Impact of the NOx SIP Call on Respiratory Hospitalizations in New York State

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Background/Objectives

Asthma is a serious public health problem in New York State (NYS), affecting 8.4% (370,000) children and 7.6% (more than 1.1 million) adults.[1] Asthma burden in New York's urban areas is consistently higher than the national average, with marked differences in prevalence and severity by socio-economic strata.[2] Poor air quality from traffic pollution and other sources has consistently been linked to asthma morbidity. More specifically, nitrogen oxides, criteria pollutants which serve as a precursor to ozone, have been implicated as a player in respiratory irritation.[3]

This study investigated whether the U.S. Environmental Protection Agency-mandated NOx State Implementation Plan (NOx SIP) in NYS, aiming to reduce nitrogen oxide emissions from major sources during the summer months, had an impact on hospitalizations for asthma and other respiratory illnesses. More specifically, hospital admissions due to respiratory diseases (1997-2006) were compared during the period before the legislation, during the period of partial NOx SIP implementation, and post-implementation.

METHODS

Population

Several existing data sources were used: (1) the Statewide Planning and Research Cooperative System (SPARCS) is a legislatively mandated database, maintained by the NYS Department of Health, of hospital discharges from all hospitals in the NYS (excluding psychiatric and federal hospitals); and (2) ozone concentrations via a kriged surface prediction at 12 km horizontal resolution. Ozone data was provided by the EPA and incorporated air quality data from AIRS, CASTNet and NAPS monitoring systems, which span the entire Northeastern U.S. and parts of Canada.

All residents of NYS were included in the analysis. Health outcomes included hospitalizations for respiratory disease, years 1997 to 2006. Specifically, respiratory diseases included the following principal diagnoses based on the International Classification of Disease, 9th Revision (ICD-9): bronchitis (491), emphysema (492), asthma (493), and chronic obstructive pulmonary disease (496). In addition, for children ages 0 – 4 years, a diagnosis of acute bronchitis and bronchiolitis (466) and bronchitis, not specified as acute or chronic (490) were also included because they

are common respiratory diseases among very young children and the symptoms are difficult to distinguish from asthma at this age. The control admissions included hospitalizations for gastrointestinal diseases (009) and accidental falls (E880-E888).

Monthly, seasonal, and yearly respiratory hospital admission rates during the study period were calculated. The rates of seasonal and yearly hospital admissions for combined disease categories were compared across three different time periods. Based on the actual timing of the regulation, these periods were defined as follows: (1) 1997-2000 (pre-NOx regulation or baseline); (2) 2001- 2003 (partial-NOx SIP implementation); and (3) 2004-2006 (post-NOx SIP or post implementation).

Periodic trends in respiratory hospitalizations during the three NOx time periods (baseline, partial-implementation and post-implementation) were compared by geographic region, race/ethnicity, gender, age, and disease sub-groups. We then calculated the percent change in annual respiratory admissions partial- and post- implementation compared to the average daily admissions during the baseline period.

Statistical Methods

Time series models using an intervention analysis approach were used to investigate the temporal trends for the three NOx study periods. ARIMA models were used to examine the change in average daily ozone levels, respiratory hospitalizations, and their relationship during the summer months (June-August) between each of the time periods, after adjusting for day-of-the-week, temperature, secular trend, and other temporal/seasonal effects. The temporal/seasonal effects included a long term trend indicator variable for capturing the baseline, partial implementation and post implementation effect, as well as a separate indicator variable capturing the seasonal trend of summertime effect during these periods. In addition, the respiratory analysis included terms for holidays and day-of-the-week to control for their potential confounding effects. The autocorrelation of the residuals were investigated at various lags. The final model was determined when it included sufficient orders of autocorrelations and moving averages such that the model residuals contained no signal beyond random variation. Following passage of these autocorrelation tests, statewide and region-specific time series models were estimated separately for ambient ozone concentrations and respiratory admissions. To examine the intervention effect, the baseline time period was compared against the partial and post implementation periods. Analyses were stratified by eight NYS regions as defined by the NYS Department of Environmental Conservation (DEC), including: Long Island, New York City (NYC) Metro, Lower Hudson, Upper Hudson, Adirondack, Central, Eastern Ontario and

Western region. All analyses were conducted using SAS v. 9.2 and the criterion for statistical significance was α=0.05.

RESULTS

Daily average ozone declined during the summer months of the post-implementation period (compared to baseline) in all regions of NYS. Adjusted modeling analysis showed evidence of regional differences in these summertime declines; the southwestern Long Island and NYC Metro regions experienced the greatest declines (4.79% and 3.15%, respectively), while in the rest of the regions ozone levels showed declines in the range of 1.32-2.54%. In contrast, daily average temperature generally increased for all NYS regions during these time periods.

Post-implementation respiratory admissions did not follow such clear patterns as ambient ozone levels. Hospitalizations declined in the southwestern regions of the state during the post-implementation time period, but across all regions of NYS the greatest reduction in respiratory admissions occurred during the fall and winter months. Adjusted summertime respiratory admissions in the Lower Hudson region declined non-significantly by 5.28% (95% CI: -11.56, 1.44), in the Central region by 1.29 (95% CI: -6.00,3.66) and in the Western region by 2.21 (95% CI: -7.24,3.09). Conversely, daily respiratory admissions increased in each of the other regions, from 0.24 to 9.5%. This result is particularly interesting as we hypothesize that the greatest impact of the NOx SIP Call will occur in the southern regions of NYS due to prevalent wind patterns that transport ozone from the Ohio River Valley (Figure 1).

Stratified analyses showed greater reductions in admissions in NYC, among those aged 0-4 years old, and whites than among upstate, other age groups, and other racial/ethnic groups (data not shown). In contrast, admissions for the control diseases, gastroenteritis and accidental falls, were higher during the post-implementation period compared to baseline (data not shown).

Conclusion

Preliminary findings show significant reductions in ozone concentrations during the summer season after the NOx SIP Call went into effect. However temperatures increased across these same time periods, indicating that the ozone reductions are not related to temperature. Although not significant, analyses identified reductions in admission rates during the fall and winter season in all NYS regions following the NOx SIP call, after controlling for multiple confounding factors. The findings also identified that the intervention effect has regional differences that may be accounted for by the NOx implementation which reduced ozone transport from

neighboring states into the southern portions of NYS. Further studies will examine the potential effects of NOx SIP call on sensitive sub-populations, effects by urbanicity, and relationships based on meteorlogical and wind-flow patterns.

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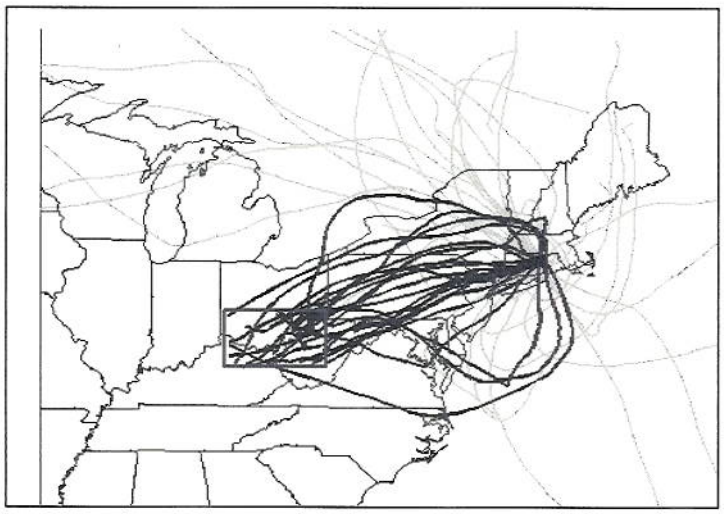

Figure 1: Back-trajectories from a site in the northeastern U.S. showing prevalent wind patterns. Black lines show those trajectories passing through the Ohio River Valley, a major emission source impacted by the NOx SIP Call.

Speaker: Lin

Questioner: D. Bert
Question: Accountability studies are very important but also difficult to do when changes in pollution as a result of regulatory actions are gradual. The challenges can be overcome but they require careful thought and very targeted study designs. We agree that determining the impact of a regulation is extremely difficult. The signal associated with a change in emissions is embedded within the overall health endpoint that is confounded by other factors. We believe multiple approaches will be needed to discern this signal using a "weight of evidence" approach. This paper presents one approach for such an analysis.