Time scales of air pollution exposure health effects: what do they mean for local air quality management?

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Presentation points:

- lags vs. exposure duration
- time scales
  - very short, short (acute), longer, longest (chronic)
  - PM vs. ozone effects
- air quality management
  - averaging times and the EPA risk assessment

lags vs. exposure duration:

- lag =
  - time between air pollutant measurement and health endpoint, e.g.,
    - 0,1,2,3 (individual day lags)
    - distributed lag (e.g., lags 0-3)

- exposure duration
  - short-term (days) vs. long-term (year or longer)

exposure time scales:

- very short → hours
- short (short-term) → days
- longer → weeks - months
- longest (long-term) → year and longer

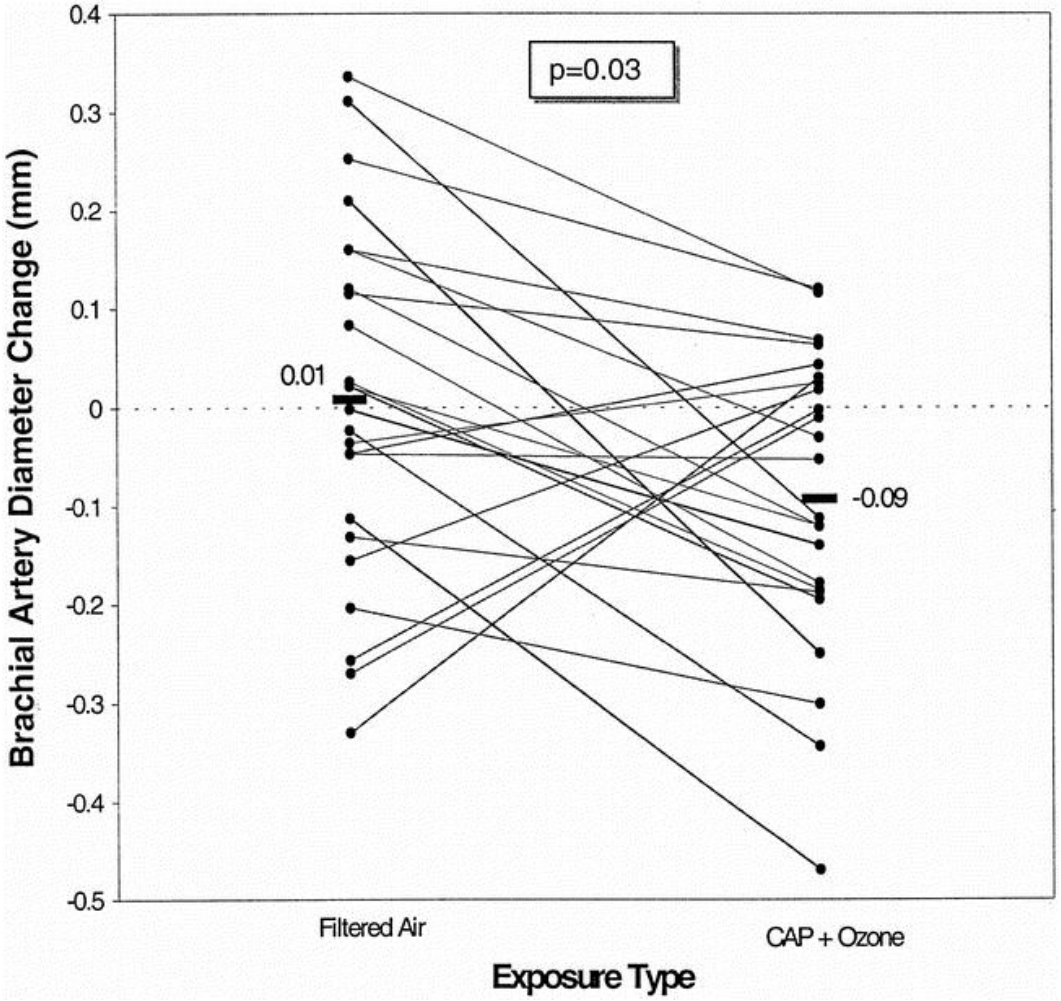
exposure duration: PM vs. ozone

- very short-term (epi & experimental) - hrs
  - good evidence for ozone (much human experimental)
  - unclear for PM
    - intriguing published pilot findings
      - myocardial infarction - Peters A. Circulation 2001
      - not confirmed in unpublished findings (HEI report # 124, June 2005)
    - some negative findings
      - myocardial infarction - Sullivan JH. Epidemiol 2005.
    - but, human experimental and toxicology

Human experimental:

Exposure to CAPs plus O_3 resulted in systemic artery constriction

(10 min after 2-hr exposure) (Brook *et al*. Circulation 2002)



Toxicology:

Inhalation of Concentrated Ambient Air Particles Exacerbates Myocardial Ischemia in Conscious Dogs

Gregory A. Wellenius,[1] Brent A. Coull,[2] John J. Godleski,[1,3] Petros Koutrakis,[1] Kazunori Okabe,[1,4] Sara T. Savage,[1] Joy E. Lawrence,[1] G. G. Krishna Murthy,[1] and Richard L. Verrier[1,3,5]

[1]Department of Environmental Health and [2]Department of Biostatistics, Harvard School of Public Health, Boston, Massachusetts, USA; [3]Harvard Medical School, Boston, Massachusetts, USA; [4]Thoracic Surgery Division, Brigham and Women's Hospital, Boston, Massachusetts, USA; [5]Beth Israel Deaconess Medical Center, Boston, Massachusetts, USA

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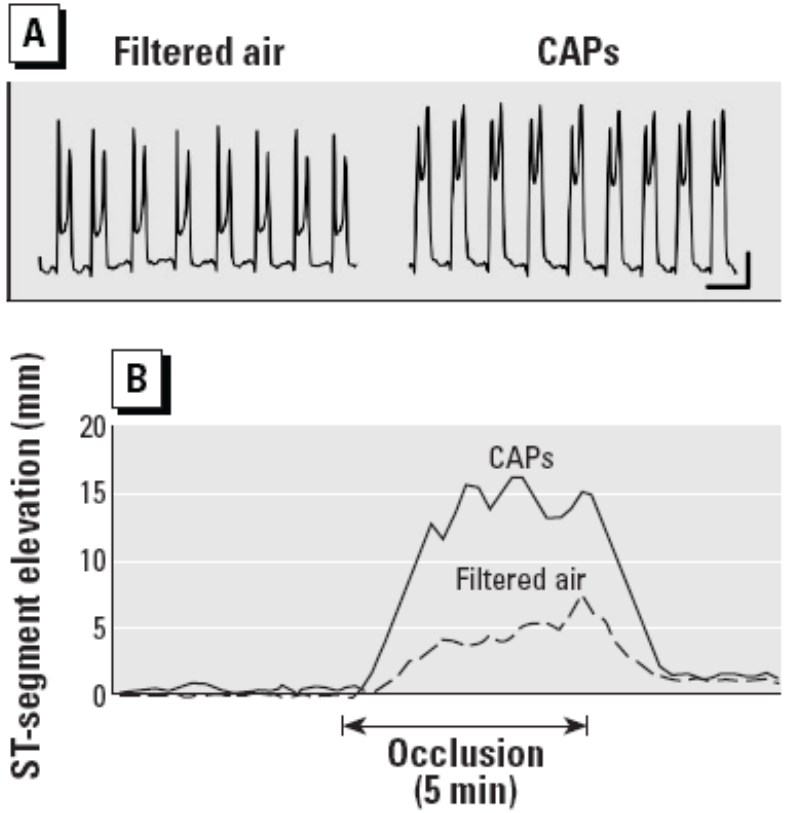


exposure duration: PM vs. ozone

- short-term (epi) - days
  - time series (case-crossover) studies
  - panel studies

    (multiple measurements on each person in a panel over time)
  - longitudinal - cross-sectional hybrid studies

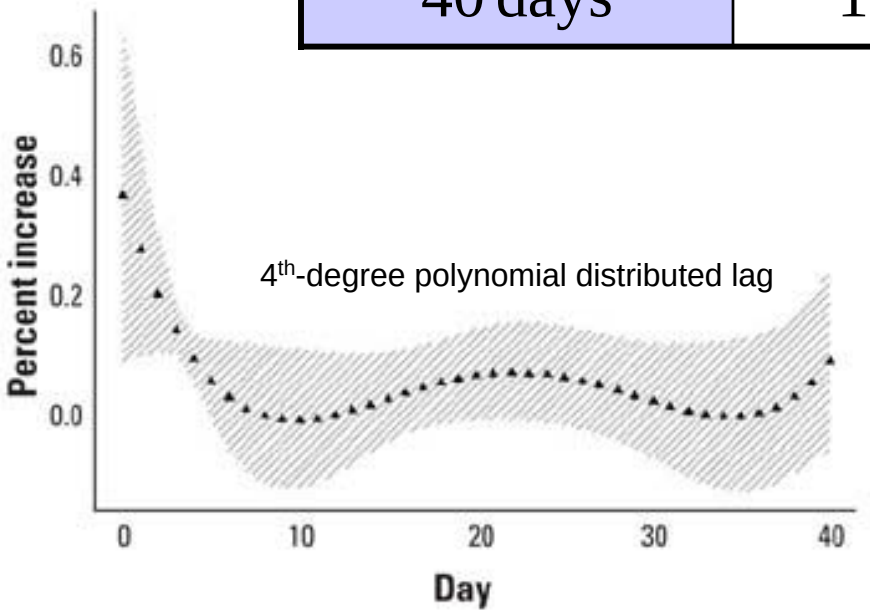
    (one measurement for each person, but different times for different people)

Not much here to distinguish PM and ozone

exposure duration: PM vs. ozone

- longer term – weeks to months
  - time series studies (here distinction between lag and exposure duration gets confusing)
  - evidence for PM only
  - how to interpret these longer time scale studies? (control for “time”)

Daily CVD mortality change for $10\mu g/m^3$ increase in PM_{10}: 10 cities		
unconstrained distributed lag	%	95% CI
20 days	1.34	0.89-1.79
30 days	1.72	1.20-2.25
40 days	1.97	1.38-2.55



4th-degree polynomial distributed lag

Zanobetti A. Environ Health Perspect 2003; 111: 1188-93

exposure duration: PM vs. ozone

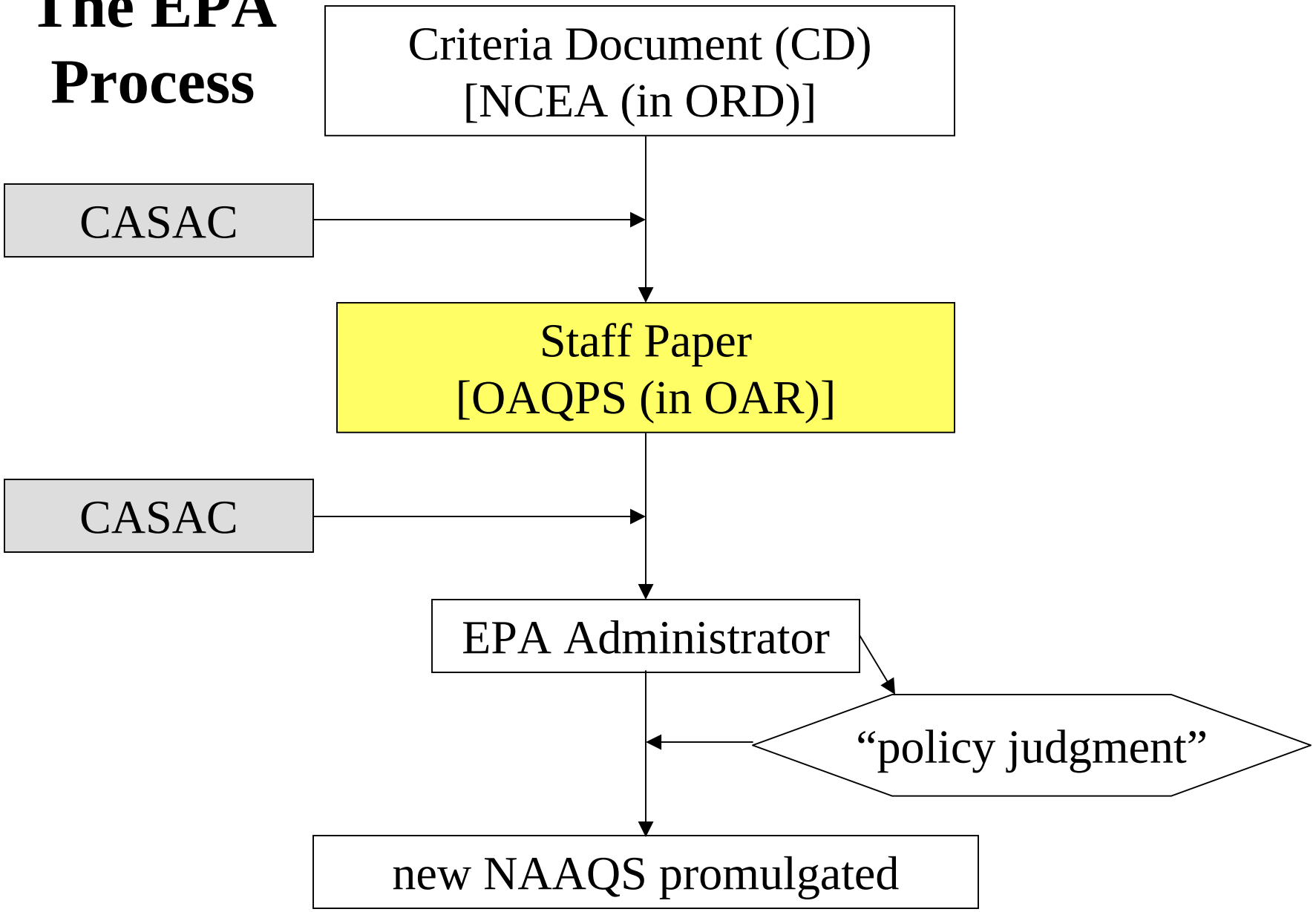
- long-term - years
  - toxicology - support for both PM (Sun Q. JAMA 2005; 294: 3003-10) and ozone (Hyde DM. Am J Respir Crit Care Med 2002; 185: A811)
  - epidemiology - largely only evidence for PM (vs. ozone) (ACS study - Pope JAMA 2002; WHI study - Miller NEJM 2007; Gauderman WJ NEJM 2005)

air quality regulations:

implications of different effects for different durations of exposure

1. obvious for the averaging time of a standard/objective

The EPA Process



PM: averaging period and level of the NAAQS

- 24-hr average $PM_{2.5}$: 35 $\mu g/m^3$
- annual average $PM_{2.5}$: 15 $\mu g/m^3$
- shorter averaging time?

Ozone: averaging period and the NAAQS

- current 8-hr average O_3: 82ppb
  - averaging period based on:
    - 6.6-hr human exposure studies
    - daily time course of ozone concentrations

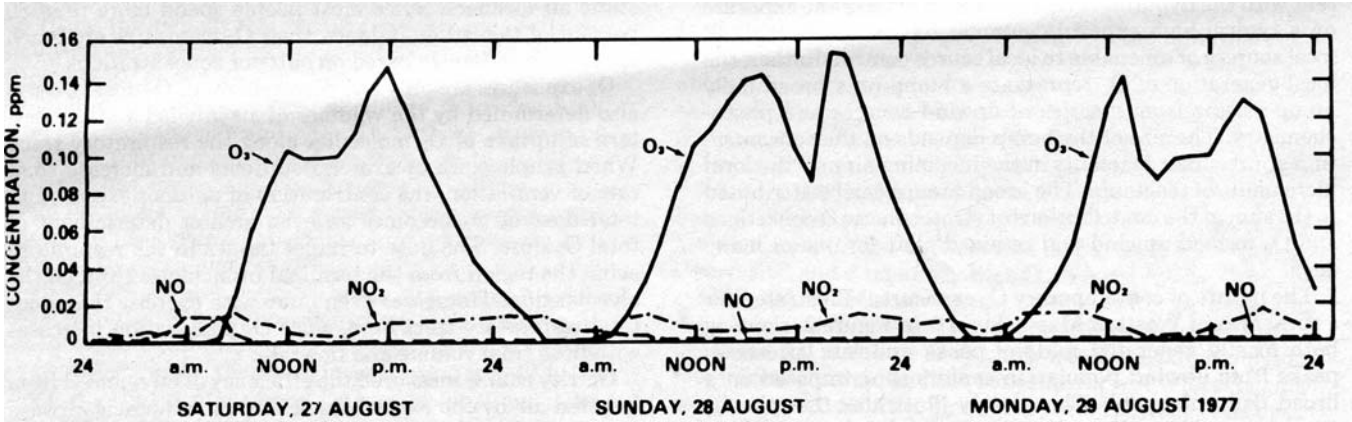


Figure 2. Three-day sequence of hourly ozone concentrations at Montague, MA, SURE station showing locally generated midday peaks and transported late peaks. From: EPA.[7]

Lippmann M. JAWMA 1989

air quality regulations:

implications of different effects for different durations of exposure

1. obvious for the averaging time of a standard/objective

2. lowering concentrations at one averaging time may also lower them for other averaging times

EPA risk-based approach to translating health effects findings into policy

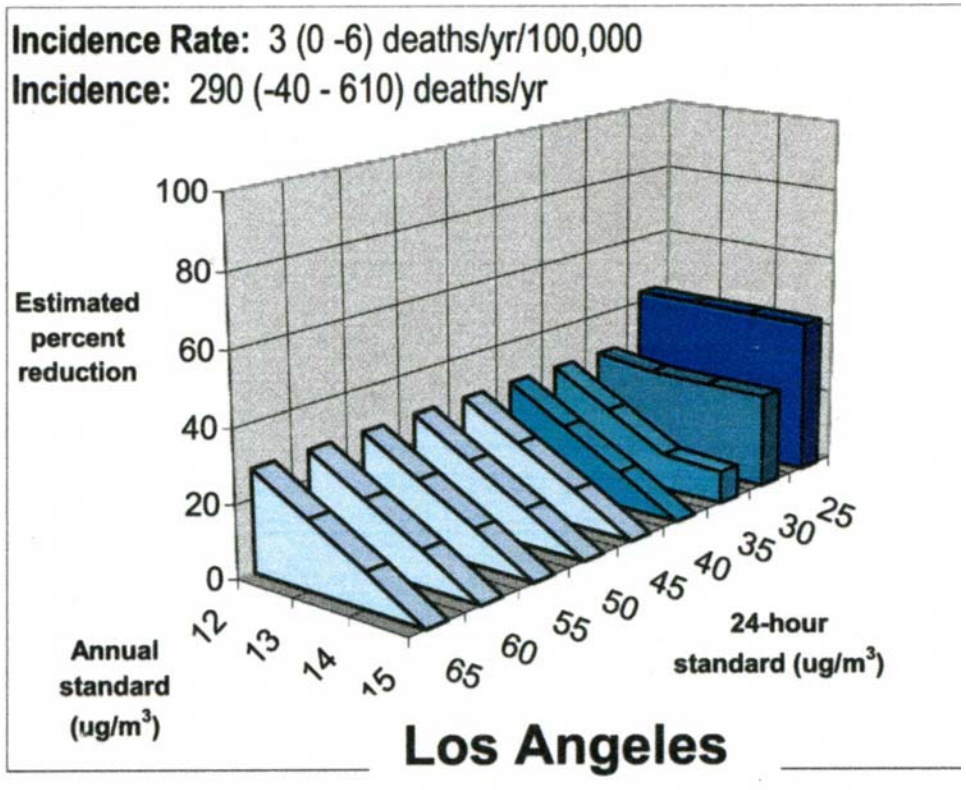
1. utilizes risk assessment
   - selected cities (and their air pollution concentrations) to illustrate health impacts of lowering standards
   - concentration-response functions from epidemiological studies

2. takes a sensitivity approach to handling uncertainty
   - vary threshold assumptions

3. evaluating short- and long-term standard impacts <u>together</u>

Example of risk-based assessment for $PM_{2.5}$

- effect of short-term exposure
- background concentration threshold



EPA OAQPS PM Staff Paper, 2005

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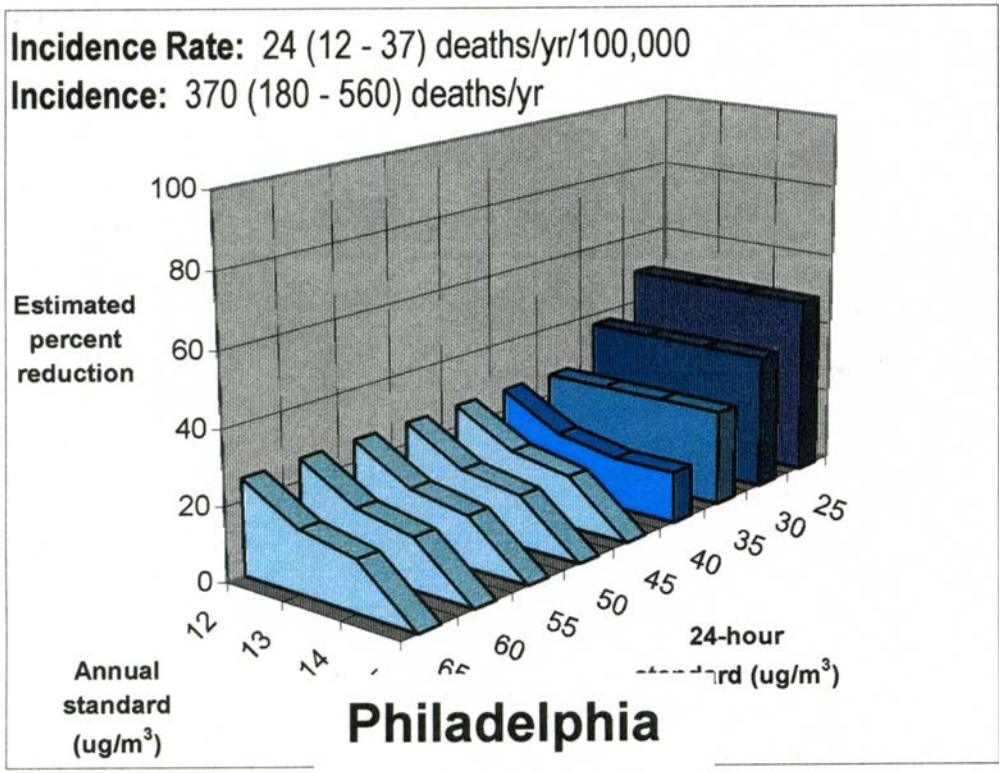

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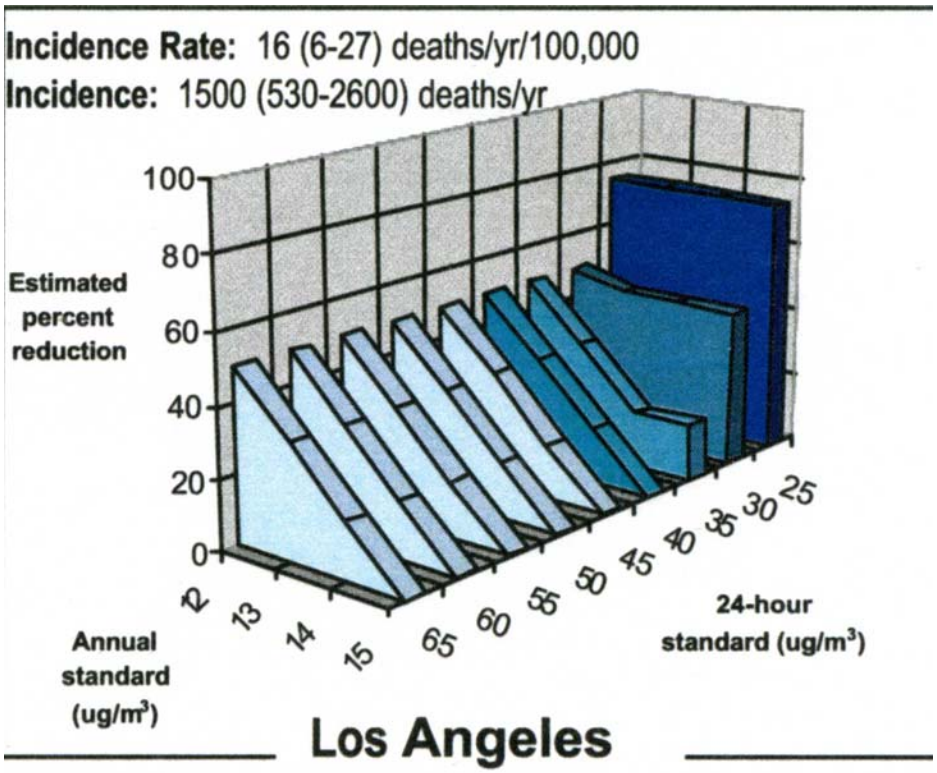
Example of risk-based assessment for $PM_{2.5}$

- effect of long-term exposure
- 7.5 µg/m^3 threshold



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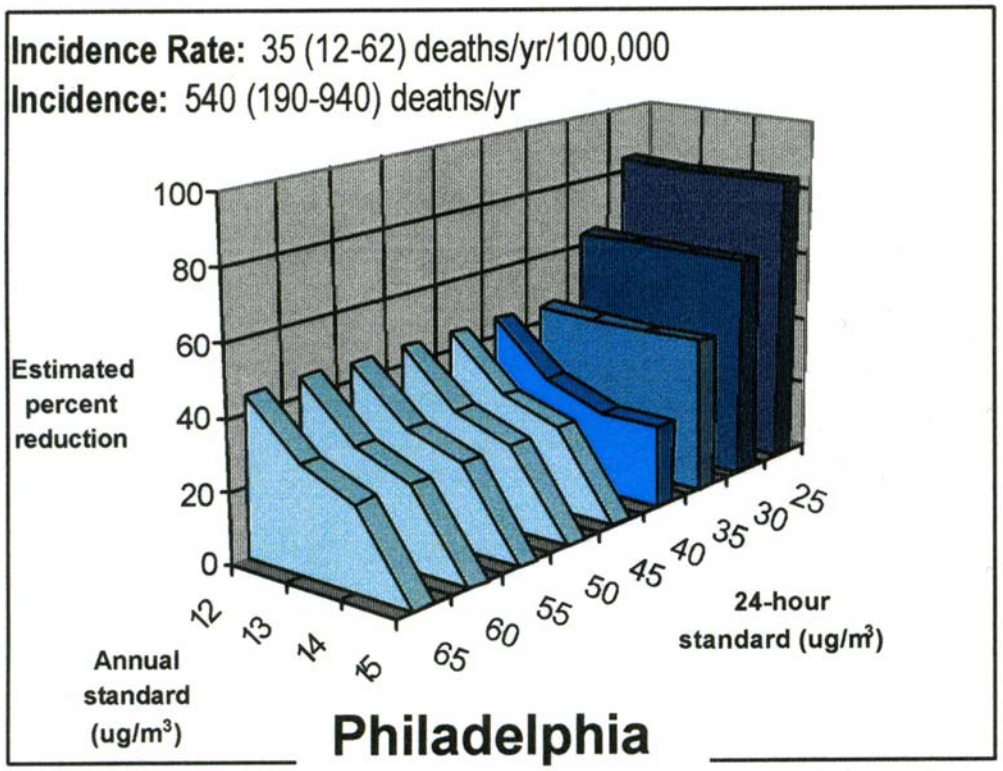

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The level of the $PM_{2.5}$ standard:

- CASAC recommendations:
  - 24-hr average $PM_{2.5}$: 30 - 35 $\mu g/m^3$
  - annual average $PM_{2.5}$: 13-14 $\mu g/m^3$

- Administrator:
  - 24-hr average $PM_{2.5}$: 35 $\mu g/m^3$
  - annual average $PM_{2.5}$: 15 $\mu g/m^3$

EPA "largely ignored recommendations for tighter control from its own scientists and from an independent panel of outside experts." Michael Janofsky, NY Times, Dec 21, 2005.

other criteria pollutants: averaging period and level of the NAAQS

SO_2

- annual: 140ppb
- 24-hr: 30ppb

NO_2

- annual: 53ppb

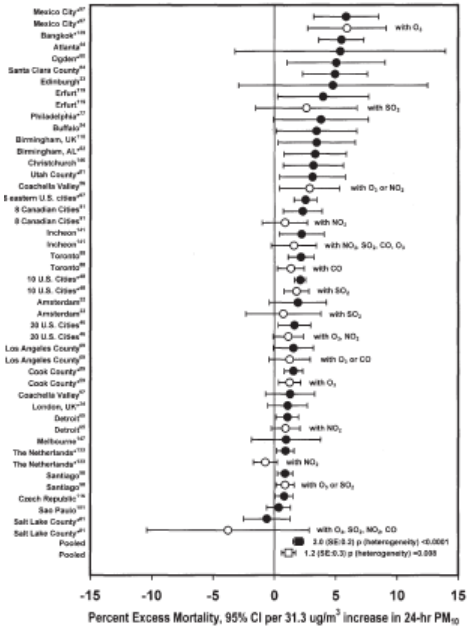
CO

- 1-hr: 35ppm
- 8-hr: 9ppm

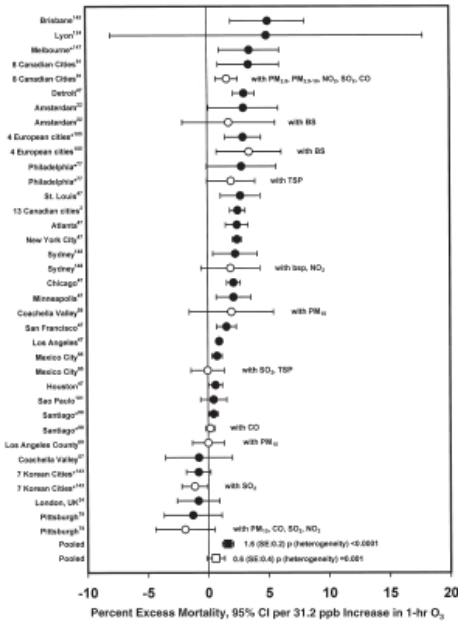
Time series (short-term) effects of the criteria pollutants

Stieb D. JAWMA 2002

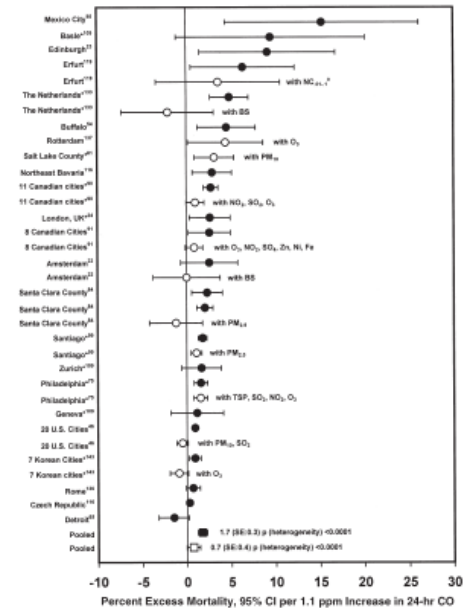
PM_{10}



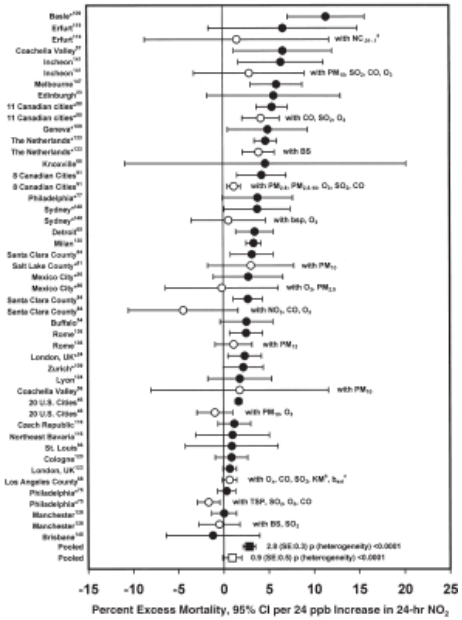
O_3



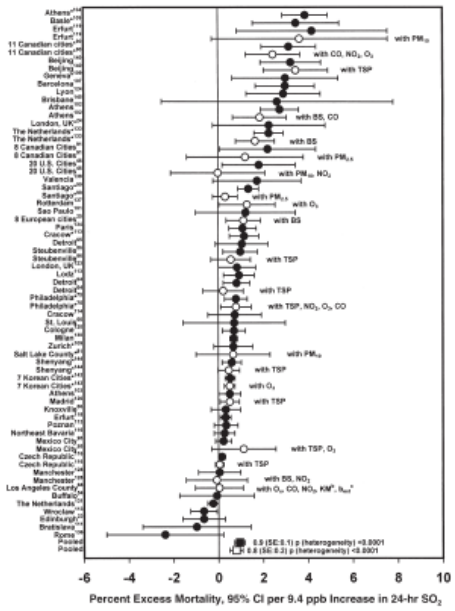
CO



NO_2



SO_2



long-term effects of NO_x and SO_2?

- for SO_2, at least, findings on effects of long-term exposures are as strong or stronger than those associated with $PM_{2.5}$ (Hong Kong intervention - Hedley AJ. Lancet 2002; ACS study - Pope CA. JAMA 2002)

- why isn't this reflected in more stringent standards? (because few believe it's SO_2)

Time scales of exposure effects:

challenges for future air quality management

1. translating *operationalized* exposure periods used in health studies into standards and guidelines

Health effect estimates by varying exposure averaging times (estimated percent changes in HRV)

$Log_{10}SDNN$	4-hr average	24-hr average	48-hr average
$PM_{2.5}$	-0.1	-2.2	-5.4
O_3	-3.6	-5.3	-2.2

Park SK. Environ Health Perspect 2005; 113: 304-9

Time scales of exposure effects:

challenges for future air quality management

1. translating *operationalized* exposure periods used in health studies into standards and guidelines

2. the multi-pollutant/PM component/source world