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Some Limitations of Aggregate Exposure Metrics

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Aggregate exposure metrics based on sums or weighted averages of component exposures are widely used in risk assessments of complex mixtures, such as asbestos-associated dusts and fibers. Allowed exposure levels based on total particle or fiber counts and estimated ambient concentrations of such mixtures may be used to make costly risk-management decisions intended to protect human health and to remediate hazardous environments. We show that, in general, aggregate exposure information alone may be inherently unable to guide rational risk-management decisions when the components of the mixture differ significantly in potency and when the percentage compositions of the mixture exposures differ significantly across locations. Under these conditions, which are not uncommon in practice, aggregate exposure metrics may be "worse than useless," in that risk-management decisions based on them are less effective than decisions that ignore the aggregate exposure information and select risk-management actions at random. The potential practical significance of these results is illustrated by a case study of 27 exposure scenarios in El Dorado Hills, California, where applying an aggregate unit risk factor (from EPA's IRIS database) to aggregate exposure metrics produces average risk estimates about 25 times greater—and of uncertain predictive validity—compared to risk estimates based on specific components of the mixture that have been hypothesized to pose risks of human lung cancer and mesothelioma.

KEY WORDS: Aggregate exposure metrics; asbestos; mixture exposures; value of information

1. INTRODUCTION

Many regulatory risk assessments for known and suspected carcinogens use linear nonthreshold exposure-response models of the form:

$$\text{Excess risk caused by exposure} = K \times \text{Exposure}, \quad (1)$$

where K is the potency of exposure, i.e., the increase in risk per unit of exposure, for an adverse human health effect. Typical units for expressing excess risk are excess numbers of illnesses, deaths, quality-adjusted life years (QALYs) lost, etc. per person-year in an exposed population. In symbols, the linear model is $r = Kx$, where x = exposure and r is the excess risk (e.g., in units of additional illnesses per person-year) when the exposure level is x.

When the exposure variable x represents a *mixture* of components with different potencies, fitting the simple linear model of Equation (1) to data consisting of (x, r) pairs raises the possibility of *aggregation errors* in risk estimation, arising from the fact that the same value of the exposure metric, x, can represent different mixtures having different corresponding risks. This article explores how such aggregation errors can affect the quality of risk-management decisions.

2. AGGREGATE EXPOSURE INFORMATION MAY NOT SUPPORT IMPROVED DECISIONS

Suppose that there are n types or categories of particles in a mixture, having different potencies. If

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