EPA
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Exposure Assessment (EXA)
Course Series

Obtaining and Using Exposure Factor Data

Reading Packet

EXA 406



EPA's Risk Assessment Training and Experience (RATE) Program

EXA 406: Obtaining and Using Exposure Factor Data

READING PACKET

Exposure Assessment (EXA)
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EXA 406: Obtaining and Using Exposure Factor Data

The objective of this course is to familiarize participants with the selection and use of exposure factor data for exposure assessment. It will review key sources of data on human behaviors and characteristics that affect exposure to environmental contaminants, including the Exposure Factors Handbook and the Child-Specific Exposure Factors Handbook. The types of factors that will be covered include: ingestion of water and other select liquids; non-dietary ingestion via hand-to-mouth and object-to-mouth contact; soil and dust ingestion; inhalation rates; dermal exposure factors (i.e., skin surface area and adherence of solids to the skin); body weight; intake of fruits, vegetables, fish and shellfish, meats, dairy products, fats, and grain products; intake of home-produced foods; total food intake; human milk intake; human activity factors; use of consumer products; life expectancy; and building characteristics for assessing indoor air exposures. The recommended values for various exposure factors will be highlighted along with the confidence in the recommended values. Recommended age groupings and indicators of variability will also be discussed. Related topics will include the physiological differences between adults and children as well as other demographic factors (e.g., gender) that may affect exposure.

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1. INTRODUCTION

When characterizing risk to an individual or population from chemical exposure, exposure data is combined with dose-response information to help quantify risk. To conduct an exposure assessment, the source of the contamination must be identified along with the affected media and fate and transport characteristics that will allow for the calculation of chemical concentration. From there, exposure scenarios are constructed to identify potential human receptors and exposure pathways (see EXA 403). **Exposure factors** are "factors related to human behavior and characteristics that help determine an individual's exposure to an agent." They are not chemical specific but instead "summarize data on human behavioral and physiological characteristics and provide exposure and risk assessors with recommended values for these factors" (U.S. EPA, 2011). Examples of exposure factors include body weight, skin surface area, life expectancy, inhalation rate, and ingestion rates for different types of food.

Among other things, exposure factors can be used in the equation we've seen several times to calculate potential dose (see **Figure** 1). Exposure factors can help characterize the effect of intake rate (IR), absorption, exposure duration (ED), and exposure frequency (EF) to estimate a body-weight normalized, average dose over time. Exposure factors provide a means for risk assessors to carry out calculations using data on hand in order to estimate current and potential future exposures (U.S. EPA, 2011).

Figure 1. Potential Dose Equation

$$\text{Potential Dose} = \frac{(C \times IR \times CF \times ED \times EF)}{(AT \times BW)}$$

C	=	Concentration (mg/m^3, mg/kg)	EF	=	Exposure frequency (days/yr, events/day)
IR	=	Intake rate (mg/day, L/day)	AT	=	Averaging time (min., hours, days, years)
CF	=	Contact fraction (unitless)	BW	=	Body weight (kg)
ED	=	Exposure duration (min., hours, days, years)			

1.1 Exposure Factor Guidance at EPA

Figure 2. Timeline of Development of Exposure Factors

1985	Development of Statistical Distribution or Ranges of Standard Factors Used in Exposure Assessments – provided ranges of values for body weight, skin surface area, and ventilation rates (U.S. EPA, 1985).
1989	Exposure Factors Handbook (U.S. EPA, 1989)
1997	Exposure Factors Handbook – Update (U.S. EPA, 1997)
2004	Example Exposure Scenarios (U.S. EPA, 2004)
2005	Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants (U.S. EPA, 2005).
2008	Child-specific Exposure Factors Handbook(U.S. EPA, 2008).
2009	Exposure Factors Handbook – Update (U.S. EPA, 2009)
2011	Exposure Factors Handbook (U.S. EPA, 2011).

U.S. EPA's history of providing exposure factor guidance began in 1985, as shown in Figure **2**. Additional exposure factor data are available from EPA regions, EPA program offices, state agencies, and industry groups. For example, officials in Alaska collected information on fish consumption by conducting a traditional diet survey in an attempt to quantify the intake

of subsistence foods among residents of villages in rural Alaska (ATSDR, 2004; Ballew et al., 2004). Similarly, information on product usage has been collected by industry groups.

1.2 Types of Exposure Factors

The main categories of exposure factors commonly used by EPA are described below with examples and descriptions for each factor (U.S. EPA, 2011).

Physiological Exposure Factors

- **Body weight –** All other things being equal, lower body weight will result in a higher exposure dose per unit of body weight. In that case, the dose per unit of body weight in a child would exceed that of an adult. Similarly, because the average body weight for females is lower than for males, an assessor might consider evaluating male and female exposures separately to more accurately reflect the exposed population as opposed to using the U.S. EPA-recommended body weight of 80 kg for "adult" exposures.
- **Inhalation rate** – Age and activity level will affect inhalation rate. Activity-specific inhalation rates by intensity level are provided in the *Exposure Factors Handbook*. There is also a distinction between short-term (less than 30 days) and long-term inhalation rates. Conservative estimates can be made using higher values that are more protective of the most active members of a target population.
- **Dermal and surface area factors** – Surface area is an estimate of the amount of skin that can be exposed to chemicals. The more skin exposed the greater potential for dermal absorption. Another dermal factor is the adherence factor—the quantity of soil or solids that may adhere to the skin surface after contact—and this varies with activity.
- **Lifetime** – Average life expectancies differ by gender and ethnicity. This is a particularly important exposure factor when calculating lifetime average dose.

Food and Water Intake Rates

Food and water intake rates are critical to estimating ingestion exposures and can vary by type of food, source of food or water, and population. (U.S. EPA, 2011)

- **Type of food** – Intake rates can be defined by individual food types, such as beef, fish, carrots, and apples, or by categories of foods, such as total vegetables, total fruits, aboveground produce, or root vegetables. Another potential type of food is human milk, relevant for only one population life stage.
- **Source of food** – Intake can vary by the source of food. For example, the *Exposure Factors Handbook* provides different intake rates for fruits and vegetables for the general population versus individuals who produce their own fruits, vegetables, and meats. Similarly, fish intake rates are presented for the general population, individuals who catch their own fish (subsistence fishers), and recreational anglers. Consumption of home-grown vegetables by a "backyard gardener" is another exposure scenario commonly evaluated. These scenarios could involve different types of food and different rates of consumption depending upon seasonal availability so it could be important to consider quantities of foods consumed on a seasonal basis.
- **Population** – Intake rates might differ across different populations. For this reason, U.S. EPA presents intake rates for different age groups, races, and ethnic groups as well as some

occupational groups such as fishermen. It is important to select exposure values that are appropriate for the particular population of concern.

- **Source of water** – Consumption rates of drinking water are needed if the exposure scenario, for example, involves ingesting water from a well with contaminated groundwater. The consumption of drinking water from surface water sources might also be of concern unless treatment of the water mitigates concerns about its contamination.
- **Other factors** – There are other factors that affect intake rates. For example, the *Exposure Factors Handbook* presents "consumer-only" and "per capita" intake rates for certain types of food.

Mouthing Behavior and Soil and Dust Ingestion Rates

Mouthing behavior and soil/dust ingestions rates account for inadvertent soil/dust ingestion, particularly in children, as a result of "hand-to-mouth" or "object-to-mouth" activities in which objects (including fingers) are touched by or put into the mouth, resulting in incidental exposure. Adults may also be exposed by ingesting soil that adheres to food or objects that have been handled. Exposure factor data for this category include separate values for adults and children. (U.S. EPA, 2011)

- **Source** – Ingestion rates may differ depending upon the source (e.g., indoor dust, outdoor soil).
- **Soil-pica and geophagy** – Inadvertent ingestion of soil should be differentiated from soil-pica and geophagy. **Soil-pica** is the recurrent ingestion of unusually high amounts of soil. **Geophagy** is the intentional ingestion of earths and is usually associated with cultural practices. Central tendency estimates for soil ingestion for individuals 1 year of age and older are 50 mg/day. It is estimated that soil-pica behavior can result in ingestion of 1,000 mg/day, and geophagy behavior can result in ingestion of 50,000 mg/day. Soil-pica and geophagy are considered uncommon events and represent the high end of exposures.

Consumer Product Use

Consumer product use is another potential source of exposure to toxic chemicals. (U.S. EPA, 2011)

- **Product type and use** – The *Exposure Factors Handbook* provides information about the use of typical consumer products found in U.S. households. These data are used primarily to estimate exposure frequency and duration of use as well as the amount of product used per event.
- **Active versus passive** – Exposure to consumer products can be either active or passive. "Active" exposure could occur when cosmetic products or cleaning and painting products are used as directed. "Passive" exposure can occur when individuals come in contact with a product or byproduct through other means. Examples of passive exposure include touching countertops treated with a cleanser or pesticide, hand-to-mouth contact with treated clothing, or inhalation of vapors that have off-gassed from products like carpet, cabinetry, or recently-painted surfaces.

Activity Factors

Activity factors account for how different populations will be exposed to a contaminant as a function of varying activities and settings (e.g., time spent indoors versus outdoors, at work versus at home). (U.S. EPA, 2011)

- **Activity patterns** – Includes typical amounts of time spent doing specific activities (e.g., time spent indoors/outdoors; time spent bathing, showering, swimming).

- **Occupational mobility** – Includes data on how long people typically stay at a job and the distribution of job types across the population.
- **Population mobility** – Refers to, for example, how long an individual stays in a particular house at a particular location.
- **Human activity databases** – In addition to the *Exposure Factors Handbook*, EPA's Consolidated Human Activity Database (CHAD) and the National Human Activity Pattern Survey (NHAPS) provide information on activity patterns.

Microenvironments

Microenvironments are the various changing spaces in which people spend their time that will influence how they will be exposed to chemicals. This term is commonly used when discussing inhalation exposures. A microenvironment can be defined as a space with a contaminant concentration that is assumed to be relatively well-mixed, homogeneous, and temporally constant while an individual is located within the microenvironment. Examples of microenvironments included in EPA assessments are automobiles, schools, work places, and other buildings. The *Exposure Factors Handbook* presents data on the amount of time that an individual is expected to spend in various microenvironments. For buildings, important factors might include size, volume, number of windows, and air exchange rates, and the *Exposure Factors Handbook* provides information about these factors for both residential and nonresidential buildings. (U.S. EPA, 2011)

2. SELECTING VALUES FOR EXPOSURE FACTORS

The values for a given type of exposure factor can vary widely and are impacted by several considerations. For example, population variability, including differences in age, life stage, population, and susceptibility, influence choice of the appropriate exposure factors. Another important consideration is data uncertainty. Before using specific exposure factor data, the user should assess the confidence in the data and the original purpose of the data when it was collected versus its intended use in the exposure assessment. Additional considerations in the selection of exposure factor values are described below.

Figure 3. Variability and Uncertainty Considerations

Variability (Known) Considerations	Uncertainty (Unknown) Considerations
• Differences between children and adults • Age groups • Life stages • Population groups (e.g., race/ethnicity, fishers, farmers) • Susceptibility	• Confidence in data • Original purpose of data vs. intended use

2.1 Differences between Children and Adults

Physiological and behavioral differences between children (including infants) and adults result in differential exposures. For example, children can be exposed to some chemicals at higher rates or higher concentrations than adults because they consume more of certain foods per unit of body weight and have a higher ratio of body surface area to volume compared with adults. Important behavioral differences can also lead to greater exposures in children. Infants and children handle food more often and put their hands and other objects in their mouths more frequently than adults, and child-specific exposure factor data are available to assess this hand-to-mouth and object-to-mouth activity. Additionally, infants and children spend more time on the floor (indoors) or on the ground (outdoors) and explore surfaces and objects such as toys more frequently than adults. Therefore, children are more likely to have increased oral and dermal exposures at those locations or during those activities. For these reasons, children's behavior and physiology can increase their exposure to environmental contaminants. If possible, it is important to consider children separately in exposure assessments using the available child-specific exposure factor values as published in the *Child-Specific Exposure Factors Handbook* (U.S. EPA, 2008).

2.2 Selecting Age Groups for Children

Just as child and adult exposures vary based on behavior and physiology, exposures among children in different age groups also vary. Rapid changes in behavior and physiology can lead to differences in exposure as a child ages. Exposures among infants, toddlers, adolescents, and teenagers can vary widely. To this end, EPA has provided guidance on selecting age groups when assessing childhood exposures to environmental contaminants based on the current understanding of when developmental changes occur that could affect exposure (U.S. EPA, 2005).

Figure 4. Recommended Age Groups for Children

Age Groups <1 Year	Age Groups >1 Year
• birth to < 1 month	• 1 to < 2 years
• 1 to < 3 months	• 2 to < 3 years
• 3 to < 6 months	• 3 to < 6 years
• 6 to < 12 month	• 6 to < 11 years
	• 11 to < 16 years
	• 16 to < 21 years

Narrow age groups have been identified for life stages in which rapid developmental changes occur (age groups <1 year), and broader age groups are identified as the rate of development slows (age groups >1 year). Interestingly, EPA recommends that individuals aged 18–21 be included in a 16–21 age group as opposed to being assessed as adults. When available and appropriate, these age-group-specific exposure values should be used in an exposure assessment. However, it is not always practical or necessary to evaluate exposures for every age group within a population. It depends on the purpose and scope of the assessment (U.S. EPA, 2008, 2005).

2.3 Life Stages

Life stages in addition to childhood should also be considered in exposure assessments. **Life stages** are defined by EPA as temporal stages of life that have distinct anatomical, physiological, and behavioral or functional characteristics that contribute to potential differences in vulnerability to environmental exposures. Other important life stages to consider include pregnancy, nursing, and old age. Human exposure assessments might need to consider all life stages of a population (U.S. EPA, 2006a).

2.4 Life Stages vs. Population Groups

It is important to distinguish between the terms "life stage" and "population group." EPA, and specifically the Office of Children's Health Protection[1], has defined these two terms.

- **A life stage** refers to a distinguishable time frame in an individual's life. Examples of life stages in childhood are conception through fetal development, infancy, toddlerhood, and adolescence. Life stages are inclusive of the entire population.
- **A population group** refers to a relatively fixed portion of the population. For example, ethnic groups are types of population groups. Occupational workers or farmers would also be considered distinct population groups. There are other terms used to describe population groups; often they are referred to as subpopulations.

[1] Additional information is available online from EPA's Office of Children's Health Protection: http://yosemite.epa.gov/ochp/ochpweb.nsf/content/lifestage.htm

Exposures to individuals at different life stages vary as do exposures to different population groups. Life stage and subpopulation considerations should be factored into human exposures assessment.

2.5 Susceptibility

An individual's life stage might affect his or her susceptibility to chemicals or pollutants. Different population groups might also experience varying susceptibilities. **Susceptibility** is an increased likelihood of an adverse effect or exposure, often discussed in terms of relationship to a factor that can be used to describe a human population group (e.g., life stage, demographic feature, genetic characteristic) (U.S. EPA, 2006a). There are intrinsic and extrinsic factors that affect an individual's or population's susceptibility to pollutants.

Intrinsic, or biological, susceptibility factors include age, life stage, gender, race/ethnicity, and genetic polymorphisms. These biological factors cannot be changed. Specific life stages, especially the infant and toddler stages, might be more susceptible to chemical exposure. Older adults might also be more susceptible because, as humans age, the body's ability to defend against diseases and to heal injuries diminishes. Toxicokinetic differences among individuals that affect how easily a chemical is absorbed, metabolized, and excreted are also important factors. Critical windows of exposure need to be identified as part of the risk assessment process.

Figure 5. Factors Affecting Susceptibility

Intrinsic Factors (biological)	Extrinsic Factors (exposure-related)
• Age and life stage	• Socioeconomic status
• Gender	• Disease status
• Race/ethnicity	• Nutrition status
• Genetic polymorphisms	• Lifestyle

Extrinsic, or exposure-related, factors include socioeconomic status, disease status, nutrition status, and lifestyle. In many cases, these factors can be changed. For example, susceptibility can vary based on diet (e.g., consumption of nutritious food) or lifestyle factors (e.g., exercise) that can be modified to build the immune system and reduce susceptibility. Individuals with pre-existing diseases could be more susceptible to pollutants. For example, an individual with asthma might be more susceptible to air pollutants. These types of data are often difficult to collect and are not included in the *Exposure Factors Handbook*; however, assessors should be aware that these factors may affect population susceptibility.

2.6 Confidence in Data

It is important to consider the source of exposure data when selecting the appropriate exposure factors for an assessment. To assess confidence in exposure factor data, EPA has defined five "general assessment factors" that should be considered when selecting exposure factor data (U.S. EPA, 2011, 2009, 2006b). These factors were used when EPA scientists compiled the *Exposure Factors Handbook*.

- **Soundness** is the extent to which the scientific and technical procedures, measures, methods, or models employed to generate the information are reasonable for, and consistent with, the intended application.

- **Applicability and utility** describes the extent to which the information is relevant for the intended use.
- **Clarity and completeness** refers to how well the data, assumptions, methods, quality assurance procedures, sponsoring organizations, and information generation processes are documented.
- **Uncertainty and variability** is the extent to which uncertainty and variability in procedures, measures, methods, or models are qualitatively and quantitatively evaluated and characterized.
- **Evaluation and peer review** refers to the extent of independent verification, validation, and peer review of procedures, measures, methods, and models.

2.7 Original Purpose of Data vs. Intended Use

It is critical that a risk assessor think about how the results of an exposure assessment will be used in a risk assessment when selecting exposure factors values. The original purpose of the data collected should be evaluated in comparison to the intended use of the data for the exposure assessment. Some data are collected on a national scale, so their applicability to site- or regional-specific assessments needs to be assessed; other data are collected from specific regions and applicability to other regions should be evaluated. Most of the data collected on exposure factors are based on short-term observations, so careful consideration is needed when extrapolating to long-term behaviors.

Recommended values in the *Exposure Factor Handbook* are presented as single-point estimates (e.g., mean, 95th percentile). These numbers come from a larger distribution of data that may be available in the *Exposure Factors Handbook* chapters or from the original sources of the data. Selection of the most appropriate single-point estimate(s) should be done carefully. For example, using upper percentile consumer-only intake estimates to represent intake for the general population might not be appropriate and may result in unreasonably high estimates (U.S. EPA, 2011).

2.8 Per Capita vs. Consumer Only

Some exposure factors (e.g., food intake rates) are provided as per capita and/or consumer-only data. **Consumer-only rates** are intake rates pertaining only to those individuals who reported eating the foods during the surveyed period. **Per capita rates** are defined as rates pertaining to the whole population, and include both individuals who ingested the food during the survey period and individuals who did not. Per capita intake rates should be used in exposure assessments of the general population for which average dose estimates are of interest. Consumer-only intake rates are more pertinent for assessing specific populations (e.g., consumers of self-caught fish, homegrown fruits/vegetables).

For food items that are generally consumed by all, per capita and consumer-only intake estimates will likely be similar. For food items that are consumed more frequently by particular segments of the population, per capita and consumer only estimates could be significantly different because of the high number of consumers who will report not eating a food. (U.S. EPA, 2011)

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