they were based on data, analogy, or professional judgment. Where uncertainty is high, a sensitivity analysis can be used to estimate upper limits on exposure by way of a series of "what if" questions.

Although assessors have historically used descriptors (e.g., high-end, worst case, average) to communicate risk variability, the 1992 *Guidelines for Exposure Assessment* (U.S. EPA, 1992) established quantitative definitions for these risk descriptors. The data presented in this handbook are one of the tools available to exposure assessors to construct the various risk descriptors. A thorough risk assessment should include particular assumptions about human behavior and biology that are a result of variability. A useful example is given in NRC (1994):

> "…a poor risk characterization for a hazardous air pollutant might say 'The risk number R is a plausible upper bound.'" A better characterization would say, "The risk number R applies to a person of reasonably high-end behavior living at the fenceline 8 hours a day for 35 years."

In addition to presenting variability in exposure, frequently, exposure assessments include an uncertainty analysis. An exposure assessment will include assumptions about the contaminant, contaminant exposure routes and pathways, location, time, population characteristics, and susceptibilities. Each of these assumptions may be associated with uncertainties. Uncertainties may be presented using a variety of techniques, depending on the requirements of the assessment, the amount of data available, and the audience. Simple techniques include risk designations, i.e., high, medium, or low (un)certainties. Sophisticated techniques may include quantitative descriptions of the uncertainty analysis or graphical representations.

The exposure assessor may need to make many decisions regarding the use of existing information in constructing scenarios and setting up the exposure equations. In presenting the scenario results, the assessor should strive for a balanced and impartial treatment of the evidence bearing on the conclusions with the key assumptions highlighted. For these key assumptions, one should cite data sources and explain any adjustments of the data.

The exposure assessor should describe the rationale for any conceptual or mathematical models. This discussion should address their verification and validation status, how well they represent the situation being assessed (e.g., average versus high-end estimates), and any plausible alternatives in terms of their acceptance by the scientific community.

To the extent possible, this handbook provides information that can be used in a risk assessment to characterize variability, and to some extent, uncertainty. In general, variability is addressed by providing probability distributions, where available, or qualitative discussions of the data sets used. Uncertainty is addressed by applying confidence ratings to the recommendations provided for the various factors, along with detailed discussions of any limitations of the data presented.

2.9. REFERENCES FOR CHAPTER 2

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