HEI

STATEMENT

Synopsis of Research Report 210

HEALTH EFFECTS INSTITUTE

A Global Assessment of Burden of Disease from Exposure to Major Air Pollution Sources

INTRODUCTION

Exposure to air pollution has long been associated with mortality and shortened life expectancy and has been acknowledged as one of the main risk factors that affect people's health worldwide. Among all air pollutants, fine particulate matter ($PM_{2.5}$) has been identified as a substantial public health concern. The Global Burden of Disease (GBD) Study and similar assessments provide information on the impacts of outdoor $PM_{2.5}$ and other air pollutants on air quality and health, but they have not provided detailed information on which sources of air pollution are the biggest contributors to health burden.

HEI initiated the Global Burden of Disease from Major Air Pollution Sources (GBD MAPS) project to determine which air pollutant sources or fuels — including coal combustion, residential fuel burning, windblown dust, and waste combustion — contribute most to the outdoor $PM_{2.5}$ concentrations and their associated health burden. The first two GBD MAPS reports examined this question in China and India.

The current report conducted by Dr. Erin McDuffie and Dr. Randall Martin of Washington University in St. Louis, Missouri, Dr. Michael Brauer at The University of British Columbia in Canada, and colleagues, contains a global analysis of estimated source contributions to outdoor air pollution and related health effects using updated emissions inventories, satellite and air quality modeling, and relationships between air quality and health at global, regional, country, and metropolitan-area scales. The intent was to incorporate the data into annual updates to annual State of Global Air reports on global air quality and associated health effects in a joint project of HEI and the Institute for Health Metrics and Evaluation) (*www.stateofglobalair.org*) and to help identify priorities for source-specific policies and interventions.

What This Study Adds

- The study provides the first comprehensive estimates of source contributions to $PM_{2.5}$ levels and cause-specific disease burden at global, regional, and national scales to help inform policy.
- It used updated emissions inventories categorized by sector and fuel, satellite data and air quality modeling, and the most recent estimates of relationships between air quality and health.
- Major sources of $PM_{2.5}$ varied substantially by country, with notable contributions from energy generation, industry, transportation, windblown dust, and agriculture sectors in certain locations.
- Combustion of fossil fuels (coal, oil, and natural gas) contributed to an estimated one million deaths globally (27.3% of all mortality); 800,000 of those deaths were in South Asia or East Asia (32.5% of air pollution related deaths in those regions).
- The results are valuable additions to our understanding of how various sources of air pollution contribute to exposure and health burdens.
- All input data and results have been made publicly available to support the active development of finer scale air quality management strategies that focus on specific source sectors.

APPROACH

The GBD MAPS Global project was designed to assess potential health benefits that could result from air quality strategies targeted towards specific sector and fuel combinations. The approach was built on the existing GBD Study and GBD MAPS framework. The investigators applied globally consistent data and methods to inform policy to enable inclusion of results into future iterations of the GBD Study and State of Global Air reports.

McDuffie and colleagues started by expanding and updating the only publicly available global emissions inventory to generate monthly emissions data for 1970 to 2017 for seven key atmospheric pollutants

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Erin McDuffie (project lead) and Dr. Randall Martin (co-PI) of Washington University in St. Louis, Missouri, Dr. Michael Brauer (co-PI) at The University of British Columbia in Canada, and colleagues.

(nitrogen oxides, carbon monoxide, sulfur dioxide, ammonia, nonmethane volatile organic compounds, black carbon, and organic carbon), 11 anthropogenic sectors (including agriculture, energy, industry, and transportation), and four fuel categories (coal, biofuel, liquid fuel, and a remaining category that included such industrial processes as fugitive emissions).

The investigators used the emissions data in an updated global air quality model and combined those results with satellite data to model outdoor $PM_{2.5}$ at a final spatial resolution of 0.01° × 0.01° (about 1 km × 1 km at the equator). They compared the modeled concentrations of outdoor $PM_{2.5}$ with measurements made at many stations in different countries to confirm that the model gave realistic values. They then calculated average exposures to outdoor $PM_{2.5}$ for all the people living in different countries and world regions for the source sectors and fuel categories. To find the contributions of each sector or fuel in 2017, they looked at the changes in modeled outdoor $PM_{2.5}$ concentrations when they omitted that sector or fuel from the analysis. Finally, the investigators applied relationships between air pollution and health at different ages to calculate the numbers of deaths that were related to the outdoor $PM_{2.5}$ sources. They calculated historical impacts by assuming that the percentage contributions of the various source sectors and fuels had not changed.

KEY RESULTS

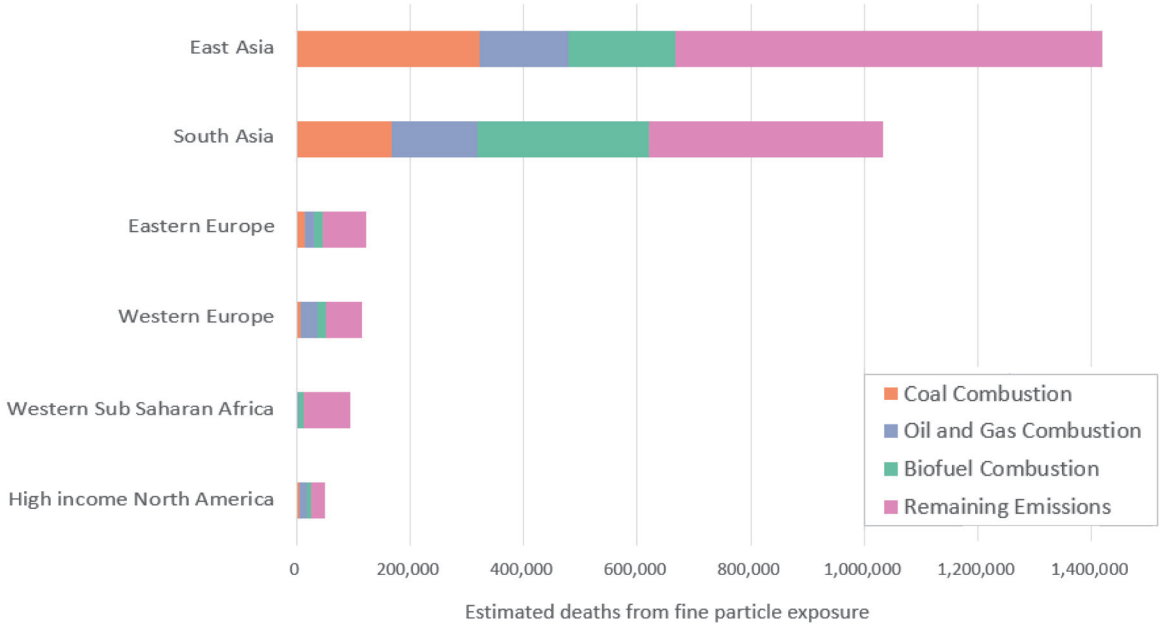
McDuffie and colleagues provide the first comprehensive estimates of source contributions to exposure to $PM_{2.5}$ and cause-specific disease burden at global, regional, and national scales. The investigators used detailed publicly available emissions inventories and found that the major sources of $PM_{2.5}$ varied substantially by country. Energy generation (including both electricity and residential cooking and heating was the largest source sector. Energy generation (including both electricity and fuel production) and industry were important source sectors in many countries. Windblown dust was the source sector that had the most variation; it accounted for 1.5% of deaths related to exposure to outdoor $PM_{2.5}$ in Bangladesh and 70.6% in Nigeria. Agriculture was an important contributor to health burdens from exposure to outdoor $PM_{2.5}$ in some regions because of emissions of ammonia, which is a precursor to $PM_{2.5}$. Combustion of fossil fuels (coal, oil, and natural gas) contributed to an estimated one million deaths globally (27.3% of all mortality); 800,000 of those deaths were in South Asia or East Asia (32.5% of deaths in those regions) (Statement Figure). Of the fossil fuels, coal contributed the highest emissions and related deaths. International shipping and agriculture sectors had higher impacts than are widely recognized. Biofuel and remaining emissions from fossil fuels and other sources also had substantial contributions that exceeded those of fossil fuels in some places.

When comparing their findings to the earlier studies in China and India, the investigators reported that the mix of air pollutant sources had remained similar in India between 2015 and 2017 but that emissions from combustion of coal and biofuels in China were reduced between 2014 and 2017. The patterns in the results were generally the same as in previous studies, although there were some variations because different relationships between air quality and health, emissions inventories, and air quality models were used. The research team has made all datasets, code, and visualizations publicly available to allow for future extensions and comparisons by other researchers (*gbdmaps.med.ubc.ca*).

EVALUATION AND CONCLUSIONS

In its independent review of the report, the ad hoc Special Review Panel identified as strengths of the study the global perspective, the application of standardized methods across countries, and the availability of data and code. The report includes a new contemporary and comprehensive global emissions inventory categorized by sector and fuel and new high-resolution $PM_{2.5}$ exposure estimates. The Panel commended the investigators for their work and observed that the rich data generated by this study will be a valuable resource to mine for additional details for years to come. Strengths of the approach are that it used (1) the most recent updated emissions data available, (2) current methods for modeling air pollution sources and combining the models with observations to assess and improve model performance, and (3) methods consistent with GBD methods to allow comparisons with previous GBD MAPS research.

The Panel concurred with the investigators that there were several sources of uncertainty that likely vary in magnitude by location and source sector that warrant further investigation: (1) the assumption that all particle mixtures have equal effects on mortality, (2) the quality and quantity of emissions and air quality data in different regions, and (3) the method to exclude emissions from source sectors one by one. The assumption that all particles are equally toxic in particular could have important implications for policy given that natural sources with high uncertainty in emissions estimates appear to dominate anthropogenic sources in several regions (e.g., windblown dust in the western sub-Saharan Africa region).



Statement Figure. Estimated deaths for selected regions resulting from exposure to fine particles from combustion of coal, liquid oil and natural gas, biofuel, and remaining emissions that could not be cleanly allocated to combustion of one of those fuels (e.g., fugitive emissions, windblown dust, or industry sources that use multiple fuels).

Having said that, the Panel found that overall, the major conclusions of the analysis, especially at the global scale, are valuable additions to our understanding of how the range of different sources of air pollution contribute to exposure and health burdens. This report provides information on air pollutant source sectors and fuel types that contribute to mortality associated with outdoor concentrations of $PM_{2.5}$ in various countries and regions and will have important implications for the prioritization of which air pollution source sectors to address with policies given the profound differences in source contributions across locations. The results and new datasets will support the active development of finer scale air quality management strategies that focus on specific source sectors and be incorporated in future GBD assessments and the associated State of Global Air communications.

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