HEI

STATEMENT

Synopsis of Research Report 217

HEALTH EFFECTS INSTITUTE

Long-Term Exposure to Outdoor Ultrafine Particles and Black Carbon and Effects on Mortality in Montreal and Toronto, Canada

BACKGROUND

There remain important limitations and challenges when estimating long-term air pollution exposure for use in epidemiological studies. In 2019, the Health Effects Institute therefore issued Request for Applications 19-1 to develop and apply scalable novel approaches to improve assessments of long-term exposures to outdoor air pollutants that vary highly in space and time. Dr. Weichenthal was one of the five investigators funded under this Request for Applications. Dr. Weichenthal and colleagues assessed associations of long-term exposures to outdoor UFPs and black carbon with mortality in Toronto and Montreal, Canada, using several exposure modeling approaches.

APPROACH

Weichenthal and colleagues conducted mobile monitoring campaigns in both cities in 2020 and 2021, thus during the COVID-19 pandemic, covering various times of day, weekdays, weekends, and all four seasons. They measured UFP number concentrations, UFP size, and black carbon in real-time. Data were calculated for each 100-m road segment (equivalent to about 6 seconds of observation per visit) and averaged over all sampling days. On average, each road segment was visited on 10 different days.

The investigators developed three new exposure models for each city separately: (a) land use regression models based on the mobile monitoring data combined with detailed land use and traffic information; (b) machine learning models, specifically convolutional neural network models using mobile monitoring data and aerial images from Google Maps; and (c) a combination of these two models. They examined the new exposure models with and without backcasting to 2006 based on historical trends in traffic information and nitrogen oxide emissions. They also used survey data to examine the exposure models with and without accounting for neighborhood-level daily mobility patterns.

What This Study Adds

- The study assessed associations of long-term exposures to outdoor ultrafine particles (UFPs) and black carbon with mortality in Canada, using several exposure modeling approaches.
- New mobile monitoring campaigns in Toronto and Montreal in 2020 and 2021 provided detailed data to develop high-resolution exposure models, including land use regression and machine learning models.
- The investigators then applied those exposure models to 1.5 million Canadian adults from the Canadian Census Health and Environment Cohort residing in both cities.
- The exposure models that combined land use and machine learning model predictions performed slightly better versus models that used land use regression alone.
- Long-term exposures to UFP number concentrations and black carbon were positively associated with mortality in single-pollutant models, but effect estimates were sensitive to adjustment for co-pollutants and UFP size.

The investigators then applied those models to a large representative sample of Canadian adults (1.5 million) from the Canadian Census Health and Environment Cohort residing in Toronto or Montreal. The study population included adults who were 25 years and older from multiple Census years (1991–2006), with mortality follow-up from 2001 to 2016. Exposures were assigned to participants based on home postal code (about the size of a city block) and accounted for address changes over time. The investigators used both single and multipollutant Cox proportional hazard models to assess the association between exposures to UFP number

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Scott Weichenthal at McGill University in Montreal, Quebec, Canada, and his colleagues. The complete report, *Long-Term Exposure to Outdoor Ultrafine Particles and Black Carbon and Effects on Mortality in Montreal and Toronto, Canada*, ©2024 Health Effects Institute, can be downloaded from *www.healtheffects.org/publications*.

concentrations and black carbon, and nonaccidental and cause-specific mortality. They adjusted the health analyses for important confounders, such as sociodemographic factors and co-pollutants. Specifically, the UFP number concentration analyses were adjusted for fine particulate matter, oxidant gases (a combination of nitrogen dioxide and ozone), UFP size, and black carbon; the black carbon analyses were adjusted for fine particulate matter, oxidant gases, UFP size, and UFP number concentrations.

KEY RESULTS

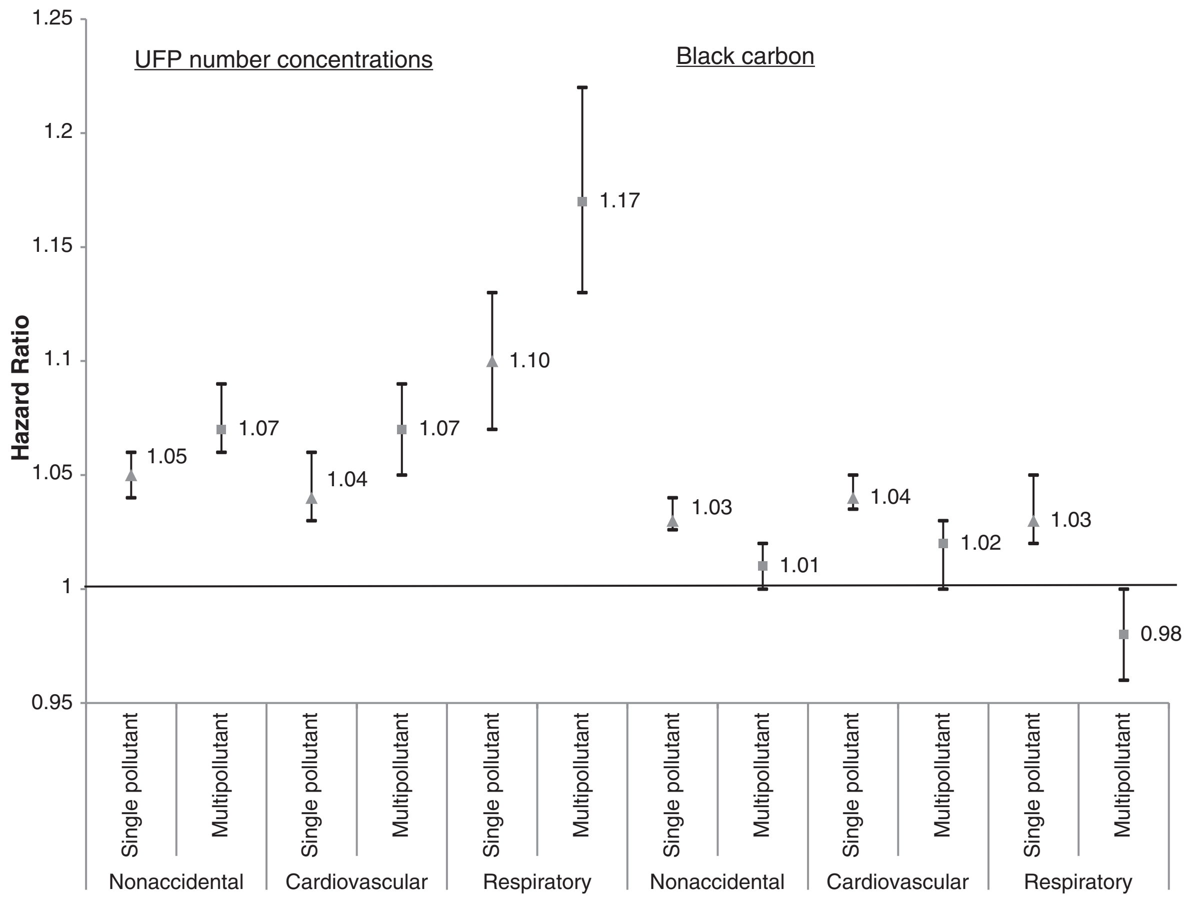
The exposure models that combined land use regression and machine learning model predictions performed slightly better as compared to land use regression models alone. The combined model explained half or more of the observed spatial variation in UFPs and black carbon.

Using the combined exposure model with backcasting, the investigators documented that long-term exposures to UFP number concentrations and black carbon were positively associated with mortality in single-pollutant models. However, these results were sensitive to adjustment for co-pollutants and UFP size. Associations between UFP number concentrations and mortality increased after adjusting for UFP size, whereas associations between black carbon and mortality became generally weaker or null (**Statement Figure**).

Generally, similar findings were reported for black carbon across various alternative exposure assessment approaches, including without backcasting and accounting for mobility patterns. For UFP number concentrations, the association's magnitude — but not the direction — differed substantially across the various alternative exposure approaches.

INTERPRETATION AND CONCLUSIONS

In its independent review of the study, the HEI Review Panel thought the research was well-motivated and addressed a clear research gap because there are few long-term air pollution and health studies on UFPs. The extensive year-long mobile monitoring campaign and the rigorous development and innovative features of the new high-resolution models were considered to be strengths of the study. Another strength was the use of a large representative sample of Canadian adults to evaluate the sensitivity



Statement Figure. Adjusted hazard ratios for UFP number concentrations (per 10,000 particles/cm³) and black carbon (per 500 ng/m³) and selected mortality outcomes using the combined exposure model with backcasting.

of the epidemiological analyses to different exposure assessment approaches.

Although the Panel broadly agreed with the investigators' conclusions, some limitations should be considered when interpreting the results. Importantly, the adjustment for UFP size in health analyses of outdoor UFP number concentrations and black carbon was intriguing. However, it remains unclear how to interpret UFP size and this remains an area that warrants further research. More advanced multipollutant statistical approaches might be needed to capture the complex relationships across the different pollutants. The monitoring and exposure assessment approaches contained some uncertainties, such as the lack of fixed-site monitoring and the temporal mismatch between the period captured by the mobile measurements and the exposure window most relevant for epidemiological purposes. The findings in the current study of two Canadian cities might not be generalizable to other settings, partly due to distinct characteristics of these cities.

In summary, data from mobile monitoring are useful for developing high-resolution machine learning models and other exposure models but can have important limitations. Therefore, careful consideration is needed when using them in exposure assessment or epidemiological analyses.

HEALTH
EFFECTS
INSTITUTE

75 Federal Street, Suite 1400
Boston, MA 02110, USA
+1-617-488-2300 phone
+1-617-488-2335 fax
www.healtheffects.org