

From Sources to Biomarkers: A Hierarchical Bayesian Approach for Human Exposure Modeling

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The objective of this study is to characterize single- and multi-pollutant human exposures by linking sources to biomarkers using a multi-scale (areal, residential, and personal) hierarchical Bayesian model (HBM) that describes how multi-media pathways contribute to direct routes of exposure (inhalation, ingestion, dermal). We hypothesize that by incorporating several different sources of data that inform about pollutant pathways, our model will discern patterns in human exposures and allow us to draw more informed conclusions about current and future distributions of biomarkers. Our approach is to use a hierarchical Bayesian multivariate statistical model that has explicit stages for sources, regional environmental levels, indoor (residential) environmental levels, personal exposures, and biomarkers. The primary data sources are the National Human Exposure Assessment survey (NHEXAS) Phase I data from EPA Region 5 and Arizona, supplemented by census data, ambient air monitoring data, and emissions data. The expected results of this study include, but are not limited to, characterizations of (a) the distribution of biomarkers across the population as a whole and within subpopulations (defined geographically or by personal, behavioral, or housing conditions); (b) the impact of source emissions reductions on personal exposure levels; (c) the impact of personal, behavioral, and housing conditions on the distribution of biomarkers; and (d) the relative contribution to biomarkers from various pathways and routes of exposure. The multi-scale, multi-media, and multi-pollutant exposure models developed in this study will also serve as examples, illustrating how the HBM approach can be used to aid in the risk assessment process for other pollutants and in other settings.

Implications: By incorporating several different sources of data that inform about pollutant pathways, our model will discern patterns in human exposures and allow us to draw more informed conclusions about current and future distributions of biomarkers. The multi-scale, multi-media, and multi-pollutant exposure models developed in this study will also serve as examples, illustrating how the HBM approach can be used to aid in the risk assessment process for other pollutants and in other settings

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Presentations:

Cressie, N., Buxton, B.E., Calder, C.A., Craigmile, P.F., Dong, C., McMillan, N.J., Morara, M., Santner, T.J., Wang, K., Young, G., and Zhang, J. (2005). From sources to biomarkers: A Bayesian approach to human exposure modeling. Poster presented at Ohio State University-Battelle Research Forums, November 2005.

Cressie, N. (2006). A hierarchical Bayesian approach for human exposure modeling. Invited paper presented at the XXIII International Biometric Conference, Montreal, Canada, July 2006.

Cressie, N. (2006). A multivariate hierarchical Bayesian approach for human exposure modeling. Invited paper presented at the Multivariate Methods in Environmetrics Conference organized by the Section for Statistics and the Environment of the American Statistical Association, Chicago, IL, October 2006.

Cressie, N., Calder, C., Craigmile, P., McMillan, N., and Ryan, L. (2006). Bayesian hierarchical modeling of exposure pathways. Invited session at the Annual Joint Statistical Meetings, Seattle, WA, August 2006.

McMillan, N. and Cressie, N. (2006). From sources to biomarkers: A hierarchical Bayesian approach to human exposure modeling. Invited poster presented at the ICCA Workshop on Interpreting Biomonitoring Data, Minnesota, July 2006.

A series of eight weekly seminars titled Environmental Exposure and Health Data (EEHD) Seminar. (2007). Columbus Campus, Ohio State University, January – March 2007.

Buxton, B. and Calder, C. (2007). Spatial and temporal statistical modeling of human exposure and adverse health effects. Symposium at the Annual ISEA Conference, Research Triangle Park, NC, October 2007.

Calder, C. (2007). Bayesian modeling of exposure pathways. Invited seminar presented in the EEHD Seminar, February 2007.

Calder, C. (2007). Arsenic exposure pathways in subpopulations: Bayesian inference from NHEXAS data. Invited poster presented at ACC/ICCA/EPA workshop, Research Triangle Park, NC, September 2007.

Paul, R. (2007). Demographic and behavioral modifiers of arsenic exposure pathways: A Bayesian hierarchical analysis of NHEXAS data. Contributed paper presented at the Annual Joint Statistical Meetings, Salt Lake City, UT, July 2007.

Craigmile, P. (2008). Hierarchical model building, fitting, and checking: A behind-the-scenes look at a Bayesian analysis of arsenic exposure pathways. Invited seminar presented at the Roberston Center for Biostatistics, University of Glasgow, Scotland, June 2008.

Peer-reviewed publications:

Cressie, N., Buxton, B.E., Calder, C.A., Craigmile, P.F., Dong, C., McMillan, N.J., Morara, M., Santner, T.J., Wang, K., Young, G., and Zhang, J. (2007). From sources to biomarkers: A Bayesian approach to human exposure modeling. *Journal of Statistical Planning and Inference* 137: 3361-3379.

Santner, T.J., Craigmile, P.F., Calder, C.A., and Paul, R. (2008). Demographic and behavioral modifiers of arsenic exposure pathways: A Bayesian hierarchical analysis of NHEXAS data. *Environmental Science and Technology* 42: 5607-5614.

Calder, C.A., Craigmile, P.F., and Zhang, J. (2008). Regional spatial modeling of topsoil geochemistry. *Biometrics*. Published Online April 16, 2008.

Craigmile, P.F., Calder, C.A., Li, H., Paul, R., and Cressie, N. (2009). Hierarchical model building, fitting, and checking: A behind-the-scenes look at a Bayesian analysis of exposure pathways. *Bayesian Analysis*. (In press).

Other publications:

McMillan, N.J., Morara, M., and Young, G.S. (2006). Hierarchical Bayesian modeling of human exposure pathways and routes. *2006 Proceedings of the Joint Statistical Meetings, Section on Statistics and the Environment*. American Statistical Association, Alexandria, VA, 2492-2503.

Paul, R., Cressie, N., Buxton, B.E., Calder, C.A., Craigmile, P.F., Li, H., McMillan, N.J., Morara, M., Sanford, J., Santner, T.J., and Zhang, J. (2007). A Bayesian hierarchical model of arsenic exposure based on NHEXAS data: A comparison of US EPA Region 5 and Arizona. *2007 Proceedings of the Joint Statistical Meetings, Section on Statistics and the Environment*. American Statistical Association, Alexandria, VA, 1055-1062.

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