Communication 15

Proceedings of an HEI Workshop on Further Research to Assess the Health Impacts of Actions Taken to Improve Air Quality

Health Effects Institute

Appendix E. Accountability Workshop Presentations

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Appendix E. Accountability Workshop Presentations:

What Has Accountability Done for Us? Jonathan M. Samet

Evaluating the Effectiveness of Air Quality Interventions: HEI’s Research Program on Accountability, Annemoon van Erp

Data Sources and Access: A Street Level View from a City Health Department, Thomas Matte

Accountability Studies: Exposure Contrasts, Bert Brunekreef

Accountability Assessment of Long-Term Regulatory Action: Warm Season O₃ and Cardiac Mortality, Ira B. Tager

Statistical Methods for Accountability Research, Francesca Dominici

Accountability Studies: Evaluating Shorter-Term and Small Scale Actions, Jennifer L. Peel

Evaluating Shorter-Term and Small Scale Actions, Douglas W. Dockery
What has accountability done for us?

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Professor and Flora L. Thornton Chair
Department of Preventive Medicine
USC Keck School of Medicine
Director, USC Institute for Global Health
HEI Workshop
December 17-18, 2009

What is accountability?

Accountability is a concept in ethics and governance with several meanings. It is often used synonymously with such concepts as responsibility, answerability, blameworthiness, liability, and other terms associated with the expectation of account-giving. As an aspect of governance, it has been central to discussions related to problems in the public sector, nonprofit and private (corporate) worlds. In leadership roles, accountability is the acknowledgment and assumption of responsibility for actions, products, decisions, and policies including the administration, governance, and implementation within the scope of the role or employment position and encompassing the obligation to report, explain and be answerable for resulting consequences. (Wikipedia 2009)

Accountability Assessment

- To answer the question: What benefits have been realized from regulation?
- Look along “accountability chain”—from sources to health effects
- How to assess?
  - “Found experiments”
  - Surveillance approach

Source-to-Response Framework

Mechanisms determining emissions, chemical transformation (including formation of secondary particles from gaseous precursors), and transport in air

Human time-activity patterns, indoor (or microenvironmental) sources and sinks of particulate matter

Deposition, clearance, retention and disposition of particulate matter

Mechanisms of damage and repair

NRC PM Committee 1998
What did Communication 11 propose?
• Chain of accountability
• Conceptual framework
• Research recommendations

Rationale for accountability studies
• There is a call for it.
• Strengthen case for causal inference ($\beta^+$ vs $\beta^-$).
• Assess consequences of specific interventions.
• Provide “validation” of risk assessments.

Communication 11: Recommendations
• Developing and implementing new study designs
• Identifying targets of opportunity
  – PM and O$_3$ NAAQS implementation
  – Air Toxics Control Plan
  – Targets at local level
• Developing surveillance systems

What has HEI funded?
• Shorter-term, step-change interventions
  – Source modification:
    • Woodstoves: Montana
    • Sulfur in fuels: Hong Kong
  – Source operation
    • Short-term limits: Atlanta and Beijing Olympics
    • Restriction: London CCS
• Longer-term
  – Title IV 1990 CAA Amendments
  – Coal bans in Irish cities

Has accountability been useful?
• For developing a research agenda?
• For providing evidence that is useful for evidence-based regulation?
• For benefitting public health?
Steps in Evidence-Based Public Health

- Search for Problems
  - Surveillance
  - Etiologic research
  - Systematic reviews
- Identify Causes
  - Meta-analysis
  - Causal guidelines
  - Quantitative risk assessment
- Assess Size of Problem
  - Policy analysis
  - Decision sciences
  - Cost-benefit
- Policy & Intervention
  - Surveillance
  - Accountability studies
- Reassess

The Clean Air Act

Section 109 (42 U.S.C. 7409) directs the Administrator to propose and promulgate “primary” and “secondary” NAAQS for pollutants identified under section 108. Section 109(b)(1) defines a primary standard as one “the attainment and maintenance of which in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, is requisite to protect the public health.”

What are the Benefits and Costs of the CAA?

The Clean Air Act:

- **Benefits and Costs of the Clean Air Act**
  - Final Report to Congress on Benefits and Costs of the Clean Air Act, 1999 to 2010
  - EPA 410-R-04-001
  - Final Report to Congress on Benefits and Costs of the Clean Air Act, 1970 to 1990
  - EPA 410-R-07-002

Success in the United States

- **Clean indoor air**
- **Medical treatment, taxation, product regulation**

A Systems Approach: Final Causal Map

ASSIST Model

- ASSIST & Other Coalitions
- Strength of Industry Counter-Efforts (SIC)
- Intermediate Outcomes in Attitudes & Behavior
- Final Outcomes in Prevalence & Consumption
- Mass Media Advocacy
- Staffing Resources
- Policy Advocacy
- Developing Local Capacity
- Interagency Relationships
- Statewide Coalitions
- Funds
- Individual Behaviors
- Policy Advocacy
Tobacco Control Research Framework

Stillman et al., 1999

State Conditions
Age, education, regulation, poverty status, race/ethnicity, sex, urban/rural, region, population
Economic value of tobacco

Efforts
SoTC
Resources
Capacity
SoTC
State of Industry Counter-efforts

SmokeLess States Settlement Funds
State and Local Clean Indoor Air Ratings
Smoke-free Worksites
Cigarette Price

Norms
Behaviors
Prevalence
Consumption

People
Smoking

Judge Kessler Speaks:
"An immeasurable amount of human suffering"

The tobacco industry has marketed and sold their lethal product with zeal, with deception, with a single-minded focus on their financial success and without regard for the human tragedy or social costs that success exacted.

NRC: Science and Decisions

NRC: Science and Decisions

Morton Levin’s Attributable Risk Formula

• Estimate the Relative Risk (RR)
• Estimate the prevalence (P) of each risk factor.

PAR = \frac{P (RR - 1)}{1 + P(RR - 1)}
PM$_{10}$ and Mortality: Have the Risks Changed from 1987 to 2000?
Evaluating the Effectiveness of Air Quality Interventions:
HEI’s Research Program on Accountability

Annemoon van Erp
Aaron Cohen
Health Effects Institute

HEI workshop
December 17-18, 2009

Some issues and questions relevant to designing studies

- How do emissions, exposures, and health effects respond to different types of interventions?
  - Step-change vs. gradual change in air quality (AQ)

- Methodologic issues
  - Which study designs?
    - Large-scale, periodic monitoring to track population exposure versus smaller scale studies of specific subpopulations
  - Which health outcomes?
  - How to obtain adequate pre-intervention baseline data
  - Compare model-based predictions with actual outcome

Some issues and questions (cont’d)

- How to pursue unique opportunities (intentional, unintentional) that come up relatively quickly
  - Opportunities at national, regional, local levels
  - Identify and publicize opportunities

- How can accountability studies provide stronger tests of causal relations and contribute to scientific research on health effects of specific sources?
  - Steel mill closure was unplanned but provided important evidence regarding possible causality

HEI studies: Shorter-term actions

Actions to improve fuels & combustion technologies
1. Curtis Noonan: Wood stove change-out program in Montana (draft report due summer 2010)
2. Chit-Ming Wong: Reducing sulfur in fuel in Hong Kong (completed and under review)

Actions to reduce vehicular traffic
3. Frank Kelly: Congestion charging scheme in London (in press)

Multiple actions
5. Jim Zhang: Air quality improvements during the 2008 Olympic Games in Beijing (draft report due summer 2010)

Medium- to long-term actions

Actions to reduce the impact of mobile, area, or stationary sources
6. Doug Dockery: Coal bans in Irish cities (draft report imminent)
7. Frank Kelly: London low emission zone baseline study (in press)
8. Multiple actions
   a. Dick Morgenstern: Air quality improvement under Title IV of the 1990 Clean Air Act Amendments (draft report due summer 2010)
   b. Annette Peters: Air quality improvement after German reunification: (HEI Research Report 137, June 2009)
**Cleaner wood stoves (Montana)**

PI: Curtis Noonan, University of Montana

- Community intervention project by Montana DEQ & others
- Change-out of 1200 uncertified wood stoves during two winters (2005 and 2006)
- Assess PM$_{2.5}$ levels outdoors, in schools, and in some homes before, during and after wood stove replacement
- Relate air quality to children’s respiratory symptoms, infections, and illness-related school absences

**Woodstove change-out – preliminary findings**

- Air quality improvement inside homes
  - PM$_{2.5}$: 50 → 15 µg/m$^3$, peak levels 435 → 100 µg/m$^3$
  - Levoglucosan (woodsmoke marker) reduced
- Improved ambient PM$_{2.5}$ concentrations (25% lower)
- Health studies still ongoing, preliminary data:
  - School absences not affected
  - Respiratory symptoms somewhat reduced in children grades 1-8

**Challenges**

- Delays in wood stove change-out
- More gradual change in air quality
- Variation in stove usage and operation
- Other wood smoke markers not reduced
- Possible reporting bias by parents

**Fuel sulfur content (Hong Kong)**

PI: Chit-Ming Wong, University of Hong Kong

- Effect of 1990 regulation to reduce sulfur in fuel on AQ in Hong Kong
  - Affecting both power plants and vehicles
  - Shown to reduce SO$_2$ and mortality (Hedley et al, Lancet 2002)
- Develop methodologies for assessing change in life expectancy and years of life gained
- Focus on PM composition
- Relation between short-term and long-term benefits

**Sulfur ban – preliminary findings**

- Changes in PM composition: decreased Ni and V
- Reduced PM$_{10}$ and SO$_2$ associated with reduced nonaccidental mortality
- Reduced respiratory mortality associated with Ni and V
- Life expectancy changes

**Challenges**

- Complications due to other long-term trends
- Sulfur was not the only compound affected
- Would benefit from further evaluation of changes in sources, especially regarding Ni and V

**Hong Kong fuel sulfur content (Hedley et al 2002)**

![Figure 1: Average of pollutant concentrations at five monitoring stations](image)

Vertical line represents date of introduction of fuel regulation.

**Congestion charging scheme (London)**

PI: Frank Kelly, King’s College London

- Implemented in February 2003 to reduce traffic congestion in London’s inner city (charge was £5/day, now £8)
- Concomitant increase in public transportation
- Show that traffic reduction has led to pollution reduction
- Also looking at potential changes in pollutant composition
- Oxidative properties of PM collected on filters before and after implementation (*in vitro*)
- If pollution reduction evident, follow up with health study:
  - Mortality & hospital admissions
  - Respiratory and cardiovascular conditions in children and elderly obtained from primary care records
London Congestion Charging – findings

- Air quality changes very small: PM$_{10}$ and CO levels may have slightly decreased in the zone.
- NO$_x$ levels not changed, but NO$_2$ levels may have slightly increased within the zone.
- Oxidative potential variable; highest at roadsides, possibly related to brake and tire wear.

Challenges

- CCS not designed to reduce pollution.
- Offset in part by taxi and bus trips.
- Few data monitoring stations inside the zone; missing data; weather inversion in February 2003.
- Power to detect changes in health outcomes deemed too low.

- Calculated potential benefits (based on modeled AQ changes) are presented in Tohive et al. 2008.

1996 Olympic Games (Atlanta)

PI: Jennifer Peel, Colorado State University

- Efforts to reduce traffic in downtown Atlanta during the Olympic Games.
- Earlier study showed a decrease in ozone and childhood asthma (Friedman et al., JAMA 2001).
- Evaluate emergency department visits for cardiovascular and respiratory outcomes; also arrhythmic events in patients with ICDs.

Atlanta Olympics – some observations

- Importance of the time window studied.
  - Evaluate same period in previous and subsequent years.
- Importance of looking at a broader geographic area.
  - Regional weather & air quality.
- Difficult to study outcomes with small numbers of events and short, temporary intervention.
  - ICD data.

Atlanta Olympics – findings

- Significant reduction in asthma acute care events (-41%), peak daily ozone levels (-28%), and morning traffic (-22%).
2008 Olympic Games (Beijing)

Pi: Jim Zhang, University of Medicine and Dentistry of New Jersey

- reduce emissions from traffic and industrial sources in period leading up to and during Olympic Games
  - changes already started, targeting industry in Beijing area
  - two-tiered approach during the Olympics:
    1. keep highly emitting vehicles off the road and restrict operation of high emitting industries (July 25 – September 17)
    2. restrict additional vehicles and factories during actual competition (August 8–24)
- follow medical students before, during, and after Olympics to measure blood coagulation and systemic inflammation

Beijing Olympic Games – preliminary findings

- reductions in PM$_{2.5}$, SO$_2$, and CO, but not O$_3$
- ~450 deaths and ~7,500 ER visits avoided
- changes in biomarkers of oxidative stress
  - decreased exhaled nitric oxide
- improved vascular function in healthy young people

Challenges

- complicated regional and local actions that started up to a year earlier
- favorable weather, thus unclear to what extent the AQ actions contributed

Coal ban in Irish Cities

Pi: Douglas Dockery, Harvard School of Public Health

- based on earlier study showing reduction in black smoke and mortality after a 1990 coal ban in Dublin (Clancy et al, Lancet 2002)
- include 11 other cities: Cork (1995 ban) and 10 other major cities (1998 ban)
- quantify the effect of the ban on coal sales on black smoke and sulfur oxide levels
- total and cause-specific mortality, and cardiovascular and respiratory hospital admissions

Dublin 1990 coal ban

(Clancy et al 2002)

- clear black smoke reductions in Dublin and elsewhere
- reduction of peak concentrations in winter
- SO$_2$ less affected, some decreases and one increase

Challenges

- smaller populations in the additional cities → statistical power issues
- relatively smaller cumulative AQ improvements
- long-term mortality and AQ trends
**Low emission zone (London)**

PI: Frank Kelly, King’s College London

- reduce pollution levels by excluding high emitters, several stages starting February 4, 2008 through 2012
- affects much larger area (Greater London)
- much higher charges
- prospective study: baseline assessment
  - collect filters for oxidative properties
  - obtain access to primary care data
- improved monitoring network

**LEZ implementation plan**

<table>
<thead>
<tr>
<th>Type</th>
<th>Start Date</th>
<th>End Date</th>
<th>Emission Standard</th>
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<td>Heavier HGV</td>
<td>February 2008</td>
<td>January 2012</td>
<td>Euro III for PM</td>
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<tr>
<td>Lighter HGV</td>
<td>July 2008</td>
<td>January 2012</td>
<td>Euro III for PM</td>
</tr>
<tr>
<td>Buses and coaches</td>
<td>July 2008</td>
<td>January 2012</td>
<td>Euro III for PM</td>
</tr>
<tr>
<td>Heavier LGV</td>
<td>October 2010</td>
<td>Postponed until 2012</td>
<td>Euro III for PM</td>
</tr>
<tr>
<td>Minibuses</td>
<td>October 2010</td>
<td>Postponed until 2012</td>
<td>Euro III for PM</td>
</tr>
<tr>
<td>Private cars, small vans, motorcycles</td>
<td>Not included</td>
<td></td>
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</tr>
</tbody>
</table>

HGV = heavy goods vehicles; LGV = light goods vehicles

**London Low Emission Zone – findings**

- additional monitoring put in place
- access to primary care health data could be worked out
- large variability in oxidative potential of filter samples across London
- filters from roadside locations possibly more toxic; linked to coarse PM / metals (tire and brake wear)

**Challenges**

- gradual fleet changes in anticipation of the 2008 rule
- less improvement expected with subsequent stages
- uncertainties in AQ modeling at zip code level

HEI: need air quality data for several more years before designing a health study

**SO₂ from power plants (eastern US)**

PI: Richard Morgenstern, Resources for the Future

- reduction of SO₂ emissions from power plants under Title IV of the 1990 Clean Air Act Amendments
  - two phases, targeting largest, dirtiest plants first
- source-by-source analysis of to determine where and when reductions occurred
  - using EPA emissions inventories and transaction data
- source-receptor models to establish relationship between emissions reduction and air quality improvement
  - estimate pollution levels in absence of policies
- study on health effects to be finalized

**Morgenstern study – challenges**

- complex, multistage modeling
- difficulties collecting data
- estimating impact of missing data:
  - had to relax requirement for inclusion of monitors
- final analyses pending

**SO₂ air quality trends (EPA)**

Source: [http://www.epa.gov/air/airtrends/sulfur.html](http://www.epa.gov/air/airtrends/sulfur.html)
German reunification

Pi: Annette Peters, GSF-National Research Center for Environment and Health (HEI Report No. 137)

- conversion from brown coal to natural gas in homes, factories, and power plants
- conversion of cars with two-cycle engines to cars equipped with catalytic converters
- general increase in traffic, including diesel cars & trucks
- track daily cause-specific mortality in Erfurt at various lagged times with levels of pollutants of interest
- develop methods to track dynamic changes in health risks over time during interventions or source changes (1991–2002)


German reunification – findings

- gradual decrease in PM10, PM2.5, SO2, CO
- smaller decreases in NO2, O3, ultrafine PM (UFP)
- associations between UFP and mortality, CO and mortality (3 or 4 day lag)
- association between O3 and mortality (2 day lag)
- time varying coefficient model showed that relative risks were lowest near the end of the study period

Challenges

- small population in Erfurt (200,000 people)
- socioeconomic and demographic changes
- effects of UFP but not PM10 / PM2.5 unexplained

HEI comment: need to look at distributed lags (Breitner et al, EHP 2009)

Summary and conclusions

- Important to establish AQ improvement before starting a study of health benefits
- need sufficient exposure contrast
- Flexibility needed to take advantage of new opportunities for prospective studies
- expand AQ monitoring, if possible
- Influence of weather patterns and other variables
- sensitivity analyses: time windows, geographic areas
- Even if AQ improvement cannot be tied directly to action, evidence of improved health is still important
- Studies of long-term actions remain underrepresented
Data Sources and Access
A Street Level View From a City Health Department

Tom Matte
HEI Accountability Workshop
December 17, 2009

Overview

• Standardized data
  – Hospital discharge
  – Vital statistics
  – Surveys for covariates
• Near-real-time ‘syndromic’ surveillance
• Other non-traditional data
• Data access – no simple answers – barriers and levers
• Environmental Public Health Tracking Network

What’s available?

• Geographically resolved rates for prospective accountability studies
  – Available, accessible, and improving.
  – May improve prospective RIA
• Record level health events for retrospective studies – available.
  Accessibility is a work in progress.

Environmental Public Health Tracking Program

• CDC funded –22 state and one city
• Data linkage
• Public portals
• Common health data
  – Hospital admissions (AMI, Asthma, CO poisoning)
  – Cancer incidence
  – Birth outcomes
  – Childhood lead poisoning
• States, city provide minimally aggregated data for national portal with approval of stewards
Population susceptibility varies. What about burdens and benefits?

- Students, fellows, academic investigators can be credentialed as paid or volunteer consultants
- 'Non-identifying' ~ safe harbor:
  - Used for our public portal
  - DUR permits sharing aggregated data with CDC for national portal
- Similar to SID/SEDD HCUP
- NYC Vital Statistics query is evaluated using K-anonymity and L-diversity criteria
- NYS hospital discharge data requires < 6 cell suppression
- Data stewards are busy

- IRB and DUR 1997-2006 data
- Application process (~9mos) (same as outside request)
- Credentialed academic co-investigator

Concepts for Shared Data Access

- Central broker (e.g. secure portal, HCUP)
- Investigator works within authorized data user environment (e.g. NCHS, DOHMH)
- State/local standardization of data for remote query by investigators
- Fellow model (e.g. CDC PHP, Informatics fellows)
- State/local health agency role in communication to stakeholders
- Behavioral Risk Factor Surveillance System

- State level
- 350k adults/yr
- Selected MSAs
- Core and state added quest
- Covariates - Health status and behaviors

Behavioral Risk Factor Surveillance System

- State level
- 350k adults/yr
- Selected MSAs
- Core and state added quest
- Covariates - Health status and behaviors
New York City Community Health Survey – ‘NYC BRFSS’

- RDD telephone survey, started in 2002
- ~10,000 adults (18+)
- Estimates for UHF neighborhoods, zip with multi-year

Mortality Rate Ratio, Age 65+ on HI>100 days vs all warm season days


“Syndromic” surveillance: ED visits

- After 9/11/01, CDC deployed dozens of epidemiologists for 24/7 data collection in selected NYC EDs
- November 2001 – ED logs by fax, email
- Data entry, scanning, text processing
- Syndrome coding algorithms refined
- Now – all electronic reporting, automated analysis, electronic delivery of results (<12h lag)
- Mostly used to track communicable diseases
- Researchers can apply – no public use data

Asthma ED syndrome tracks asthma hospital admissions

Source: Ito et al. ISEE 2009

Change in % Excess Risk per 1 S.D. of Effect Modifier
In the second stage regression model of air pollution risk estimates from 115 zip-code areas, estimated traffic intensity was a significant effect modifier for PM2.5 and NO2.

FIGURE 2-- Mean weekly over-the-counter pharmacy sales of nicotine replacement therapy products: New York City, July 29, 2001, to January 17, 2004

Pharmacy Sales

FIGURE 2-- Mean weekly over-the-counter pharmacy sales of nicotine replacement therapy products: New York City, July 29, 2001, to January 17, 2004

School attendance and school nurse visits

DOHMH Providers
Near Real Time Surveillance
Decision support

Conclusions

- One stop access to identifiable traditional data sources (vital statistics, hospital admissions) is still a work in progress
- These may help:
  - Show that the public has a stake
  - Feedback locally-relevant information
  - High level leadership
- State and local data sources are rapidly evolving
- Near-real time surveillance for non-communicable conditions shows some promise

Althoff et al. Journal of Urban Health 2009;86:729-44
Accountability studies: exposure contrasts

Bert Brunekreef, PhD
Institute for Risk Assessment Sciences
University of Utrecht, Netherlands

The HEI solution to vehicular pollution

Affordable bicycles

HEI’s Research Program on the Impact of Actions to Improve Air Quality: Interim Evaluation and Future Directions
Annemoon M. van Erp and Aaron J. Cohen

HEI’s Research Program on the Impact of Actions to Improve Air Quality: Interim Evaluation and Future Directions
Annemoon M. van Erp and Aaron J. Cohen

The Accountability Chain

An evaluation of the indoor air quality in bars before and after a smoking ban in Austin, Texas

Nguyen, H., Mikami, K., and A. S. Nriagu

Figure 4. Mean nitrogen per- and post-smoking PM2.5 concentrations for all values. *Values accept unprompted risk; † Indicates values could not be calculated.

Risk assessment and health impact assessment.
Smoke-free Legislation and Hospitalizations for Acute Coronary Syndrome

Reversing the chain...

- Epidemiological studies need power
- Power comes from study size & exposure contrast
- Typically, range in concentrations factor $>\approx 2$, range in $5 - 95\%$ or IQR $>\approx 1.5$

What was found? (1)

- Noonan: 70-75% decrease in indoor PM2.5 (woodstoves)
- Wong: $\approx 50\%$ decrease in SO2 but not PM (Hong Kong fuel sulfur)
- Kelly: very small changes in NOx, PM, CO, oxidative potential (London CCZ)
- Peel: ozone reductions not associated with Olympic traffic measures (Atlanta)

Greater London air quality monitoring network

Location of long-term continuous pollution monitoring sites within Greater London

Facts and results from the Stockholm Trials
What was found? (2)

- Zhang: 40-60% decreases in AP during Beijing Olympics, not yet clear to what extent due to policy measures
- Dockery: 45-70% reductions in BS (Irish coal ban studies)
- Kelly: 3 μg/m³ decrease in NO₂, 0.75 μg/m³ decrease in PM10 predicted (LEZ)
- Morgenstern: changes in ambient PM2.5 due to 1990 clean air act
- Peters: large SO₂ reduction, 50% PM reduction (German Reunification)

Effect of 20 mph traffic speed zones on road injuries in London, 1985-2006: controlled interrupted time series analysis

<table>
<thead>
<tr>
<th>Periods</th>
<th>Asthma events (/day)</th>
<th>PM0.15 (μg/m³)</th>
<th>U₉ (ppb)</th>
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<tbody>
<tr>
<td>Baseline period</td>
<td>12.5</td>
<td>78.8</td>
<td>63.8</td>
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<tr>
<td>Pre-Olympic period</td>
<td>16.5</td>
<td>72.3</td>
<td>74.6</td>
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<tr>
<td>Olympic period</td>
<td>7.1</td>
<td>46.4/61.5</td>
<td>61.0</td>
</tr>
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</table>
Life expectancy increases in the US are associated with decreases in air pollution.

Mean: 15-25 µg/m³; A_PM2.5: 4-10 µg/m³ = ~30%
Dutch Accountability studies (1)

- Busy roads in Amsterdam, The Hague, Utrecht, Tilburg, The Hague
- Background locations in same city/region
- Traffic measures planned to comply with EU regulations for PM10
- Health measurements in subjects living at street & background locations before & after implementation (symptom questionnaire, spirometry, eNO)

Dutch Accountability studies (2)

<table>
<thead>
<tr>
<th>Location</th>
<th>Participants</th>
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<td>Amsterdam road 1</td>
<td>46</td>
</tr>
<tr>
<td>Amsterdam road 2</td>
<td>36</td>
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<td>Bussum background</td>
<td>50</td>
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<td>Tilburg road</td>
<td>94</td>
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<tr>
<td>Den Bosch road 1</td>
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<td>Den Bosch road 2</td>
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<td>Bilthoven background</td>
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<td><strong>TOTAL</strong></td>
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Dutch Accountability studies (3)

Black Smoke in Utrecht

<table>
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<tr>
<th>Year</th>
<th>PM10</th>
<th>PM2.5</th>
<th>EC*10</th>
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<tr>
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<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>97</td>
<td>10</td>
<td>2</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>98</td>
<td>5</td>
<td>1</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>99</td>
<td>2</td>
<td>0.5</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0.1</td>
<td>0.01</td>
<td>0.001</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>0.05</td>
<td>0.005</td>
<td>0.0001</td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>0.01</td>
<td>0.001</td>
<td>0.00001</td>
</tr>
<tr>
<td>3</td>
<td>0.05</td>
<td>0.005</td>
<td>0.0005</td>
<td>0.000001</td>
</tr>
</tbody>
</table>

Buslane closed

Wit Jong Backgr
**Observations (1)**

- Pollution reductions as result of regulatory actions in HEI accountability studies range from very small to well over 50%.
- Not surprising some studies have difficulty documenting health benefits.
- Traffic studies (e.g., CCS, LEZ) may need other metrics than PM, NOx and other than area-wide health studies.
- Studies from other domains (e.g., smoking bans) lend support to expecting public health benefits from regulatory action to reduce air pollution.

**Observations (2)**

- Great potential for supporting causality esp. in studies of temporary changes (Olympics, factory closings etc.).
- Health effects of large-scale pollution reductions only observable in large populations over long periods of time: potential for confounding by secular trends.
- Lack of power ≠ lack of effect!
Accountability Assessment of Long-Term Regulatory Action
Warm Season O₃ and Cardiac Mortality

Ira B. Tager, M.D., M.P.H.,
Division of Epidemiology
School of Public Health UC, Berkeley
Member HEI Research Committee

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Vic Brajer, Ph.D.; Cal. State Fullerton
Jane Hall, Ph.D.; Cal. State Fullerton
Fred Lurmann, MS; Sonoma Technology, Inc.
Kelly Moore, Ph.D, Div. Of Biostatistics
Romain Neugebauer, Ph.D.; Div. of Biostatistics
Mark van der Laan, Ph.D.; Division of Biostatistics

A Pilot Study to Quantify the Health Benefits of Incremental Improvements in Air Quality—CARB, 2002 RFA

- CARB issues an RFA to evaluate health effects of improved air pollution in Southern CA
- Investigate the feasibility of relating health changes in residents to air quality improvements in the South Coast Air Basin (SoCAB)

Issues for Design
- Biggest concern was temporal trends
  - Air pollutants
  - Demography
  - Changes in health care practices
  - Changes in smoking

Thoughts About “Long-Term” In the Context of Time and Study Design for Accountability Studies

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Level of Design</th>
<th>“Long-term”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time series</td>
<td>Ecologic</td>
<td>Change in or departure from expected trend</td>
</tr>
<tr>
<td>2. Cohort</td>
<td>Individual</td>
<td>Hazard, YLL, CI</td>
</tr>
<tr>
<td>3. Cross-sectional across populations</td>
<td>Ecologic</td>
<td>Cumulative exposure</td>
</tr>
<tr>
<td>4. Cross-sectional serial w/in populations</td>
<td>Ecologic</td>
<td>Combination of 1 &amp; 3 above</td>
</tr>
</tbody>
</table>

Concerns That Time Poses for “Long-Term” Accountability Studies

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Level of Design</th>
<th>Confounders Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time series</td>
<td>Ecologic</td>
<td>weather (w), trend ((t)-health outcomes, cars, habits, environ. demography)</td>
</tr>
<tr>
<td>2. Cohort</td>
<td>Individual</td>
<td>w, t, individual, censor</td>
</tr>
<tr>
<td>3. Cross-sectional across populations</td>
<td>Ecologic</td>
<td>“Survival”, non-exchangeability of people and exposure</td>
</tr>
<tr>
<td>4. Cross-sectional serial w/in Pop.</td>
<td>Ecologic</td>
<td>Combination of 1 &amp; 3 above</td>
</tr>
</tbody>
</table>

Focus on South Coast Air Basin

- 195 of 200 10x10km grids used

Time Trends for Ozone by Quarter from 1980 - 2001

Same trends seen for CO and NO₂
Processing of Data

- Air pollutants
  - Monthly averages → quarterly averages
  - Initially chose 1-hr maximum O₃ since it was the standard for most years of the study period
  - Correlation with 8-maximum = 0.99
  - Assigned to grids by inverse distance weighting to grid centroid based on 4 nearest monitors within 50 km
  - 86% <25 km; 13% with monitor in grid
  - Results similar to those based on kriging

Categories of the Grid and Quarter-Specific 54 Covariates

- Demographic
  - Race
  - Education
  - Income
  - Employment
  - % time at current residence in past 5 years
  - Country of birth (state, if U.S.)
  - Number of persons/household
  - % above poverty
  - Previous quarter proportion of cardiac deaths

Selected Demographic Variables, Ages >55 years, 1983-2000

<table>
<thead>
<tr>
<th>Variables</th>
<th>Grid Med (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population (N)</td>
<td>989,000 (938,000-1,049,000)</td>
</tr>
<tr>
<td>Males (46.8%, 38.1-100.0)</td>
<td>1,285,000 (1,229,000-1,350,000)</td>
</tr>
<tr>
<td>Females (53.2%, 0.0-61.5)</td>
<td></td>
</tr>
<tr>
<td>Hispanic (15.7, 9.8-24.7)</td>
<td></td>
</tr>
<tr>
<td>White (74.5, 60.3-83.2)</td>
<td></td>
</tr>
<tr>
<td>African American (2, 1-5)</td>
<td></td>
</tr>
<tr>
<td>Asian (3 (1-7))</td>
<td></td>
</tr>
<tr>
<td>Born in California (%)</td>
<td>51 (46-57)</td>
</tr>
<tr>
<td>Foreign Born (%)</td>
<td>30 (25-40)</td>
</tr>
<tr>
<td>Residence in Same House 5 Years Prior</td>
<td>44 (37-50)</td>
</tr>
<tr>
<td>Below Poverty Level (%)</td>
<td>10 (6-13)</td>
</tr>
</tbody>
</table>

Specification of Exposure and Outcome

- Grid-specific quarterly mean O₃ for months April-June (q 2) and July-Sept. (q3)
- Male Mortality expressed as grid-specific % of eligible population
- Progressive decline over time as expected

Number of Males/Qtr

- Median 968,879
- IQR 914,688 - 1,039,471
- Range 864,740 - 1,101,659
**Statistical Analysis**

- **Assumption about spatial correlations between grids**
  - Assumption that each spatial unit is a random variable, $O_i$ ($i=1, \ldots, 195$), each with distribution, $P_i$.
  - Thus, we do not assume that each unit was sampled from one common distribution.
  - i.e., assume each unit sampled from $n$ distinct distributions, $P_i$, that may be similar for units close spatially.
  - Therefore, model observed data with average distribution:

$$P = \frac{1}{n} \sum_{i=1}^{n} P_i$$

**Assumption about spatial correlations between grids**

- Assume that $W$ is stationary in space and time
- Assume that $A$ is stationary in space and time
- Assume that $Y$ is stationary in space and time

**Statistical Analysis**

- How data structured
  - $W(71), A(71), Y(72)$
  - Where:
    - $W =$ history of confounders
    - $A =$ history of O$_3$ exposure
    - $Y =$ history of cardiac mortality over the 36 quarters of time

**Time Ordering**

- Investigate $A(t-1)$ on $Y(t)$, but both measured in same quarter
  - We assume that a given exposure precedes outcome
  - Use of monthly means to maximize the assumption
  - Use of previous quarter creates exposure problems
  - Assume most of O$_3$ population effect would be over a single quarter

**Methods**

- Traditional regression—gives conditional effect estimate (i.e., stratum-specific)
- History restricted marginal structural models—gives population effect estimate
  - Permits specification of time interval over which history of exposure is considered
  - Has a causal interpretation
- Flexible model fitting with deletion-substitution-addition algorithm (DSA)
  - Based on multiple cross-validation and minimization between observed minus expected values for proportion cardiac mortality based on model

**Some Results**

- Conventional regression with adjustment for confounders and repeated measures showed only + association between quarterly 1-hr max [O$_3$] and ↑ cardiac mortality
  - Included multiple interaction terms with race, temperature, relative humidity
  - Due to interactions, marginal estimates not obtained
- Model with Interaction
  - History Restricted MSM Based on Continuous O$_3$

**Control for Temporal Confounding Asthma Hospital Discharges**

Moore, et al. EHP 2008

- Predicted Proportions of Quarterly Hospital Discharges for Population 0-19 Year With Asthma
  - Model with only time (up to 3rd order polynomial)
  - Model with time and demographic variables
DISTRIBUTION OF GRIDS HAVING:
- <50% probability of quarterly 1-hour max [O3] > 80 ppb (red circles)
- less than 70 ppb (blue circles)

**Statistical Analysis “Realistic MSM” -- Solution**

- Treatment Rules
  - Set intervention being above the standard, if \( P(Q_o > \text{std grid covariates}) \geq 0.1 = 3; \) otherwise = 0
  - Set being below the standard if \( P(Q_o < \text{std grid covariates}) < 0.1 = 1; \) otherwise = 0
- Where \( a \) is a probability above which the intervention is considered “realistic” based on the covariate pattern of each spatial unit
- No formalism as yet for choice of \( a \)
- Trade off between bias and variance
- Estimation includes units that cannot receive either intervention in estimation of mean and variance
- Shrinks estimate of the mean and accounts for variance

**Distribution of Grids that Have a Very Low Probability to Move from “High” O3 Concentrations to “Low” Concentrations Based on Various Quarterly Average 1-hour O3 Concentration Cut-points**

<table>
<thead>
<tr>
<th>Proposed Cut-Point</th>
<th>Number (%) of grids &gt; cut-point</th>
<th>% of grids above cut-points that have a p(O3 &lt; the 75th %tile of “low” grids, given covariates) &lt; a=0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 ppb</td>
<td>3319 (47)</td>
<td>89.9 ppb</td>
</tr>
<tr>
<td>110 ppb</td>
<td>1178 (26)</td>
<td>92.5 ppb</td>
</tr>
</tbody>
</table>

**Statistical Analysis**

**“Realistic MSM”**

- When the experimental treatment assignment assumption (ETA) is violated, “usual” MSMs cannot be estimated reliably
- Neither can estimates from other regression techniques
- I.e., we cannot learn anything from a unit of observation that cannot experience a hypothetical intervention based on the characteristics of that unit
- I.e., the intervention is “unrealistic”
- Dichotomize the exposure distribution

In our case, we use:
- Current maximum 8-hr ozone standard (80 ppb)
- Proposed EPA standard (75 ppb)
- Standard proposed by CASAC (70 ppb)


- Due to violation of the ETA with continuous O3, used HRMSM and realistic model with cut-points

<table>
<thead>
<tr>
<th>MSM Model</th>
<th>Coefficients (SE) 75 ppb Cut-point</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRMSM</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>5.5 \times 10^4 (6.0 \times 10^4)</td>
</tr>
<tr>
<td>1. Quarter (t-1) 1-hr max O3</td>
<td>1.3 \times 10^4 (8.2 \times 10^4)</td>
</tr>
<tr>
<td>2. Quarter Number</td>
<td>9.9 \times 10^4 (1.2 \times 10^5)</td>
</tr>
<tr>
<td>Interaction 1 &amp; 2</td>
<td>-1.7 \times 10^5 (1.2 \times 10^5)</td>
</tr>
</tbody>
</table>

“Realistic”

| Intercept | 1.6 \times 10^4 (2.4 \times 10^4) |
| 1. Quarter (t-1) 1-hr max O3 | -0.6 \times 10^7 (2.1 \times 10^7) |
| 2. Quarter Number | -2.7 \times 10^4 (3.7 \times 10^4) |
| Interaction 1 & 2 | 2.2 \times 10^4 (3.6 \times 10^4) |

**More Results: 8-Hr Max Warm Season Maximum O3 Male Mortality 1991-2000**

<table>
<thead>
<tr>
<th>MSM Model</th>
<th>Coefficients (SE) 75 ppb Cut-point</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRMSM</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>8.5 \times 10^4 (1.8 \times 10^4)</td>
</tr>
<tr>
<td>1. Quarter (t-1) 1-hr max O3</td>
<td>8.7 \times 10^4 (2.8 \times 10^4)</td>
</tr>
<tr>
<td>2. Quarter Number</td>
<td>-2.0 \times 10^4 (3.2 \times 10^4)</td>
</tr>
<tr>
<td>Interaction 1 &amp; 2</td>
<td>-1.5 \times 10^5 (5.6 \times 10^5)</td>
</tr>
</tbody>
</table>

“Realistic”

| Intercept | 8.7 \times 10^5 (1.8 \times 10^5) |
| 1. Quarter (t-1) 1-hr max O3 | -2.0 \times 10^7 (3.1 \times 10^7) |
| 2. Quarter Number | -2.4 \times 10^4 (3.1 \times 10^4) |
| Interaction 1 & 2 | -1.7 \times 10^4 (3.3 \times 10^4) |
### Estimated Percentage Reduction in Male Cardiac Mortality Based on 8-Hr Max O₃ Concentrations, 1991-2000 Selected Quarters—75 ppb Cut-point

<table>
<thead>
<tr>
<th>Year/Qtr</th>
<th>% of Grids with low Probability of Going Below 75 ppb</th>
<th>% ↓ Mortality If All Grids Could Be Set Below 75 ppb</th>
<th>Attributable Population Mortality (%) - PIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991 / 2</td>
<td>4.6</td>
<td>37.7</td>
<td>10.5</td>
</tr>
<tr>
<td>1991 / 3</td>
<td>3.1</td>
<td>36.8</td>
<td>28.8</td>
</tr>
<tr>
<td>1994 / 2</td>
<td>28.7</td>
<td>26.5</td>
<td>11.5</td>
</tr>
<tr>
<td>1994 / 3</td>
<td>12.9</td>
<td>25.4</td>
<td>15.8</td>
</tr>
<tr>
<td>1998 / 2</td>
<td>90.3</td>
<td>1.1</td>
<td>0.0</td>
</tr>
<tr>
<td>1998 / 3</td>
<td>32.8</td>
<td>-1.3</td>
<td>0.0</td>
</tr>
<tr>
<td>2000 / 2</td>
<td>74.4</td>
<td>--**</td>
<td>0.0</td>
</tr>
<tr>
<td>2000 / 3</td>
<td>61.5</td>
<td>--**</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Summary and Conclusions
- Estimates of population-level effects of 1- and 8-hour maximum ozone on cardiac mortality are decreased over time.
- Results very sensitive to choice of model and metric of population exposure.
- Population estimates based on continuous data and “traditional” regression methods not:
  - Estimable due to multiple interactions between ozone and other variables.
  - Valid due to violation of the experimental treatment assignment (positivity) assumption.

- Estimates of changes in population burden need to take into account how likely it is for a given spatial unit to achieve a target concentration of pollutant over some fixed period of time.
- Typical measures of attributable risk over-estimate burden due to—
  - Inclusion of areas/populations that cannot achieve target level.
  - Failure to account for accelerated outcomes that would have occurred at later time, if intervention would not have taken place.
  - Is not the same as harvesting in short-term time-series studies.

- Summary and Conclusions
Statistical Methods for Accountability Research

Francesca Dominici

December 17 2009

Accountability Assessment of Long Long-Regulatory Action
Warm Season O3 and Cardiac Mortality (Tager et al)

- Estimated time trend for ozone (1983-2001) for every grid cell (195 cells of 10x10 km)
- Estimated time trend for several demographic variables (54 variables) for every grid cell (use linear interpolation)
- Exposure: previous year average CO, NO₂, PM₁₀, SO₂
- Regression modeling: estimating the effect of historic exposure to ozone on the history of cardiac mortality (main assumption: all areas could experience all levels of ozone)
- Marginal Structural Models for estimating the effect of population-level intervention (counterfactual arguments)
- Data-adaptive algorithm to identify exposures and confounders

Challenges

- Why doing the analysis by grids?
  - 24% of the grids have population smaller than 200
  - Instability in the estimated trends by grid
  - Instability in the estimation of the mortality rates
  - Instability in the estimated trends of the confounders
- How about restricting the analysis to the most highly populated areas surrounding the monitoring stations (approx 40 monitoring stations)
- Temporal confounding is always an issue, results are highly sensitive to temporal confounding
- MSM as an elegant way of evaluating the assumptions about counterfactuals
- However results are model and metric dependent, conventional regression methods give biased results

Scientific Questions in Accountability Research

- Are short-term effects of PM on mortality from time series studies declining over time?
- Are recent declines in air pollution concentrations leading to improved life expectancy in the United States?
Map of 100 US counties: The color scale is proportional to the yearly percentage change in PM$_{10}$ levels during the period 1987-2007. The bold outlines denote declines that are statistically significant.

On average across the 100 counties, PM$_{10}$ decreases yearly by 2.2%. The PM$_{10}$ has been decreasing in 97 of the 100 counties studied.

Question:
Are recent declines in air pollution concentrations leading to improved life expectancy in the United States?

Confounding:
When assessing the association, how best to avoid common sources of confounding in air pollution studies?

Trends in yearly PM$_{2.5}$ [μg/m$^3$] averages

Spatio-Temporal Information and Confounding

Decompose the evidence (James, Dominici & Zeger, Epidemiology, 2007):

$$
\log(\tau^2) = \log(\tau^2_0) + \log(x_i(x)) + PM_{10} + PM_{2.5} - PM_{10} - PM_{2.5}$$

with PM$_{10}$ the national average PM$_{10}$ at time $t$ (from complete time series).

This approach:
- Does not see purely spatial information differences in PM$_{2.5}$ levels between locations absorbed by location intercept $\rightarrow$ no cross-sectional confounding.
- Decomposes remaining information into purely temporal ($\beta_t$) and residual spatio-temporal ($\beta_s$) $\rightarrow$ might be differently affected by confounding.
Summary

- Methods for causal inferences can be very valuable in accountability research
- Estimation of air pollution trends can be challenging
- National data are useful because we can compare results across areas that have experienced very different changes in air quality
- It is of critical importance to look at association between “global” and “local” trends
Accountability Studies: Evaluating shorter-term and small scale actions

Jennifer L. Peel, PhD, MPH
Colorado State University
HEI Accountability Workshop
December 17, 2009

Short-term / small scale accountability studies

- Examples
  - Fuel sulfur reductions on Hong Kong
  - London congestion charging scheme
  - 1996 Atlanta Summer Olympics

- Challenges

- Considerations for studies

Types of short-term / small scale actions

- Small scale, permanent
  - Potential for both short-term and longer-term impacts
- Short-term, reversible
  - Likely small in scale
  - Focus on short-term, reversible health endpoints

Sulfur reduction in fuels

- Hong Kong (Hedley et al. Lancet 2002)
- Restriction on sulfur content of fuel July 1990
- Immediate reduction of SO2 (45% over 5 years)
- Short-term reduction of sulfate (2 years), then levels increased again
- Immediate reduction in cool season mortality (first year); increase the 2nd year
- Decline in average annual mortality trend; 20-41 days per year gained in life expectancy per year at lower pollution levels

![Graph of pollution concentration and months](Hedley_et_al_Lancet_2002)
London Congestion Charging Scheme

- Tonne et al. 2008
- Feb 2003 – Feb 2007; drivers charged to drive in designated zone in Central London
- Impacted areas had 200,000 of 7 million London residents
- Modeled NO$_2$ and PM$_{10}$ (assumed meteorology and fleet remained constant)
- Small reductions in annual NO$_2$
- Small increased in modeled life expectancy (based on other cohort studies)

Impact of Improved Air Quality During the 1996 Atlanta Olympic Games on Cardiovascular and Respiratory Outcomes

Jennifer L. Peel, Mitch Klein, W. Dana Flanders, James A. Mulholland, Paige E. Tolbert

Study Motivation

- Efforts to reduce traffic during the 1996 Summer Olympics in Atlanta
  - Reduced traffic
  - Reduced levels of air pollutants

Study Motivation

- Previously published study reported decreases in pediatric Medicaid asthma ED and hospitalization claims during the Olympic time period compared to 4 weeks before and after (Friedman et al., JAMA 2001) (RR=0.48; 95% CI 0.44, 0.86)
  - Smaller reductions in pediatric asthma ED visits
    (RR=0.93; 95% 0.71, 1.22)
  - Reductions attributed to reduced traffic
  - Questions about confounding by time trends and behavioral changes during the Olympics

Methods – Emergency Department Visits

- Billing records from all Atlanta EDs
- Atlanta residents only
- Multiple cardiovascular and respiratory case groups defined based on primary ICD-9 codes
  - Pediatric and all ages
  - 1993 – 2004: 41 hospitals, 20 counties
  - 1996: 12 hospitals, 5 counties

Methods – Air Quality Data

- EPA AQS networks, 1993 - 2004
  - Ozone: 2 sites
  - PM$_{10}$: 1 site
  - CO: 2 sites
  - NO$_2$: 2 sites
  - SO$_2$: 2 sites
- Hourly traffic counts, 18 sites
- Meteorologic data
Methods

- Poisson time-series models, 1995-2004 summers
  - Adjusted for day of week, holidays, temp, dewpoint, day of summer, indicator for 1996 vs. other years, interaction term for 1996 x exposure
  - Offset = log (total non-accidental, non-case ED visits)
  - Exposure = Olympic time period (yes/no) in 1996
  - 12 hospitals (all ages)
  - 2 pediatric hospitals (pediatric visits)

Results – Ozone (1-hour max)

Results – Sunshine

Results – Pediatric Asthma Visits

ED Visits (all ages)

Pediatric ED Visits
Additional Results

- Observed similar reductions in ozone throughout Southeastern US
- Proportions of age groups, gender, payment, racial groups similar during the Olympics
- No difference when restricted to Medicaid visits
- Estimates were sensitive to control for temporal trends and choice of model

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Summary

- Ozone levels ~30% lower during Olympics compared to 4 weeks before and after
  - PM_{10}, NO\textsubscript{2}, CO also slightly lower
  - 1-hour max (morning rush hour) traffic counts reduced ~10-15%
- Observed similar reductions in ozone at various sites throughout the Southeast
  - Not impacted by traffic intervention

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Summary

- Both the intervention and prevailing meteorology likely played a role in reduced ozone
  - Regional evidence suggests meteorology
  - Role of traffic unclear
  - Observed little or no evidence of reductions in emergency department visits

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Limitations

- Behavioral changes may have contributed to reductions in ED usage
  - URI
- Entirely retrospective
- Limited time period of intervention (17 days)
- Limited monitoring sites for pollutants, traffic
- Intervention likely not sustainable

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Considerations: Intervention

- Designed to reduce pollution?
- Area affected
- Length of time
- Multiple pollutants affected? Increase or decrease?

Considerations: Pollutant Measure

- What to measure?
  - Multiple pollutants? Components?
  - Peak? Average?
- Where to measure?
  - Relevant locations
  - Near road, background, residences
  - How many sites?
- Other sources?
  - Vehicle counts, fleet composition, speed/flow, age
Considerations: Other

- Baseline pollution level and expected reduction
- Assuming linearity at all levels?
- Subtle effects per IQR increase in pollutants
  - What effect do we expect to see?
- What else is changing in population
  - Unintended side effects
    - E.g., reduce vehicle use, increase bike use
- What is the objective?
  - Evaluate intervention method
  - Strengthen evidence

Results – Traffic Counts

Considerations: Health Outcome

- Available data
  - Mortality, hospital admission
  - Small numbers
  - Capture affected population?
- Panel study design
  - Limited power
  - Healthy? Underlying respiratory or cardiovascular disease?
- Short or long term
- Reversible?

Objective

- Assess impact of reduced air pollution levels during the 1996 Olympics on multiple cardiovascular and respiratory outcomes
  - ED visits (pediatric and other age groups)
  - Various control for time trends

December 17, 2009
Evaluating Shorter-Term and Small Scale Actions

Douglas W. Dockery
Harvard School of Public Health

Experience in Dublin

- Oil crisis in late 1970's led to programs to encourage use of solid fuels, primarily coal
- 1980's - switch from oil to coal
- Dominant source of air pollution in Dublin was smoke from domestic fires

Deterioration in air quality after switch to coal
(Flanagan, 1986)

During winters of 1980's, Dublin experienced number of severe air pollution episodes.

Dublin County Borough

Dublin 1980-1990

Ban on Coal Sales

Dublin Black Smoke
Effect of Air Pollution Control on Mortality in Dublin

Clancy et al, Lancet 2002

- Effect of ban on sale of coal on air pollution in Dublin
  - 36 μg/m³ BS (-71%)
  - 11 μg/m³ SO₂ (-34%)

- Estimated improvements from time series studies
  - -7% Total Mortality
  - -13% Cardiovascular
  - -16% Respiratory
  - -3% Other

Evidence of effects down to lowest exposures

Dublin Total Mortality

Dublin Cardiovascular

Dublin Respiratory Deaths

Dublin 1990-1996: Cardio-Respiratory Deaths
COAL SALE BANS

- Sept 1, 1990 - Dublin
- Oct 1, 1995 - Cork
- Oct 1, 1998 - Limerick, Dundalk, Drogheda, Wexford, Arklow

Effect of sequential coal bans in BS

<table>
<thead>
<tr>
<th>Ban Year - City</th>
<th>Pre Mean Black Smoke (ug/m³)</th>
<th>Post Mean Black Smoke (ug/m³)</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990 Dublin</td>
<td>50.4</td>
<td>15.0</td>
<td>-35.1 (-70%)</td>
</tr>
<tr>
<td>1995 Cork</td>
<td>33.7</td>
<td>17.2</td>
<td>-21.6 (-49%)</td>
</tr>
<tr>
<td>1998 Arklow</td>
<td>40.0</td>
<td>18.4</td>
<td>-21.6 (-54%)</td>
</tr>
<tr>
<td></td>
<td>Cork</td>
<td>33.7</td>
<td>-21.6 (-49%)</td>
</tr>
<tr>
<td></td>
<td>Limerick</td>
<td>27.1</td>
<td>-14.6 (-54%)</td>
</tr>
<tr>
<td></td>
<td>Dundalk</td>
<td>23.0</td>
<td>-11.1 (-48%)</td>
</tr>
<tr>
<td></td>
<td>Drogheda</td>
<td>24.0</td>
<td>-14.8 (-61%)</td>
</tr>
</tbody>
</table>

Detecting effect of step change on long term background trends?

Cork Coal Ban - October 1, 1995

Percent change in mortality rate in the Post-ban period compared to the Pre-ban period, Pooled and county specific estimates for each of the 1998 counties

<table>
<thead>
<tr>
<th>Disease Group</th>
<th>Pre-Ban Deaths/1,000 per year</th>
<th>Post-Ban Deaths/1,000 per year</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL, NON-TRAUMA</td>
<td>9.71</td>
<td>7.22</td>
<td>-22%</td>
</tr>
<tr>
<td>CARDIOVASCULAR</td>
<td>386-418</td>
<td>5.01</td>
<td>3.44</td>
</tr>
<tr>
<td>Ischemic Cardiac Disease</td>
<td>410-414</td>
<td>1.92</td>
<td>1.83</td>
</tr>
<tr>
<td>Congestive</td>
<td>430-436</td>
<td>1.08</td>
<td>0.88</td>
</tr>
<tr>
<td>RESPIRATORY</td>
<td>480-487</td>
<td>1.35</td>
<td>1.15</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>480-487</td>
<td>0.45</td>
<td>0.27</td>
</tr>
<tr>
<td>Chronic Obstructive Pulmonary Disease</td>
<td>490-496</td>
<td>0.59</td>
<td>0.44</td>
</tr>
<tr>
<td>CANCER</td>
<td>140-165</td>
<td>2.28</td>
<td>2.07</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>160-165</td>
<td>0.46</td>
<td>0.38</td>
</tr>
<tr>
<td>DIGESTIVE</td>
<td>320-329</td>
<td>0.26</td>
<td>0.24</td>
</tr>
<tr>
<td>NON CARDIO/RESPIR</td>
<td>&gt;390, &gt;519</td>
<td>3.36</td>
<td>3.11</td>
</tr>
</tbody>
</table>

Contrast to reversible interventions
Beijing HEART Study
Junfeng (Jim) Zhang, UMDNJ and Rutgers

Air Pollution Concentrations and % Change

Reduction in Emergency Room Visit during the Olympic Air Pollution Controlled Period in Beijing

Lives Saved during the Olympic Air Pollution Controlled Period in Beijing

- ~ 300 deaths per day
- 1% reduction per 20 μg/m³ reduction in PM₁₀
- On average PM₁₀ reduction of 50 μg/m³ for 60 days.
- Death count reduction: ~450 = 7.5 deaths per day

- ~ 2500 cardio-respiratory visits per day-
- 1% reduction per 10 μg/m³ reduction in PM₁₀
- On average PM₁₀ reduction of 50 μg/m³ for 60 days.
- ER visits reduction: ~ 7,500
- 125 ER visits per day
Issues for short-term small scale studies

- **Permanent short-term step changes**
  - Depends on surveillance data
  - Large numbers, but low sensitivity/specificity
  - Detecting in presence of long term trends
  - Competing explanations

- **Reversible short-term step changes**
  - Surveillance data
    - Short changes \(\Rightarrow\) small number of events
  - Prospective studies
  - Sensitive/specific markers
  - Competing explanations
  - Behavioral, economic, weather, ... changes