HEALTH EFFECTS INSTITUTE

STATEMENT

Synopsis of Research Report 179

Development and Application of an Aerosol Screening Model for Size-Resolved Urban Aerosols

BACKGROUND

Dr. Charles O. Stanier, a recipient of HEI's Walter A. Rosenblith New Investigator Award, and Dr. Sang-Rin Lee developed, tested, and evaluated an aerosol screening model for estimating the number concentrations and size distribution of ultrafine particles, defined as particles less than 100 nm in aerodynamic diameter, in near-road environments with high spatial resolution (~10 m). In the urban atmosphere, ultrafine particles are derived primarily from motor vehicles, and their concentrations vary greatly because of steep concentration gradients near traffic sources. Thus assessing exposure to ultrafine particles is challenging, and there is a need for improved models.

APPROACH

The main goal of the study was to develop, test, and evaluate an aerosol screening model of hourly size-resolved number concentrations and distributions for particles in the size range of 3 nm to 2.5 μm. The aerosol screening model is an integrated model based on the Lagrangian modeling framework, which assumes columns of air parcels that move downwind with larger steps when far from receptors and smaller steps when close to receptors. The assumptions used by the aerosol screening model include rapid mixing of tailpipe emissions, emissions evenly mixed horizontally across the road width and carried beyond the edge of the road by diffusion and advection with the wind (i.e., downwind transport), and rapid mixing into a predefined vertical distribution.

Model design and construction were guided by the desire for the model, first, to have the ability to model concentrations over short (1-hour) and longer (24-hour) periods at sites with various traffic volumes and patterns and at various distances from roads and, second, to use a large database of road segments and emission factors derived from different data sources. It was also important that the model estimates could be compared with field measurements made with a condensation particle counter (CPC) and a scanning mobility particle sizer (SMPS), which have different lower size cutoffs.

What This Study Adds

- Stanier and Lee developed and tested an aerosol screening model to simulate the dispersion of ultrafine particles near roadways using a Lagrangian dispersion framework. The model estimated particle numbers and size distributions at 11 sites in Los Angeles and Riverside counties in California.
- The performance of the model was mixed. The model predictions for the 24-hour average number concentrations were close to the preset performance targets; the predictions for the 1-hour average number concentrations were poor and did not capture the diurnal variations observed at several sites. Particle size distributions also were not well represented by the model.
- The study demonstrates the challenges involved in modeling ultrafine particles in urban areas. Although it remains unclear what the most useful applications of this model will be, it offers promise for further improvements.

This Statement, prepared by the Health Effects Institute, summarizes a research project funded by HEI and conducted by Dr. Charles O. Stanier and Dr. Sang-Rin Lee at the University of Iowa, Iowa City. The complete report, *Development and Application of an Aerosol Screening Model for Size-Resolved Urban Aerosols* (© 2014 Health Effects Institute), can be obtained from HEI or our Web site (see next page).

The model was run to predict hourly and 24-hour concentrations and size distributions of particle number and mass at 11 sites in California where real-time measurements were made in previous studies. These included seven sites around the port of Long Beach (one of the busiest commercial ports in the United States) that were part of the Harbor Community Monitoring Study (HCMS) and four sites near retirement communities in Los Angeles and Riverside counties that were part of the Cardiovascular Health and Air Pollution Study (CHAPS).

RESULTS AND INTERPRETATION

The investigators assessed the performance of the aerosol screening model by comparing the 1-hour and 24-hour-average simulations with the corresponding measured concentrations. Correlations between the modeled and measured 1-hour and 24-hour average number concentrations differed.

For the 24-hour measurement, the model's performance was not far from the preset targets. For the 1-hour average number concentrations, the model's performance was poor and did not capture the diurnal variations observed at several sites. In general, the performance was better at the CHAPS sites, which were further from freeways and had a lower volume of heavy-duty vehicles compared with the majority of the HCMS sites. The investigators found that when the modeled values failed to fall in the specified ranges, the model typically underestimated the particle concentrations. Sensitivity analysis showed that the model was sensitive to traffic volume and type, as well as to road class.

The investigators compared modeled and measured size distributions at two of the Long Beach sites, LB4 and LB5. The modeled size distributions differed from the measured distributions for many of the simulations. The investigators concluded that the model underpredicts particle number concentrations for all particles sizes ≥ 15 nm and overpredicts concentrations for particle sizes < 15 nm.

CONCLUSIONS

Modeling the number and size distributions of ultrafine particles in epidemiologic studies is challenging, and only a few approaches have so far been tested. Thus the Committee thought that the study addressed an important research need. This ambitious study was carefully planned and performed, and the work was of high quality. The Committee felt that Stanier and Lee had chosen a high level of complexity for a screening model, that the model would require additional simplifications for actual screening applications, and that additional information would be needed for more detailed applications.

The strengths of the model are its flexibility to incorporate additional processes, the automated procedure to process road network and traffic data, and the synthesis of emission data for particle number by size from various research groups (a complex task). Model limitations are implicit in the Lagrangian approach, which assumes that all the air parcels move downwind at the same rate and communicate by diffusion, but which does not allow any movement through their boundaries associated with changes in wind speed and direction.

Evaluation of the model indicated that the predictions of the 24-hour average number concentrations were close to the preset performance targets; the predictions of the 1-hour average number concentrations were poor and did not capture the diurnal variations observed at several sites. Particle size distributions were not well represented by the model, at least in part because of uncertainties in the emission factors.

The Committee agreed with the investigators' overall assessment that the performance of the model in predicting particle number and size distribution was mixed. The results suggest that the model might be more suitable for studies that require long-term (i.e., 24-hour or longer) averages.

The study reflected the challenges involved in modeling dynamic concentrations of UFPs in urban areas, including the complex behavior of UFPs in the atmosphere as well as our limited knowledge not only of size-resolved emission factors as a function of vehicle types and operating modes, but also of emissions from non-mobile sources. Given the complexity of the model and the limitations of the Lagrangian framework in modeling the behavior of ultrafine particles, it remains unclear what the most useful application of this model will be. However, the model offers promise for further improvements and has the flexibility of incorporating additional inputs such as fleet information and emissions from off-road sources.

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