HEI STATEMENT

Synopsis of Research Report 226

Comparison of Long-Term Air Pollution Exposure from Mobile and Routine Monitoring, Low-Cost Sensors, and Dispersion Models

BACKGROUND

Important limitations and challenges remain when estimating long-term exposure to ambient air pollution for use in epidemiological studies. In 2019, the Health Effects Institute issued the Request for Applications 19-1 to develop and apply novel, scalable approaches to improve assessments of long-term exposures to outdoor air pollutants that vary widely in space and time.

Dr. Hoek was one of the five investigators funded under this Request for Applications. Dr. Hoek and colleagues compared the performance of a suite of air pollution exposure assessment methods in the Netherlands, including a comparison of health effects estimates among different methods. They assessed four pollutants — ultrafine particles, black carbon, fine particulate matter, and nitrogen dioxide — and used existing data and models from previous collaborative projects where available.

APPROACH

The investigators evaluated annual average outdoor air pollution concentrations using a suite of exposure assessment methods that differ in their monitoring data and modeling approaches, such as land use regression models and air pollution dispersion models (see **Statement Figure 1**). In addition, to better accommodate nonlinearity and complex interactions in the data, they tested various model development algorithms beyond linear regression, including machine learning methods.

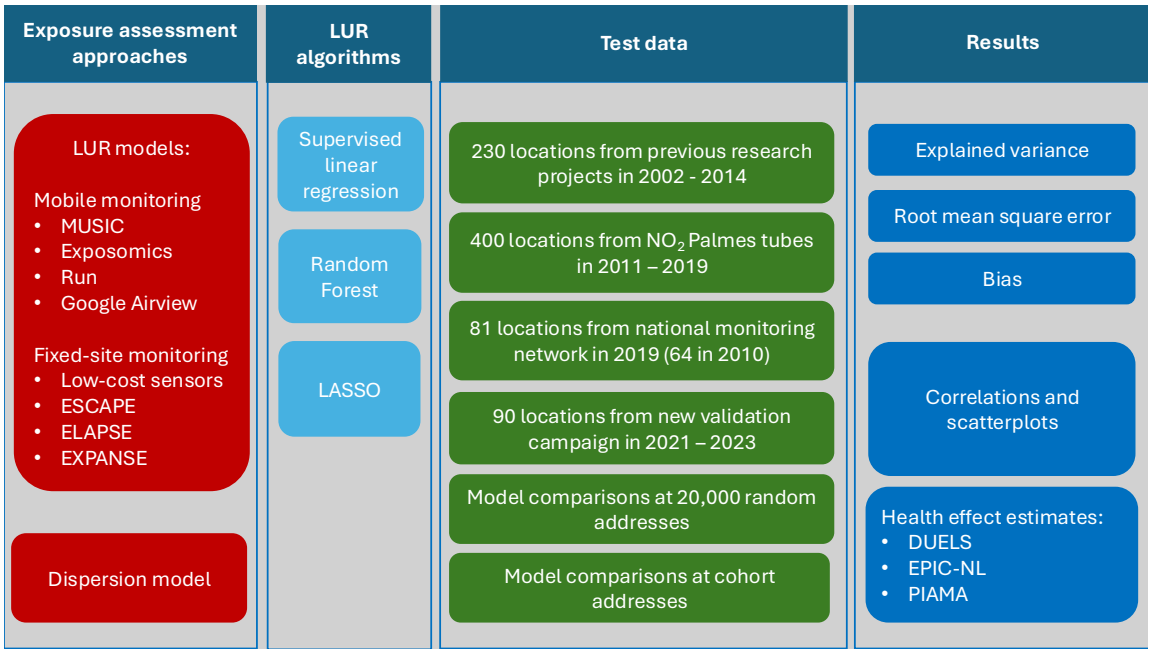
The investigators compared predictions of the exposure models at 20,000 random residential addresses in the Netherlands and used existing and new validation data spanning a 20-year period at residential locations where appropriate. The investigators reported multiple measures to test the performance of the exposure models, including correlations, explained variance, and bias.

They conducted epidemiological analyses in three population-based cohort studies (DUELS, EPIC-NL, and PIAMA) to compare health effect estimates using various exposure assessment methods. For all cohort participants, the various exposure estimates were assigned to the residential address at the time of recruitment to the cohort. The investigators used single-pollutant Cox proportional hazard models for mortality and morbidity outcomes in DUELS and EPIC-NL, and linear regression and discrete-time hazard models for lung function and asthma incidence in PIAMA. All results were adjusted for age, sex, and individual and area-level socioeconomic status. EPIC-NL and PIAMA results were further adjusted for various lifestyle factors. The investigators expressed the effect estimates using fixed increments across methods and method-specific interquartile ranges of exposure. In further explorative analyses, the investigators examined if and why effect estimates differed among exposure assessment methods.

What This Study Adds

- The study compared the performance of a suite of long-term exposure assessment methods in the Netherlands for four air pollutants: ultrafine particles, black carbon, fine particulate matter, and nitrogen dioxide.
- The predictions of the exposure models were compared at 20,000 random residential addresses in the Netherlands and tested on existing and new validation data over a 20-year period.
- The various exposure models generally resulted in moderately to highly correlated exposure predictions for all pollutants except fine particulate matter.
- The study included a comparison of health effects estimates of the various exposure methods in three cohort studies.
- Similar findings were reported on the presence of an association with various mortality and morbidity outcomes among the various exposure estimates, albeit with sometimes notable differences in the magnitude of the associations.

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Gerard Hoek at Utrecht University, the Netherlands, and his colleagues. Research Report 226 contains the detailed Investigators' Report and a Commentary on the study prepared by the HEI Improved Exposure Assessment Studies Review Panel.



Statement Figure 1. Schematic overview of the study design. LUR = land use regression

KEY RESULTS

The various exposure models generally resulted in moderately to highly correlated exposure predictions for black carbon, nitrogen dioxide, and ultrafine particles at residential sites across the Netherlands (correlation coefficient $R > 0.7$). In some cases, the predicted exposure levels and exposure contrast varied widely between methods. For fine particulate matter, the correlations between the different models were generally lower ($R < 0.4$), particularly for the poorly performing mobile monitoring models, and exposure contrast was comparatively low. In most comparisons, the investigators observed only small differences among the three land use regression algorithms.

Exposure models explained a low to moderate amount of spatial variance in ultrafine particles and nitrogen dioxide measurements at the new validation sites, and a positive bias (overestimation) was reported for all models. Most models explained a moderate amount of spatial variance in past exposures at existing validation sites for black carbon and nitrogen dioxide and explained less variance for ultrafine particles. Most models predicted past exposures of fine particulate matter poorly.

The application of the various exposure assessment approaches in health studies led to similar findings on the presence of an association with various mortality and morbidity outcomes, albeit with sometimes notable differences in the magnitude of the associations. Positive (adverse) associations were observed most clearly in DUELS and to a lesser extent in PIAMA. Null or sometimes even negative associations were reported in the EPIC-NL cohort. There were no consistent differences in effect estimates between exposure assessment approaches based on mobile monitoring, fixed-site monitoring, or dispersion models.

Factors that explained some of the heterogeneity of effect estimates included the performance of the model at external validation sites and the predicted exposure contrast. The year of the exposure model did not explain the heterogeneity, and the investigators documented stable spatial contrasts over a 10-year period in a subset of models that had multiyear predictions available.

INTERPRETATION AND CONCLUSIONS

In its independent review of the study, the Panel thought the study was well-motivated and effectively leveraged a wealth of air pollution and health data. The comparison of a large suite of exposure models commonly used in epidemiological studies was notable, making the results relevant and widely applicable. The extensive validation efforts and the reporting of multiple measures to test the performance of the exposure models were considered additional strengths. Applying those models in relation to various health outcomes in three different cohorts was another strength. In particular, the health analysis for a very large population

(10.8 million in DUELS) that included all Dutch adult citizens aged 30 years or older was considered informative.

Although the Panel broadly agreed with the investigators' conclusions, some limitations should be considered when interpreting the results. The comparison of the different exposure approaches using new validation data was hampered by the short duration of the measurements, the nonsimultaneous sampling, and the small number of repeated measurements for the different seasons. Those issues limited the ability to extrapolate the measurements reliably to annual mean exposures and then compare them with the various predictions from annual average air pollution models. Some comparisons using existing validation data were limited by similar temporal coverage issues.

Substantial heterogeneity was found in the magnitude — but not the direction — of the air pollution associations of the different exposure assessment methods within and across studies. The Panel thought the heterogeneity was not fully explained by the various factors considered in the study and warrants further examination.

Overall, the comprehensive report includes many findings that will be of broad interest and value to a wide audience.