Adjusting epidemiological C-R relationships for particle size dependent processes: infiltration and uptake

O. Hänninen

National Institute for Health and Welfare (THL), Department of Health Protection, P.O. Box 95, 70701 Kuopio, Finland

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Presenting author email: otto.hanninen@thl.fi

Epidemiological studies have shown that particles in ambient air cause premature mortality. Particles also increase hospital admissions and incidence rates of cardiovascular and pulmonary diseases. Burden of disease studies have shown that $PM_{2.5}$ is likely to be by far the most significant environmental exposure threatening human health in developed countries (e.g. Hänninen et al., 2014).

However, as we well know, $PM_{2.5}$ consists of particles ranging from few nanometers to the upper cut size of 2.5 µm. Particle size depends on the emission source and atmospheric processes. Substantial fraction of $PM_{2.5}$ particles are created from gaseous by atmospheric chemistry.

While epidemiology has associated the urban background $PM_{2.5}$ concentrations (C) with health responses (R) as estimated corresponding C-R relationships, actually two significant processes modify the aerosol composition before the particles reach the human respiratory system. The particle size affects both infiltration of ambient particles indoors, where modern humans spent more than 85% of their time, as well as uptake of the particles in the respiratory system. Acting together with time- and physical activity, these two processes modify significantly the relationship of concentrations (C) measured outdoors and resulting uptake (U) of particles in the respiratory tract. These processes are relevant for mass concentrations that have been extensively used in epidemiological studies, but also particle number and particle surface area doses, which have been suggested as potentially more relevant determinants of health effects.

The aim of this paper is to outline an integrated model to quantify the C-U relationships.

Methods. To estimate the impact of proposed adjustments on the epidemiological concentration response relationships we need information on the particle size distributions outdoors and simplified algorithms to estimate the infiltration and respiratory tract uptake processes. Particle size resolved measurement data is becoming more and more widely available due to advancement of especially optical but also other monitoring techniques. Sorjamaa et al. implemented an infiltration model for mass concentrations and tested it against population based measurements in Helsinki (Hänninen et al., 2013) to estimate the indoor particle size distributions originating from outdoor air. These can readily be utilized together with previously developed respiratory tract models. Based on the review by Hofmann (2011) we chose the ICRP (1994) model that has been widely used and validated well against the newer experimental and theoretical models.

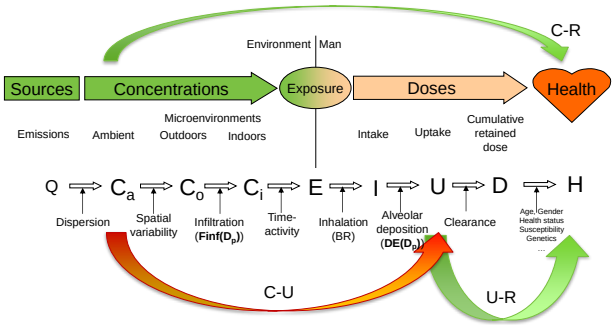

Figure 1. Exposure chain and modification of the C-R relationship by C-U relationship.

Results. Even though the human respiratory tract models show that 20-60 nm particles have the highest probability of being captured by the alveolar region of lung, as commonly is pointed out in ultrafine particle studies, these particles also are efficiently removed from intake air by buildings. Similarly, also coarse particles of ambient origin above 1 µm in diameter and certainly above 2.5 µm in diameter are efficiently removed by the infiltration process. Therefore exposures indoors are clearly dominated by accumulation mode particles in the size range 100 nm – 1000 nm.

Even accounting for the lower uptake probability of the accumulation mode particles (roughly about 20% of the maximum alveolar uptake probability around 30 nm) by the respiratory tract models still leaves the accumulation mode particles dominant for the uptake in the alveolar region. In the upper parts of the respiratory tract the supermicron particles play still a more significant role.

These methods need to be integrated with more detailed handling of time-activity and physical activity to see how the time spent especially in traffic and outdoors affects the uptakes.

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