Modeling Exposures to VOCs via an Individual-Based Approach Part II: Application to an "Air Toxic Hot-Spot" Area in Camden, NJ

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Abstract

An Individual Based Exposure Modeling (IBEM) application of the MENTOR-1A system was completed for an "air toxic hot-spot" area in Camden, NJ to characterize ambient and personal exposure levels for two air toxics (benzene and toluene). The IBEM application of the MENTOR-1A system used subject-specific information collected from the field study, such as demographic, housing characteristics, time-activity patterns, etc. to estimate personal exposures in the framework of a source-to-exposure sequence. The emissions-based ambient concentration estimates of air toxics at the residence of each subject were calculated using atmospheric dispersion models, specifically the Industrial Source Complex Short Term Version 3 (ISCST3) and the AMS/EPA Regulatory Model (AERMOD). Calculated outdoor concentrations, and those measured during the study were then combined with information from activity diaries completed by the subject as inputs to the MENTOR-1A system for estimating personal exposures resulting from outdoor sources. The modeling results were compared to the measurements of neighborhood and personal air concentrations collected in a field study for model evaluation. The MENTOR-IBEM approach involved the use of local ambient measurements and subject-specific time-activity pattern data to estimate the percentage contributions of air toxics to personal exposures resulting from ambient sources. This approach facilitated the interpretation of factors such as location, day-of-the-week, and seasonal effects on personal exposure measurements.

Objectives

The aims of this study were to:

(a) Conduct an IBEM application of the MENTOR-1A system for a "hot spot" area in Camden, NJ and evaluate the viability of the IBEM application by comparing modeling results with ambient and personal measurements collected from the field study;

(b) Characterize the impact of local industrial and mobile air toxics sources on personal exposures and local air pollution in the area of Camden, NJ; and

(c) Establish the refinements necessary for applying the modeling tools of the MENTOR system for future population exposure and health assessments in "hot spot" areas.

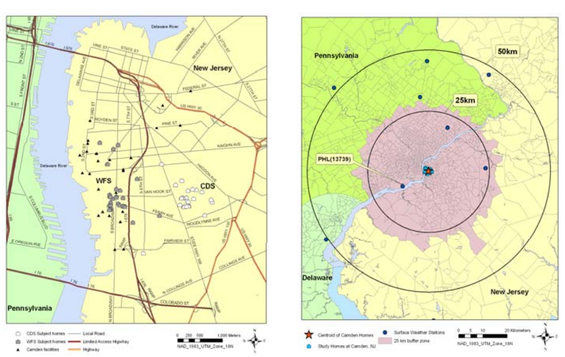
Approach

The IBEM implementation of MENTOR-1A was exercised for each of the 108 subjects living in Waterfront South (WFS) and Copewood/Davis Streets (CDS) of Camden, New Jersey (NJ) during the study period from 2004 to 2006. The generalized 7 step approach of MENTOR-1A, accounting for the processes determining exposures/doses from source-to-dose, is employed in this study (see the flowchart in Part I).

Geographic Location of Study Area

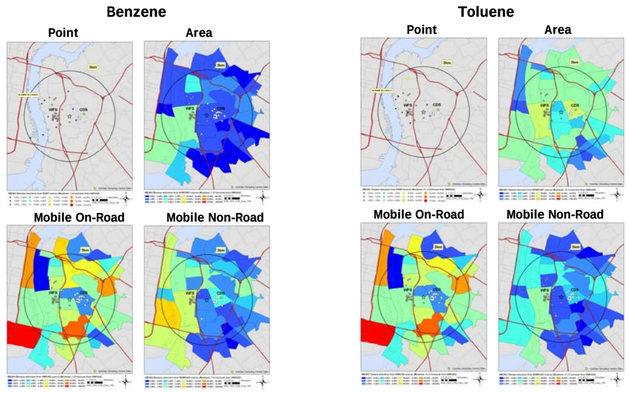
The geographic locations of the subjects' homes in the neighborhoods of Waterfront South (WFS) and Copewood/Davis Streets (CDS) in Camden, NJ are shown in (a). The emission modeling domain, including all the census tracts located within the 25km radius from the geographical center of the sampling homes in Camden, NJ is shown in (b).

(a) (b)



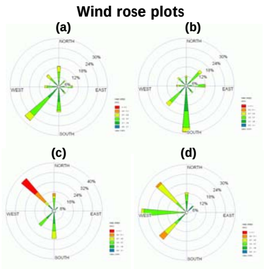
Fine-Scale Allocation of Source Emissions

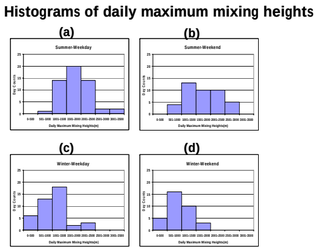
The Emissions Modeling System for Hazardous Air Pollutants Version 3 (EMS-HAP [Strum et al., 2004]) was used to process the 2002 National Emission Inventory data (NEI-2002) for the subsequent ambient air quality modeling using ISCST3 and AERMOD. The EMS-HAP modeling outputs are presented below for benzene and toluene emissions from all sources located within a 3km radius from the centroid of the sampled homes in Camden, NJ. Mobile and area sources were allocated per census tract.



Meteorological conditions

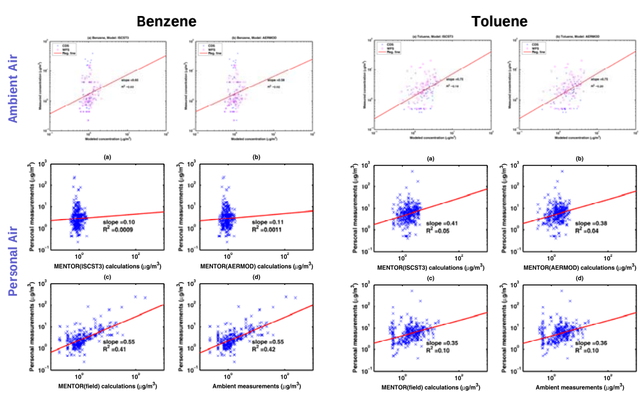
Wind rose plots summarizing the wind speeds and wind directions as well as histograms of daily maximum mixing heights are presented for the following four categories: (a) summer weekday, (b) summer weekend, (c) winter weekday, and (d) winter weekend, during the period of April 2004 - July 2006. The data for wind speeds and wind directions were obtained from the meteorological station of Philadelphia International Airport (WBAN number 13739). The direction of winds shown is the direction from which the wind is blowing.





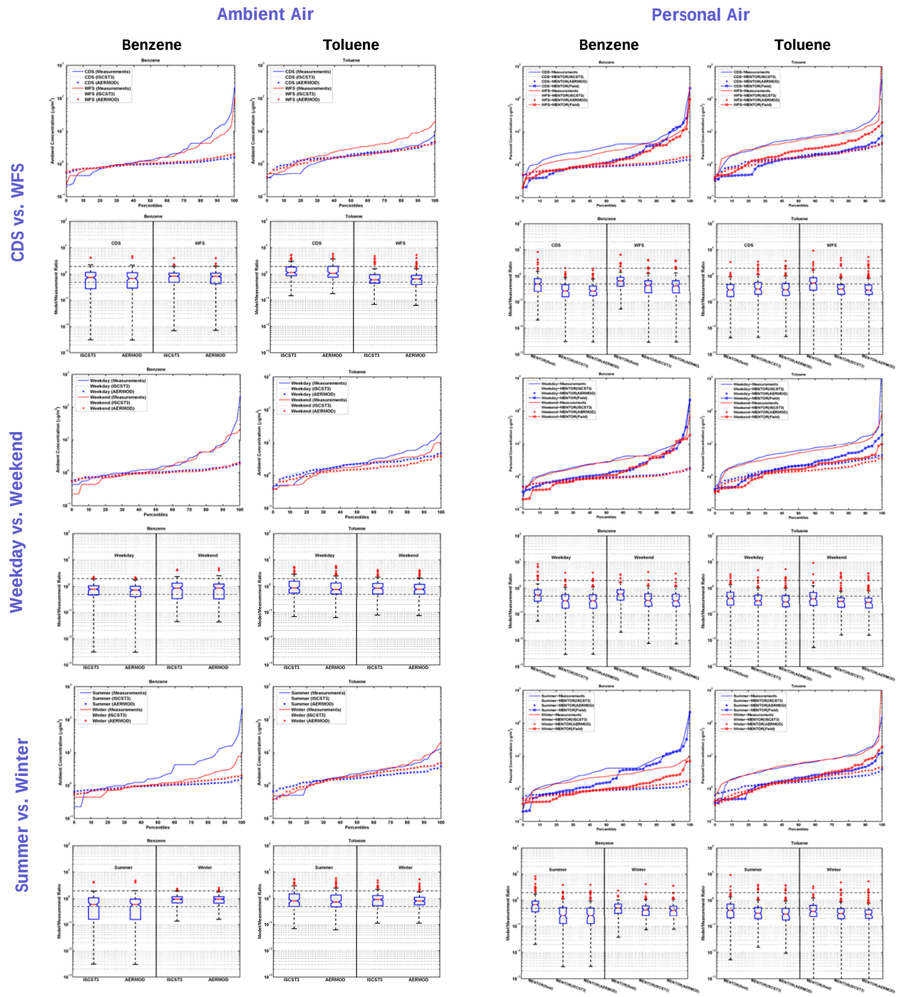
Results of Ambient and Exposure modeling

Scatter plots (along with linear regression statistics) of the ambient benzene and toluene measurements at the two stationary sites (CDS and WFS) versus the corresponding dispersion model predictions are shown in the 1st row of the 6-panel plots below. The 2nd and 3rd rows correspond to the scatter plots (along with linear regression statistics) of benzene and toluene personal measurements versus the MENTOR predictions of personal exposures due to ambient sources with the inputs of (a) ISCST3 ambient estimates, (b) AERMOD ambient estimates, and (c) the ambient measurements, while in (d) the personal vs. ambient measurements. All measurement data collected during the period of April 2004 - July 2006 are used.



Operational Model Evaluation

Two types of plots were generated to facilitate comparisons between measurements and model predictions: (1) cumulative distribution functions (CDF) and (2) box-plots of model-to-measurement ratios. CDF plots reveal differences between measurements and model predictions for the whole distribution without pairing the values. CDF plots can also show the general trends in differences between groups of measurements and corresponding model predictions stratified by their attributes such as location (i.e., WFS vs. CDS). The box-plots of the model-to-measurement ratios are used for more rigorous model performance evaluation, by pairing them in space and time. If the model predictions consistently agreed with the measurement data for the pollutant, the box plots would be short, and centered at "1".



Conclusions

The IBEM implementation of MENTOR-1A was applied to a "hot-spot" area in Camden, NJ for characterizing ambient and personal exposure levels for two air toxics (benzene and toluene). Model predictions were evaluated against ambient and personal measurements collected in the field study. The evaluation results provide insights and identify limitations and data gaps in applying the MENTOR-IBEM approach to "hot-spot" areas. The MENTOR-IBEM approach demonstrated in this study involves the use of local ambient measurements and subject-specific time-activity pattern data to estimate the percentage contributions of air toxics to personal exposures resulting from ambient sources, which has not been pursued in previous studies. This approach has been applied in this study to characterize the impacts of local ambient concentrations on personal exposure levels and also to facilitate the interpretation of location, day-of-the-week, and seasonal effects on the personal measurements.

Acknowledgements

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