An Integrated Exposure-Response Function for Estimating the Global Burden of Disease Attributable to Ambient PM$_{2.5}$ Exposure


Estimating the global burden of disease attributable to long-term exposure to ambient PM$_{2.5}$ requires cause-specific mortality relative risk (RR) functions which must apply over a global range of annual average concentrations from $< 10 \, \mu g/m^3$ to $>100 \, \mu g/m^3$. Cohort studies of long-term exposure to PM$_{2.5}$ and mortality from chronic disease have not been conducted in the most polluted regions of the world, and there is little direct evidence to identify the shape of mortality RR functions at high ambient concentrations.

We developed RR functions for the 4 leading global causes of adult mortality: ischemic heart disease (IHD), cerebrovascular disease (Stroke), chronic obstructive pulmonary disease (COPD), and lung cancer (LC)) over the global range of annual average PM$_{2.5}$, and an additional risk function for incidence of acute lower respiratory illness (ALRI) in children $< 5$ years.

We fit eight functional forms of a RR model to RR from different combustion sources on a common PM$_{2.5}$ scale, integrating RR from studies of ambient PM$_{2.5}$ (AAP), second hand smoke, household solid fuel use, and active smoking to estimate unknown model parameters. We simulated the uncertainty in RR predictions based on uncertainty in input RR values due to sampling error and model fit. We estimated the Population Attributable Fractions (PAF) for ambient PM$_{2.5}$ for 187 countries using PM$_{2.5}$ concentrations estimated at a 10km x 10km spatial resolution.

A three-parameter exponential decay saturation model with a power of PM$_{2.5}$ concentration fit best across the five health outcomes. The country-specific PAF (%) for AAP estimated from this model varied from: 2-41 for IHD, 1-43 for Stroke, <1-21 for COPD, <1-25 for LC, and <1-38 for ALRI.

PM$_{2.5}$ mass-based RR models for cause-specific mortality can be developed that cover the global range of exposure to AAP by integrating RR information from different combustion sources of PM$_{2.5}$. A specific RR model form was identified that provides superior predictive power compared to a range of alternative model forms.