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Challenges in estimating health effects of indoor exposures to outdoor particles: Considerations for regional differences

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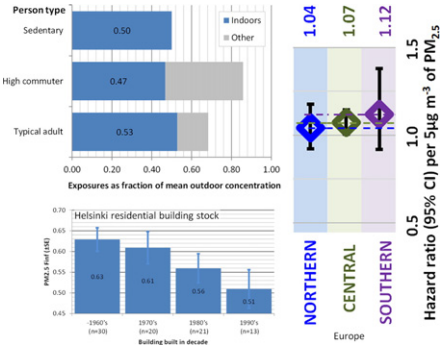
HIGHLIGHTS

- Potential regional differences in particle C-R functions are only partly explained by building stocks in Europe.
- Impact of toxicity of particles or aerosol properties such as particle size distribution cannot be ruled out.
- Confidence intervals of cohort studies are largely overlapping and thus minor differences in toxicity are also difficult to be confirmed.

GRAPHICAL ABSTRACT



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ABSTRACT

Ambient air pollution is a leading environmental risk factor causing substantial losses of life and significant morbidity. Concentration-response (CR) functions used globally to estimate such effects are largely based on ambient epidemiology, using centrally monitored outdoor air quality as an exposure indicator and various indices of population health as an outcome. Similar common understanding is mostly missing regarding indoor exposures. Less studied are health impact modifying factors such as particle size, infiltration, time-activity and population differences. In this discussion paper we aim at looking at one of these, infiltration.

The sensitivity of overall personal exposure to indoor exposures was quantified by a simple probabilistic time-activity model to calculate fractional exposures for indoor, outdoor and in traffic time-activity. To demonstrate the potential regional differences in epidemiological C-R relationships we re-analysed the ESCAPE results for natural-cause mortality, focusing on geographical grouping of the cohorts: pooled estimates were calculated for the Nordic, Central European and Southern European cohorts.

When comparing the relative differences in the regional hazard ratio increments, the Central European value (7%) is 1.75 times higher than the Nordic one, and Southern European value (12%) 3 times higher, respectively. While towards the expected direction when aiming to explain these differences at least partly with differences in $PM_{2.5}$ infiltration, the differences are not statistically significant and only the Central European and the all cohorts combined estimates reach borderline statistical significance. As the analysis of $PM_{2.5}$ infiltration factors by similar regions yielded only 10–15% differences, it seems possible that that the available data could also accommodate

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other regional factors, such as those originating from regional differences in population and contribution of indoor sources of PM, time-activity, behaviour, or compositional differences in the particulate matter.

1. Introduction

Ambient particulate matter (PM) has been one of the most studied environmental risk factors in epidemiology of this century, publications approaching lead and exceeding dioxins and second hand smoke studies of the 20th century (811 k, 26 k, 188 k hits, respectively, in Google Scholar before 2000 vs. 705 k for PM after 2000). Harmfulness of particulate matter has been observed in numerous epidemiological studies (summarized e.g. Pope & Dockery, 2006, Hoek et al., 2013, Burnett et al., 2014), confirmed using in vitro and in vivo studies (e.g. Nemmar et al., 2013), and in several intervention setups planned (Clancy et al., 2002) or occurring for other reasons (Pope et al., 2007) as well as follow-up studies comparing the development of air quality and health in cohorts that were analysed previously (e.g. Laden et al., 2006).

Almost all of the above referred and generally well accepted evidence is based on ambient epidemiology, using centrally monitored outdoor air quality or modelling as an exposure indicator and various measures of population health as an outcome. Similar common understanding is largely missing regarding indoor exposures in developed countries. This is true for exposures originating from indoor sources such as second hand smoke (e.g. Cohen et al., 2004), indoor use of combustion devices (Smith et al., 2014) or cooking (IARC, 2010) as well as for indoor exposures to air pollution originating from outdoors. In this paper we focus only on the indoor exposure to outdoor air pollution and therefore are interested in the exposure modifiers occurring along the exposure chain depicted in Fig. 1.

The chain of physico-chemical events leading from emission sources to health impacts in human populations can be outlined as in Fig. 1. Emissions are mixed in the atmosphere, causing ambient and microenvironmental contamination, to which humans are exposed. The exposure process involves both indoor and outdoor environments and is modified by time- and physical activity. In the human domain, intake, uptake, and dose can be defined and actually required based on the presumption that actual biological responses to the pollution particles and molecules are the causal factors leading to the health impacts.

Particles originating from different sources such as road dust, combustion generated particles, sea salt etc. or generated in the atmosphere from gaseous precursors have chemically diverse composition. The original components are mixed in aerosol processes, creating accumulated particles that compositionally are mixtures from many sources. This is especially true for the accumulation mode aerosols that typically create a substantial part of mass concentrations of fine particles known as $PM_{2.5}$ (all particles with aerodynamic diameter cut size below 2.5 μm). Since the publication of the Harvard Six Cities – study results (Dockery et al., 1993) the hypothesis that some elements and compounds present in ambient particles have to be more harmful to human health than others has remained one of the most studied aspects of the human exposures. Many of studies have applied receptor modelling and source apportionment methods such as positive matrix factorization on aerosol samples, and the results have been used in epidemiological analysis in attempt to observe differences in the various chemical constituents or the sources of origin of the particles. The analysis by Bell (2012) can be used as a general overview, showing that the observed variations in relationships between PM and health effects could only partly be explained by variation in the chemical composition of $PM_{2.5}$.

Less studied but equally obvious – when looking at Fig. 1 – health impact modifying factors would be particle size, infiltration, time-activity and population differences. In this discussion paper we aim at looking at one of these, infiltration. We will (i) create a time-activity model to demonstrate the significance of indoor exposures to overall exposure to ambient particles; (ii) review the literature and reanalyse reported data by European climatological regions for differences in

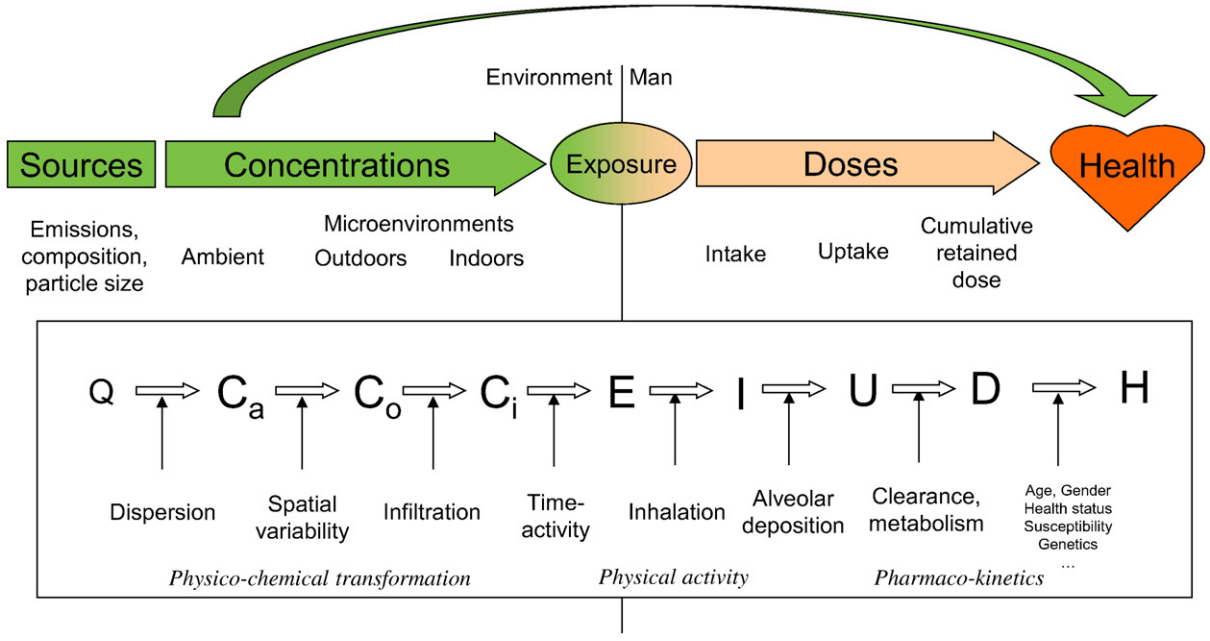

Fig. 1. Exposure chain and characteristic processes. Ambient epidemiology associates ambient (or in some cases outdoor) concentrations with health outcomes (the green arrow) skipping over microenvironments, time-activity, and intake processes. Thus differences in these can be expected to affect the observed concentration-response (CR) relationship.