Factor Recommendations

EXPOSURE ROUTE	EXPOSURE FACTOR	POPULATION	VOLUME	CHAPTER	RECOMMENDATIONS SECTION / RATINGS TABLE
Ingestion					
Inhalation					
Dermal					
(All Routes) Human Characteristics					
(All Routes) Activity Factors					
(All Routes) Consumer Product Use					
(All Routes) Residential Building Characteristics	Water Use Air Exchange Rates House Volumes Building Characteristics	General Population	III	17	17.6/17-32, 17-33

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