Variability, Confidence and Uncertainty: Sorting Out the Confusion

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The concept of uncertainty is usually framed in the context of probability. However, there are two dominant concepts for the meaning of probability, both of which are applicable to problems encountered in bioassay and environmental radiochemistry. An objective definition of probability, favored by classical statistics, is the relative frequency with which an event occurs. A primary assumption of frequentist statistics is that there exists a distribution from which values can be sampled, and that the parameters of this distribution are constants. Inferences are made by drawing attention to a reference set of hypothetical data vectors that could have been generated by the probability model given the parameters for the distribution. Estimators for the parameters, which are functions of the data in a sample, are computed. Reference sets are generated for the parameters based on the hypothetical data vectors, and inferences are based upon the similarity between the sampled data and the reference data sets.

The second concept for the meaning of probability regards it as a mathematical expression of one's degree of belief or confidence with respect to a certain proposition (Savage 1954, Box and Tiao 1973). Distributions of confidence are frequently used in risk assessment to represent the uncertainty about a value that is unknown. For example, the breathing rate of a specific individual may not be known but be an important parameter in a risk assessment. Risk assessors may assign a distribution to a constant but unknown quantity in order to reflect their uncertainty in that value. This process is sometimes viewed disparagingly, but in fact has parallels in classical experimental statistics.

In classical statistics, confidence intervals are used to provide an idea of how far from the true values the calculated estimates might be, based on the empirical data. For example, one may test the hypothesis that the mean value of a quantity measured at one location is different than the mean value estimated at another. Although there are only two means, the test (a t-test) is based on the assumption that one would have observed variation in the two estimates of the means if one collected many sets of data at each location and computed a mean for each set. However, the reality usually is that the "distribution of mean values" is not a frequency distribution but rather a function that represents one's confidence that the true mean lies within some distance of the estimated mean. Confidence can thus be seen to represent a different concept than that of a measured frequency.

Uncertainty associated with simple measurements, such as estimates of mass, usually reflects confidence in the estimates. Uncertainty in complex measurements, such as activities of radionuclides measured with alpha or gamma detectors, often include components of uncertainty defined in terms of both natural variability and confidence, with little consideration being given to the problem of interpretation that can arise from confounding the two concepts. Most environmental risk assessments also combine uncertainties due to natural variability (objective uncertainty) and to lack of knowledge (subjective uncertainty). However, there is now growing interest among scientists and decision makers to partition the contributions from subjective and

objective uncertainties (Helton 1994, Hoffman and Hammonds 1994). The presentation will focus on clarifying the differences between subjective and objective uncertainties, and will discuss the confusion than can arise when the two types of uncertainty are combined. The discussion will illustrate the nature of the problem using examples drawn from the field of risk assessment, and using simple Monte Carlo models.

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