Health responses to changes in PM concentration and composition across New York State from 2005 to 2016

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Background

- Although the United States has been steadily reducing air pollution since the enactment of the Clean Air Act Amendments of 1970, there have been significant changes in air quality particularly with respect to PM_{2.5} during the period since 2000.
- These changes are due in part to the promulgation and enforcement of regulations to reduce emissions from coalfired power plants and motor vehicles
- However, there have also been significant economic drivers of changes in emissions as a result of the 2008 recession and the availability of low cost fracked natural gas.



Mitigation strategies

- ✓ Reducing emissions for both light- and heavy-duty vehicles and electric power generation
- ✓ The NOx SIP (State Implementation Plan) Call (1998) and the NOx Budget Trading Program (2003) as well as the Clean Air Interstate Rule (2009) strongly reduced summertime NOx
- ✓ Tier II Tailpipe NOx Emissions Standard
- ✓ Particle control traps (2007) and NOx control (2010) for new heavy duty vehicles
- ✓ On-road diesel fuel sold after October 1, 2006, was required to have ultra low sulfur concentrations (<15 ppm)
- ✓ 2004, Renewable Portfolio Standard, approved by the New York State Public Service Commission, aimed to include a higher proportion of renewable energy sources in the state electricity generation mix
- ✓ July 1, 2012, New York State required that all distillate fuels sold within the state for any purpose to be ultralow sulfur
- ✓ Beginning in 2010, New York City began forcing a switch from No 6 oil to No 2 for large building heating
- ✓ Electricity policy changes in Ontario and the Clean Air Interstate Rule/Cross-State Air Pollution Rules to reduce SO₂ and NOx emissions from coal-fired power plants



Economic Effects





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Atmospheric Environment 183 (2018) 209-224

Economic Effects





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Changing Concentrations: PM_{2.5}





PM_{2.5} and ST-Elevation Myocardial Infarction (MI)



Image from NEJM Resident 360

Rate of MI associated with each IQR increase in $PM_{2.5}$ concentration

Gardner et al. Particle and Fibre Toxicology 2014, **11**:1 http://www.particleandfibretoxicology.com/content/11/1/1



Triggering of myocardial infarction by increased ambient fine particle concentration: effect modification by source direction



stations and the WSW sector. Dotted line separates the WSW sector into WSW1 (top) and WSW2 (bottom).







Ito et al. Environmental Health Perspectives 119:467–473 (2011)

- NYC cardiovascular hospitalizations and mortality data (SPARCS)
- **2000-2006**
- Monitors within NYC
 - 24 hour concentrations
- Poisson time series analyses

RESULTS: The CVD mortality series exhibit strong seasonal trends, whereas the CVD hospitalization series show a strong day-of-week pattern. These outcome series were not correlated with each other but were individually associated with a number of $PM_{2.5}$ chemical components from regional and local sources, each with different seasonal patterns and lags. Coal-combustion–related components (e.g., selenium) were associated with CVD mortality in summer and CVD hospitalizations in winter, whereas elemental carbon and NO₂ showed associations with these outcomes in both seasons.



CONCLUSION: Local combustion sources, including traffic and residual oil burning, may play a yearround role in the associations between air pollution and CVD outcomes, but transported aerosols may explain the seasonal variation in associations shown by $PM_{2.5}$ mass.

New York State Accountability Study

Cardiovascular, Respiratory, Respiratory Infectious Disease Hospitalizations and Emergency Department Visits





- 1. Estimate the rate of acute cardiovascular, respiratory, and respiratory infectious disease hospitalizations and emergency department (ED) visits associated with increased PM_{2.5} concentrations in the previous 1 to 7 days.
- 2. Examine whether these relative rates were different BEFORE, DURING, and AFTER the air quality policies/economic changes



Cardiovascular Disease Hospitalizations



Study **Population**

SPARCS – All Hospitalizations of NYS residents to non-VA and non-psychiatric hospitals for (ICD9 and ICD10):

- Cardiac Arrhythmia
- **Congestive Heart Failure**
- Hypertension
- Cerebrovascular (and ischemic stroke)
- Ischemic Heart Disease (and myocardial infarction)
- **Chronic Rheumatic Heart Disease**
- **Pulmonary Embolism**
- \leq 15 miles of 6 monitoring stations

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Sampling stations NYS boundaries

Counties

Albany (ALB) Buffalo (BUF) Rochester (ROC)

NYC Queens (QUE) NYC Bronx (IS52)

NYC Manhattan (DIV)

Methods

PM_{2.5} concentrations retrieved from USEPA AQS

- 24 hour values from each site
- Lag day(s) 0, 0-1, 0-2, 0-3, 0-4, 0-5, 0-6
- Temperature and Relative Humidity
 - From major airport closest to Buffalo, Rochester, Albany, Bronx, Queens
 - From Central Park weather station for Manhattan
- Time-stratified Case-crossover Study Design
- Conditional logistic regression
 - Adjusting for natural splines of temperature (4 df) and relative humidity (3df) at same lag time as PM_{2.5}



Excess rate of <u>cardiovascular</u> hospital admissions associated with each interquartile range increase in $PM_{2.5}$ concentration





Excess rate of <u>cardiovascular</u> hospital admissions associated with each interquartile range increase in $PM_{2.5}$ concentration







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Environmental Pollution 242 (2018) 1404-1416

Excess rate of respiratory infectious disease ED visits associated with each IQR increase in PM_{25}





Lag

Day

Ann Am Thorac Soc Vol 16, No 3, pp 321–330, Mar 2019

Excess rate of <u>respiratory infectious disease</u> hospitalizations associated with each IQR increase in PM_{2.5}





Ann Am Thorac Soc Vol 16, No 3, pp 321-330, Mar 2019

Strengths and Limitations

- Strengths
 - Large sample size
 - Six urban locations across the state
 - 3 Upstate
 - 3 New York City
- Limitations
 - Exposure misclassification central site monitor
 - No data on event onset time, only day of admission



Conclusions

- Increased rate of cardiovascular hospitalizations associated with increased PM_{2.5} concentrations
 - Cardiac Arrhythmia
 - Ischemic Stroke
 - Congestive Heart Failure
 - Ischemic Heart Disease
 - Myocardial infarction
- Ischemic Heart Disease relative rates were greater in the AFTER period
- Similar findings with:
 - NYS Respiratory Infectious Disease Hospitalizations and ED visits
 - NYS Respiratory Hospitalizations and ED visits
 - Rochester Myocardial Infarctions
- May not be confounding by subject characteristics
- Why? Is same mass of PM more toxic?

²³ PM_{2.5} composition – Inter-period differences



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24 PM_{25} composition – Inter-period differences



Secondary organic carbon

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Environmental Pollution 242 (2018) 1404-1416

$PM_{2.5}$ sources – Inter period differences



Pre 2005-2007 During 2008-2013

Post 2014-2016



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Excess rate of cardiovascular hospitalizations associated with each IQR increase in $PM_{2.5}$ source concentration





Excess rate of cardiovascular hospitalizations associated with each IQR increase in PM_{2.5} source concentration



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Excess rate of cardiovascular hospitalizations associated with each IQR increase in $PM_{2.5}$ source concentration





Excess rate of cardiovascular hospitalizations associated with each IQR increase in $PM_{2.5}$ source concentration



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- PM_{2.5} sources associated with increased rates of cause-specific CV hospitalizations:
 - Spark-ignition emissions (GAS)
 - Diesel (DIE)
 - Road Dust (RD), Secondary Nitrate (SN), Residual Oil (RO)
- But not:
 - Secondary Sulfate (SS), Road Salt (RS), Industrial (IND), Biomass Burning (BB), Pyrolyzed Organic Rich (OP), or Aged Sea Salt (AGS), or Fresh Sea Salt (FSS)
- Similar findings for respiratory infectious disease



Synthesis Across Studies

- Increased rates of hospitalizations and ED visits for cardiovascular, respiratory, and respiratory infectious disease associated with increased PM_{2.5} concentrations in the previous 1 to 7 days
- For some outcomes, this relative rate is greater in the AFTER period (2014-2016) than in the DURING (2008-2013) and BEFORE (2005-2007) periods
- Similar findings for ST-elevation myocardial infarction in Monroe County
- Increased rates of CV Hospitalizations associated with increased concentrations of GAS, DIE, SN, RD, RO
- But not SS, RS, IND, BB, OP, FSS, or AGS



Synthesis Across Studies

- Preliminary hypothesis: The aerosol is becoming more oxidizing, more SOA formation, with more fresh SOA delivering greater dose of ROS to the lung
 - Could lead to systemic inflammation and other effects contributing to triggering of these events
- Need to evaluate whether further controls past 2016 have impacted, slowed down, or reversed this trend
 - E.g. new vehicle emissions standard in 2017
- Need to evaluate this in other parts of the country with different PM composition and sources, and perhaps different localized air quality policies or actions



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