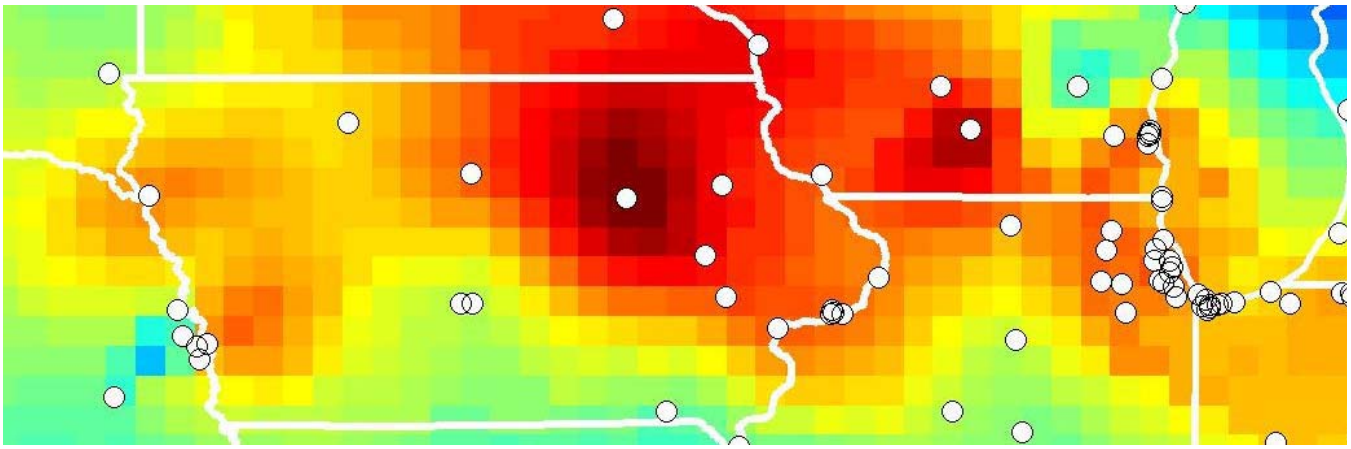
Understanding Episodes of High Airborne Particulate Matter in Iowa



Center for Global and Regional Environmental Research at the University of Iowa
Charles Stanier, Editor

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A report commissioned by the Bi-State State Regional Commission (www.bistateonline.org)

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http://www.engineering.uiowa.edu/~cs_proj/iowa_pm_project/iowa_pm.htm

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EXECUTIVE SUMMARY

Introduction. The 2006 United States standard for particulate matter smaller than 2.5 microns ($PM_{2.5}$) under the Clean Air Act is 35 micrograms per cubic meter of air ($\mu g\ m^{-3}$) taken over a 24 hour average. This standard was a revision of a previous standard of 65 $\mu g\ m^{-3}$. Many locations around the country were in compliance with the earlier 65 $\mu g\ m^{-3}$ limit, but not with the new value of 35 $\mu g\ m^{-3}$. The rationale for the standard is for the protection of human health, especially sensitive individuals such as the elderly, infants, and those with cardiovascular and respiratory disease.

Two $PM_{2.5}$ monitors in the state of Iowa have 2005-2007 values that are above the 35 $\mu g\ m^{-3}$ attainment threshold (Scott Country/Davenport Wellman St., and Muscatine's Garfield School). Furthermore, many other Eastern Iowa monitors are just below the standard. While it is widely accepted that pollution levels at individual sites are the combination of regional episodic processes, urban scale pollution, and local source impacts, an in depth investigation of these elements for Iowa sites was desired as part of overall efforts to deal with $PM_{2.5}$ levels at or near the 35 $\mu g\ m^{-3}$ threshold.

Final attainment or nonattainment status will be heavily influenced by 2006-2008 monitoring data (which has the two sites in question below the attainment threshold). However, the objectives and results of this work are applicable regardless of attainment status. Furthermore, as the report shows, unless ongoing decreases are achieved in the contributing impact categories identified herein, future years of non-attainment are likely

Objectives. The University of Iowa was contracted by the Bi-State Regional Commission to (1) review published reports and papers on the topic of wintertime Midwestern particulate matter formation; (2) analyze available $PM_{2.5}$ monitoring data; (3) analyze meteorological conditions

associated with episodes; (4) separately analyze local episodes (those at single monitors) and regional episodes (those at multiple monitors); and (5) discuss scientific uncertainties regarding wintertime PM formation and its prediction in air quality models.

Results.

Episode Occurrence and Frequency

- An analysis of the available peer-reviewed literature on Midwestern particulate matter formation, and an analysis of seven years of Iowa and Midwestern meteorological and particulate matter monitoring data, reaffirms the conceptual model for Midwestern PM discussed in the literature. Multi-day episodes of elevated $PM_{2.5}$ levels are an important factor in air quality, especially when considering peak concentrations as the 24-hour average $PM_{2.5}$ regulations do.

- PM episodes occur during both warm and cold seasons. The warm and cold weather episodes are important to attainment/nonattainment of both the annual and daily $PM_{2.5}$ standards. For the period 2002-2008, the cold weather episodes had a small edge in both number and severity.

- Depending on the surrounding land use, population density, and level of industrialization, each monitor is additionally impacted by locally emitted primary particulate matter. At the Muscatine and Davenport Wellman St. locations, the local impacts are severe enough to add to the regional background at levels sufficient to cause nonattainment with the 35 $\mu g\ m^{-3}$ standard during some years.

- A comprehensive list of 44 regional PM episodes (with $PM_{2.5}$ elevated for at least three Iowa monitors) was created for the years January 2002 – July 2008, along with a companion list of non-regional episodes. Detailed time series of pollution levels and meteorological variables were created and are available in appendices to the main report. A time series of daily $PM_{2.5}$ values for the period January 2002 – July 2008 was created from the median of Eastern Iowa monitors. This Eastern Iowa median concentration is useful for evaluating local impacts relative to a regional background value.

- Statistical analysis shows that regional episodes in excess of 35 $\mu g\ m^{-3}$ are unlikely to put monitors in Eastern Iowa into noncompliance unless they experience additional impact from local sources. The accuracy of this conclusion is predicated on the assumption that the period 2002-2008 is representative of future conditions.

Episode Chemistry and Meteorology

- Analysis of speciated $PM_{2.5}$ data during episode and non-episode periods confirms a major role for ammonium nitrate during wintertime episodes, with nitrate rising to ~45% by mass of the total $PM_{2.5}$. During episodes, concentrations of all species increase, but the increase is strongest for ammonium nitrate.

- There is insufficient evidence to definitively mark either nitric acid or ammonia as limiting during wintertime episodes. The best available studies to date have the sensitivity of ammonium nitrate concentrations balanced between the influences of ammonia and nitric acid in Iowa during wintertime. There is likely variability from place-to-place within Iowa and from episode-to-episode on which compound is more limiting to aerosol formation.

- Nitric acid from the NO_3 radical and N_2O_5 is likely to be important in Iowa in winter. The kinetics of this process are uncertain.

- One area of interest for this study was the relationship between $PM_{2.5}$ ammonium nitrate episodes and fog. The literature review identified one paper that studied this relationship; in that study, fog was found NOT to be a contributor.

- Cold weather regional episodes generally occur on the back end of a warm front. Signature meteorological trends during high $PM_{2.5}$ events are a sudden change in wind direction (to be predominately easterly in flow), pressure decrease, rising temperature, dew point, and relative humidity, and a decrease in wind speed.

Model Performance During Episodes

- Two episodes in 2002 were compared to their corresponding model predictions from a regional implementation of the CMAQ air quality model. Even though this model was not configured for urban scale predictions, the model reproduced the episodes fairly well. Spatial patterns of total $PM_{2.5}$ and nitrate, as well as temporal patterns agree fairly well. The model showed high bias during some periods (predicting too high a concentration), for example sometimes predicting > 40 $\mu g\ m^{-3}$ on an hourly basis when less than 10 $\mu g\ m^{-3}$ were registered by the monitor. However, the agreement is sufficient to explore control scenarios for reducing average and peak daily concentrations. If combined with observations of inorganic aerosol speciation, accurate scenarios for reducing PM through NOx and or ammonia controls could be developed.

Quantification of Local Source Impacts

- At the Davenport Wellman St. monitor, conditional probability analysis of hourly wind direction vs. hourly $PM_{2.5}$ showed a strong local impact when the wind was from 210 degrees. This bearing is consistent with what would be expected from emissions from Blackhawk Foundry, which is located approximately 400 meters from the monitor. The magnitude of the conditional probability function is that 20% of hours with wind from 210° have $PM_{2.5}$ values of 30 μg m^{-3} or more above the estimated regional background level. Analysis of the hourly $PM_{2.5}$ readings shows that daily peaks (in hourly $PM_{2.5}$) in excess of 50 μg m^{-3}, and sometimes in excess of 100 μg m^{-3}, are not uncommon; they occur most frequently in morning or midday. Regression analysis of hourly wind direction vs. daily $PM_{2.5}$ levels gives a similar result, with evidence of a local source when wind blows from between 160 and 260 degrees. At the most impacted direction (220 degrees) the average increment over background is 10 μg m^{-3} over a 24 hour period.

- Statistical sampling of attainment vs. nonattainment probabilities at the Davenport Wellman St. monitor puts a **preliminary estimate** of future attainment at 25% under the status quo, and at 81% under elimination of the above background PM that is coming from the 160 to 260 degree direction. The confidence of this preliminary estimate is low because the lack of definitive source apportionment data for the site.

- At the Muscatine monitor, regression analysis of hourly wind direction vs. daily $PM_{2.5}$ levels indicates a strong source impact when wind blows from between 60 and 130 degrees, with the strongest impact at 100-110 degrees. This direction is consistent with the local impact originating from Grain Processing Corp. At the most impacted direction, the average increment over background was 25 μg m^{-3} over a 24 hour period.

- Statistical sampling of attainment vs. nonattainment probabilities at the Muscatine monitor puts a **preliminary estimate** of future attainment at 43% under the status quo, and at 98% under complete control of the above background PM that is coming from the 60 to 130° direction. The confidence of this preliminary estimate is low because of the lack of definitive source apportionment data for the site.

- Evidence of significant local source impacts at other locations was not found, with the exception of a moderately large impact at Clinton (23rd and Camanche) when wind blew from the south (150 to 230°). The average magnitude of this source, as determined by similar regression analysis to that used at Muscatine and Davenport Wellman St., was 20 μg m^{-3} over background levels for a 24 hour stable south wind. This impact is consistent with the local impact originating from the nearby ADM corn processing facility.

Recommendations

- Additional data analysis of speciated $PM_{2.5}$ data from the Midwest ammonia monitoring project is warranted, in concert with thermodynamic partitioning computer modeling in use at the University of Iowa, to determine whether nitric acid or ammonia is limiting during episodes.

- A modest program of regional air quality modeling is warranted to investigate the spatial scales for effective control of SO_2, NOx and ammonia. Special focus would be given to the relative impacts of county-specific emissions, as compared to more broad Iowa/Illinois Mississippi river corridor emissions, and to emissions from more distant locations.

- The State of Iowa, and the stakeholders for air quality in Iowa and the Quad Cities, should take a proactive stance toward further understanding the relative contributions of various air pollution sources to episodes both from a geographical standpoint (where would source controls be effective at reducing episodes), and from a source apportionment standpoint (what source categories should be controlled). A three part effort is recommended: (a) pilot study source apportionment in winter 2010; (b) program of collection and storage of filters for later analysis of episode PM chemistry; and (c) <u>if needed</u> for future air quality management decisions, analysis of the archived filters from b during baseline or episode periods. This would be a cost effective and proactive stance which would be especially important should the EPA lower the annual $PM_{2.5}$ standard to less than 15 $\mu g\ m^{-3}$, or lower the 24-hour standard below 35 $\mu g\ m^{-3}$.

Full report available online at

http://www.engineering.uiowa.edu/~cs_proj/iowa_pm_project/iowa_pm.htm

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