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Personal exposures to VOC in the upper end of the distribution—relationships to indoor, outdoor and workplace concentrations

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Abstract

Evaluation of relationships between median residential indoor, indoor workplace and population exposures may obscure potential strategies for exposure reduction. Evaluation of participants with personal exposures above median levels in the EXPOLIS study in Athens, Helsinki, Oxford and Prague illustrated that these participants frequently showed a different relationship to indoor and workplace levels than that shown by the population median. Thus, prioritization of environments for control measures based on median exposures may exclude important areas where effectively focused control measures are possible, and may therefore have little impact on the highest and most harmful exposures. Further, personal exposures at the upper end of the distribution may exceed the US EPA inhalation reference concentration (Rfc), illustrated here using hexane, naphthalene and benzene. For example upper 90th percentile personal exposures to benzene in Athens and Prague were 64 and 27 $\mu g\,m^{-3}$ with peak exposures of 217 and 38 $\mu g\,m^{-3}$, respectively for non-ETS exposed participants relative to an Rfc of 30 $\mu g\,m^{-3}$. Strategies to reduce exposures to individual compounds, therefore, may benefit from focus on the high end of the distribution to identify activities and behaviors that result in elevated exposures. Control strategies targeting activities that lead to exposures in the upper end of the distribution would reduce the variability associated with population median values by bringing the upper end of the exposure distribution closer to median values. Thus, compliance with health-based standards would be more protective of the higher exposed fraction of the population, in whom health effects would be more expected.
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1. Introduction

Current distributions of exposures to individual VOC and corresponding concentrations measured in different microenvironments have frequently been described as log normally distributed or more highly skewed (Brown et al., 1994). A fundamental question, therefore, is whether there are effective control methods that may be employed by reducing exposures in the upper end of the distribution and reducing the variability associated with population median or mean exposures. Directing control measures across the population are likely to be difficult to implement, requiring significant effort and regulation in reducing emissions. Reduction of the upper end of exposures, thus narrowing the distribution would allow health-based standards to be more protective of a higher exposed fraction of the population, while also reducing mean and median values.

Control measures directed at the upper end of the exposure distribution relies on characterizing sources and activities that lead to greater exposures, and the microenvironments in which the exposures occur. Frequently, median values are used to evaluate relationships between microenvironment concentrations and personal exposures. While such an approach may identify more general relationships for the majority of the population, these may not be indicative of the relationships in the upper end of the exposure distribution. Prioritization of environments based on median exposures may therefore exclude important areas where effectively focused control measures are possible, and may therefore have little impact on the highest and most harmful exposures. This is especially relevant if multiple sources are present in different environments, and exposures represent the combined contributions from multiple environments.

Many indoor sources have been largely ignored in regulation, as sources are individually relatively small. They may contribute disproportionately to personal exposures, however, as they are emitted in close proximity to where people spend significant portions of their time, and a greater fraction of the pollutant emitted may come into contact with an individual relative to the mass emitted into the environment. This concept is encompassed by the term "intake fraction" (Bennett et al., 2002). This concept is especially relevant to VOC exposures as emissions from multiple indoor sources may result in indoor levels that are often higher than outdoor levels (Edwards et al., 2001a). Thus careful attention to the emissions profile of items and products for residential indoor use, which have traditionally not been considered as environments where pollution should be controlled, may achieve significant reduction in exposures and control measures may be more cost effective.

A further potential area for control measures occurs through activities or locations in a small number of individuals that do not appear as major sources on a population basis. They may, however, be significant sources of exposure for those involved. For example, home workshops have been associated with elevated levels of benzene (Edwards and Jantunen, 2001). Others may be related to specific hobbies, or product uses. Greater controls over the content of products that are used in these locations could therefore significantly reduce exposures in these individuals. Such reductions may be related to individual compounds that are only detected in a few individuals and are thus usually excluded from statistical analysis, or they may occur as superimposition of exposure on sources prevalent in the majority of the population (e.g. exposure to ETS or automobile exhaust), and may be easily overlooked in relation to the more prevalent sources. It is important, therefore, that both the common population sources and specific sources affecting small sub-populations are evaluated in the context of control measures.

The EXPOLIS project is well placed in being able to evaluate some of these effects within adult populations of four European cities, Athens, Helsinki, Oxford and Prague. In the EXPOLIS centers personal exposures were measured with concurrent measures of both inside and outside the home environment and inside the work environment during the time that the participant reported they would spend in the residential or workplace environment. Thus the contribution of VOC concentrations in each microenvironment to the personal exposure concentration could be assessed in each location. This enables comparison of personal exposures and microenvironment concentrations, and the implications for control measures across the distribution.

The purpose of the current paper is to examine if different implications about the patterns of personal exposure and areas for control strategies may be derived from looking at relationships between microenvironmental concentrations and personal exposures in the upper end of the distribution rather than median levels across populations. Since the distributions are highly skewed to the right (upper end), we attempt to identify activities and microenvironments associated with elevated exposures that do not become apparent in investigating population median levels. We focus in particular on naphthalene, hexane, benzene, butoxyethanol and cyclohexane.

2. Methods

2.1. The different centers

The EXPOLIS study focused on air pollution exposures for active working age adults between 25

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