Current Knowledge on Adverse Effects of Low-Level Air Pollution: Have We Filled the Gap?

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“How Low? Testing Health Effects at the Lowest Levels of Air Pollution”

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Unexpected Quiz

Who Wrote *Limbo Rock*?
The Narrowing Range of Exposure: Declining Particulate Matter (PM) Levels in the US

NAAQS 1971
TSP: 75 µg/m³

NAAQS 1987
PM₁₀: 50 µg/m³

NAAQS 1997
PM₂.₅: 15.0 µg/m³

NAAQS 2006
PM₂.₅: 15.0 µg/m³

NAAQS 2012
PM₂.₅: 12.0 µg/m³

National Ambient Air Quality Standards (NAAQS)
http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html
Parsing the Question

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Current Knowledge Continues to Increase
PubMed Results for “Particulate Matter and Mortality,” 2014-2018

Number of Publications vs. Year

N=1569

Add “Epidemiology”: N=801
Summary of associations between short-term PM$_{2.5}$ exposure and total (non-accidental) mortality in multicity studies per 10 $\mu$g/m$^3$ increase in 24-hour average concentration.
Associations between long-term exposure to PM$_{2.5}$ and total (non-accidental) mortality in recent North American cohorts
Global PM$_{2.5}$ Exposure and Study Ranges

Annual average PM$_{2.5}$ concentration estimates:
- CanCHEC: 0-18 µg m$^{-3}$
- Medicare: 6-16 µg m$^{-3}$
- Six Cities Study: 10-35 µg m$^{-3}$
- ESCAPE: 3-37 µg m$^{-3}$
- ACS CPS-II: 9-34 µg m$^{-3}$

Figure 3. Global and regional distributions of population as a function of annual (2013) average ambient PM$_{2.5}$ concentration for the world’s 10 most populous countries. Plotted data reflect local smoothing of bin-width normalized distributions computed over 400 logarithmically spaced bins; equal-sized plotted areas would reflect equal populations. Dashed vertical lines indicate World Health Organization Interim Targets (IT) and the Air Quality Guideline (AOG).
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The range of Adverse Effects continues to widen
What Is An “Adverse Effect”

2017 statement of the American Thoracic Society

“A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework”

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Pertinent questions</th>
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<tbody>
<tr>
<td>1. Fatality</td>
<td>Does air pollution exposure lead to an increase of short-term or long-term mortality? How persistent over time is the effect? (Generally, chronic effects such as the induction of new disease are given greater weight, although short-term exposures may lead to changes that increase risk for triggering acute adverse events, such as myocardial infarction)</td>
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<tr>
<td>2. Persistence of effect</td>
<td>Is there a shift in the population risk distribution of an adverse event? Are the very young, older adults or individuals with pre-existing health conditions or specific genetic characteristics more likely to be affected?</td>
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<td>3. Population risk</td>
<td></td>
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<td>4. Susceptibility</td>
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<td>5. Medical/functional significance</td>
<td>Is there evidence of one or more of the following? 1) severe interference with a normal activity of the affected person or persons; 2) incapacitating illness; 3) permanent injury; 4) progressive dysfunction; 5) reduced quality of life</td>
</tr>
</tbody>
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Adverse Effects

Mortality: all-cause ADHD Blood Pressure

Adverse Effects

Autism Obesity COPD exacerbation Inflammation

Pneumonia and ARI and ARI

Vestibular function Metabolic disorders Suicide, Mental Health and Well-being ADHD

Pulmonary Autism Obesity Depression Atopic Dermatitis

Morbidity: all cause

Birth Weight Miscarriage Mortality: all-cause COPD exacerbation

Pulmonary Autism Obesity

Morbidity: all cause Inflammation

Metabolic disorders Respiratory

Pulmonary Autism Obesity

Morbidity: all cause Inflammation

Suicide, Mental Health and Well-being ADHD Respiratory

Morbidity: all cause Inflammation

Cancer: Lung and others Mortality: cause-specific

Brain Aging
Parsing the Question

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What is the Gap
The Gap: Contexts

• For methods for improved estimation
• For reducing scientific uncertainty?
• For risk assessment and burden estimation?
• For setting standards that provide public health protection?
• For carrying out cost-benefit analyses?
• For directing further research?
Using Concentration-Response (C-R) Functions to Guide Standards

- Research
- Epidemiology
- Toxicology

C-R Functions
- Form
- Slope

Burden from Current Exposures

Reduction of Burden Under Different Regulatory Scenarios
Using Concentration-Response

- Risk
- Concentration
- Actual
- Target
- Residual
- Background
- Benefit
Form Matters:
The Political Morphology of Dose-Response Curves

Proctor (1995)
Cancer Wars
What is the Form of the Relationship and what is the Slope?

- Sublinear
- Supra-linear
- Linear, Threshold
- Linear, No-threshold
Is the model the message?

George Box

All models are wrong, but some models are useful. So the question you need to ask is not "Is the model true?" (it never is) but "Is the model good enough for this particular application."?
Back to the Gap

• What level of certainty is needed (what level of uncertainty is tolerable) around:
  • The form of the concentration-response relationship
  • The slope of the concentration-response relationship at different concentrations

• How does uncertainty/certainty affect decision-making in different contexts: regulatory, costing and burden estimation, and setting scientific agendas.
Some Bottom Lines

• We are close to filling “the Gap” for some outcomes with observational evidence
  • Methods have been refined
  • For many adverse effects the observations are in the range of regulatory interest
  • Mechanistic uncertainties persist
  • Emerging evidence points to some Adverse Effects for which further research is warranted

• Some empiric work might be useful to assess potential sensitivity of decision-making to various scenarios of exposure and risk
Editor’s Note
(George Comstock)

Epidemiologic science can give only general guidance to those who must decide upon acceptable limits of air pollutants. Judgment in this area depends much more on the art of epidemiology, the drawing of reasonable conclusions from imperfect data.