March 27, 1997

EPA-SAB-IHEC-LTR-97-005

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Subject: Science Advisory Board Review of the Office of Research and Development's (ORD) draft Exposure Factors Handbook

Dear Ms. Browner:

The current Exposure Factors Handbook (EPA/600/8-89/043) was first published in July 1989 by the ORD's Office of Health and Environmental Assessment. This Handbook was prepared in response to requests from many EPA regulatory program offices for additional guidance on selecting values for exposure factors when performing risk assessments. The Handbook was intended to encourage consistency in exposure assessments, while allowing risk assessors the flexibility to tailor assessment approaches to specific situations. Since its publication, new data on exposure factors have become available, and revisions were necessary to update the Handbook. The current revised draft Handbook updates information on the consumption of drinking water, fruits, vegetables, beef and dairy products, and fish. It also addresses factors such as soil ingestion, inhalation rates, skin surface area, length of life, activity patterns, and body weight. In addition, the current draft adds new chapters dealing with grain consumption, consumer products use, and the reference residence.

Following a request from the ORD, the SAB's Integrated Human Exposure Committee (IHEC) met on December 19-20, 1996 in Arlington, VA to review the draft revised Handbook. The Charge for the meeting called for the Committee to focus on the following questions:

a) Is the Handbook consistent with the EPA Exposure Guidelines?
b) Are the data presented in a way that is useful to exposure assessors?
c) Are groupings of background studies into “Key” and “Relevant” categories done in an appropriate manner?
d) Do the Handbook’s recommendations reflect the proper interpretation of the data and the appropriate characterization of the data’s limitations and uncertainties?

In terms of an overall assessment, the Committee finds that the revised edition of the Exposure Factors Handbook has been substantially expanded relative to the first edition, and that it provides a great deal of useful data for exposure assessment. The Committee commends the Agency on its efforts to assemble, evaluate and present up-to-date data for exposure assessors in this revision to the Handbook.

Addressing item a) of the Charge, we note and commend the Handbook’s emphasis on presenting distributions of data wherever possible. This approach, in particular, helps harmonize the Handbook with the Exposure Assessment Guidelines. The Committee noted, however, that the Handbook must be made more consistent with the Exposure Assessment Guidelines with respect to the definitions and usage of the terms “exposure” and “dose.” In addition, revisions (detailed below and in the Technical Appendix to this letter) to the summary tables at the end of the Handbook’s various chapters would also serve to increase the document’s consistency with the Exposure Guidelines.

In the Exposure Assessment Guidelines, the Agency did a very good job of clearly defining many of the terms used in exposure assessment and of showing their relationships (In fact, these definitions have been adopted by the Journal of Exposure Analysis and Environmental Epidemiology as Key Words and definitions). The Factors Handbook should use these definitions. With respect to the tables summarizing the recommended data for use, the Committee recommends that these tables should present the 50%, 90% and the 99.9% (bounding estimate) wherever possible to emphasize the relations to key distributional percentiles in the Exposure Assessment Guidelines. Because of the importance and usefulness of these tables, the Committee also recommends that some way be found to make it easier to find these key tables in each chapter, e.g., by changing the print size or through some other formatting changes.

Vis-a-vis Charge element b), the IHEC found that the data in the Handbook are generally presented in a way that is useful to exposure analysts. In order to make it

even more useful and user-friendly, the Committee recommends that the Handbook be carefully edited to achieve consistent reporting of summary statistics in the text and tables throughout the document and consistency with respect to regional and ethnic groupings in the tables, wherever possible.

Addressing item c) of the Charge, the Committee found that the groupings of background studies into “Key” and “Relevant” categories were, in most all cases, done in an appropriate manner. The only significant exceptions to this finding were the “Key” and “Relevant” ratings given in those chapters utilizing obsolescent data on food consumption (see below and the Technical Appendix).

The final element of the Charge, item d), asked the Committee to determine if the Handbook’s positions reflected a proper interpretation of the data and characterized appropriately the presented data’s limitations and uncertainties. The Committee has identified some problems in this area. Summary tables at the end of each chapter of the Handbook present an assessment of the confidence in the recommended data, and provide information with respect to the criteria used to make this judgment. The Committee noted, however, that it is not clear how the overall rating in each table was derived. Presumably some criteria were more heavily weighted than others. This needs to be more clearly defined. The Committee also noted that the precision and accuracy of the measurements appeared to be a heavily weighted (but implicit) criterion used in arriving at the overall rating, and suggests that these criteria be decoupled from the others and made more explicit.

Addressing other issues arising during the review, the Committee recommends that the Chapter on variability and uncertainty be revised to emphasize variability, which is clearly related to the distributional nature of the data presented in the Handbook. The material on the distinction between natural variability and uncertainty should be retained, but much of the material on uncertainty should be edited to shorten and de-emphasize it, since the purpose of the Handbook is to provide data for exposure analysis, not to provide a treatise on the complex subject of uncertainty and how to treat uncertainty in exposure analysis. In particular, sections on both uncertainty and variability which are not clearly related to other materials in the Handbook should be reduced or removed.

Although not discussed by the IHEC as part of the public review, one Member of the SAB Executive Committee identified an additional issue concerning uncertainty. The Handbook (page 1-10) discusses cases in which only a ranges of values is known for an exposure factor, and offers, as an option, use of a mid-point value. This is not

considered to be a good option unless there is reason to believe that distribution within the range is uniform, and/or a sensitivity analysis has been performed.

Finally, as mentioned above, the Committee found that some of the tables on food intake (meat products in particular) were not as up-to-date as they should (and could) be. We urge the Agency to obtain more current data available from the department of Agriculture and revise the relevant sections of the Handbook as quickly as possible. Food production, the dynamic change in consumer food practices and consumption, and a vast number of new food technologies and products, etc., require data that is contemporary for appropriate use in risk assessment processes. However, we also recognize that dietary intake is a "moving target" and that the risk analysis community cannot wait another year or more for the revised Handbook. One possibility would be to issue Volumes 1 and 3 immediately, and delay issuing Volume 2 until the tables are brought up to date. Another, less desirable option, would be to issue Volume 2 with the other volumes, with the out of date food consumption tables, but with an alert to the user, and a statement that replacement tables with more up-to-date data will be issued as soon as possible. *Vis-a-vis* the issue of timely dissemination of the Handbook, the Committee suggests that the document might be issued in a binder-type format so that relevant updated sections could be incorporated as they are produced. The Committee also discussed the possibility, as raised by one of the public commentors, of posting the document to the World Wide Web in an interactive format. Given the current "state-of-the-art, however, the Committee has some reservations about this proposal and does not recommend it at this time.

Beyond dealing with the specific food data problems in the Handbook, the Committee suggests that EPA consider supporting an Agency initiative, potentially in collaboration with other Federal agencies, to develop and maintain a contemporary database on food exposure factors. Two factors support this suggestion. First, as noted by the Committee, some of the data that EPA must rely on is up to 20 years old and there have been extensive changes in the production and consumption of agricultural products including grains, dairy and meat and poultry products.

Secondly, agricultural business has increasingly become an international market in which American farmers and industry must compete. Food and animal exports worldwide have increased five-fold in the last 25 years and continue to expand (Reference: Codex Alimentarius). Many of the issues on harmonization and standardization of food safety standards are being addressed by U.S. participation in the Codex Alimentarius Commission. Specific examples include the Codex Committees on Pesticide Residues, Food Additives, Food Hygiene, Residues of Veterinary Drugs in

Food, and potentially the Codex Committee on Import/Export Inspection and Certification. Specific risk assessments and development of international food safety standards require the best available food consumption data to develop contemporary scientifically based standards.

We appreciate the opportunity to review this document, and look forward to the Office of Research and Devlopment's response to the issues we have raised.

Genevieve M. Matanoski

Dr. Genevieve Matanoski
Chair, Science Advisory Board

Joan M. Daisey

Dr. Joan M. Daisey
Chair, Integrated Human Exposure Committee

ENCLOSURES

APPENDIX A
DETAILED TECHNICAL COMMENTS

Specific Comments and Corrections for Chapter 1 (Risk Calculations)

p.1-10, column 2, line 2: IR and ED are not defined; the symbols can be inserted in the paragraphs below which define intake rate and exposure duration.

p.1-10, column 2, line 2: “total exposure can be expressed as .... total potential dose...” - Exposure is defined as the integral of concentration in the exposure medium times time. The equation which is given in the Handbook defines a dose. The definitions of exposure and dose should be made consistent with those in the Exposure Assessment Guidelines. In addition, the text should be carefully reviewed to ensure that the usage of these terms is consistent with the definitions.

p. 1-11, paragraph 4: “Exposure can be expressed as ...” - This is not consistent with the Exposure Assessment Guidelines. This sentence addresses dose and it is not correct to say that “exposure can be expressed as...”

p. 3-10, Table 3-11: Units are not given.

Specific Comments and Corrections for Chapter 2 (Analysis of Uncertainty)

The concepts, sources and treatments of uncertainly presented in the chapter on the *analysis of uncertainty* do follow the USEPA's Guidelines for Exposure Assessment. This chapter provides very important information for exposure assessors on the issues of uncertainty. However, the way that uncertainty is handled may cause some confusion to readers who attempt to distinguish uncertainty from variability.

The authors of this Handbook have made a clear distinction between uncertainty and variability, based on the USEPA's Exposure Guidelines, by defining *"uncertainty" as a lack of knowledge about factors affecting exposure, whereas "variability" is true heterogeneity across people, place or time. In other words, uncertainty can lead to inaccurate or biased estimates, whereas variability can affect the precision of the estimates and the degree to which they can be generalized.* (p. 2-2) It is also further stated in Section 2.2, by quoting USEPA's position, that variability should not be treated as a specific type or component of uncertainty. But inconsistent with the above statement, variability has been repeatedly treated as a subclass of uncertainty in many parts of the document. Here are some examples:

- On the next page (p. 2-3), readers will be puzzled by Table 2-1 where uncharacterized variability is included as one of four sources of parameter uncertainty. The related text of this table can be found on the following page (p.2-4) where "*Sources of **parameter uncertainty** include measurement errors, sampling errors, **variability**, and use of generic or surrogate data*" is stated.

- In Chapter 1, Section 1.3.1. under General Considerations, *"Minimal (or defined) uncertainty in the data: Studies were sought with minimal **uncertainty** in the data, which was judged by evaluating all the considerations listed above"* (p. 1-2). The considerations include variability in the population. This inclusion is also stated in the next sentence: *"At least, studies were preferred that identified uncertainties, such as those due to inherent variability in environmental and exposure-related parameters or possible measurement error."*

- Section 2.6. deals with both variability and uncertainty, but its title is "Presenting Results of Uncertainty Analysis." Chapter 2 has separate sections on variability and uncertainty, however only uncertainty is identified in the chapter title ("Analysis of Uncertainty"). The heading of uncertainty alone, instead of referencing both uncertainty and variability, in the section and chapter titles implies that variability is a component of uncertainty.

Occasionally, the authors make no distinction between variability and uncertainty, such as in Section 2.5 ("Methods of Analyzing Uncertainty and Variability"). Although both terms are defined initially as different entities in this chapter, the whole section treats them as inter-changeable entities. Based on the methods of quantitative analysis presented in this section, readers have no guidance on how to deal with them differently. Four approaches to quantitative analysis of uncertainty are described in Section 2.5. But readers still do not know how to apply these four approaches to increase precision and reduce bias/errors quantitatively. Users of this Handbook would expect to see the exact operative procedures to handle uncertainty and variability quantitatively during the process of exposure assessment.

For exposure assessment, variability in measurements is important for contaminant concentration and other exposure factors. In addition to measurement errors mentioned under parameter uncertainty, measurement variation deserves some attention also. In this chapter, the measurement variability has not been addressed at all. The need to address measurement variability lies in the inherent nature of measurement. It is also a very important consideration by evaluators for their overall ratings of exposure factors. Although the precision of measurement tools is not listed

as one of the considerations for overall rating, it is the implicit consideration by evaluators for their judgement. As the overall ratings in Table 1-2, physical measurements with high precision and accuracy such as inhalation, body surface area, lifetime, and body weight are all rated high. Although food intake surveys, which are complicated in nature, subject to recall bias and difficult to quantify, are in general rated as medium to low. Surveys of time-activity patterns, which are less complex, more reliable and consistent than food consumption surveys, are rated as medium to high. Measurement variability is clearly the most important consideration for the overall rating of factors.

To avoid confusion and improve clarity, the following changes are suggested:

a) Shift the emphasis from uncertainty to variability. The term "variability" is clearly defined and well addressed in the Handbook. For all factors, variability has been presented in numerous tables of means, standard deviations and percentiles. While there is a lack of consensus on the definition of uncertainty as well as its distinction from variability. The treatment of uncertainty in this Handbook is far less extensive and systematic than that of variability.

b) Change the title of Chapter 2 to "Variability and Uncertainty" to indicate the shifting of the weight of treatment.

c) Define and address variability before uncertainty. Alter the sequence of sections and rename some of the titles to reflect the emphasis on variability.

d) Remove or reduce the parts that are not related to the other chapters and cannot be easily used by exposure assessors.

Specific Comments and Corrections for Chapter 3 (Drinking Water Intake)

The Exposure Guidelines are not cited in the Exposure Factors Handbook, but given that the guidelines are largely policy and definitions, the Exposure Factors Handbook is mostly data. Therefore, there is not a big potential for error with regard to inconsistency. In one specific case, however, there is an overlap in the Handbook's description of percentile of exposure. Fig 5-1 of the Exposure Guidelines has the terms "high end of exposure" "and bounding estimate" which correspond to particular percentiles. It would be convenient if Table 3-30 (Summary of Recommended Drinking Water Intakes)

in the Handbook had 50th, 90th and 99.9th percentile values to match decision points of the guidelines.

The summary table should be introduced with its own subsection in the Recommendations section, rather than its current location in the High Activity and Hot Climate section. The table citations for pregnant and lactating women, high activity and active adults appear to be wrong

High activity data in the Recommendations does not appear to come from the cited "Key Studies." This is confusing to the reader because the summary table cites a table (which seems to be wrong) and not the study.

The Summary table would be improved by:

a) Retaining the age group/population category, eliminating the mean values, and using exposure guidance percentiles of 50, 90, and 99.9

b) Addressing multiple percentiles and fitted distribution items with footnotes, and citing the relevant study directly in its own column instead of the indirect table reference.

In general, provide table numbers for tables noted in the recommendation section

Specific Comments and Corrections for Chapter 4 (Soil ingestion/Pica)

Overall, the Agency has performed a good evaluation of the available literature on the highly controversial topic of incidental soil ingestion.

Chapter 4 is consistent with the 1992 Exposure Guidelines. It provides recommendations for mean and high end soil intake for children (<6 years of age), and mean values for adults and pica behavior. Given the many limitations of the extant data, detailed and reliable distributions of intake cannot be derived at this time and this precludes full consistency with the Exposure Guidelines. The term "upper percentile" exposure should be more explicitly defined in a manner consistent with the guidelines (i.e., should this be considered as a 98th percentile, or a bounding estimate?). The available information on purposeful ingestion by children, and incidental ingestion by adults is even more limited. In spite of the limitations of the studies and, as the Chapter

indicates, the data presented are rather consistent in terms of average intakes across studies. Since there are a number of on-going investigations trying to characterize incidental soil intake specially by children (for example, the National Human Exposure Assessment Survey (NHEXAS)), it may useful for the Agency to coordinate with these investigators to try to fill the data gaps in this area. As most of the studies reviewed indicate, there is a large variability in incidental soil ingestion among children and it is important to know the factors which affect this variability so they can be included in future revisions of the Handbook. The Agency might consider adding some resources to on-going studies to investigate these factors.

The data are presented in a manner useful to exposure assessors. A paragraph should be added, however, to the effect that the recommended values should be used with caution. Incidental soil intake can occur not only via direct ingestion through hand-to-mouth or object-to-mouth contact, but also through the contamination of foods inside the home. There has been some preliminary investigation of micro-environmental contamination of foodstuffs once brought inside the household (these data were presented by Linda Sheldon of RTI at the last Exposure Assessment meeting in New Orleans). This factor, in addition to the large variability in intake estimates among individual subjects in the studies reviewed, suggests that assessors should consider each specific application carefully in order to avoid underestimating intake for specific cases.

The grouping of key and relevant studies is appropriate, although the order in which they are presented within the key or relevant groupings is unclear, neither following an alphabetical or time-of-publication pattern (this is also true of the other Chapters), or a hierarchical one. This may be confusing to the users of the Handbook. A presentation of the studies by date of publication may be the most appropriate.

The citations to foreign studies (e.g., the Dutch investigations in child care centers) should be viewed with caution. One of the factors that could be instrumental in affecting soil intakes is hygiene (e.g., frequent washing of hands). Hygienic practices can vary across countries and cultures and may be more stringently emphasized in the highly structured environment of Dutch or other European countries child care centers than among children in the US (the reverse is true for other countries). Also, note that the description of the Stanek and Calabrese, 1995a, study on page 4-1 contains an error: the time period for day 1 of the fecal sample was noon (not midnight) on Monday to noon on Tuesday.

In general, the document addresses the limitations of the available data. A sentence

should be added, however, about the limited information available on factors which may affect individual soil intake and could help explain the observed inter-subject variability and identify situations that are conducive to higher intakes, indicating that this is an area where more research is needed.

Specific Comments and Suggestions for Chapter 5 (Inhalation Route)

Chapter 5 provides a comprehensive listing of information on inhalation. The relationship between inhalation and dose of toxic agents to the lung is complex, varying with route and ventilation rate, and the physical and chemical characteristics of the inhaled material. The document gives insufficient attention to the need to conceptualize inhaled dose rather than simply the concentration at which exposure is received. In this regard, there is a lack of consistency with the Agency's Exposure Guidelines. At a minimum, the introduction to the chapter should cover the complexity of the relationship between exposure and dose. Example cases might be given, such as a soluble gas like sulfur dioxide which is removed in the upper airway, and radon progeny, inhaled in the form of very small particles that are deposited in the airways. Reference should also be given to standard lung models.

A more focused treatment is needed of the inhalation route. The respiratory tract has a number of physical zones, the upper airway, the lower airways--subdivided into the bronchi, and bronchioles, and the gas exchanging region of the lung, the alveoli. There are diverse target cells within the lung. A short paragraph reminding the reader of the complexity of the architecture of the lung should be included.

The population includes a substantial proportion of persons with abnormal lungs, including cigarette smokers, persons with asthma, and persons with chronic obstructive pulmonary disease. These conditions affect the exposure-dose relation and make some individuals susceptible. The significance of lung disease in conceptualizing lung dose should be covered.

With regard to the overall approach and the selection of the reference materials, there are a few gaps. Relevant work by Samet and colleagues in New Mexico and McCool at Brown University was not covered. A report of the Health Effects Institute provides these data which address the ventilation-heart rate relationship.

Page 5-1: The text makes the statement that alveolar ventilation rate is of particular interest. In fact, the inhaled volume of air (minute ventilation) is the relevant quantity. Air inhaled into the physiologic dead space of the lung contains contaminants. This paragraph needs to be corrected.

Page 5-8, paragraph beginning “A limitation of this study...”: This sentence may be incorrect. The wider variety of exercise would simply extend the range over which the heart rate to ventilation ratio would be observed.

Page 5-11, second paragraph: The Committee suggests not using the term “macho effect.”

p. 5-12, column 2, paragraph 3 - The California Air Resources Board sponsored research .... CARB did not conduct the research, but rather sponsored the research by Adams (1993). Also, the reference should be Adams, 1993, NOT CARB, 1993, and the text in this section should be corrected to reflect this change. This should be: Adams, William C. (1993) Measurement of Breathing Rate and Volume in Routinely Performed Daily Activities, Final Report. California Air Resources Board Contract No. A033-205.

Page 5-21, Table 5-22: In this table, and throughout the document, the term ‘confidence rating” is used in reference to literature evaluation. The Handbook reads as though these confidence ratings were an indication of the degree of certainty. The Committee interprets the ratings in a different fashion; i.e., that they offer a measure of the quality of the source information. In the introduction and throughout the text, the authors should revisit the use of this term, particularly as they take on the difficult task of reassessing the handling of uncertainty throughout the report.

p.5-22, Table 5-23, Summary of Recommended Values for Inhalation: It is not clear why children from 1-12 years old are combined in this table since there is a substantial change in inhalation rate as a function of age. A more appropriate grouping might be 1 to 5 and 6 to 12 years.

Specific Comments and Suggestions for Chapter 6 (Dermal Route)

The dosage terms are inconsistent. The terms "dermal dose" and "absorbed dose" which are used in the Exposure Factors Handbook (eq 6-1 and 6-2) are not found in the relevant sections of the Exposure Guidelines. The Exposure Guidelines' dose terms (fig 2-1) for the dermal route are: potential dose, applied dose, internal dose and biologically effective dose. The term "applied dose" in the Handbook is probably not

the same as the "applied dose" in the exposure guidance but actually the "potential dose."

Two formulas (Equations 6-1 and 6-2) are discussed in Section 6.1 (pages 6-1 and 6-2). Equation 6.1 predicts dermal absorption of contaminants in water; equation 6.2 is identified as a variant of 6.1 for estimating dermal absorption from soil. The second paragraph on page 6-2 states that the soil equation is simpler because it does not have to deal with an infinite contaminant sources, as does the water-borne exposure scenario. It appears, however, that equations 6.1 and 6.2 are computationally identical. The term “EV” (events per day) appears in equation 6.1 but not in 6.2, and the term “EF” has units of “days/years” in 6.1 and “events/year” in 6.2. When the mathematical operations dictated by the two equations are carried out, however, the results are the same -- absorbed dose per event is multiplied by the number of events. It appears that either equation could be used for both water and soil exposures (with an explanation of the term “DA” which incorporates the actual difference in soil vs. water-borne contaminant uptake).

The Handbook's recommendations summary table lists the 50th and 95 percentile, but should refer to the 50th, 90th and 99.9th percentile to be consistent with the Exposure Guidelines. Finally, the text refers to these values at one point as a 90th percentile, and at another point as a 95th percentile.

Specific Comments and Suggestions for Chapter 7 (Body Weight Studies)

Among the many factors reported in the Handbook, body weight is considered one of the factors with the least uncertainty. However, the data were collected in 1976-1980, 16 to 20 years ago. Only when the average body weight and the demographic composition of our population have not changed significantly since the data were collected, can the average body weight be used as an unbiased estimate for the current national population. Otherwise, the average and distribution of body weight should be adjusted based on the current population data. Consequently, the Agency should start considering the data collected during NHANES III, which would have more recent body weight information, and would also provide data for Hispanics.

Body weight is a function of age, gender, and race. The populations of many geographic regions are very different from the national population. The users should be warned that when applying the percentiles to other geographic regions with different age, gender and race composition, appropriate adjustment should be made.

Strictly speaking, the rating of “currency” is not consistent with the rules of considerations in Chapter 1. Based on the rules, currency should be rated as low, if data were collected prior to 1980. But the rating of currency cited the year of publication (1987), rather then the years of collection, and ranked currency as medium.

Body weight is one of the key factors for the calculation of dose. It is widely used to calculate the average daily dose for the national population as well as various subpopulations. In this chapter, values for adults and children are recommended separately, and no body weight is formally recommended for the entire population that includes both adults and children. In other parts of the Handbook, however, 60 kg is recommended for the whole population. This Chapter on body weight should make a formal recommendation for users. Body weight data for infants younger than 6 months are not provided. If reliable data can be obtained, body weights of this age category should be included. Among various ethnic groups, only data for whites and blacks are given. If it is feasible, data for other ethnic groups should be provided also.

Specific Comments and Suggestions for Chapter 8 (Lifetime)

The chapter provides life expectancy data for the years 1970-1993 by gender and black/white ethnicity. These data were derived from the Department of Commerce Statistical Abstracts and should be representative for the populations included. Although this information dates to 1993, and life expectancy is increasing, this increase would probably be only a few months, as shown by the 1995 projection included in the table. As with the body weight data, other ethnic groups are not included and their life expectancy may be at variance with those presented in these tables. An effort should be made to include data for these groups in future revisions.

Also, as part of a future revision, the Agency might consider providing information on life expectancy, not only at birth, but also according to current age. In this manner, an assessor can derive exposure estimates based on the age distribution of a particular population.

Specific Comments and Suggestions for Chapter 9 (Intake of fruits/vegetables)

In this chapter, USEPA has decided to combine three years of relatively current data (1989-1991 from the Continuing Survey of Food Intakes by Individuals (CSFII) as a basis for their recommendations on fruits and vegetables. This approach provides a more stable base upon which short term and long term consumption patterns may be based. Use of these data are more relevant than either the 1977-78 and 1987-88

Nationwide Food Consumption Survey (NFCS) because these data are relatively old and based on a poor response rate (37%).

In spite of using the 1989-1991 data base, it is surprising that in Table 9-5 there is no specific entry for relatively common fruits (e.g., oranges and bananas) and vegetables (e.g., green beans) in the tables, while there are some less common ones that do have specific entries. In Table 9-8 there may be a data entry or format error. For example, the first column contains a two line entry for "cow peas, field peas, black-eyed peas," presumed to be one entry, yet in subsequent columns in this entry there are double entries. In Table 9-10, there is a possible error in column three, first entry. It states that 86.8 percent of the population use (consume ?) fruit per day, yet in all subsequent entries in that column, no demographic unit listed has a consumption rate of 70 percent

and 14 entries are less than 60 percent. In Table 9-18, there may be a registration error in column 2, non-citrus fruits.

Specific Comments and Suggestions for Chapter 10 (Intake of Fish/shellfish)

There are two summary tables in Recommendations-General Population section (RGP) and Recommendations-General Population- Fish Serving Size (RFSS).

Section 10.10.1 (Recommendations - General Population) contains a discussion on pages 49-50, on changes of mean intake of 20.1 g per day based on the 1989 CSFII study and compares that to the 13.5 g per day in the TRI study. Acknowledging that the CSFII short term data cannot be used to extrapolate to long term average daily fish intake, the report states that because the TRI data are over 20 years old, it was "felt" that these data could be "adjusted" to account for the recent increase in fish consumption. Therefore, the report says, the TRI should be "shifted upward by 50 percent". Using this approach the authors recommended percentiles of long-term average daily fish consumption as those of Javitz (1980) adjusted 50 percent upward. This is not an acceptable rationale. In a technical and science-based document this change should be supported by relevant data and studies.

In general, the summary tables are not well explained in the recommendations section of the text. They should be given numbers and referred to directly with an unambiguous explanation of the numbers and where they came from. It is possible in most cases to reconstruct this information by referring to the numbered tables in the body of the text, but it is a time-consuming process for the user.

Acknowledging that EPA assigned the most relevance to the 1989-1991 USDA “Key” study for its recommendations, the data base, includes a “Key” study conducted by the *Tuna Research Institute* (TRI) in 1973-74, reflecting a primary concern on key studies - it is too old to qualify as a key study considering the changes that have occurred in production (e.g., aquaculture) and consumption that would tend, at the least, to suggest this study be a “Relevant” study in spite of its size and one year duration for collection of the data. Studies such as the CSFII, although much more current, suffer by having data provided on 3 consecutive days. In addition to requiring respondents to estimate serving sizes, it is hard to extrapolate the data to “long term” exposure. Somewhat troubling, though not unexpected, is the variability of results from different studies reviewed in the early portion of the chapter. As an example, the Javitz (1980) study estimates high mean consumption rates, exceeding similar estimates for anglers, possibly reflecting bias due to the 3-day recall period method of data collection. It may highlight a particular concern with this chapter because it addresses a food commodity that is, by the vast majority of consumers, eaten only intermittently (although when consumed, it may be in portions greater than 100 g). This offers great opportunity to misrepresent consumption by U.S. consumers, and hence, exposure factors. In addition, there is not a clear distinction, whether it makes a difference or not, of the fish or shellfish being of domestic or international origin. This may be relevant to this chapter because of the uniqueness of the fish industry - the U.S. is among the largest exporters and largest importers of edible fish and shellfish in the world. It would be constructive to consider some discussion on this point.

The large and complex tables in this chapter should be reviewed for consistency of units (e.g., see Tables 10-8 through 10-12). Consistency of units may reduce possible errors of interpretation by risk assessors.

The discussion sections on recreational anglers is extremely extensive and seems out of proportion to the total estimated contribution of daily consumption. However, the Committee acknowledges that there is concern for subsistence anglers and susceptible populations that may not be properly recognized in exposure assessments. EPA may wish to consider consolidating or streamlining this portion of the report.

In section 10.9 (Other Factors), there is an extensive tabulation of moisture and fat composition data. With it is the assumption that “the residue levels of contaminants in fish are reported as the concentration of contaminant per gram of fat.” This is true only for lipophilic contaminants. However, there are other veterinary medical products relatively often used in aquaculture that are not lipid soluble. Specific examples are some of the antibiotics such as the tetracyclines. This consideration is not addressed

in the narrative of this section. The Codex Committee on Residues of Veterinary Drugs in Food for example, has recommended an maximum residue limit for oxytetracycline in giant prawns and principles have been elaborated for use of muscle tissue as the target tissue for other maximum residue limits. The discussion, therefore, needs to be broadened and more inclusive.

The Tables 10-50 through 10-53 do not seem to reflect the confidence ratings in Table 1-2. An explanation of the ratings in the tables in the recommendation sections of the individual chapters would be helpful to justify the entries in Table 1-2.

Specific Comments and Suggestions for Chapter 11 (Intake of Meat/dairy Products)

The issue of "Key" and "Relevant" studies is a critical issue in Chapter 11. Extensive reference is made to the 1977-78 NFCS and to the 1989-91 CSFII study. These data are insufficient to recommend exposure factors as noted by the following USDA publication *"Meat and Poultry Inspection - 1994 Report of the Secretary of Agriculture to the U.S. Congress"* (USDA, March 1995). Between 1984 and 1994, using 1984 meat and poultry production (animals presented for inspection) as a reference point, cattle production increased less than one percent; market hog production increased about 10 percent; chicken production increased approximately 70 percent; turkey production increased approximately 75 percent; total poultry production increased approximately 67 percent. These data clearly indicate the dynamic changes in consumption patterns by consumers and the inadequacy of relying on "old" data. In addition, consumption patterns have changed as has the introduction of a significant number of new food products, including "ready to eat" entries and several others. Indicative of the changing technology is the significant number of meat and poultry product labels approved by USDA in 1994 (about 180,000). Considering that there are many label changes that are for non-technical reasons such as a label for a different product size, for example, there are substantial numbers of new food products being introduced in response to consumer demand and developments in food technology. Though it may be difficult for EPA to use a reference point for the EFH, a strong recommendation is made to use the most current published data.

EPA should reconsider the discussion in Section 11.2 (Fat Content of Meat and Dairy Products) and limit the discussion accordingly. The section begins by stating that "in some cases, the residue level of contaminants in meat and dairy products are reported as the concentration of contaminant per gram of fat." The entire section is written on the assumption that all chemical contaminants in meat and dairy products are in fat or

lipid tissue. This is not a correct assumption for many food animal health products. This is valid for the fat and lipid soluble pesticides, but is not applicable to most veterinary drugs that are approved for use in food producing animals. With these products, organ tissue (liver and kidney) or muscle tissue may be the target tissue. Of a secondary nature, the discussion on poultry fat does not indicate whether it does or does not include adhering skin.

EPA should reconsider the discussion in Section 11.3 (Conversion Between As Consumed and Dry Weight Intake Rates). Although this is a short section, it has little value for exposure assessment considerations of chemical contaminants, pesticides or veterinary drug residues in meat products because none of the EPA pesticide or FDA veterinary drug residues are reported on a dry weight basis for determining compliance with a U.S. food safety tolerance.

The data in Table 1-2 need some clarification. Whereas the data from Chapter 11 (Total meat intake rate) recommend an exposure factor of 2.1 g per kilogram-day, while the data from Home Produced Food Intake suggests total meat of 2.2 g per kilogram-day. The latter figure reflects only those that consume home produced foods.

EPA should also consider food exposure consumption factors based on the individual animal and bird slaughter classes identified by USDA. The reason for the recommendation is that historical residue data and knowledge of current production practices indicate significant differences in residue contamination profiles. For exposure/risk assessments, this may be pertinent information.

Specific Comments and Suggestions for Chapter 12 (Intake Rates for Home-produced Food Products)

This chapter relied on the NCFS 1977-78 and 1987-88 studies for its recommendations, which limits its value, as noted previously. It is not clear that the equations 12-2 and 12-3 achieve their intended objective and there do not appear to be entries in the tables that include the data identified in components of the above noted equations. Perhaps some additional review and clarification is needed on this section. The 50 percentile summaries in Tables 12-8, 13, 18, 23, and 28 do not seem to agree with the entries in Table 1-2. Some explanation may be necessary or a footnote in the summary table. In some cases, the entries for home grown products in Table 1-2 are higher than the exposure factor for total fruits, vegetables and meat listed from assessments of these respective commodity chapters.

Specific Comments and Suggestions for Chapter 13 (Breast Milk Intake)

In general, the Chapter is consistent with the guidelines in that it provides average and upper-percentile estimates of breast milk intake for children from 1 month up to 1-year of age, and it recognizes that there is socio-demographic and ethnic variability in the proportion of and extent to which children are breast fed. The chapter, however, does not issue any specific recommendation for infants under 1 month of age (when a larger number of infants are totally breast fed and the intake, on a body weight basis, may be also larger than for older infants, although the net volume ingested may be smaller). With the exception of the DARLING study (Dewey, K. G., *et. al*, in *Pediatrics* 87:828-837, and in *J. Pediatrics* (119:538-547), which has a strong population sample bias, most of the studies were published almost 10 years ago or earlier (with the data having been collected even earlier), and have other limitations such as sample size. There may be some more recent data available from the FDA or other state agencies, that should be included in a follow-up revision of the Handbook. As with other exposures, there may be special groups with potentially high exposures that are not captured in these data. In this case, these may be groups of women highly committed to breast feeding exclusively for periods of time longer than one year; these groups should be identified. This may also be true of subgroups on the other end of the distribution, i.e., women who may not breast-feed or do so minimally.

The section on breast milk intake as a function of energy needs/consumption could be improved by adding a sentence on the uses of this information to estimate exposures of breast milk intake (this is not included in the recommendations). The practical relevance of this information to the exposure assessor is not clearly stated in the chapter.

Specific Comments and Suggestions for Chapter 14 (Activity Factors)

Many of the tables are not clearly labeled; they could also benefit from some editing to remove unnecessary symbols for groups. In addition, since there is blank space on many of these pages, the print on some of these tables could be enlarged to make them more easily readable.

p.14-1, column 1, paragraph 2, line 6 - should be "micro"environments; also, the term “micro environments” should be explicitly defined.

p. 14-2, column 1, last paragraph - the reference to CARB is incorrect. This should be Wiley, J. A., J. P. Robinson, T. Piazza, K. Garrett, K. , Cirksena, Y.T. Chang and G. Martin. (1991) Activity Patterns of California Residents. Final Report, Survey Research

Center, University of California, Berkeley, CA. California Air Resources Board Contract No. A6-177-33.

p. 14-3, column 1, paragraph 3 - Should the mean or geometric mean be presented for modeling purposes?

p. 14-3, column 1, paragraph 3 - Were these statistically significant differences?

p. 14-3, column 1, last paragraph, last sentence - Suggest that these activities be listed in order of time.

p. 14-3, second column, paragraph 2, on limitations.“ This may somewhat bias the CARB data set” - presumably what is meant here is “..with respect to its application to other populations.”

p. 14-4, column 2, paragraph 2, line 6 - suggest that some indication of what short-term recall is be provided, e.g., 24-hour?

p. 14-9, column 2, paragraph 2, lines 13-16 - Playground/park data are also available in:

Phillips, T. J., P. L. Jenkins, and E. J. Mulberg. (1991) *Children in California: Activity patterns and presence of pollutant sources.* Paper No. 91-172.5, Proceedings of the 84th Annual Meeting of the Air and Waste Management Association, Vancouver, B.C.

Timmer, S.G., J. Eccles and K. O’Brien. (1985) How *children use time*, pp. 353-382, In: Time*, Goods and Well-Being*, F. T. Juster and F. P. Stafford, Eds., Institute for Social Research, University of Michigan, Ann Arbor, MI.

Medrich, E. A., J. Roizen, V. Rubin, and S. Buckley. The *Serious Business of Growing Up: A Study of Children’s Lives Outside School*, University of California Press, Berkeley, CA, 1982.

Michelson, W. M. From *Sun to Sun: Daily Obligations and Community Structure in the Lives of Employed Women and Their Families*. Rowman and Allanheld, Totowa, N J, 1985.

p. 14-14, column 2, paragraph 2 (Section 14.4.1) - Cooking should also be included

here based on the results of the PTEAM study and results reported by Brauer, M.(1995) *Assessment of indoor aerosols with an integrating nephelometer*. Journal of Exposure Analysis and Environmental Epidemiology, 5: 45-56.) on exposures to particles from cooking. More recent results on exposures during cooking were also reported by Brauer at the recent ISEA meeting in New Orleans. There are likely to be exposures to other pollutants during cooking. Even if the specific pollutants (other than particles) have not yet been determined, it is worth anticipating the need for this data.

p. 14-15, column 1, paragraph 2 - "Time spent gardening." This may be retrievable from the CARB 1991 study by using a crosstab of "plant care" with location codes for outside.

p. 14-15, last two paragraphs and p. 14-16, column 1, paragraph 1 - Suggest including 95th and 99.9th percentiles for consistency with the Exposure Assessment Guidelines.

Specific Comments and Suggestions for Chapter 15 (Consumer Products)

It should be noted at the outset that this information is a very useful addition to the Handbook!

In many of the tables at the end of the chapter, however, some clarification of the time period needs to be provided. For example, Table 14-35 provides data on the number of time an automobile or motor vehicle was started, but there is no indication of whether this is per day or per week. Also the print in many of these tables is very, very small and difficult to read. In most cases, there is sufficient space on the page so that the type could be made larger and more readable.

Specific Comments and Suggestions for Chapter 16 (Reference Residence)

This chapter is a very useful addition to the Exposure Factors Handbook and makes data on volumes of residential buildings much more readily accessible for exposure assessment than it is in the RECS database. Figure 16-1 captures many of the key features of residential buildings which must be considered in modeling indoor air exposures, and in general, the background discussions on the material in this chapter are well written and provide a good explanation of the nature and use of the data in the chapter.

Overall, the chapter is generally consistent with the Exposure Guidelines and provides valuable distributional data for estimation of exposures. The title of the chapter,

however, is not consistent with the distributional nature of the data presented in the Handbook. "Reference Residence" implies that a single house is representative of U.S. housing. A more appropriate title would be "Reference Residences" or, more simply and directly, "Residential Building Characteristics."

There are two key sets of data in this chapter - distributions of residential building volumes and distributions of air exchange rates. Although the presentation of volume data by geographical regions is appropriate, the air exchange rates should not be grouped by zones that are geographical, since these are more non-homogeneous statistically than is necessary or appropriate. Air exchange rates (infiltration and natural ventilation by window opening) as well as building characteristics related to air exchange rates, are determined by climate zones and meteorology. It would be more appropriate to present the air exchange rates grouped by climate zones such as those defined by EPA's BASE study. This would make the data easier to use and would emphasize the physical determinants of air exchange rates, i.e., meteorology and housing type. It should also be noted that the age of housing can be a significant determinant of air exchange rates. Newer, more energy-efficient homes are much "tighter" and therefore have lower infiltration rates (see Sherman and Dickerhoff, 1996, enclosed).

There should also be some consideration of the addition of a table presenting house volumes grouped by climate zone, which could be used with a climate-zone based table on air exchange rates.

It may not be appropriate to classify any of the studies on air exchange rates as "key studies" since this classification seems to imply a representativeness and accuracy that these data do not have. If the sample size for any given climate zone or season is small, it is much less likely to be representative and weighting does not correct for this. The subsets of data on air exchange rates should be checked to see how many measurements there actually are for a subset.

With respect to section 16.3.5, (Interzonal Airflows), it is strongly recommended that section 16.3.5.2 be completely eliminated. It is highly phenomenological rather than scientific and it is very likely to give incorrect answers because of the lack of representativeness of U.S. residences and conditions. More scientifically accurate interzonal airflow models have been developed and these should be used for situations in which such modeling is required.

The tables which presents the limitations and uncertainties of the data in each Handbook chapter are well designed and useful, although there needs to be some clarification on how things were weighted to arrive at the overall rating. In the chapter on residential building characteristics, however, the table on air exchange rates (Table 16-31) does not capture all of the uncertainties associated with air exchange rate measurements and also has some inappropriate rationales listed.

The PFT measurements of air exchange rates assume uniform mixing of the tracer within the building. This is not always so easily achieved. Furthermore, the degree of mixing can vary from day to day and house to house because of the nature of the factors controlling mixing, e.g., convective air motion, driven by weather, the type and operation of the heating system. The relative placement of the PFT source and the sampler can also cause variability and uncertainty. It should be noted that sampling is typically done in a single location in a house which may not represent the average for that house. In addition, very high and very low values of air exchange rates based on PFT measurements have greater uncertainties than those in the middle of the distribution. The low ones are more uncertain because of analysis uncertainties, while the high air exchange rates can be very strongly biased by imperfect mixing that is more common under such conditions. The limitations in the representativeness of the data with respect to climate zones are also reason for concern. Given the uncertainties in the PFT (tracer) measurement method for air exchange rates and, more significantly, the lack of representativeness for the U.S. housing database, it is not clear why the overall rating is medium. It would probably be more appropriate to give these data a "low" overall rating and to provide some information to the Handbook user on the specific limitations of the PFT ventilation measurements. This doesn't mean that they are not useful. It does mean that the user should be cautious about interpretation of results based on such data, particularly if data from under-represented climate zones are used.

With respect to the rationales for ratings for "Reproducibility," the rationale is that the methodology was clearly presented. This is not the same as reproducibility. If there is no information on reproducibility, e.g., duplicate or triplicate measurements made in a house over the same time period, then the table should so indicate. Similarly, it is not appropriate to characterize "Validity of Approach" by saying that the method is practical. Validity of approach must address the underlying physics of the situation and the suitability of the measurement with respect to the underlying physics. In the case of the PFT measurements, the assumption of perfect mixing and the placement of the PFT source and the sampler, as well as the sampling and analysis uncertainties, need to be considered.

Other, more specific comments and corrections noted for Chapter 16:

p. 16-1, column 2, line 1 - “deposition to and re-emissions from ...”

p. 16-2, column 2, paragraph 3, line 8, “The RECS also provides... volumes ..” should be “floor areas” rather than “volumes”

p. 16-6, Table 16-5 - It is not clear how the surface covered would be useful for the first 6 items; shouldn’t these be given as mass applied per m^2?

p. 16-6, The discussion on mechanical system configurations is well done and useful.

p. 16-8, 16-9 - It would be appropriate to point out that the EPA regions and census regions are not appropriate for statistical sampling to characterize air exchange rates or housing characteristics and that the climate zones designated in the EPA BASE study are more appropriate for such purposes.

p. 16-8, in column 2, under “Local circulation” , it should read “Convective and advective ...”

p. 16-10, column 2 line 1 - delete “because outdoor levels are generally assumed to be zero.” This assumption is not necessary and is frequently not made. Air exchange still provides the major mechanism for removal of most indoor air pollutants (via both dilution from infiltration and by exfiltration), so the remainder of the sentence is still correct.

p. 16-12, column 2, paragraph 1 - The statement that the highest air exchange rates occur in the warmest climates region during the summer should be checked to see if this result is simply a limitation in the number of measurements in the subset of data. In the very warm regions, homeowners tend to use their air-conditioners in the summer months and to keep homes closed up for energy efficient use of air-conditioners.

p.16-13, column 1, end of paragraph 2 - the last sentence is not exactly correct. Leakage areas are inferred from an infiltration model developed by Sherman and Grimsrud (“The measurement of infiltration using fan pressurization and weather data, “ Proceedings of the First International Air Infiltration Centre Conference, London, England. Also, Lawrence Berkeley Laboratory Report LBL-10852,

October, 1980). Blower door measurements made when houses are weatherized can be used with a model to infer the leakage areas and, these can be used with meteorological data to estimate infiltration rates for residences. See Sherman and Dickerhoff, ("Air-tightness of U.S. dwellings," In: The Role of Ventilation, 15th AIVC Conference, Buxton, Great Britain, 27-30 September 1994; and "Air-tightness of U.S. dwellings," Lawrence Berkeley Laboratory Report No. LBL-35700, 1996; both enclosed). The latter provides a more detailed explanation of how to estimate infiltration rates from blower door measurements. This sentence should be modified to indicate how infiltration models can be used with blower door measurements to estimate infiltration rates since there is a large body of blower door measurements available from state weatherization programs; many of these data have been assembled into a database by M. Sherman of the Lawrence Berkeley National Laboratory..

p.16-13, column 2 - This deals with the very large impact of window opening on ventilation rates. This is an important point. We suggest giving a numerical example here, e.g., 0.2 h^{-1} to 10 h^{-1}, and pointing out that measured values of very high air exchange rates are considerably less reliable and meaningful because mixing is typically much less complete under high ventilation conditions.

p. 16-15 - Interzonal Flows - See comments above recommended deletion of section 16.3.5.2.

p. 16-21, Table 16-26 - What is "totalized?" I think this should be "Total." Also, the units for dust load should be clarified with a hyphen between g and m-2 so that this doesn't look like grams -2.

p. 16-22, column 1, last paragraph - "Emanation sources..." Also, line 3, second column. This term is used for radon emanation from radium-bearing soils and rocks, but not for solid sources of vapor-phase organics. It may confuse readers. We suggest using the term "solid sources" and including examples, e.g., carpet backing, furniture, flooring, dried paint.

p. 16-22, column 2, line 4 - "latch" should be "relate" or "link."

p. 16-23, Equation 16-6 seems out of place. It probably was meant to be placed somewhere near the end of column 2, p. 16-22. It will have to be re-numbered if placed before 16-5.

p. 16-24, Equation 16-9 - the symbol “A” for area has been omitted.

Specific Comments and Suggestions for Chapter 17 (Grain Consumption)

The same general comments apply to this food group on the timeliness of the data. The data used in this chapter for exposure factors are, to a great extent, too old for this assessment. More current data are necessary for determining exposure factors. Data from more contemporary studies are available from USDA as noted above.

NOTICE

This report has been written as a part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide balanced, expert assessment of scientific matters relating to problems facing the Agency. This report has not been reviewed for approval by the Agency and, therefore, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

U.S. Environmental Protection Agency
Science Advisory Board

Integrated Human Exposure Committee
December 19-20, 1996

Chair
Dr. Joan Daisey, Lawrence Berkeley Laboratory, Berkeley, CA

Members
Dr. Paul Bailey, Mobil Business Resources Corporation, Paulsboro, NJ

Dr. Robert Hazen, State of New Jersey Department of Environmental Protection and Energy, Trenton, NJ

Dr. Timothy Larson, Department of Civil Engineering, University of Washington, Seattle, WA

Dr. Kai-Shen Liu, California Department of Health Services, Berkeley, CA

Dr. Paul Lioy, Environmental and Occupational Health Sciences Institute, Piscataway, NJ

Dr. Maria Morandi, University of Texas School of Public Health, Houston, TX

Dr. Jonathan M. Samet, The Johns Hopkins University, Baltimore, MD

Mr. Ron White, American Lung Association, Washington, DC

Dr. Lauren Zeise, California Environmental Protection Agency, Berkeley, CA

Federal Experts
Dr. Richard Ellis, US Department of Agriculture, Washington, DC

Ms. Alanna J. Moshfegh, U.S. Department of Agriculture, Riverdale, MD

Science Advisory Board Staff
Mr. Samuel Rondberg, U.S. Environmental Protection Agency, Science Advisory Board, Washington, DC 20460

Staff Secretary
Mrs. Dorothy M. Clark, U.S. Environmental Protection Agency, Science Advisory Board, Washington, DC 20460

Distribution List

Administrator
Deputy Administrator
Assistant Administrators
Deputy Assistant Administrator for Pesticides and Toxic Substances
Deputy Assistant Administrator for Research and Development
Deputy Assistant Administrator for Water
Deputy Assistant Administrator for Air and Radiation
EPA Regional Administrators
EPA Laboratory Directors
EPA Headquarters Library
EPA Regional Libraries
EPA Laboratory Libraries
Staff Director, Scientific Advisory Panel