Acute effects of fine particulate matter constituents on mortality: a systematic review and meta-regression analysis

Souzana Achilleos1, Marianthi-Anna Kioumourtzoglou1, Chih-Da Wu2, Joel D. Schwartz3, Petros Koutrakis2, and Stefania I. Papatheodorou4

1 Department of Environmental Health, Harvard T.H. Chan School of Public Health, Boston, MA, USA; 2 Department of Environmental Health Sciences, Columbia University Mailman School of Public Health, New York, NY, USA; 3 Department of Forestry and Natural Resources, National Chiayi University, Chiayi, Taiwan; 4 Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA, USA; 5 Cyprus International Institute for Environmental and Public Health, Cyprus University of Technology, Limassol, Cyprus

Introduction

The link between PM2.5 exposure and adverse health outcomes is well documented from studies across the world [1]. Yet, the reported health effect estimates vary across studies, locations and constituents, and it is still not clear which constituent(s) are associated with the highest risks to human health [2].

We conducted a meta-analysis on associations between short-term exposure to PM2.5 constituents and mortality using city-specific estimates, and explore factors that may explain some of the observed heterogeneity.

Methods

- We systematically reviewed epidemiological studies on particle constituents and mortality using PubMed and Web of Science databases up to July 2015.
- We included studies that examined the association between short-term exposure to PM2.5 constituents and all-cause, cardiovascular, and respiratory mortality in the general adult population.
- We extracted city-specific mortality risk estimates for each constituent and cause of mortality. For multi-city studies, we requested the city-specific risk estimates from the authors unless reported in the article.
- We screened for publication bias using Egger’s asymmetry statistical test.
- We performed random effects meta-analyses using city-specific estimates, and examined whether regional differences and city characteristics explained the observed heterogeneity.
- We also tested for inter-city heterogeneity in the reported effect estimates, and we provided the $p$-values of the $I^2$-based Cochran Q test and the $T^2$ metric of inconsistency.
- Only two of our studies adjusted for PM2.5 mass in their health models. Therefore, we can separate meta-analyses for the PM adjusted and un-adjusted effect estimates.

Results

- Our meta-analysis included 42 studies (142 cities) from the Americas, Europe, and Western Pacific; 38 studies were used for all-ages analysis and nine for the subgroup analysis of the population ≥65 years of age.
- PM2.5 effects (per 10 μg/m³)

All-cause mortality:
- PC: 0.89%; 95% CI: 0.68, 1.10% (Egger’s test $p$-value = 0.001)
- Adjusting for publication bias (): 0.53%; 95% CI:0.39, 0.67 %
- Single day () versus two-day exposure: 0.50%; 95% CI: 0.06, 0.94%; lag1 versus 1.01%; 95% CI: 0.77, 1.26%; lag0–1
- Highest effects were observed in North Central US (): 1.74%; 95% CI: 0.97, 2.50%

Cardiovascular mortality:
- PC: 0.80%; 95% CI: 0.41, 1.20% (Egger’s test $p$-value = 0.32)
- Adjusting for publication bias (): 0.78%; 95% CI: 0.52, 1.04%

Respiratory mortality:
- PC: 1.10%; 95% CI: 0.59, 1.62% (Egger’s test $p$-value = 0.04)
- Adjusting for publication bias (): 0.96%; 95% CI: 0.42, 1.50%

- Constituents effects

PM2.5-unadjusted effects:
- We observed significantly positive associations between all-cause mortality and Black Smoke (BS), EC, OC, SO2, Na, and Si (Figure 2). The association between all-cause mortality and EC (2.4%; 95% CI: 1.05, 3.66% per 2.6 μg/m³), and BS (0.74%;0.46,0.42% per 10 μg/m³) was stronger among the elderly.
- Similarly, positive associations were observed between cardiovascular mortality and BS, EC, NH4, NO3, Cl, and Ca and respiratory mortality with BS (not shown here).

PM2.5-adjusted effects:
- PM2.5-adjusted constituents effect estimates gave statistically significant associations between: 1) all-cause mortality and EC, K, and Cu; 2) cardiovascular mortality and V; and 3) respiratory mortality and V, and Zn.

Conclusions

Our meta-analysis suggests that (a) local combustion elements such as EC and K have a stronger association with mortality, (b) single lag studies underestimate effects, and (c) estimates of PM2.5 and constituents differ across regions. Accounting for PM mass in constituent’s health models may lead to more stable and comparable effect estimates across different studies.

References


Acknowledgements

This study was supported by the Harvard Cyprus Program and the Cyprus International Initiative for Environmental and Public Health in association with Harvard T.H. Chan School of Public Health. In addition, this publication was made possible by U.S. EPA grant numbers R8341701 and R8358721, and NIEHS grant ES007089. Its contents are solely the responsibility of the grantee and do not necessarily represent the official views of the USEPA. Further, U.S. EPA does not endorse the purchase of any commercial products or services mentioned in the publication. The authors also like to thank Dr. K. Basagaña, Dr. J.R. Knibb, Ms. D. Liu, Prof. K. Katsouyanni, Dr. E. Samaei, Dr. F. Bellúmero, Prof. R. Agusti, Dr. M. Cardin, Dr. H. Kan, Dr. A. Zambrano, and Dr. A. Vladi for providing us the city-specific mortality effect estimates of their studies.