ONGOING NEEDS FOR AIR QUALITY MONITORING IN HEALTH EFFECTS RESEARCH
Who is the Health Effects Institute?

Progress in Air Quality

Major research questions that we still get asked
  - Some research projects we’ve hoped might help answer them

Are we there yet?
  - Some reflections on the ongoing need for AQ monitoring
WHO IS THE HEALTH EFFECTS INSTITUTE?

- An independent, nonprofit corporation chartered in 1980 with balanced funding from USEPA and the worldwide motor vehicle industry
- Commissioned to provide high-quality, impartial, and relevant science on the health effects of air pollutants

*HEI’s goal is “simply to gain acceptance by all parties of the data that may be necessary for future regulation.”*

Willam Ruckleshaus, Former EPA Administrator
We’ve come a long way…
US Burden of Disease 2013: Air pollution ranked 10th among risk factors

79,000 deaths PM$_{2.5}$ and 12,000 deaths ozone

Among top risk factors (#10 deaths, #11 DALYs)

Institute for Health Metrics and Evaluation
http://vizhub.healthdata.org/gbd-compare/
Lancet. 2015 Sep 10
What health benefits have regulations actually achieved?
  - Do changes in air pollution actually cause changes in health?

Are the expected health benefits of reducing air pollution likely to be the same at the low concentrations observed today as they were when levels were higher?
  - i.e. what’s the real shape of the concentration response at low concentrations?
HEI Accountability Research: The “Chain of Accountability”

Compliance, effectiveness

Atmospheric transport, chemical transformation, and deposition

Human time-activity in relation to indoor and outdoor air quality; Uptake, deposition, clearance, retention

Regulatory or other action

Emissions

Ambient air quality

Exposure/dose

Susceptibility factors; mechanisms of damage and repair, health outcomes

Human health

IMPROVED ACTIONS
Traffic diversions during the 1996 Summer Olympics in Atlanta, Georgia?
- Peel et al. 2010

A small town in Montana that replaces all old wood stoves?
- Noonan et al. 2011

Title IV of the 1990 Clean Air Act Amendments?
- Morgenstern et al. 2012

Policy driven air quality improvements in California?
- Gilliland et al. 2016

2006 CARB Regulations on Goods movements around Ports?
- Meng et al. ongoing

Control programs imposed on major stationary sources (e.g., CAIR) and mobile sources (e.g., Tier II, Heavy Duty Diesel/Low Sulfur)?
- Russell et al. ongoing
LATEST ACCOUNTABILITY RESEARCH

RESEARCH REPORT

Causal Inference Methods for Estimating Long-Term Health Effects of Air Quality Regulations

Corwin Matthew Zigler, Chanmin Kim, Christine Choiwat, John Barrett Hansen, Yun Wang, Lauren Hund, Jonathan Samet, Gary King, and Francesca Dominici

Case study 1:
What was the effect of $PM_{10}$ nonattainment designation on ambient AQ and Health?

Case study 2:
What was the impact of installing $SO_2$ scrubbers on emissions and ambient $PM_{2.5}$ concentrations?

Zigler et al. 2016
# NEW STATISTICAL APPROACHES:
CAUSAL INFERENCE METHODS, BAYESIAN ESTIMATION

<table>
<thead>
<tr>
<th>Causal Inference Methods</th>
<th>Case Study 1</th>
<th>Case Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential outcomes framework (Framing as a randomized experiment)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Propensity scores (confounding)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Principal stratification</td>
<td>X</td>
<td>X (multipollutant)</td>
</tr>
<tr>
<td>Causal mediation analysis</td>
<td></td>
<td>X (multipollutant)</td>
</tr>
</tbody>
</table>
CASE STUDY 1:
LINKS IN THE CHAIN OF ACCOUNTABILITY

Regulatory or Other Action

IMPROVED ACTION

Emissions

Compliance, effectiveness

Atmospheric transport, chemical transformation, and deposition

Ambient Air Quality

Human time-activity patterns in relation to indoor and outdoor air quality
Update, deposition clearance, retention in body

Exposure/Dose

Susceptibility factors; physiologic mechanisms of damage and repair

Human Health Response

Zigler et al. 2016
CASE STUDY 1: PM10 NONATTAINMENT DESIGNATIONS IN THE WESTERN U.S.

- U.S EPA – AQS data
  - Daily and annual measurements:
    - PM10
    - Ozone
  - Monitoring stations that were operating between 1990 and 2001
  - Annual PM$_{10}$ assumed “Missing” if <67% valid measurements
  - Linked to Medicare beneficiaries living within 6 miles of a monitoring location in 2001

Zigler et al. 2016
CASE STUDY 1:
AIR MONITORING DATA ARE NOISY

...But on average, PM$_{10}$ levels were lower in attainment areas

Zigler et al. 2016
CASE STUDY 1:
CAUSAL EFFECTS OF NONATTAINMENT DESIGNATION ARE CHALLENGING TO SEE

Interpretations:
Decreases in mortality and respiratory, but not CVD hospitalizations.
Not always associated with nonattainment designation.
CASE STUDY 2: LINKS IN THE CHAIN OF ACCOUNTABILITY

Zigler et al. 2016
CASE STUDY 2:
WHAT WAS THE IMPACT OF INSTALLING SO₂ SCRUBBERS ON EMISSIONS AND AMBIENT PM₂.5 CONCENTRATIONS?

- U.S EPA – AQS data
  - Average ambient PM2.5 in 2005
  - Monitors (●) located within 150-km radius of each power plant
    - 63 with scrubbers
    - 195 without scrubbers

- Other data:
  - SO₂, NOₓ, CO₂ emissions
  - Scrubber unit characteristics

Zigler et al. 2016
CASE STUDY 2 RESULTS: SHOW STRONGEST EFFECT OF SCRUBBERS ON AMBIENT PM$_{2.5}$ MEDIATED BY SO$_2$

- Average causal reduction in ambient PM$_{2.5}$ of 0.6µg/m$^3$ in 60% of plants installed with scrubbers (🔴)

- Little or no effect in 30% of plants with scrubbers (🔵)

- Causal increase in PM$_{2.5}$ in 10% of plants! (〇)

- Overall, results highly uncertain

Zigler et al. 2016
The chain of accountability

- Political interference, human behaviour
- Questionable emissions inventories, non-target pollutants
- Many confounding and concurrent factors
- Relatively small impact on exposure and/or power (area of effect)

(Real) Ambient air quality

(Regulatory or other action)

IMPROVED ACTION ???

(Emma) Relatively small health signals

(Ben Barratt, HEI Annual Conference 2013)
US Regulatory Impact Assessments (RIAs) assume:
- Linear concentration-response relationship extending through zero
- A science policy decision, based on the best evidence (Krewski et al. 2009 reanalysis of the ACS cohort)
- Evidence constrained by study size and power

HEI has launched a new research program with 3 large studies in the US, Canada, and Europe

What will we see?
- Threshold below some level?
- Steeper at low concentrations? (as in Global Burden of Disease model)
- Protective at lowest levels?
Hybrid exposure strategies:
- USEPA ACS data, including IMPROVE and STN
- NASA satellite data at 1km x 1km grid
- Chemical transport models
- Land use data
- Cross-validation

Zip-code level PM$_{2.5}$, selected PM species, ozone, and NO$_2$

Evaluation of exposure measurement error

Causal inference methods

US Medicare and Medicaid enrollees
- ~28 million each
- 2000-2014
Hybrid exposure strategies:
- Satellite data (1km x 1km)
- Validation of satellite predictions with co-located monitors in both US & Canada and
- Chemical transport models

Longitudinal address-level exposures to PM$_{2.5}$ (1981-2011)

Sensitivity of concentration response to ozone and NO$_2$

- 3 Canadian census datasets
- ~3-4 million people
- 1991 to 2011
Not yet. We’re still answering some of these questions:

- What health benefits have regulations actually achieved? Do changes in air pollution actually cause changes in health?

- Are the expected impacts of reducing air pollution likely to be the same at low concentrations observed today?

And there are more questions to be answered:

- What’s the impact of changing technologies and fuels on exposures to:
  - PM$_{2.5}$?
  - PM composition?
  - NO$_2$?
  - Ultrafine particles?
  - Components of brake and tire wear?
- And their impact on human health?

- What’s the value of denser monitoring networks of low cost monitors to improved individual-level exposure and health assessment?
Not yet!

Our existing monitoring system form the core of many health effects research studies:
- AQS
- MOVES
- Speciation network
- Near-road monitoring network

There’s an increasing demand for very large data sets so an ongoing need for long-term, high quality, complete data from as many existing monitors as possible.

It may not be enough. We need more systematic evaluation of the information added by higher density, low cost monitors.

We need your continued expertise and involvement in epidemiologic and other studies to make sure the data are appropriately used and interpreted.
ACKNOWLEDGEMENTS

My colleagues at HEI:

- Dan Greenbaum, President
- Robert O’Keefe, Vice President
- Hanna Boogaard, Senior Scientist
- Aaron Cohen, Principal Scientist (retired)
- Maria Costantini, Principal Scientist
- Annemoon van Erp, Managing Scientist
- Kathryn Liziewski, Research Assistant
- Hilary Polk, Managing Editor
- Hope Green, Assistant Editor

And to all our investigators...


Meng Y-Y Improvements in Air Quality and Health Outcomes Among California Medicaid Enrollees due to Goods Movement. HEI report in progress.


