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Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants

Risk Assessment Forum
U.S. Environmental Protection Agency
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FOREWORD

Based on the peer review and public comments, the Risk Assessment Forum technical panel has made a number of changes to the earlier draft of this document, including clarifying the relationship between this report and other exposure assessment guidance/models/tools, improving illustrative diagrams, expanding the citations, and adding language to the preface to discuss scientific, regulatory, and legal constraints associated with the consideration of this guidance. EPA expects to develop case examples to illustrate the use of this guidance; these case studies would then be made available on the Risk Assessment Forum's Web site.

PREFACE

The roots of this guidance reach back to the late 1980s with the advent of planning for an EPA program in the area of residential exposure methods and data development, which was followed by the Risk Assessment Forum's revision of EPA's *Guidelines for Exposure Assessment* in 1992. Soon thereafter, the National Academy of Sciences released its seminal reports, *Science and Judgment in Risk Assessment* and *Pesticides in the Diets of Infants and Children*. Both of these reports contained recommendations on how EPA should improve its approaches to assessing potential risks to children. Since that time, there has been considerable effort across the Agency's program offices and research activities directed at developing risk assessment guidance applicable to children's particular exposures. The purpose of this document is to complement existing EPA guidance and experience to assist Agency risk assessors in improving the accuracy and consistency of children's exposure assessments. The document describes a set of age groupings that can be used, and when necessary adapted, for purposes of designing monitoring studies and conducting risk assessments focused on children.

This guidance was developed by a technical panel under the auspices of the Risk Assessment Forum. The Risk Assessment Forum was established to promote scientific consensus on risk assessment issues and to foster the implementation of this consensus into the Agency's risk assessment practices. To accomplish this, the Forum assembles experts from throughout EPA in a formal process to study and report on issues from an Agency-wide perspective. The document reflects the Forum's long-standing commitment to advancing exposure assessment and to supplement the Agency's *Guidelines for Exposure Assessment*. This activity was initiated by Agency risk assessors, who requested that the Forum study and provide recommendations on a set of early-lifestage age groupings for initial consideration.

As an initial step, the Forum hosted a peer involvement workshop in 2000 to bring together for the first time scientific experts in the areas of child development and exposure assessment to answer the question of how knowledge of behavioral, anatomical, and physiological changes in children can guide the development of a generic set of age groupings. This workshop resulted in a recommended set of early-lifestage age groupings. Following the workshop, the Forum's technical panel commissioned an expert review and reevaluation of the data available for the groupings recommended by the workshop. The data sources gathered in developing the draft *Child-Specific Exposure Factors Handbook* were used for this reevaluation.

The expert review provided a number of recommendations for short-term analyses and longer-term research to improve the current database for childhood exposure. The Exposure Factors Program and individual research grants administered by the National Exposure Research Laboratory have begun to implement the findings of the 2000 workshop and the 2001 expert review to guide future data-gathering and research activities.

Finally, an earlier draft of this document was internally and externally peer reviewed in 2003 and made available for public comment at that time. The generic children's age group recommendations were selected on the basis of the aforementioned reviews and subsequent discussions with Agency risk assessors.

This document recommends a set of age groupings based on current understanding of differences in lifestage behavior and anatomy and physiology that can serve as a starting set for consideration by Agency risk assessors and researchers. In specific situations, it is recognized that exposure factors data may not be available for many of the recommended age groupings or that a specific age group may not need to be the subject of a particular assessment, so flexibility and professional judgment are essential in applying these generic age groupings. In order to use the age groupings appropriately, one should, within the problem formulation step of any assessment, consider the available exposure data and the objectives of the assessment. The process of matching age groups to existing exposure data and combining these with toxicity data can vary according to the circumstances; therefore, this document should be used in combination with other exposure and risk assessment tools and guidance.

There are many efforts underway within the Agency to address developmental issues and to characterize physical variations that occur in different lifestages throughout the life span. There will always be a need to balance the added value of increased resolution against the cost of generating the necessary exposure data. The recommended age groupings can focus future research and data collection efforts so that one can move toward a goal of conducting exposure assessments that address all significant variations in lifestage. Ultimately, as our understanding of the factors determining potential susceptibility as a function of age improves, exposure assessors will be able to make more informed choices about the level of resolution needed to make the best public health decisions.

EPA exposure assessments may be conducted differently than envisioned in this guidance for many reasons, including but not limited to, chemical- or route-specific exposure, hazard or exposure/dose-response information, new scientific information or understanding, or differences

in science policy judgment. The practice of assessing exposure to toxicants continues to develop, and specific components of this guidance may become outdated or may otherwise require modification in individual settings. It is EPA's intent to use, to the extent practicable and consistent with Agency statutes and regulations, the best available science in its risk assessments and regulatory actions, and this guidance is not intended to provide any substantive or procedural obstacle in achieving that goal. Therefore, this guidance has no binding effect on EPA or on any regulated entity. When EPA does use this guidance in developing exposure and risk assessments, it will be because it has decided in the context of that assessment that the approaches from this guidance are suitable and appropriate. This judgment will be tested through peer review, and the exposure/risk assessment will be modified to use different approaches, if appropriate.

This guidance does not establish any substantive "rules" under the Administrative Procedure Act or any other law and has no binding effect on EPA or any regulated entity, but instead represents a nonbinding statement of policy.

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EXECUTIVE SUMMARY

Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants provides a set of early-lifestage age groups for U.S. Environmental Protection Agency (EPA, or the Agency) scientists to consider when assessing children's exposure to environmental contaminants and the resultant potential dose. These recommended age groups are based on current understanding of differences in behavior and physiology that may impact exposures in children. A consistent set of early-life age groups, supported by an underlying scientific rationale, is expected to improve Agency exposure and risk assessments for children by increasing the consistency and comparability of risk assessments across the Agency, improving accuracy and transparency in assessments for those cases where current practice might too broadly combine behaviorally and physiologically disparate age groups, and fostering a consistent approach to future exposure surveys and monitoring efforts to generate improved exposure factors for children.

A current impediment to the creation and use of a consistent set of age groupings is the lack of adequate data to characterize a number of physiological, behavioral, and other relevant parameters across age groups. *It is important to note that the recommended age groups are based on exposure considerations and, as such, are not intended to take into account chemical-specific toxicological variability that can also impact risk;* such considerations, as discussed later, should occur through an iterative dialogue between exposure assessors and toxicologists.

Prior to the release of its revised *Guidelines for Carcinogen Risk Assessment* in 2005, the Agency often described all types of subgroups of individuals as subpopulations. The guidelines recognized that it is helpful to distinguish between subgroups that form a relatively fixed portion of the population (e.g., subgroups based on ethnicity) and subgroups such as age groups that are potentially inclusive of the entire population over time. Accordingly, following the revised cancer guidelines, this guidance views childhood as a sequence of **lifestages** and, therefore, treats age subgroups of children as lifestages, not subpopulations

This guidance is expected to assist the Agency in implementing such regulatory initiatives as Presidential Executive Order 13045 (http://yosemite.epa.gov/ochp/ochpweb.nsf/content/whatwe_executiv.htm), which directs all Federal agencies to (a) make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately

affect children, and (b) ensure that their policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks.

Historically, various programs within EPA have independently developed approaches (including the use of age groupings) to address children's exposure. These approaches were, in part, influenced by a combination of circumstances, including the goals of the enabling legislation, the assessment question at hand, and the availability of data. The Agency risk assessor community, in an effort to foster greater cross-Agency consistency in approaches to children's risk assessment, requested that EPA's Risk Assessment Forum (RAF) study and recommend a set of early-lifestage groupings for initial consideration in children's risk assessments. Primarily on the basis of scientific discussions held during the EPA RAF July 2000 peer involvement workshop and subsequent technical analysis by an RAF work group, the Forum is recommending that the following age groups be considered in Agency exposure assessments for children and used as a guide for future exposure data collection and analysis efforts:

- Less than 12 months old: birth to <1 month, 1 to <3 months, 3 to <6 months, and 6 to <12 months.

- Greater than 12 months old: 1 to <2 years, 2 to <3 years, 3 to <6 years, 6 to <11 years, 11 to <16 years, and 16 to <21 years.

Note that this guidance has adopted the age group notation "X to <Y" (e.g., the age group 3 to <6 years is meant to span a 3-year time interval from a child's 3rd birthday up until the day before his or her 6th birthday). These age groupings and the supporting rationale for their selection have been subjected to internal and external scientific peer review and reflect the comments of the reviewers. Other scientific bodies, such as the International Life Sciences Institute, have also recommended evaluating children's exposure as a series of lifestages.

Due to limits in currently available data on age-specific exposure factors for young children, criteria used to select these age groupings were often qualitative in nature. Narrow age groups were identified where rapid developmental changes occur, and broader age groups were identified as the rate of development decreased. The experts involved in defining these age groupings have also recommended that this guidance be a "living document" and be updated as new data and analyses become available. After the workshop, the RAF work group commissioned an expert review and reevaluation of the data available for the recommended

groupings: the data gathered to support the draft *Child-Specific Exposure Factors Handbook* were used for this reevaluation. This resulted in an issue paper that provided a number of recommendations for short-term analyses and longer-term research to improve the database for childhood exposure.

Because childhood is a time of rapid behavioral and physiological changes, it is important that exposure assessors consider these significant differences when conducting an exposure assessment. There may be instances for a particular chemical and/or exposure scenario where combining some of the recommended age groups (e.g., combining the first three <1 year age groups into one representing birth to <6 months) is indicated; i.e., variation in exposure factors and resulting exposures is insignificant. In addition, there may be instances where it is not necessary to address every age group listed above because exposure is unlikely or the focus of the risk assessment may be a health effect for which only one or two of the above groups represent a critical window. Where there is a lack of exposure data for a particular age group of potential importance, the risk assessor should still consider how exposure for this age group might differ and the possible implications for not explicitly including the age group. In such cases, the uncertainty associated with these assumptions should be discussed with the underlying rationale for splitting, combining, or excluding particular age groups.

A key component of this guidance involves aggregating age-specific differences in exposure across time when assessing long-term exposure, as well as integrating these age-specific exposures with age-specific differences in toxic potency in those cases where information exists to describe such differences: an example is carcinogens that act via a mutagenic mode of action. When assessing chronic risks, rather than assuming a constant level of exposure for 70 years (usually consistent with an adult level of exposure), the Agency has been moving to consider exposure at different lifestages; this guidance is meant to be an aid in this continuing process. An assessor should sum across time-weighted values for all age periods when exposure is likely to occur. This approach is expected to increase the accuracy of risk assessments because it will take into account lifestage differences in exposure. Depending on whether body-weight-adjusted childhood exposures are either smaller or larger as compared with those for adults, calculated risks could either decrease or increase as compared with the approach of assuming a lifetime of a constant level of exposure. If age-related differences in toxicity were also found to occur, differences in both toxicity and exposure would need to be integrated across all relevant age intervals.

The scope of this guidance is limited to recommending a generic set of age groupings. However, it should be emphasized that other factors not discussed in this document can also have a significant impact on exposure and dose, such as special population considerations associated with ethnic and cultural variability (e.g., consideration for higher fish consumption rates among some Native American populations), gender differences, and socioeconomic, geographic, and seasonal effects. When assessing exposure, an assessor should consider the potential impact of these other factors in arriving at a final set of age groupings. For example, the Agency recognizes that maternal behavior patterns, including dietary intake, can affect fetal exposure. However, at the time of this writing, Agency methodologies have not been developed to separately evaluate fetal exposure (SAB, 2004). The Agency will be following scientific advances in understanding the implications of such exposures and is currently developing a risk assessment framework for children (U.S. EPA, 2003a) that will allow for the incorporation of such advances. Future guidance is anticipated.

It is expected that the age groups identified in this guidance will be used as the basis for future updates of EPA's interim final *Child-Specific Exposure Factors Handbook*. Accordingly, this document highlights a number of areas for research that will address filling exposure factors data gaps. These areas of further analysis and research are summarized in the appendix to the main text, and it is expected that this guidance will direct the design of future exposure-monitoring studies. Finally, any future revisions to the Agency's 1992 *Guidelines for Exposure Assessment* will reflect the recommendations of this RAF guidance.

1. INTRODUCTION

The recommendations contained in this document are designed to provide guidance to U.S. Environmental Protection Agency (EPA, or the Agency) scientists on a standard set of age groups to consider when assessing, modeling, or monitoring childhood exposures and potential doses to environmental contaminants. This guidance is intended to complement existing exposure assessment guidance, principles, approaches, and tools. Since 1992, EPA has released other Agency-wide guidance and other tools to aid scientists in the assessment of early-life exposure, including

- Food Quality Protection Act Implementation (U.S. EPA, 1996).
- *Exposure Factors Handbook* (U.S. EPA, 1997a). A summary of the available statistical data on various factors used in assessing human exposure.
- *Guiding Principles for Monte Carlo Analysis* (U.S. EPA, 1997b). A set of principles for applying the various techniques for conducting quantitative analyses of variability and uncertainty associated with exposure assessment.
- *Standard Operating Procedures (SOPs) for Residential Exposure Assessments* (U.S. EPA, 1997c). Procedures designed for those who assess exposure to pesticides in a residential setting.
- *Child-Specific Exposure Factors Handbook* (Interim Report) (U.S. EPA, 2002). A summary of the available and up-to-date statistical data on various factors assessing children exposures.
- "Consolidated Human Activity Database" (CHAD) (http://www.epa.gov/chadnet1/). Contains data obtained from pre-existing human activity studies that were collected at city, state, and national levels. CHAD is intended to be an input file for exposure/intake dose modeling and/or statistical analysis. It is a master database providing access to other human activity databases using a consistent format.
- "Stochastic Human Exposure and Dose Simulation" (SHEDS) (http://www.epa.gov/heasd/emrb/emrb.htm). A modeling system being developed for analyzing multimedia multipathway exposures of both the general and sensitive groups or populations, such as children and the elderly.

In 1993, the National Academy of Sciences (NAS) released *Pesticides in the Diets of Infants and Children* (NAS, 1993), which highlighted important differences between children and adults with respect to risks posed by pesticides. Some of the principles in the NAS report

provided the foundation for the Food Quality Protection Act of 1996 (FQPA) and Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risk." One of the provisions of the FQPA requires that children's aggregate exposure be considered when establishing pesticide tolerances (legal limits for residues in food). Executive Order 13045 also broadened consideration of impacts on children by stating that "each Federal agency: shall ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks" (Clinton, 1997). In response to these regulatory initiatives, EPA has been investigating ways to improve Agency risk assessments for children.

An EPA workgroup, convened under the auspices of the Risk Assessment Forum (RAF), concluded that a major issue facing the Agency is how to consistently consider age-related changes in behavior and physiology when assessing early-lifestage exposure and potential dose. This issue is critical for scientists involved in preparing exposure assessments applicable to children and for use in evaluating lifestage-integrated lifetime exposures. Therefore, the RAF convened a technical peer involvement workshop in July 2000 to consider developmental changes when assessing exposures in children and commissioned a subsequent expert analysis of existing exposure factors data (U.S. EPA, 2000).

The RAF work group that developed the recommended age groupings also recognized that human development is best treated as a continuum—physiologically, anatomically, behaviorally, and for other parameters. However, there are identifiable periods of development that occur in successive stages in each individual. Because of the inherent differences between each lifestage, it is important to characterize exposure as a function of lifestage and to develop methods to assess the factors contributing to these exposures. This document addresses the changes prior to adulthood; future documents may deal with characteristics particular to other lifestages, such as maternity and senescence.

Early-lifestage exposures to environmental contaminants are often different from those in later stages of life for a number of reasons. For example:

- Early-lifestage behaviors may contribute to higher exposures. Physically, children are closer to the ground than are adults and therefore live in a dustier, more contaminated environment. Young children spend time playing on the ground outside or on the floor indoors. Generally, children often spend more time outdoors than do adults. Infants and toddlers engage in mouthing behaviors that can increase exposure to environmental contaminants. Young children are known to inadvertently and/or

intentionally ingest significant amounts of the soil that adheres to their hands. Children of all ages engage in risky behaviors that may increase exposure to environmental agents.

- Physiologically, children's metabolic rates and activity levels tend to be greater than those of adults. Accordingly, children consume more water and food per unit of body weight than do adults. Additionally, during their first few years, children consume larger amounts of a narrower range of specific foods than do adults. Also consistent with their higher metabolic rates, children have higher respiratory rates on a per-body-weight basis. The greater metabolic rates of children as compared with those of adults may lead to greater doses of those chemicals that are created by metabolic processes.

- The skin of infants (particularly newborns) is more permeable to many environmental chemicals than is the skin of older children and adults. Children may have more cuts, scrapes, and rashes that would compromise this barrier. Similarly, the blood-brain barrier is less well developed in infants. Some studies indicate that lead may be absorbed more efficiently from the gastrointestinal tract in very young children than in adults, although there are many factors affecting this (e.g., iron and calcium status).

- Additionally, infants and adults exhibit differences in their metabolism and excretion of absorbed environmental contaminants, leading to potential differences in biologically effective dose. Metabolic pathways are generally less developed in infants as compared with those in adults. Depending on the specific substances involved, impaired metabolism may either increase or decrease the toxicity of environmental agents. The liver and kidneys of infants (younger than 1 year) also are less effective at removing certain environmental toxicants from the bloodstream than those of adults.

Prior to the release of its revised cancer guidelines (U.S. EPA, 2005a), the Agency often described all types of subgroups of individuals as "subpopulations." The revised guidelines recognized that it is helpful to distinguish between subgroups that form a relatively fixed portion of the population (e.g., subgroups based on ethnicity) and subgroups such as age groups that are potentially inclusive of the entire population over time. Accordingly, following the revised cancer guidelines, this guidance views childhood as a sequence of **lifestages,** and as such, treats age subgroups of children as lifestages, not subpopulations.

This guidance defines "lifestage" as a distinguishable time frame in an individual's life characterized by unique and relatively stable behavioral and/or physiological characteristics that are associated with development and growth. Note that although the upper and lower bounds of lifestages may be both variable and uncertain, the age groups recommended in this guidance were chosen to represent typical lifestages relevant to environmental contaminant exposure.

This emphasis on childhood as a sequence of lifestages has evolved from the earlier view of children as a subpopulation. For example, when EPA released its *Guidelines for Exposure Assessment* (U.S. EPA, 1992), lifestages were considered to be covered by the term "subgroup" and/or "subpopulation." The 1992 guidance described the general concepts of exposure assessment, including definitions and associated units, the planning and conduct of an exposure assessment, and recommendations on presenting the results of the exposure assessment and characterizing uncertainty. The focus of the guidance was on exposures in humans. According to Section 5.3.5.2 of the guidelines.

> It is often helpful for the risk assessor to describe risk by an identification, and if possible, characterization and quantification of the magnitude of the risk for specific **highly exposed** subgroups within the population. This descriptor is useful when there is (or is expected to be) a subgroup experiencing significantly different exposures or doses from that of the larger population. It is also helpful to describe risk by an identification, and if possible, characterization and quantification of the magnitude of risk for specific **highly sensitive or highly susceptible** subgroups within the population. This descriptor is useful when the sensitivity or susceptibility to the effect for specific subgroups within the population is (or is expected to be) significantly different from that of the larger population. In order to calculate risk for these subgroups, it will sometimes be necessary to use a different dose-response relationship.… A special case of a subpopulation is that of **children**.

Typically, Agency assessors have classified individuals under the age of 21 years as youth or children. However, a system for subdividing this group in a consistent and scientifically supported manner has been somewhat elusive. Other scientific bodies, such as the International Life Sciences Institute, have also recommended evaluating children's exposure as a series of lifestages. Historically, Agency scientists have applied expert judgment to create age groups used for exposure scenario building and/or model "binning" of exposure factors that capture periods of potentially high exposure or unusual exposure patterns (e.g., the frequency and duration of mouthing hands and objects during early childhood). In some cases, expert judgment has been applied to capture vulnerable periods of development or critical windows when exposure to an environmental contaminant may be particularly damaging to a specific physiologic system (e.g., the effects of lead on hemoglobin due to age-related differences in iron deficiency). In many cases, the selection of age groups has been heavily influenced by the quality and quantity of existing data to support the development of exposure and potential dose estimates.

The case-by-case consideration of vulnerable periods and/or the availability of exposure data has led to variations in the specific age groups considered by different Program Offices for assessing childhood exposure. By defining a set of recommended age groups for consideration in assessing exposure, the Agency will be better able in the future to develop exposure factors data organized around these defined age groups. It is recognized, however, that there may still be cases where exposure and/or toxicity data are not available for the age groups recommended in this guidance or where such data do not indicate use of the age groups defined here. In such cases, extrapolation of data, combining or splitting age groups, use of other age groups, or other strategies may be appropriate when assessing exposure and risk. In such cases, the uncertainties associated with the method employed should be documented in the assessment. A few examples of various ways in which Agency programs have used available data sets in the past to address children's exposure are shown in Table 1.

Table 1. Examples of Early-Life Age Groups Used in Past Agency Exposure Assessments

EPA Programs	Reference	Child Age Groups
Office of Prevention, Pesticides, and Toxic Substances, Office of Pesticide Programs	Draft Standard Operating Procedure (SOPs) for Residential Exposure Assessment	Dermal and Non-dietary Oral: Toddlers: 3 to 5 years Inhalation: (NAFTA*) 1 to 6 years
	Dietary exposure assessment models	Oral: Infants: 0 to 1 years Children: 1 to 2, 3 to 5; 6 to 12; 13 to 19 years Females: 13 to 50 years
Office of Solid Waste and Emergency Response	Risk Assessment Guidance for Superfund (RAGS) Parts E, A	Dermal and Soil Ingestion: 0 to 6 years
Office of Water	Drinking Water Program: -Water Intake	0 < 1 year
	Water Quality Criteria Program: -Water Intake -Fish Consumption	0 < 10 year 15 to 44 years (women) 0 to 14 years 15 to 44 years (women)
Office of Air & Radiation, Office of Air Quality Planning and Standards	NATA* National Scale Assessment (1996 emissions year).	0-4, 5-11, 12-17, 18-64 years
	NAAQS* 1996 Ozone Risk Assessment for Children	6-13, 14-18 years

Note: The examples of program-specific age groupings for risk assessment are selected for illustrative purposes and may vary with specific cases and media and route of exposure. Available data for specific exposure influence age group selection.
*NAFTA = North American Free Trade Agreement.
*NATA = National Air Toxics Assessment
*NAAQS = National Ambient Air Quality Standards.

2. AGE GROUPS TO CONSIDER WHEN ASSESSING CHILDHOOD EXPOSURES TO ENVIRONMENTAL CONTAMINANTS

As noted in the introduction, in the early lifestages behavior changes over time in ways that can have an important impact on exposure and potential dose. Rather than assuming an adult level of exposure for 70 years for chronic/lifetime risk assessments, incorporation of time-weighted values for all age periods where exposure is likely to occur is expected to increase the accuracy of risk assessments because it will take into account lifestage differences in exposure. Depending on whether body weight-adjusted childhood exposures are either smaller or larger as compared with those for adults, predicted risks could either decrease or increase as compared with assuming a lifetime of adult-level exposure. If age-related differences in toxicity were also found to occur (see U.S. EPA, 2005b), both differences in toxicity and exposure would need to be integrated for each relevant age interval. For example, crawling and mouthing of hands and objects during the 1- to <2-year period can potentially lead to dermal and oral potential doses that are appreciably higher than those of adults in the same physical location, particularly indoors. Further, physiology changes over time in ways that can affect potential dose, internal dose, and susceptibility to certain health effects. The key issue is how to capture these changes in an assessment of risks from exposure to environmental contaminants.

In July 2000, EPA held a workshop to examine developmental factors and how they influence the assessment of childhood exposure. Workshop participants included experts in the fields of pediatric medicine, toxicology, risk assessment, and public health. A summary of the workshop discussions is provided in U.S. EPA (2000). The discussions revealed that workshop participants preferred assessment approaches that could incorporate childhood development as a continuous function. However, although recognizing the paucity of existing data, the participants concluded that age groupings (or bins) can be useful as guides for the development of environmental exposure scenarios. To that end, they offered some preliminary advice on possible age groups related to developmental change. Due to limits in currently available data on age-specific exposure factors for early lifestages, criteria used to select these age bins were often qualitative in nature. Narrow age groups were identified where rapid developmental changes occur, whereas more broad age groups were identified as the rate of development decreased. Prenatal development was outside the scope of the workshop discussions, but participants unanimously stressed the importance of including this lifestage in future exposure and risk assessment guidance.

Accurately simulating chemical exposures of an individual continuously over a lifetime would require detailed information regarding how a person's behavior and physiology varies each day as one ages. One way exposure assessors can simplify exposure assessments is to classify individuals into age bins within which behavioral and/or physiological characteristics are likely to remain relatively stable. This allows for the execution of an exposure assessment model with sufficient resolution (i.e., number of age bins) to address all significant variations in lifestage exposure. This level of resolution may vary with the particular compound of interest and/or with the particular exposure scenario. The goal of this guidance is to recommend a starting point based on our current understanding of differences in lifestage behavior and physiology that may impact exposures. As our knowledge base and database develop, exposure assessors will be able to make more informed choices about the resolution needed to make the best public health decisions. In addition, because there is a need to balance the added value of increased resolution against the cost of generating the necessary exposure factor data, the age bins recommended here are designed to focus future research and data collection so that one can move toward a goal of conducting exposure assessments that address all significant variations in lifestage.

To organize the workshop discussion, participants were divided into two subgroups according to their specific areas of expertise. One subgroup discussed behavioral development and the other focused on physiology and anatomical growth. Participants were asked to focus their discussion on those aspects of development that are particularly relevant to exposure and potential dose. These terms are defined in the EPA's *Guidelines for Exposure Assessment* (U.S. EPA, 1992) as

> Exposure - Contact of a chemical, physical, or biological agent with the outer boundary of an organism. Exposure is quantified as the concentration of the agent in the medium [e.g., soil, water, air, food, etc.] in contact [with the organism], integrated over the time duration of that contact.
>
> Potential Dose - The amount of chemical ingested, inhaled, or in material applied to the skin.
>
> Internal Dose - The amount of chemical contained that has been absorbed and is available for interaction with biologically significant receptors.

Some workshop participants found that the concepts of potential dose, internal dose, and effects are too interrelated to narrow the focus of the discussion to potential dose alone. The relationship between the 1992 guidelines' definition of exposure and the related risk assessment concepts of dose and effects is portrayed in Figure 1. Figure 1 also lists some examples of characteristics that impact or otherwise provide an indication of exposure, dose, and possible susceptibility to effects. These example characteristics were discussed during the workshop.

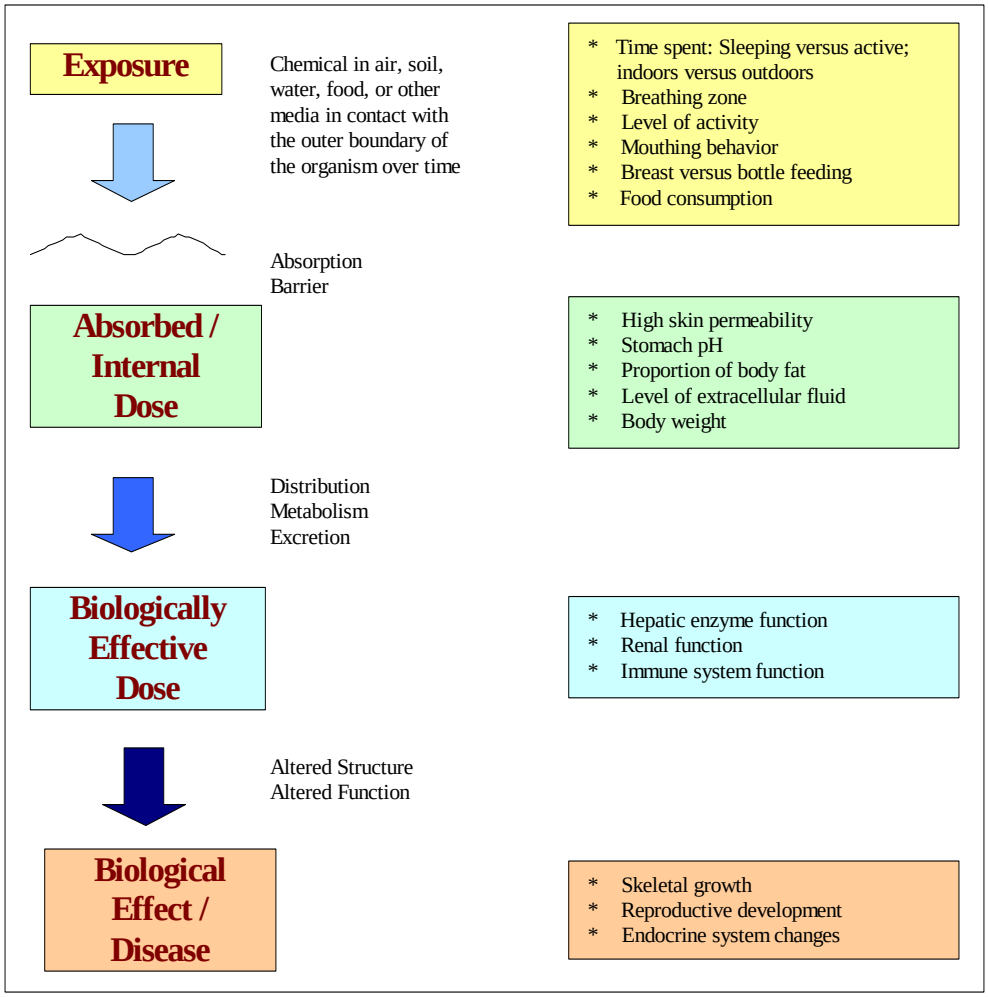

Figure 1. Relationship Between Exposure, Dose, and Effects in Risk Assessment.

The workshop subgroup addressing behavioral development recommended dividing the first year of life into three groups: 0 to <3 months, 3 to <6 months, and 6 to <12 months. After the first year of life, it recommended the following groups: 12 to <24 months, 2 to <6 years, 6 to

<11 years, 11 to <16 years, and 16 to <21 years. The participants in this subgroup arrived at these groupings by considering key factors or "major domains of behavioral development" for each route of exposure (U.S. EPA, 2000). For oral and dermal exposures, these factors included gross motor development, fine motor development, cognitive development, and social development. For inhalation exposures, the relevant factors included gross motor development, activity level, and breathing behavior (e.g., the transition from mouth to nasal breathing). Table 2 contains some examples of the specific considerations supporting the age groups derived by the behavior subgroup.

Table 2. Examples of Factors Considered in Deriving Age Groups Reflecting Behavioral Development

Age Group	Characteristics Relevant to Oral and Dermal Exposure	Characteristics Relevant to Inhalation exposure
Birth to <3 months	Breast and bottle feeding. Hand-to-mouth activities.	Time spent sleeping/sedentary.
3 to <6 months	Solid food may be introduced. Contact with surfaces increases. Object/hand-to-mouth activities increase.	Breathing zone close to the floor.
6 to <12 months	Food consumption expands. Children's floor mobility increases (surface contact). Children are increasingly likely to mouth nonfood items.	Development of personal dust clouds.
12 to <24 months	Children consume full range of foods. They participate in increased play activities, are extremely curious, and exercise poor judgment. Breast and bottle feeding cease.	Children walk upright, run, and climb. They occupy a wider variety of breathing zones and engage in more vigorous activities.
2 to <6 years	Children begin wearing adult-style clothing. Hand-to-mouth activities begin to moderate.	Occupancy of outdoor spaces increases.
6 to <11 years	There is decreased oral contact with hands and objects as well as decreased dermal contact with surfaces.	Children spend time in school environments and begin playing sports.
11 to <16 years	Smoking may begin. There is an increased rate of food consumption.	Increased independence (more time out of home). Workplace exposure can begin.
16 to <21 years	High rate of food consumption begins.	Independent driving begins. Expanded work opportunities.

The subgroup addressing anatomy/physiological development recommended the following groupings: birth to <1 month, 1 to <3 months, 3 to <6 months, 6 to <12 months, 1 to <3 years, 3 to <8 (female) or <9 (male) years, and 8 or 9 years to <16 (female) or <18 (male) years. The discussion that led to these age groups focused on anatomical characteristics (e.g., weight and proportion of body fat) and specific organ and physiological systems. These systems included skin, skeleton, liver, immune system, reproductive system, endocrine system, lung and respiratory tract, gastrointestinal tract, circulatory system, renal system, cardiac system, central nervous system, muscle, and sensory organs. Table 3 contains some examples of the specific considerations supporting the age groups derived by the anatomy/physiology subgroup. The age groups listed in Table 3 were derived largely from considering the rate of change in the listed characteristics.

Table 3. Examples of Factors Considered in Deriving Age Groups Reflecting Anatomical/Physiological Development

Age Group	Anatomy/Physiology Characteristics
Birth to <1 month	Rapid growth and weight gain. Proportion of body fat increases. Increased skin permeability. Deficiencies in hepatic enzyme activity. Immature immune system functions. High oxygen requirements (leading to higher inhalation rates). Stomach more alkaline. Increases in extracellular fluid. Renal function less than predicted by surface area.
1 to <3 months	Rapid growth and weight gain. Proportion of body fat increases. Deficiencies in hepatic enzyme activity. Immature immune system functions. High oxygen requirements (leading to higher inhalation rates). Stomach more alkaline. Increases in extracellular fluid. Renal function less than predicted by surface area.
3 to <6 months	Rapid growth and weight gain. Proportion of body fat increases. Deficiencies in hepatic enzyme activity. Immature immune system functions. Increases in extracellular fluid. Renal function less than predicted by surface area.
6 to <12 months	Rapid growth and weight gain. Body fat increase begins to level off. Deficiencies in hepatic enzyme activity. Immature immune system functions. Rapid decrease in extracellular fluid. Can begin predicting renal function by surface area.
1 to <3 years	Some hepatic enzyme activities peaks, then falls back to adult range. Most immune system functions have matured. Extracellular fluid becomes more consistently related to body size.
3 to <8/9 years	Period of relatively stable weight gain and skeletal growth (as opposed to a period marked by growth spurts).
8/9 to <16/18 years	Rapid skeletal growth. Epiphyseal closure (may take until age 20). Rapid reproductive and endocrine system changes, inclusive of puberty.

Note: Many of the characteristics listed in this table are repeated across age groups (especially for ages up to <12 months; e.g., rapid growth and weight gain). In determining the range of ages to include in a particular age group, the rate of change in these characteristics was often a key factor discussed at the workshop.

Early in the discussion of the anatomy/physiology subgroup, the participants concluded that developmental issues affecting exposure, potential dose, internal dose, and effects were too intertwined to allow an exclusive focus on potential dose. Therefore, its preliminary advice on possible age groups reflects some consideration of changes that impact internal dose and effects. For example, this subgroup discussed the maturity of hepatic enzyme activities (an indication of metabolic function affecting internal dose) and the rate of reproductive development (an indication of a susceptible period for effects) in developing its advice on age groups. Additional examples are noted in Table 3. Although this subgroup's recommendations do reflect some consideration of dose and effects issues, it should not be considered a comprehensive treatment of this subject. The Agency is considering childhood development and its relationship to dose and effects through other efforts.

The recommended age groups were proposed as a synthesis of the workshop recommendations from both the behavioral and anatomical/physiological factors subgroups. As a result of continuing deliberations and reviews of available exposure factors data, the RAF work group concluded that it may be necessary to further divide the 1 to <3 years age group. The data available suggested a division of 1 to <2 years and 2 to <3 years as separate groups. This grouping is supported (in part) by the behavioral subgroup discussions from workshop. In addition, it is supported by existing exposure factors information (e.g., the data for mouthing duration and frequency). The division of 3 to <6 years was deemed significant on the basis of behavioral changes occurring at or around 6 years that affect nondietary (i.e., hand to mouth) intake and exposures due to changes in activity (e.g., initiation of school). The 6 to <11 years group captures the relatively stable growth period after early childhood and preceding adolescence (the latter inducing significant behavioral, anatomical, and physiological changes). The work group further concluded that, in some cases, an additional age group spanning 18 to <21 years could be considered. It is unclear whether this age group should be considered part of the childhood lifestage or part of early adulthood. It is clear that it encompasses a period of continuing development and may capture important events such as a change in residence and epiphyseal closure.

Clearly factors other than age/developmental stage can have an impact on exposure, including sex, geographical location, family size, ethnic/cultural differences, seasonal variations, and socioeconomic status. Although these factors could be evaluated by exposure assessors, this

document defers to existing Agency guidance (e.g., U.S. EPA, 1992) and tools (e.g., U.S. EPA, 2002) for their consideration.

As discussed in EPA's *A Framework for Cumulative Risk Assessment* (U.S. EPA, 2003a), vulnerability to health effects resulting from exposures to environmental pollutants can vary on the basis of susceptibility, differential exposure, differential preparedness, and differential ability to recover. In conducting the hazard assessment portion of a risk assessment, the assessor should consider windows of vulnerability based on susceptibility to toxic effects resulting from specific exposures (dose-response). In developing the exposure assessment, the assessor should consider windows of vulnerability based on behaviors (crawling, mouthing), activities (locations, product use, diet), physiological characteristics (oxygen requirements, caloric requirements), and so on that may lead to particularly high levels of exposure. The analyses are combined to identify the lifestages that are at greatest risk on the basis of exposures and resulting effects.

It is also important to note that exposure factors and resulting developmental stages may be a function of additional individual and population characteristics. These factors may be characteristics of the communities in which children live and are raised and include, as noted above, socioeconomic status, ethnicity, cultural setting, and geographical considerations. Factors may also be characteristics of the individual, including genetic susceptibility, nutritional status, and health status. Vulnerabilities associated with individual and community characteristics will manifest as differences in susceptibility, differential exposure, differential preparedness, and differential ability to recover. The focus of this guidance is specific to addressing vulnerability associated with differential exposure due to life stage. Just as it is impossible to completely separate considerations of exposure and potential dose from consideration of internal dosimetry and response, so it is impossible to completely separate consideration of vulnerability due to lifestage from consideration of vulnerability due to the many other significant individual and community characteristics.

The Agency is addressing the full range of issues associated with characterizing risks to children through a variety of initiatives, including development of a framework for children's risk assessment and development of guidance for conducting cumulative risk assessment (U.S. EPA, 2003a). As the Agency works to address cumulative risk assessment, the full range of vulnerabilities will be considered more consistently in both exposure assessment and hazard assessment, but these are not specifically addressed in this guidance. In like manner, the Agency

may be able to address fetal exposure and developmental effects at a future date and include that lifestage in exposure assessment guidance.

The focus of this guidance is to recommend age bins that address vulnerability resulting from differential exposure. Because the focus here is on exposure or potential dose, pharmacokinetic considerations (i.e., absorption, distribution, metabolism, and elimination) were not explicitly considered unless they had direct impacts on potential dose (e.g., absorption at the portal of entry). However, it is impossible to completely separate consideration of exposure and potential dose from consideration of internal dosimetry and response. This difficulty was discussed during the workshop and is reflected in the resulting recommended age bins and in this document.

On the basis of the 2000 workshop discussions as well as subsequent deliberations and reviews of available exposure factors data, the RAF work group developed the recommendations contained in Table 4. These age groups should be considered initially when assessing childhood exposures to environmental contaminants.

Table 4. Recommended Set of Childhood Age Groups for Agency Exposure Assessments

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 months	6 to <11 years
	11 to <16 years
	16 to <21 years

The age groups covering the first year of life are broken out because behavioral and physiological changes are occurring so rapidly during this period. During this time frame, exposure may occur first through consumption of human (breast) milk or baby formula and, later, baby foods. Movement is very limited at birth, but crawling occurs during this period and first steps may also take place. Hand/object-to-mouth activities begin and then increase rapidly with increasing age. Major developmental changes in metabolic pathways occur during the first several months surrounding birth. Premature delivery can have a major physiological and metabolic impact. Exposure to environmental chemicals during the first months is generally limited.

There may be instances for specific exposure scenarios and compounds where combining some of these age groups (e.g., combining the first three <1 year age groups into one representing birth to <6 months) is indicated; i.e., variation in exposure factors and resulting exposures is insignificant. In addition, there may be instances where it is not necessary to address every age group listed above because, for example, the focus of the exposure and risk assessment may be on a health effect for which only one or two of the above groups represents a critical window. Where there is a lack of exposure data for a particular age group of potential importance, the risk assessor should consider how this age group might differ and the possible implications for not explicitly including the age group. It is recommended that if age groups are split, combined, or excluded, the underlying rationale should be provided in the exposure assessment, along with an analysis of the uncertainty associated with these assumptions.

Given sufficient data, a scientifically based approach for selecting age groups other than the ones recommended in this guidance would be to determine for which age groups there exist significant statistical differences in parameter values. An example of one such analysis is presented in Tulve et al. (2002). In this analysis, the authors use a tree analysis to identify significant age differences in mouthing behavior. The model uses a recursive partitioning algorithm that successively splits the data into homogeneous subgroups. Using this approach, the authors identified two main age groups for the data that were evaluated: less than or equal to 24 months, and greater than 24 months.

It is acknowledged here that a lack of data may be a critical impediment in conducting assessments for each of these age bins and for making decisions regarding combining or eliminating age groups. In these cases, an analysis of the available data should be conducted first, and consideration given to the distribution of the data points among the recommended age groups. The age groups can be used unless the quantitative analysis of the data shows they do not fit within one age group. Alternatively, qualitative information may lead the assessor to identify potentially significant differences within a recommended age bin. A possible approach for estimating exposure factors and potential dose when data are not available for a particular age bin includes the use of age-dependent curve fitting to help fill in the data gaps (see Phillips, 1993). Any assumptions used in assessing exposure for a particular age bin can be discussed in the assessment.

As noted above, it is recommended that if age groups are split, combined, or excluded, the underlying scientific rationale be provided in the exposure assessment. It is important for

exposure assessors to engage in an iterative dialogue with toxicologists and other health scientists to determine the age groups (or portions of age groups) that will be the focus of any particular assessment. Further, it is recommended that an assessment includes splitting, combining, and/or eliminating age groups, the exposure assessor consider the following:

- *The basis (exposure and/or toxicological or risk) for determining which age groups should be split, combined, and/or dropped from the analysis and why.* If the basis is exposure/dose considerations, what are the key factors driving the decision (behavioral and/or physiological)? If the basis is toxicological, is there a key window of susceptibility considered? If the basis is minimal risk, describe how the exposure and toxicity considerations together lead to this conclusion.

- *The criteria used to select particular age groups for assessment.* These criteria may be quantitative or qualitative, depending on the quantity and quality of available data. As described more fully in the next section on implementation, it is of paramount importance to characterize the data, how best to combine or extrapolate, and how such manipulation may change the distribution (i.e., under- or overestimate or mask outliers). An example of a quantitative criterion is when data are statistically combined across the individual ages within the proposed age category, variability could be expressed as a coefficient of variation that is no greater than XX% for the key behavioral, physiological, or anatomical parameters that govern exposure or potential dose (see, e.g., Tulve et al., 2002). An example of a qualitative criterion is when the age range will not contain stages of development that are clearly distinct from one another in terms of behavior, food consumption patterns, or maturation of physiological systems.

- *The scientific uncertainties and potential biases introduced when combining or excluding age groups.* There is no simple answer for the question "How different do two age ranges need to be before they are considered as independent age groups for exposure assessment?" A difference may or may not be extremely important, given the resulting risk estimate. This aspect could be described in either qualitative (e.g., over- versus underestimate of exposure) or quantitative terms. Examples of questions could include: Is an age group described as less than 1 year more representative of 6 to <12 months of age than younger age groups? How different are exposures for age groups that might be combined? If data for one age group are used as a surrogate for another, is this likely to increase/decrease estimates of exposure? To what extent do distributions within one age group overlap with that of another?

- *The types of data and information that, if available, would allow an analysis of whether it would be scientifically justified to combine or separate any of the recommended age groups in future exposure assessments.* Such data could include biomonitoring data (e.g., National Health and Nutrition Examination Survey), environmental monitoring data, and/or exposure factors data (such as those available in U.S. EPA, 2002). These discussions will help guide future data collection efforts to improve future exposure and risk assessments.

3. APPLYING THE RECOMMENDED SET OF CHILDHOOD AGE GROUPS TO EXPOSURE ASSESSMENT

This guidance provides a recommended set of early-life age groups for consideration in Agency exposure and risk assessments and when conducting exposure-monitoring studies. The purpose in providing this guidance is to foster greater consistency based on a sound scientific footing for program-specific assessments and research initiatives for children. To further aid the assessor, some additional issues associated with applying this guidance are discussed in this section (i.e., issues associated with application of age groupings to estimate exposure and specify exposure scenarios). In addition, case studies are planned that will illustrate how the guidance document can be applied in practice. These case studies will be posted on the Risk Assessment Forum Web page (http://epa.gov/ncea/raf).

When defining the assessment plan or model, the exposure assessor, in consultation with the toxicologist, should consider how the pathways and route of exposure, critical toxicological windows of susceptibility, and possible health outcomes fit into a risk assessment model. The scope of analysis will depend in part on whether all lifestages need to be examined or whether exposure concerns are found to be limited to certain critical periods.

3.1. CONDUCTING SCREENING-LEVEL EXPOSURE ASSESSMENTS

According to EPA's *Guidelines for Exposure Assessment* (U.S. EPA,1992), the purpose of a screening-level assessment is typically to identify pathways of greatest concern and to provide a high-end and/or "bounding level" exposure estimate to determine whether there are potential risks of concern that might require a more refined analysis. To generate such estimates, the guidelines suggest setting one or more sensitive variables at the bounding level. For example, a screening assessment might be based on specific childhood lifestages where elevated exposures and/or greater susceptibility to the stressor of interest are anticipated.

In practice, Agency programs often conduct screening-level assessments that use default assumptions that are selected to overestimate risks. If the screening-level exposures to either a particular toxic agent or combination of agents are sufficiently below regulatory exposure levels for toxicity, a full risk assessment is generally not warranted. Such screening assessments can allow more timely decisions and save resources for other actions. In many such assessments, a single estimate that usually assumes a combination of activity patterns and/or lifestages that are

likely to produce among the highest exposure levels is used. As long as the exposure estimates are designed to estimate higher-than-expected exposures and are well below regulatory levels, no specific bin for a lifestage (including children) need be considered in such an assessment.

3.2. INTEGRATING EXPOSURE ACROSS MULTIPLE AGE GROUPS

A key component of this guidance is to promote the integration of age-specific differences in exposure (and where applicable, toxicity) when assessing long-term exposure. When assessing chronic risks, an assessor should sum the exposures for all age periods when exposure is likely to occur. This approach is expected to increase the accuracy of risk assessments because it will take into account lifestage differences in exposure. Adjustments for variations in toxicity (potency) may also need to be made for different age groups, if such data are available for the contaminant of concern. Other guidance, specific for pharmacodynamic and pharmacokinetic differences in the ages during which the exposure occurs, should be consulted. Depending on whether body weight-adjusted childhood exposures are either smaller or larger as compared with those for adults, predicted risks could either decrease or increase as compared with a risk assessment assuming a lifetime of adult-level exposure.

If age-related differences in toxicity were also found to occur, differences in both toxicity and exposure would need to be integrated for each relevant age interval. The complexity of this integration will depend to a large degree on the overlap of exposure-specific and toxicity-specific age groups. For example, assume that potency (toxicity) was found to vary among the following age groups: 0 <2 years, 2 <16 years, and 16 years and older. Table 5 illustrates how to consider both exposure- and toxicity-relevant age groups. The exposure age groups are listed in the first column, and the toxicity age groups are indicated by the three shaded bands. When assessing chronic risk, time-weighted risk (a function of exposure and toxicity divided by the exposure duration) for each resulting age group would be calculated and then combined over the relevant time frame. Note that this example represents a relatively simple case where the toxicity-based age groups overlap cleanly with the exposure-based age groups.

Table 5. Integrating This Age Grouping Guidance with the Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens That Act via a Mutagenic Mode of Action

Exposure Age Groupings	Exposure Duration (yr)	Potency Adjustment
Birth to <1 month	0.083	10×
1 to <3 months	0.167	10×
3 to <6 months	0.25	10×
6 to <12 months	0.5	10×
1 to <2 years	1	10×
2 to <3 years	1	3×
3 to <6 years	3	3×
6 to <11 years	5	3×
11 to <16 years	5	3×
16 to <21 years	5	1×
>21 years (21 <70)	49	1×

If exposure occurs only for a limited number of years (e.g., consider a family that lives near a source of exposure for a 5-year period of time before moving away), it is critical to combine lifestage differences in exposure and dose-response for the relevant time interval. Example calculations are provided in U.S. EPA (2005b).

3.3. ADDITIONAL CONSIDERATIONS WHEN USING HUMAN EXPOSURE MODELS AND ALGORITHMS IN RISK ASSESSMENTS

A variety of modeling tools have been developed over the years to facilitate exposure and dose assessment as part of risk assessments. Some assessors use route-specific equations to compute average daily dose (ADD) or lifetime average daily dose (LADD), such as those in EPA's *Exposure Factors Handbook* (U.S. EPA, 1997a), with either deterministic or probabilistic inputs. Others use probabilistic time-series-based exposure models, such as the aggregate and cumulative models developed in recent years to address the FQPA (e.g., Calendex, CARES, Lifeline, SHEDS). These models simulate individuals on the basis of human activity information in databases such as those of the U.S. Census, the U.S. Department of Agriculture's Continuing Survey of Food Intake by Individuals (CSFII), EPA's Consolidated Human Activity Database (CHAD), or the National Human Activity Pattern Survey (NHAPS).

There are a few probabilistic models for characterizing aggregate exposure and cumulative risk, and several are under development. As these models continue to evolve, they could be adapted to incorporate the new age groupings into modules for sampling individuals for a simulated population and for sampling values of exposure factors to be inserted into exposure-route-specific equations. Evaluation of these age group-specific model estimates with biomonitoring data would also be helpful. In the meantime, it is critical that the exposure assessor understand the assumptions, structure, and function of the specific model version being used to conduct an assessment. Such an understanding will allow the model outputs to be interpreted in light of the recommended age groups described in this document and will allow for a more complete characterization of uncertainties associated with the model parameters used, as well as with model structure.

With respect to applying the recommended age groupings to exposure factors used by human exposure models, it is important to understand how data are binned for each model input. Model documentation should clearly present how specific data are binned and what criteria were used to develop these bins. The goal of this guidance is to provide an initial set of age groups for conducting exposure assessments and associated modeling based on our current understanding of differences in lifestage behavior and physiology that may affect exposures. However, as discussed above, this guidance recognizes that the level of model resolution (i.e., number of age bins) needed may vary with the particular compound of interest and/or with the particular exposure scenario. Therefore, there may be instances where combining some of these age groups may be considered when estimating exposure or potential dose, especially if little variation in exposure might be expected. Alternative bins may also be required for a specific model application or population of interest. If so, the scientific basis for the alternative age bins should be explicitly presented. In such cases, it is expected that binning may be different from one exposure factor to the next (i.e., criteria for binning the dietary data will be different from criteria for other, nondietary activity profiles).

Data-specific bins used in the models should follow the following principles: (1) bins should express representative and relevant metrics for the range of individuals grouped with each bin, and (2) the selected bins should not mask any truly unique profile within the bin (i.e., do not hide a significant peak). If this data-binning process is done well for each database, then the values sampled from each database should be representative for each age group. The criteria

chosen for such binning should be clearly articulated by the model developers, and the criteria rejected should be discussed also. Selection of criteria should be transparent and relevant.

In addition, data limitations and the associated uncertainties need to be discussed. For example, were the data adequate to sufficiently investigate and identify significant differences across age groups? Available data sets may not allow the modelers or the risk assessors to extract the data directly from the underlying sources to conduct the desired age group-specific analysis. Potential approaches for addressing this issue include (1) reorganizing the input dataset to conform with the age groupings needed, (2) using probabilistic sampling techniques to go beyond the categorical limits of the underlying database to use all the data and then format the probabilistic model output into the desired age groupings to represent exposure doses, or (3) developing a weighting scheme for the underlying data set to make it more aligned with the desired age groupings. For example if 10% of the observations for the 6- to 11-year-old group come from 6- and 7-year-olds and 90% come from 10- to 11-year-olds, the data need to be statistically weighted so that equal weight is given to all ages within the group when estimating the group mean and variability statistics.

It is expected that, as this guidance is applied to conduct exposure assessments using the exposure modeling tools that are currently available or under development, the recommended age groups will guide analyses of existing exposure factors data as well as the development of new exposure factors research and data collection efforts.

Another important issue associated with using the age groups recommended in this guidance involves distinguishing between uncertainty and interindividual variability in an exposure assessment. Uncertainty in the exposure estimates may be based on a lack of data for any of the significant exposure factors for a particular age group or with assumptions made in development of the model structure. With early lifestages, the issue of intersubject variability can be important due to rapid physiological and behavioral changes, such that, even within a relatively narrow age group, variability may be particularly large. This variability affects our understanding of the upper percentiles of exposure and risk and thus can be critical to early-lifestage risk assessment. Even given a high-quality, high-quantity set of data for each age group, there may still be significant variability for a particular exposure factor, set of factors, or exposure pathway. The better the data and our ability to characterize this variability, the better the basis for final selection of age groups for a specific assessment. Data characterization should

be improved by EPA's effort to update its *Exposure Factors Handbooks* (U.S. EPA, 1997a) to present available data for each of the recommended age groupings.

For most exposure models, exposure estimates can be presented in a variety of ways. Profiles of daily exposure as well as multiple-day averages, seasonal averages, and yearly averages may be developed (see Figure 2). There are models and algorithms that can be used to calculate average exposure across a season or the highest exposure and the full distribution of exposures within a season for an age group. It is important to consider which exposure estimate (median or higher percentile or a probabilistic analysis) should be evaluated in an assessment, and the best choice may be age dependent. Any approach to time-averaging exposure should be informed by a consideration of dose kinetics (e.g., absorption, distribution, metabolism, and excretion) and effects (e.g., critical windows for effects, time to effect). Therefore, exposure assessors and toxicologists should work closely to determine the most appropriate approach.

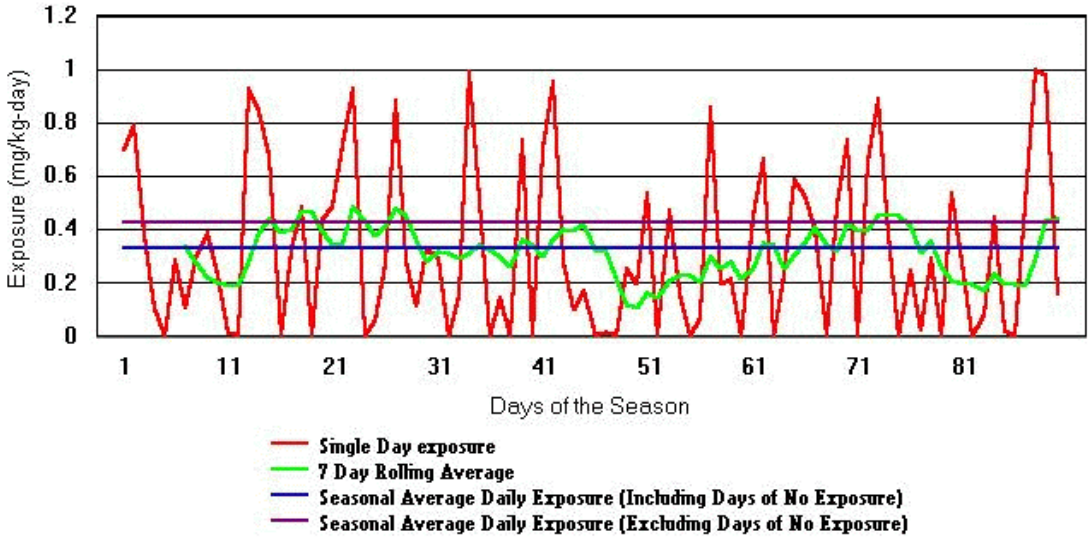

Figure 2. Comparison of Single-Day Exposure Estimates with Various Time-Averaged Exposures.

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GLOSSARY

Absorbed dose: the amount of a substance crossing a specific absorption barrier, e.g., skin, through uptake processes.

Basal metabolic rate (BMR): the metabolic rate under quiescent conditions, without the influence of activity, digestion, or other factors causing increased metabolism.

Breathing zone: the area around the nose and mouth from which air is inhaled, sometimes described as a limited spherical zone extending around the nose and mouth.

Contaminant loading: the quantity (mass per unit surface area) of environmental contaminant on a surface.

Dermal transfer coefficient: an empirically defined parameter developed to aggregate the mass transfer associated with a series of contacts with a contaminated medium. The transfer coefficient is a function of dermal exposure resulting from a particular activity and the loading of a contaminant on a surface.

Dose: the amount of a substance available for interaction with metabolic processes or biologically significant receptors. The result of an exposure to a stressor in the environment, defined by the location, e.g., dermal, oral, and the transformation of the agent after crossing the outer boundary of the organism.

Endocrine system: the glands that secrete directly into the bloodstream; e.g., thyroid, adrenals, pituitary.

Epiphyseal closure: the time at which secondary bone forming centers, i.e., at the ends of the long bones, become a part of the entire bone and cease ossification (at adulthood).

Exposure: the interface between the organism and the environment. Critical factors include the source, pathway, and route (i.e., dermal, oral, inhalation).

Exposure factors: the parameters affecting the exposure, i.e., the interface between the organism and the environment. There are physical, spatial, and temporal factors, as well as the activity of the target organism.

Exposure scenarios: for any given pathway, a set of associated exposure scenarios describes how an exposure takes place. This is needed to estimate the potential distribution of exposure by any given pathway. Exposure scenarios need to be identified to specify the values of exposure factors. An exposure scenario is defined by the combination of the following details: sources, exposed population (e.g., age or developmental stage), time frame of exposure (e.g., acute, short term, chronic, intermittent), location of exposure (e.g., residence, school, outdoors, indoors), and activity (e.g., mouthing, playing soccer, mowing lawns).

Internal dose: general term for the amount absorbed without respect to specific absorption barriers or exchange boundaries.

Lifestages: periods of development that encompass a number of common traits or parameters that are relatively constant. These have been broadly defined in colloquial terms, e.g., newborn, infant, toddler, preschooler, school-aged, pre-adolescent, adolescent. This document defines lifestages on the basis of specific anatomical and behavioral commonalities.

Macroactivity: complex activities described as an entire event, e.g., showering, gardening, cooking.

Microactivity: the simple activities that constitute more complex behaviors, e.g., an infant's mouthing behavior during indoor play, in terms of number of hand-mouth events per unit of time.

Mouthing behavior: hand-to-mouth and object-to-mouth contact. Varies by age and peaks between 1 and 3 years of age. It may include simple contact, licking, and insertion of fingers, hands, or objects in mouth.

Potential dose: similar to external dose, or loading; the total amount of contaminant or agent contacting the outer boundary or orifice of the organism. The contact rate will affect the total potential dose. Absorption is not considered, i.e., 100% absorption is assumed.

Risk assessment: a method of estimating the probability of deleterious health or environmental effects.

Variability: an expression of variation between elements of a data set, e.g., within a sample or a population, within the set of daily behaviors of an individual or a group, or in the effects seen from exposure to a stressor.

Ventilatory equivalent: the ratio of the minute volume-to-oxygen uptake at body temperature, ambient pressure, and water vapor saturated air (unitless).

APPENDIX: PRELIMINARY REEVALUATION OF EXPOSURE FACTORS DATA FOR CHILDREN

The purpose of this appendix is to describe the adequacy of data to support the recommended age groupings for children's exposure and recommend areas of research to fill in the data gaps. In the "Charge to Experts" for the July 2000 workshop (see U.S. EPA, 2000a), several questions were posed to elicit discussion on whether existing exposure information is adequate to support a fine division of childhood age groups. To explore this issue further, subsequent to the workshop, the Risk Assessment Forum work group commissioned an expert review and reevaluation of data available in the draft *Child-Specific Exposure Factors Handbook* (CSEFH) (U.S. EPA, 2000b). This reevaluation of exposure factors information resulted in an issue paper titled "Age Group Recommendations for Assessing Childhood Exposure and the Adequacy of Existing Exposure Factors Data for Children" (U.S. EPA, 2001a). This issue paper was prepared at the direction of the U.S. Environmental Protection Agency (EPA), Risk Assessment Forum. It was prepared by Versar, Inc., under EPA Contract No. 68-C99-238, Task Order 46. Mr. Steven Knott of the Risk Assessment Forum served as Task Order Manager, providing overall direction, technical assistance, and guidance. This appendix summarizes and updates the results of the reevaluation of exposure factors data discussed in the issue paper.

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The preliminary reevaluation of data available in the draft CSEFH was accomplished through a panel of experts working under contract to Versar, Inc. (Springfield, VA). The experts were asked to judge whether a reevaluation of the underlying exposure factors data would support new recommendations for the initial set of childhood age groups presented in Table 4 of the main text. In addition, the experts were asked to discuss quality assurance issues such as those considered in selecting key studies for the CSEFH. The requested quality assurance discussion includes providing new "Confidence in Recommendations Ratings" (U.S. EPA, 2000a) for each exposure factor should it be possible to derive new recommendations from the existing data. The new ratings reflect a consideration of attempting to use the existing data to address the initial set of childhood age groups.

The issue paper explored whether existing child-specific exposure factors data can be fit to the proposed EPA age groupings. The authors evaluated the following exposure factors: breast milk intake, food intake, drinking water and total fluid intake, soil ingestion and pica, nondietary ingestion factors, inhalation factors, skin surface area and soil adherence to skin (dermal), activity factors, and body weight. This issue paper provided a number of recommendations for short-term analyses and longer-term research to improve the database for childhood exposure. A summary of the issue paper's recommendations for future research is presented in the sections that follow.

The authors of the issue paper evaluated the data in the CSEFH as well as new data using the same characterization criteria used in the CSEFH. Although the authors of the issue paper provided new recommendations on each factor for the recommended age groups, EPA is not ready to adopt these recommendations until further analyses (see below) are conducted during the revisions to its draft CSEFH (U.S. EPA, 2000a). However, the issue paper serves as a starting point in identifying those areas where research is necessary to improve the database to develop recommendations for the proposed age groups.

In addition to the research needs described in this appendix, there are other data gaps that cut across all pathways of exposures. For example, accidental ingestion as well as dermal and inhalation exposures from the use of consumer products may occur. Further data are needed on the frequency and duration of use of consumer products by children. Methodologies to extrapolate from short-term studies to chronic exposures are also lacking.

It is important to note that there are efforts underway in EPA and elsewhere that may produce data to address some of these research needs. The National Children's Study, sponsored by a consortium of Federal agencies, including EPA, will examine the effects of environmental influences on the health and development of more than 100,000 children across the United States, following them from before birth until age 21. In addition, EPA, in conjunction with National Institute of Environmental Health Sciences (NIEHS), has funded a number of National Children's Health Centers across the country to study environmental contributions to children's health and disease. Table A-1 summarizes the availability of data for the proposed age bins. Recommendations for further analysis and research are provided below. These recommendations come largely from the issue paper but also include recommendations made by EPA Program Offices and Regions.

Table A-1. Availability of Data for the Proposed Age Bins

Exposure Factor	Age Bin								
	<1 month	**1–2 months**	**3–5 months**	**6–11 months**	**1–2 years**	**3–5 years**	**6–10 years**	**11–15 years**	**16–21 years**
Breast milk intake	501 mL/day (mean) SD and ranges in Tables 2-4 and 2-9 CSEFH	716 mL/day (mean) SD and ranges in Tables 2-4 and 2-9 CSEFH	797 mL/day (mean) SD and ranges in Tables 2-4 and 2-9 CSEFH	680 mL/day (mean) SD and ranges in Tables 2-4 and 2-9 CSEFH	ND	ND	NA	NA	NA
Food intake	Chapter 3 CSEFH	Chapter 3 CSEFH	Chapter 3 CSEFH	Chapter 3 CSEFH	Chapter 3 CSEFH	Chapter 3 CSEFH	Chapter 3 CSEFH	Chapter 3 CSEFH	Chapter 3 CSEFH
Tap water intake	a	a	a	Tables 4-3, 4-5, 4-7 CSEFH	Tables 4-3, 4-5, 4-7 CSEFH	Tables 4-3, 4-5, 4-7 CSEFH	Tables 4-3, 4-5, 4-7 CSEFH	Tables 4-3, 4-5, 4-7 CSEFH	Tables 4-3, 4-5, 4-7 CSEFH
Soil ingestion	ND	ND	ND	ND	a	a	a	ND	ND
Soil ingestion (pica)	ND	ND	ND	ND	ND	b	ND	ND	ND
Mouthing behavior	ND	ND	a,b	a,b	a,b	a,b	ND	NA	NA
Breathing rates	a	a	a	a	6.8 m^3/day	8.3 m^3/day	10 m^3/day	13.5 m^3/day	14.5 m^3/day
Surface area	a	a	a	a	Tables 8-1, 8-2, 8-3 CSEFH	Tables 8-1, 8-2, 8-3 CSEFH	Tables 8-1, 8-2, 8-3 CSEFH	Tables 8-1, 8-2, 8-3 CSEFH	Tables 8-1, 8-2, 8-3 CSEFH
Activity factors	ND	ND	ND	ND	a	a	a	a	a
Body weight	Table 11-1 CSEFH	Table 11-1 CSEFH	Table 11-1 CSEFH	Table 11-1 CSEFH	Table 11-2 CSEFH	Table 11-2 CSEFH	Table 11-2 CSEFH	Table 11-2 CSEFH	Table 11-2 CSEFH

[a]Data available, but reanalysis of data needed.
[b]Data very limited.

CSEFH = *Child-Specific Exposure Factors Handbook* (U.S. EPA, 2002).
NA = Not applicable.
ND = No data.
SD = Standard deviation.

A.1. DIETARY ROUTE OF EXPOSURE

Oral ingestion exposures are typically assessed by considering two major contributors: dietary exposures (from food, water, or breast milk intake) and incidental or nondietary exposures (from mouthing hands and objects or from the deliberate ingestion of nonfood items). The following summarizes the research needs for this route of exposure.

A.1.1. BREAST MILK INTAKE

- Collect data that would allow estimation of the variability (i.e., estimation of distributions) across the population for milk intake as a function of age and/or infant weight. Studies should include consideration of the major ethnic groups in the U.S. population, including Black, Asian, and Hispanic.

- Collect data that would allow estimation of the effect of a mother's nutrient status on the fat/lipid content of breast milk (both before and during lactation). Data are needed on the types of lipids that may change because of these variables and the mobility of such lipids in the milk during lactation.

- The issue paper (U.S. EPA, 2001a) noted that the 6- through 11-month age group captures a period of rapidly decreasing breast milk intake. This observation is consistent with the July 2000 workshop discussion, which noted the expanding variety of foods consumed during this time period. Therefore, future breast milk intake data collection efforts should consider that it may be appropriate to further divide the 6- through 11-month age group into two or three separate groups.

- Data are needed to determine the frequency of breast feeding in older infants and to provide statistical data on the likelihood of breast feeding as the child ages.

- Data are needed to determine the prevalence of breast feeding among women and its variability as a function of age, socioeconomic status, ethnicity. National Health and Nutrition Examination Survey (NHANES) data could be examined to study the feasibility of obtaining these data.

A.1.2. FOOD INTAKE

Incorporate the analyses of the 1998 Continuing Survey of Food Intake by Individuals (1998 CSFII) that was done by EPA's Office of Pesticide Programs (OPP) in its Food Commodity Intake Database (FCID) to substantially improve the estimates of childhood food intake. The 1998 CSFII is a supplemental study that specifically targeted childhood food consumption patterns. Combining the 1998 data with the 1994–1996 data dramatically increases the number of observations for some age groups.

A.1.3. WATER INTAKE

- Incorporate analysis of the 1998 CSFII data conducted by the Office of Water. The 1998 CSFII may substantially improve the estimates of childhood water intake. The 1998 CSFII is a supplemental study that specifically targeted childhood consumption patterns. Use of the 1998 study should improve overall confidence in the water intake estimates for children.

- Follow recommendation in the issue paper that exposures from water intake be normalized by body weight to the ¾ power ($BW^{3/4}$). This recommendation could apply equally to other exposure estimates (e.g., exposure from food intake). However, a corresponding change in the approach to normalizing the various measures of toxicity would also be needed. This issue needs to be explored further.

A.2. NONDIETARY INGESTION ROUTE OF EXPOSURE

Incidental or nondietary ingestion exposures result from the mouthing of contaminated hands and objects and from the deliberate ingestion of nonfood items (also know as pica behavior). Currently, two approaches to estimating these exposures are commonly employed. For ingestion of soil (whether deliberate or incidental) an estimate of the amount of soil ingested is needed. For the ingestion of dustborne contaminants from contact with surfaces, a microactivity approach, which takes into account the activities of the child, properties of the chemical, and physical characteristics of child, is used.

The following discussion addresses data on soil intake, exposure frequency of microactivities, and exposure duration. Skin surface area is addressed in the section discussing the dermal route of exposure (object surface area is case specific); transfer efficiencies are chemical/media specific and are not addressed in this document. Contaminant loading on hands can be estimated from a microactivity approach to dermal exposure assessment if sufficient data are available (see discussion in Section A.4).

A.2.1. SOIL INTAKE

- Collect soil ingestion data on a broader range of childhood ages (e.g., 3 months to <13 years).

- Collect data that would allow estimation of variability and distributions of intake across geographic areas, race, economic status, and other demographic variables, including pica behavior.

- Collect data that would allow the characterization of seasonal variation in soil intake. These data would support the development of distributional information for long-term exposures.

- Explore different ways of interpreting the existing mass balance soil intake data; these analyses could help improve estimates in the near term. However, the suggested approach needs to be explored further and subjected to peer review.

- Conduct research to provide a better understanding of the relative contribution of soil versus dust ingestion.

- Explore other methodologies for estimating soil ingestion rates.

A.2.2. EXPOSURE FREQUENCY AND EXPOSURE DURATION FOR DUSTBORNE AND SURFACE CONTAMINANTS

Children's microactivity data are sparse. The majority of information comes from small studies, many of which were designed to test methodologies for monitoring microactivities. The limited data focus on the frequency and duration of mouthing hands and objects. As noted

above, if mouthing duration (min/day) is used to estimate exposure, then surface area needs to be presented per unit time (i.e., cm^2/min), not per event. Given the paucity of existing data, the issue paper concluded that no new microactivity recommendations can be made at this time.

The following recommendations are made:

- A research program, including a comprehensive data collection effort, is needed to improve estimates of microactivities for nondietary exposure assessment. Existing studies are small and include a variety of methodologies.

- Systematic, probability-based studies should be undertaken that address a broad range of childhood age groups (at least to <6 years of age).

A.3. INHALATION ROUTE OF EXPOSURE

The following discussion addresses inhalation rates and the time spent in microenvironments. Note that the time spent in microenvironments is also used in some dermal exposure models. Therefore, the section on the dermal route of exposure refers back to the discussion provided in this section.

A.3.1. INHALATION RATE

The issue paper (U.S. EPA, 2001a) indicated that existing data do not support recommendations for children less than 3 years of age due to the lack of ventilatory equivalent data for these ages. Further, although the existing data may support a recommendation for children aged 3 to <6 years, the issue paper notes that the data are very limited. However, ventilatory rates may be derived using energy expenditures incorporating the latest USDA CSFII 1994–96 and 98 data. The paucity of data for young children is a particularly important source of uncertainty, given that the limited data (and the current understanding of childhood physiology) suggest that ventilatory equivalents will be higher for these age groups. The existing data do support recommendations for grouping children aged 6 to <11 years, 11 to <16 years, and 16 to <18 years.

The issue paper authors who reevaluated the inhalation rate estimates recommended several areas of further analysis and research.

- First, the more recent CSFII data can be analyzed further to obtain food energy intake/energy expenditures for the entire initial set of childhood age groups.

- For short-term, activity-specific inhalation rate estimates, the approach of Allan and Richardson (1998) could be explored further but would need to be supported with the collection of additional activity data for children.

- Activity-specific inhalation rate estimates could also be developed using the Layton (1993) approach as modified by McCurdy (2000). Specifically, inhalation is calculated in the manner described above, but energy expenditure is estimated using a factorial approach in which an individual's activities are assigned energy expenditure values based on a multiplier of basal metabolic rate (termed a MET). Daily estimates of energy expenditures derived from this method could be compared with estimates derived from the CSFII to lend insight into quality assurance issues.

- Finally, a critical area of research (especially for children less than 6 years of age) is the search or collection of ventilatory equivalent (the ratio of the minute volume to oxygen uptake at body temperature, ambient pressure, and water vapor saturated air [unitless]) data for children. These data may already be available from research in pharmacology. Any new data collection efforts should consider susceptible populations, such as asthmatic children.

A.3.2. TIME SPENT IN MICROENVIRONMENTS PURSUING MACROACTIVITIES

Children's exposures in relation to activities are generally captured as either *macroactivities*, e.g., playing a game of baseball, or *microactivities*, e.g., touching hand to mouth 10 times in 1 hour, the latter taking place within a *microenvironment*, or specific space. Given the paucity of existing data, the issue paper authors concluded that new recommendations for children less than 1 year of age and 11 years of age and older cannot be made. Referring to Hubal et al. (2000), the authors state that "the current database on children's macroactivities is sparse and data are insufficient to adequately assess exposures to environmental contaminants. However, the results of the Hubal et al. (2000) evaluation of CHAD data for children less than 12 years of age are sufficient to provide recommendations for time in microenvironments and participation in certain macroactivities for children in age groups of [1 to <3 years], [3 to <6 years], and [6 to <11 years]."

The expert authors recommended two specific areas of research.

- Develop methods for monitoring children's activities and exposures.

- Collect population-based data on children's activities and exposures to allow characterization as a function of age, gender, environmental setting (microenvironment), socioeconomic status, race/ethnicity, geographic location, and season. In particular, focus on young children (less than 4 years of age) and children aged 11 years and older.

A.4. DERMAL ROUTE OF EXPOSURE

For dermal exposures to contaminants in soil, data on body surface area in contact with the contaminated soil, soil adherence data, and exposure frequency for each microactivity are needed.

Overall, experts agree that the assessment of dermal exposures is an area that is ripe for research. The preliminary reevaluation for dermal exposure factors focused on two factors in the equation for estimating dermal exposure to contaminants in soil: total skin surface and soil adherence to skin. Surface area is discussed below in Section A.4.1. The issue paper expert providing the preliminary reevaluation concluded that soil adherence to skin is more closely related to activity than to age. Therefore, no further reevaluation was provided for this factor.

Data on the frequency of macroactivities are sparse. Research in the following areas is recommended.

- Data on the frequency of macroactivities are needed. Most studies have focused on the duration of such activities (e.g., min/day) as opposed to the number of times the activities are performed each day. Exceptions include the frequency of swimming and showering events.

- More data are needed for the development of dermal transfer coefficients. EPA's OPP has proposed an interim value of 5,200 cm^2/hour for short-term exposure for children playing outdoors on lawns and indoors on carpeted or hard flooring (U.S. EPA, 1997, 2001b).

- The macroactivity approach would benefit greatly from further research providing activity- and surface-specific dermal transfer coefficients for children. The preliminary reevaluation did not include a review of this factor.

- As with the macroactivity approach, few data exist to support the use of the microactivity approach to estimating dermal exposures from contaminated surfaces. Most of the available studies focus on the frequency of mouthing events in children. For this specific microactivity and others (e.g., specific body part contacts with surfaces) the data are extremely sparse.

- Data on the area of surface that is contacted during a microactivity event are virtually nonexistent. As noted above in Section A.2.2, a systematic, comprehensive data collection effort is needed to support these exposure factors. The remaining factors in the microactivity dermal exposure equation are chemical/media specific.

For the estimation of dermal exposure from contact with contaminated water, skin surface area is addressed in the section that follows. For estimating absorbed dose, consult the Superfund dermal guidance (U.S. EPA, 2004) for a complete discussion. One component used in determining time spent bathing, showering, or swimming is discussed above in Section A.3.2. As noted above for estimating dermal exposure to soil, data on the frequency of macroactivities were not included in the preliminary reevaluation. Surface area exposed in these scenarios is highly dependent on the activity.

A.4.1. SKIN SURFACE AREA

The expert providing the preliminary reevaluation of skin surface area data reviewed the same studies and approach as used by EPA in the draft CSEFH. The experts recommended research in the following areas:

- An analysis of the NHANES 99 plus or later data sets should be conducted to provide new recommendations for estimates of skin surface area for the initial childhood age groups 2 years of age and older (EPA used the NHANES II data for children >2 years of age in the draft CSEFH).

- For further analysis and research on skin surface area, the expert recommended collecting new height and weight data for children less than 2 years of age.

- Further, although this expert concluded that dermal soil adherence is more activity specific than age specific and, therefore, deferred to the activity-specific recommendations of the draft CSEFH, the expert recommended that more detailed studies of dermal soil adherence be conducted to determine variations among individuals and the effects of duration of activity, clothing use, and time of year on this factor.

- In addition, implicit in the expert's review is the need to update skin surface area estimates for children 2 years of age and older using the newer NHANES 99 plus data for height and weight.

The analyses should support the recommended initial set of childhood age groups provided in Table 4 of the main text.

A.5. HUMAN BODY WEIGHT

Human body weight is used to normalize daily exposure estimates in the calculation of daily potential doses. For dietary exposures, the studies used to derive intake rates for food and water (namely the CSFII 1994–96 and 1998 studies) include body weight information for each individual surveyed. Therefore, the food and water intake for a specific individual can be normalized by the body weight for that individual to yield intake rates in units of g/kg-day. For breast milk intake, nondietary ingestion exposures, inhalation exposures, and dermal exposures, such concurrent collection of body weight information is absent from the relevant exposure factors data. Typically, these exposures will be normalized by body weight information from other sources, such as average body weight estimates for the general U.S. population derived from data available in the NHANES studies. The following discussion conveys the results of the preliminary reevaluation of human body weight data for the initial set of childhood age groups.

The expert providing the preliminary reevaluation of body weight data for children highlighted several areas for further analysis of existing data.

- Further statistical analysis of the NHANES 99 plus data will allow the derivation of multiple percentiles and distributional information for the initial set of age groups.

- In addition to the relationship between age and weight, the existing data should be analyzed for other relationships (e.g., age and stature, body mass index) to develop a more complete understanding of body metrics that may have a bearing on exposures and risks.

- The NHANES 99 plus data should be analyzed further to develop body weight estimates that are specific for selected ethnic groups.

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