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Project Summary

Exposure Factors Handbook

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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 rays 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.

This Project Summary was prepared by EPA's Office of Health and Environmental Assessment, Washington, DC, to announce key findings of the research project that is fully documented in a separate report of the same title (See Project Report information at back).

Introduction

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.

Background Information

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. The EPA report, "Development of

Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments" USEPA (1985), covered body weight, body surface area, and respiration rate. The results of this study are incorporated into this handbook.

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 are covered in this handbook.

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

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

The total exposure can be expanded as follows:

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

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 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 handbook 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.

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 1986 edition of the U.S. Bureau of the Census Statistical Abstract of the United States, the average life expectancy of men and women is 74.7 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 carcinogen 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.

Exposure Factors

The handbook summarizes the available data on the following exposure factors:

- drinking water consumption
- consumption of homegrown fruits and vegetables
- consumption of homegrown beef and dairy products
- consumption of recreationally caught fish and shellfish
- soil ingestion
- inhalation rates
- body surface area
- lifetime
- body weight
- activity patterns

For each of these, the available literature is summarized and historical precedents discussed.

Exposure Scenarios

The handbook presents a series o exposure scenarios to demonstrate how to apply the exposure factor statistics summarized earlier. The following scenarios are currently included:

Ingestion of Drinking Water
Ingestion of Homegrown Fruits and Vegetables
Ingestion of Homegrown Meat and Dairy Products
Ingestion of Recreationally Caugh Fish/Shellfish
Ingestion of Soil
Inhalation of Vapors Inside Residence
Inhalation of Vapors While Showering
Inhalation of Particulates Outside Residence
Inhalation of Particulates Inside Residence

For each scenario, the following informa tion 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 fo computing cancer risk.
- Recommended default values for each parameter in the exposure equation These values are defaults in the sens that they are intended to be used onl when site-specific data are no available to make more accurat estimates. Prior sections of this repo provide data and procedures fo estimating parameter values an should be used in lieu of these defau values if feasible. These default value are presented in three ways: average ranges, and distributions. The recommended parameter values were de rived solely from our interpretation of the available data. In many situations different values may be appropriate f use in consideration of policy precedent, strategy, or other factors.
- Justifications for each recommende parameter value. To the extent poss ble, these values were derived direct from the preceding sections. In mar cases, however, no appropriate da were available and the recommend tions were based on the be

Table 1. 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.

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

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.

judgments of the authors in conjunctions with EPA. Users are encouraged to modify these assumptions based on site-specific information.

An example of the exposure scenario presentation for home water consumption is shown in Table 1.

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	0.08-2.80	1.90	Gillies and Paulin 1983
1.20	-	-	Pennington 1983
Ave. 1.4			

For 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 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 Bureau of the Census Statistical Abstract of the United States (Bureau of Census, 1986), 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.

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The complete report, entitled "Exposure Factors Handbook," (Order No. PB 90-106 774/AS; Cost: $31.00, subject to change) will be available only from:

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