



ENVIRONMENTAL AND ECONOMIC RESEARCH AND DEVELOPMENT PROGRAM

Contributions of Fossil Fuel-fired Electric Power Generation to PM_{2.5} Concentrations in Wisconsin

Executive Summary
December 2012

PREPARED BY:

PROJECT PI:

PROF. JAMES J. SCHAUER, UNIVERSITY OF WISCONSIN-MADISON

PROJECT CO-PIs:

PROF. BEN DE FOY, SAINT LOUIS UNIVERSITY;

PROF. WILLIAM CHRISTENSEN, BINGHAM YOUNG UNIVERSITY;

PROJECT CONTRIBUTORS:

PROF. DEBORAH GROSS, CARLETON COLLEGE;

DR. JONGBAE HEO, UNIVERSITY OF WISCONSIN-MADISON;

ALISON M. SMYTH, CARLETON COLLEGE;

SAMANTHA L. THOMPSON, CARLETON COLLEGE;

JEROME McGINNIS, UNIVERSITY OF WISCONSIN-MADISON;

MIKE OLSON, UNIVERSITY OF WISCONSIN-MADISON;

NICK SAGAR, UNIVERSITY OF WISCONSIN-MADISON;



focus on energysm

Partnering with Wisconsin utilities

Executive Summary

The goal of the project was to incorporate state-of-the-art receptor and inverse transport models to quantify the contribution of fossil fuel-fired electric power generation to PM_{2.5} concentrations in Wisconsin. The project integrated four main components to achieve the overall project goal: 1) analysis of trends in the concentrations and components of historical PM_{2.5} measurements in Southeastern Wisconsin, 2) application of a multi-variant receptor model to existing PM_{2.5} monitoring data collected as part of the EPA Speciation Trends Network in Milwaukee (Site 550790026), Waukesha (Site 551330027), and Mayville (Site 550270007), 3) collection of targeted high time resolution PM_{2.5} chemical composition data used to understand the climatology that lead to speciated PM_{2.5} concentrations at rural and urban locations in Wisconsin, and 3) employ an inverse transport model and Concentrations Field Analysis (CFA) to identify the spatial distribution, including point, mobile, and area sources of speciated PM_{2.5} concentrations in Wisconsin.

A key conclusion of the project was that annual average concentrations of PM_{2.5} sulfate ion and PM_{2.5} nitrate ion at the Milwaukee and Waukesha sites were not statistically different from the concentrations observed in Mayville providing strong evidence that these PM_{2.5} components are largely transported into Southeast Wisconsin and are not greatly impacted by local emissions. The urban excess of PM_{2.5} for these sites is dominated by carbonaceous aerosols, which were found to be largely associated with local emissions of mobile sources and biomass burning. Given that ammonium sulfate and ammonium nitrate contribute approximately 50-60 percent of the annual average PM_{2.5} concentrations in Southeast Wisconsin and organic carbonaceous aerosol makes up another 25-35 percent, PM_{2.5} mitigation strategies need to address these PM_{2.5} components. Analysis of meteorological data demonstrates that days with high PM_{2.5} sulfate ion concentrations are associated with long range transport from the Ohio Valley, and high PM_{2.5} nitrate ions are associated with long range transport from the Ohio Valley and other regions of the Midwestern United States. The results demonstrate that although fossil fuel fired power generation is impacting the PM_{2.5} concentration and non-attainment periods; these impacting emissions are not local to Southeast Wisconsin and are emissions in other regions of the country. Reductions of PM_{2.5} mass concentrations in Southeast Wisconsin should be

directed at carbonaceous aerosol associated with mobile sources, biomass burning and emissions from stationary power generation in the Ohio Valley.

Local point sources in Southeastern Wisconsin, including stationary power generation, does impact local concentrations of trace components of particulate matter including trace metals, black carbon, and bromine. Although these are not major contributors to PM_{2.5} concentrations and reduction in emissions of these components are not likely to provide a significant impact in reducing PM_{2.5} concentrations, there may be potential air quality and human health benefits from reducing these emissions.

The details of the study are outlined in this report and are summarized in four manuscripts that have either been accepted for publication or will be submitted for consideration for publication in the near future. These publications are listed below.

Project Publications

- 1) J. E. McGinnis, J. Heo, M. R. Olson, A. P. Rutter, and J. J. Schauer. Understanding the Sources and Composition of the Urban Excess of Fine Particulate Matter. In preparation for submission for publication.
- 2) J. Heo, J. E. McGinnis, B. de Foy, and J. J. Schauer. Identification of Potential Source Areas for Elevated PM_{2.5}, Nitrate and Sulfate Concentrations in the Southern-Wisconsin. In review for publication.
- 3) A. M. Smyth, S. L. Thompson, B. de Foy, M. R. Olson, N. Sager, J. J. Schauer, and Deborah S. Gross. Sources of Metals and Bromine-Containing Particles in Milwaukee. In review for publication.
- 3) B. de Foy, A. M. Smyth, S. L. Thompson, D. S. Gross, M. R. Olson, N. Sager, and J. J. Schauer. 2012. Sources of Nickel, Vanadium and Black Carbon in Aerosols in Milwaukee *Atmospheric Environment*. 59, 294-301.

List of Figures

Figure 1. Temporal trends of chemical species concentrations of PM _{2.5} at each site.	14
Figure 2. Variations of urban excess of major chemical species in two different sample sites....	15
Figure 3. Variations of urban excess for several trace elements in two different sample sites. ...	16
Figure 4. Source profiles from PM _{2.5} samples measured at Milwaukee, Waukesha, and Mayville sites.	22
Figure 5. Seasonal source contributions to PM _{2.5} concentrations at Mayville, Waukesha, and Milwaukee sites.	23
Figure 6. Comparison of PMF deduced source contributions between sites.....	24
Figure 7. Urban excess of PMF deduced sources between sites.....	25
Figure 8. Probable source locations for upper 25% of sulfate and nitrate concentrations measured in Milwaukee during the entire study period.	28
Figure 9. Probable source locations for upper 25% and greater than 30 µg m ⁻³ of PM _{2.5} mass concentrations measured in Madison, Milwaukee, and Waukesha during the entire winter season from 2002 through 2010.	29
Figure 10. Hourly average concentration at the WDNR-SER site in Milwaukee, WI, collected during July 15 through August 15, 2010.	31
Figure 11. CFA analysis for winter nitrate (a) and sulfate (b) data from Mayville.....	32
Figure 12. CFA analysis for summer 2010 at Milwaukee for black carbon (a), sulfate (b), and nickel (c).	33
Figure 13. Annual frequency distribution of clusters.	35
Figure 14. Windrose maps of the 8 clusters of daily averaged wind speed and direction.....	35
Figure 15. Timelines for the four correlated metals, Mo, Se, Sb, and Cd, along with PM 2.5, and SO ₂	37
Figure 16. Wind rose of the lowest 90% and highest 10% concentrations for trace Mo observed in single particles. The bar at the bottom of the figure shows the time of day that corresponds to the various colors in the roses, while the bar on the right depicts the percentage of calm winds during sampling.	37
Figure 17. Bromine STN data in Milwaukee, WI.....	38
Figure 18. Raw size distributions showing the number distribution of sampled particles and Br-containing particles during the summer of 2010.....	38
Figure 19: Contribution levels for the three sites as estimated using the common model.	43
Figure 20. Estimated regime effects (point estimates and 95% confidence intervals) for each of the nine sources.....	45
Figure 21. Mean discriminant scores of the eight regimes for the first two discriminant functions.	46

List of Tables

Table 1. Summary of regression results for urban excess	17
Table 2. Summary of mean concentration for each chemical species at three STN sites.....	18
Table 3. Posterior mean of the Λ matrix estimated from the Milwaukee site.	41
Table 4. Posterior mean of the Λ matrix estimated from all three sites.....	42

List of Abbreviations

ANOVA = ANalysis Of VAriance

AQS = Air Quality System

ATOFMS = Aerosol Time Of Flight Mass Spectrometer

BC = Black Carbon

CAMx = Comprehensive Air quality Model with eXtensions

CFA = Concentrations Field Analysis

EC = Elemental Carbon

EDAS = Eta Data Assimilation System

FIPS = Federal Information Processing Standard

HYSPLIT = Hybrid Single-Particle Lagrangian Integrated Trajectory

IC = Ion Chromatography

KENW = Climatic Data for Kenosha

KFLD = Climatic Data for Fond du Lac

KMKE = Climatic Data for Milwaukee, General Mitchell International Airport

KMSN = Climatic Data for Madison/Dane County Air port

KRAC = Climatic Data for Racine

LADCO = Lake Michigan Air Directors COnsortium

MANOVA = Multivariate ANalysis Of VAriance

MCMC = Markov Chain Monte Carlo

MDL = Method Detection Limit

NAAQS = National Ambient Air Quality Standard

NEI = National Emission Inventory

OC = Organic Carbon

PCA = Principal Component Analysis

PM2.5 = Particulate matter less than 2.5 micrometer in diameter

PMF = Positive Matrix Factorization

PSCF = Potential Source Contribution Function

QAQC = Quality Assurance/Quality Control

SER = South East Regional Headquarters

SOA = Secondary Organic Aerosol

STN = Speciation Trends Network

WDNR = Wisconsin Department of Natural Resources

WRF = Weather Research and Forecasting Model

XRF = X-Ray Fluorescence