NOVEL APPROACHES FOR ESTIMATING HUMAN EXPOSURE TO AIR POLLUTANTS

T. Watkins[a], L. Baxter[b], H. Özkaynak[c], V. Isakov[a], and D. Mobley[b]

[a] Environmental Public Health Division, National Health and Environmental Effects Research Laboratory, Office of Research and Development, U.S. EPA, Research Triangle Park, North Carolina, 27711

[b] Human Exposure and Atmospheric Sciences Division, National Exposure Research Laboratory, Office of Research and Development, U.S. EPA, Research Triangle Park, North Carolina, 27711

[c] Office of Research and Development, U.S. EPA, Research Triangle Park, North Carolina, 27711

[d] Atmospheric Modeling and Analysis Division, National Exposure Research Laboratory, Office of Research and Development, U.S. EPA, Research Triangle Park, North Carolina, 27711

Abstract

Numerous health studies have used measurements from a few central-site ambient monitors to characterize air pollution exposures. Relying on solely on central-site ambient monitors does not account for the spatial-heterogeneity of ambient air pollution patterns, the temporal variability in ambient concentrations, nor the influence of infiltration and indoor sources. Central-site monitoring becomes even more problematic for certain air pollutants that exhibit significant spatial-heterogeneity. Improving characterization of air pollution exposures involves novel approaches to estimating ambient concentrations, a better understanding of the personal-ambient relationship, and personal exposure modeling. Estimates of ambient concentrations and human exposure estimates have been enhanced by utilizing both measurements and modeling tools. Statistical interpolation techniques and passive monitoring methods can provide additional spatial resolution in ambient concentration estimates. In addition, spatio-temporal models, which integrate GIS data and other factors, such as meteorology, have also been developed to produce more resolved estimates of ambient concentrations. Hybrid modeling approaches, which integrate regional scale models with local scale dispersion models, provide new alternatives for characterizing ambient concentrations. Estimating actual personal exposures requires an understanding of factors that impact personal-ambient relationships. Publically available data on housing characteristics (e.g., age and size of home) and commuting patterns can be utilized to understand these personal-ambient relationships. In addition, personal exposure modelling approaches are being developed, such as the Stochastic Human Exposure and Dose Simulation (SHEDS) model, which provides estimates of population exposures, and the Exposure Model for Individuals (EMI), which provide individual specific estimates of exposure. Many of these exposure characterization approaches are currently being applied and evaluated in epidemiological investigations. This paper describes the novel exposure assessment approaches discussed above and will briefly present results from the application of these tools. In addition, the paper will discuss ongoing and future applications of these approaches to evaluate their use in health studies.

Keywords: air pollution, epidemiologic studies, exposure, air quality modeling

1. INTRODUCTION

Numerous health studies have used measurements from a few central-site ambient monitors to characterize air pollution exposures. Relying solely on central-site ambient monitors does not account for the spatial–heterogeneity of ambient air pollution patterns, the temporal variability in ambient concentrations, or the influence of infiltration and indoor sources (Jerrett et. al. 2005, Fuentes, et. al. 2006, Sarnat et. al, 2006, Gryparis et. al. 2007). Central-site monitoring becomes even more problematic for certain PM components (e.g., metals) or size fractions (e.g., coarse, ultrafine) that exhibit significant spatial-heterogeneity. When central site monitoring is used as a surrogate for air pollution exposure, it does not take into account the spatial–heterogeneity pattern, particularly for certain PM components and size fractions. This variation may be influenced by meteorology as well as emissions from both regional and local sources. In addition, using central site monitors does not reflect the important contributors to human exposures, such as the influence of residential ventilation or indoor sources. Given that people spend the majority of their time indoors, the infiltration of outdoor air indoors and indoor sources can greatly affect the personal-ambient exposure relationship. Improving air pollution exposure characterization will result in more accurate risk estimates of associated health effects to inform future development of NAAQS and other air pollution regulations.

Improving characterization of air pollution exposures involves novel approaches to estimating ambient concentrations, a better understanding of the personal-ambient relationships, and personal exposure modeling. Various exposure characterization approaches are currently being applied and evaluated in several epidemiological investigations supported by the USEPA (Fig. 1).

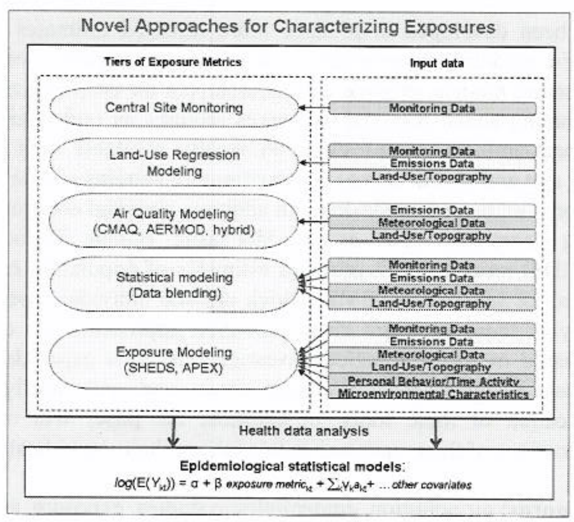

Figure 1. Various approaches to characterize air pollution exposures for use in environmental health studies.

2. NOVEL APPROACHES FOR ESTIMATING EXPOSURES

Estimates of ambient concentrations have been enhanced by utilizing both measurements and modeling tools. Statistical interpolation techniques and passive monitoring methods can provide additional spatial resolution in ambient concentration estimates. In addition, spatio-temporal models, which integrate GIS data and other factors, such as meteorology, have been developed to produce more resolved estimates of ambient concentrations. Models, such as the Community Multi-Scale Air Quality (CMAQ) model, estimate ambient concentrations by combining information on meteorology, source emissions, and chemical-fate and transport (Byun and Schere, 2006). In addition, hybrid modeling approaches, which integrate regional scale models (such as CMAQ) with local scale dispersion models, provide new alternatives for characterizing ambient concentrations. Publically available data on housing characteristics and commuting patterns can be utilized to understand the personal-ambient exposure relationships. The age and size of the home will affect the proportion of personal exposure due to ambient air, and commuting patterns will influence how representative an ambient monitor is to ambient exposure. Since publically available data are limited, estimating personal exposure modeling approaches, such as the Stochastic Human Exposure and Dose Simulation Model (SHEDS), are being developed (Burke et. al. 2001, Özkaynak et. al. 2007). The SHEDS model is a population exposure model that calculates distribution of exposures within the study population. An integrated air quality and exposure modeling system provides the means to predict the distribution of exposures for the population of interest in various microenvironments by linking air quality modeling information to SHEDS (Fig. 2). The integrated modeling system could be also operationally applied in air quality management practices such as standard setting, standard implementation, risk mitigation, accountability (Isakov et. al. 2006, Isakov et. al. 2009).

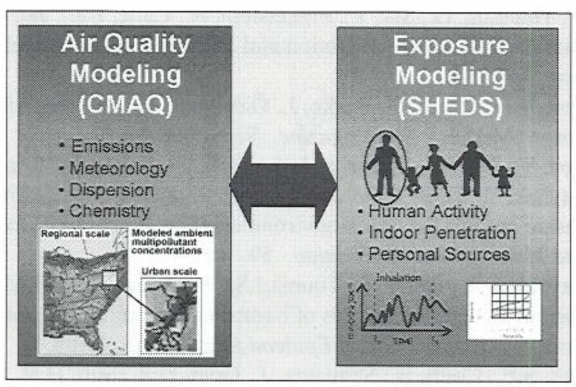

Figure 2. Integrated air quality and exposure modeling.

Improved models of ambient concentrations could be utilized in the reanalysis of existing PM health studies leading to more precise and potentially larger health effect estimates. In addition, studies have observed significant heterogeneity in PM-health effects across locations. One potential reason is that while PM mass concentrations may be similar across locations, the composition may be very different, making the understanding of sources very important. Another potential reason for the observed variability may be due to the geographic differences in the personal-ambient exposure relationships necessitating a better understanding of personal exposures. Additional model development is recommended for estimating personal exposures to PM species and specific sources and in developing an individual specific exposure model for use in cohort health studies.

Disclaimer: This paper has been subjected to Agency review and approved for publication. Approval does not signify that the contents reflect the views of the Agency nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REFERENCES

Burke, J.M., Zufall, M.J., and Özkaynak, H. 2001. A population exposure model for particulate matter: case study results for $PM_{2.5}$ in Philadelphia, PA. *Journal of Exposure Analysis and Environmental Epidemiology* 11, pp. 470 -489.

Byun, D.W. and K. Schere, 2006, Review of the Governing Equations, Computational Algorithms, and Other components of the Models-3 Community Multiscale Air Quality (CMAQ) Modeling System. *Applied Mechanics Review* 59, 51-77.

Fuentes, M., Song, H.R., Ghosh, S., Holland, D. and Davis, J. 2006. Spatial association between speciated particulate matter and mortality. *Biometrics* 62, pp. 855-863.

Gryparis, A, Coull, B., Schwartz, J., and Suh, H. 2007. Semiparametric latent variable regression models for spatiotemporal modeling of mobile source particles in the greater Boston area. *Applied Statistics* 56(2), pp 183-209.

Jerrett, M., Burnett, R.T., Ma, R., Arden Pope III, C.A., Krewski, D., Newbold, K.B., Thurston, G., Shi, Y., Finkelstein, N., Calle, E.E., and Thun, M.J. 2005. Spatial Analysis of Air Pollution and Mortality in Los Angeles. *Epidemiology* 16 (6), pp. 727-736.

Isakov, V., Graham, S., Burke, J., Özkaynak, H., Linking Air Quality and Exposure Models. *EM Magazine*. Sept 2006 26-29.

Isakov, V., Touma, J., Burke, J., Lobdell, D., Palma, T., Rosenbaum, A., Özkaynak, H., 2009. Combining regional- and local-scale air quality models with exposure models for use in environmental health studies. *Journal of Air and Waste Management Association*. 59: 461-472.

Ozkaynak,H.A., Palma,T., Touma,J.S., Thurman,J., 2007. Modeling population exposures to outdoor sources of hazardous air pollutants, *Journal of Exposure Science and Environmental Epidemiology* 18, pp. 45-58.

Sarnat, S.E., Coull, B., Schwartz, J., Gold, D.R., Suh, H.H., 2006. Factors Affecting the Association between Ambient Concentrations and Personal Exposures to Particles and Gases, *Environmental Health Perspectives* 114, pp. 649-654.