Characterizing the Spatial Variation of Air Quality near Roadways

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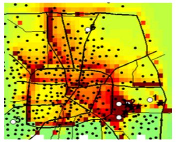
2009 AMAD Peer Review: Session 3
Linking Air Quality and Human Health

Environmental Issue

Houston population density


Modeled Benzene conc.

Over 36 million people in this country live within 100 meters of a four-lane or larger highway. A number of studies (e.g. Adar et al., 2007; Samet, 2007; Salam et al., 2008) have identified adverse health effects, including respiratory disease, cancer, and even mortality, for populations living, working, and/or attending schools near major roadways. EPA's Clear Air Research multi-year plan increases the emphasis on research to better understand the linkages between sources and health outcomes. A Near-Road Action Plan has been developed to integrate all of EPA/ORD's ongoing and planned activities addressing near-road issues. Within this five-year (2008-2012) plan to link roadway sources to health outcomes is the effort described here to further understand the atmospheric transport and dispersion of emissions within the first few hundred meters of the roadway, a region often characterized by complex flow (e.g. sound barriers, road cuts, buildings and vegetation). Examination of traffic emissions and potential population exposures near roadways has included preliminary studies of near-road emissions, and field and laboratory measurements of concentration distributions. Steep concentration gradients have been observed within the first few hundred meters of roadways. To simulate potential exposures, development has begun on improved roadway dispersion models and on assessments of low-cost mitigation strategies for schools.

Research Objectives

The ORD near-road research program's overall goal is to understand the source-to-health outcome continuum for roadway pollutants. The sub-objectives related to AMAD's work include the following:

► Characterization of the spatial variability of traffic-related pollutants near roadways using wind tunnel, computational fluid dynamics (CFD) and tracer and year-long field studies of roadway dispersion. The resulting data bases will be used for the development and evaluation of applied modeling tools.

► Assessment of how roadway design, meteorology, topography, and surrounding structures and vegetation affect near-road air quality.

► Assessment of inadequacies in applied dispersion models and development of improved modeling tools for linking traffic emissions to population exposures for use in regulatory decision-making, for evaluation of mitigation techniques and for transportation planning.

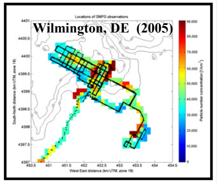
Research Approach

The overall approach to understanding the spatial distribution of traffic-related pollutants and for improving our tools for simulating the effects of roadside structures includes:
1) **Examining existing tools** - reviewing and evaluating existing models and data bases related to near road dispersion;
2) **Developing measurement methods** - developing methods for measuring near-road concentration distributions in both the laboratory and in actual urban situations;
3) **Performing new studies** - collecting and analyzing field, tracer, and wind tunnel measurements, as well as CFD results to understand the basic structure of flow and dispersion;
4) **Improving algorithms and modeling methodologies** - developing and evaluating improved algorithms and incorporating them into a selected near-field modeling platform (e.g. AERMOD) and as a subgrid algorithm within CMAQ.

Results and Discussion

1) **Examining existing tools**
An exhaustive review of 21 available dispersion models that simulate line-type sources was completed (Mactec, 2007). Based on the findings and recommendations of this report, AERMOD, was chosen as the best platform for further development for roadway scenarios. AERMOD is the current near-field and urban scale model recommended by the EPA for regulatory assessments.

2) **Developing meas. methods**
A methodology has been developed as part of this program to use mobile platform measurements over an urban area to characterize air-toxic concentration distributions (Isakov, et al. 2007). Successfully demonstrated on fine particulate and formaldehyde measurements in Wilmington, DE, the use of a mobile platform provides several advantages over fixed monitoring networks by providing measurements on a quick response basis over a large part of an urban area.

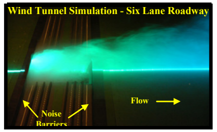


Mobile Platform - Particle Conc.

This methodology was adopted by EPA and is currently being applied with the GMAP mobile sampling vehicle in a series of intensive field studies examining the impact of roadside barriers on local air quality and their potential use for mitigation purposes.

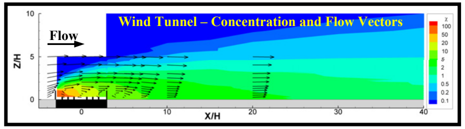

GMAP electric sampling vehicle

3) **Performing new studies**
An important tool for examining near road dispersion is the EPA's meteorological wind tunnel where the flow and dispersion around roadway scenarios (e.g. barriers, road cuts) have been examined.



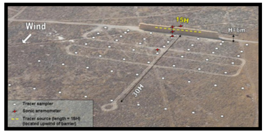
Double-barrier smoke visualization

Results and Discussion (cont'd)

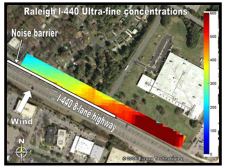


Double-barrier mean flow vectors and concentration distribution

Complementing the wind tunnel studies, (e.g.. to examine atmospheric stability) is a tracer study of line-source emissions upwind of a single 6 meter high wall typical for a road-side noise barrier.

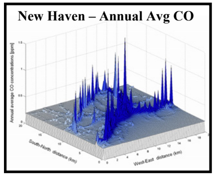


Single-barrier tracer study, Idaho Falls



Field measurements have been conducted along an eight-lane expressway in Raleigh, NC, examining the concentration gradient in a clearing and behind a noise barrier. The barrier influence is substantial. These data are critical for model development and evaluation.

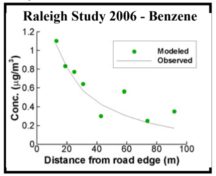
4) **Improving algorithms and modeling methodologies:**



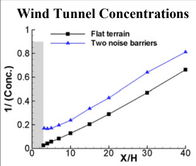
CO hot spots along major roadways

Cook et al. (2008) describe an approach for developing detailed highway emission inventories based on emission factors and traffic inventories for individual road links. This approach was applied with a hybrid model (poster 3.1) in New Haven, CT. Substantial spatial gradients were observed near roadways.

Applying a line-source model of Venkatram et al. (2007), the eight-lane expressway in the Raleigh 2006 field study was simulated for an area with no terrain changes or obstructions to the flow. The concentration gradient for benzene was matched well.



AERMOD line source algorithm

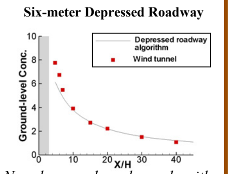


Double-barrier conc. gradient

Results of EPA wind tunnel studies provide initial indications that for distances beyond the cavity zone of the barrier, the effects of noise barriers can be simulated with a no-barrier model by adjusting the effective source location upwind by a distance of 5 to 10 barrier heights (Heist et al., 2007).

Results and Discussion (cont'd)

Based on previous wind tunnel studies (Perry et al., 1994), an algorithm has been developed for inclusion into AERMOD for simulating the influence of depressed roadways. The figure at right compares the modeled concentration gradient with newly-collected independent wind tunnel data.



New depressed-roadway algorithm

Future Directions

- Continued improvement of line-source type algorithms for the AERMOD and hybrid modeling for regulatory applications.
- Further wind tunnel studies and possible tracer studies to examine additional roadway configurations, wind direction and atmospheric stability influences.
- Collaboration with other EPA laboratories and the FHWA on field campaigns in Las Vegas, Detroit, and Raleigh to better understand the relationship between traffic emissions and roadway-related air pollution concentration gradients.
- Computational fluid dynamics modeling of near-road dispersion to complement wind tunnel and tracer studies.
- Use of the improved near-road dispersion models to support planned environmental health studies in Atlanta during 2009. This is an integral part of the "Air Pollution Exposure and Health Cooperative Agreement" between EPA/NERL and Emory University.

Impact

This research will impact a broad range of federal, state, and local programs and actions related to the protection of human health. With a focus on improving our understanding of the relationships between mobile emissions and adverse health effects and developing tools to assess roadway impacts and mitigation strategies, the products of this work will inform decision making within EPA and Federal Highway regulatory programs such as the National Environmental Policy Act, the Conformity rule, and enforcement of the NAAQS. Additionally, programs within the Departments of Health and Human Services, Education, and Housing and Urban Development and the Centers for Disease Control and Prevention will benefit from this research in developing guidelines for the location of schools, hospitals, and residential housing.

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