



Air Pollution and Cardiovascular Disease: From Air Quality Data to Policy

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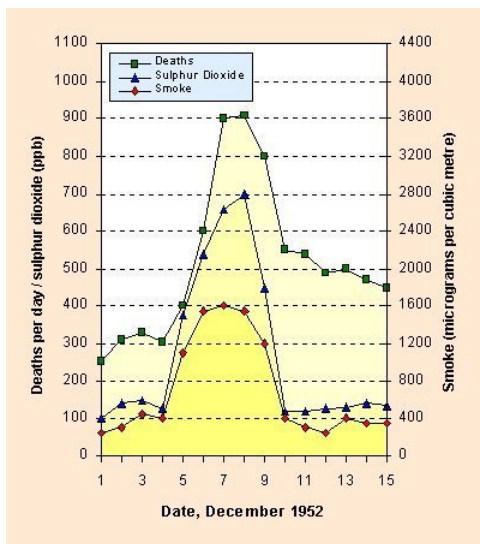
EPA AQS Conference: 8/22/2012

London Smog, 1952



Greater London
Authority, 2002

London Smog, 1952



www.portfolio.mvm.ed.ac.uk

Boston, MA



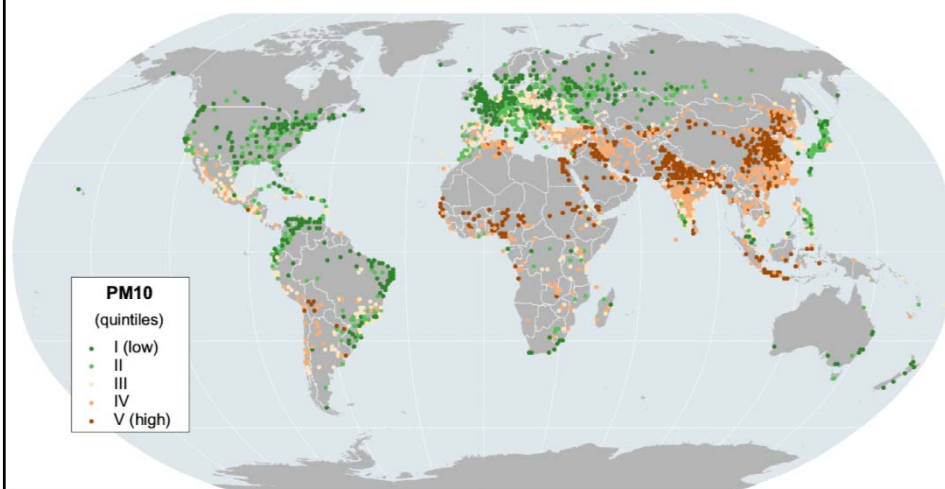
www.hazecam.net

Boston, MA



www.hazecam.net

Estimated PM₁₀ Levels in Large Cities

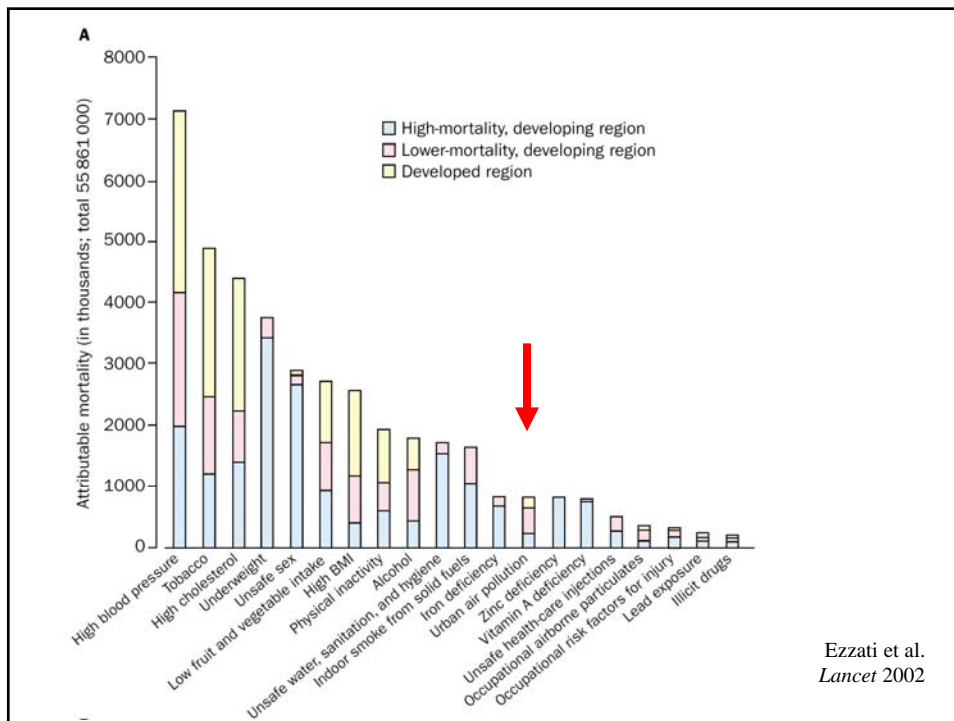


Cohen et al. *GBD* 2002

Annual Mortality Attributable to Outdoor Air Pollution

Environmental risks	Global estimate	Asian estimate (S, SE Asia + W Pacific)
Unsafe water	1,730,000	730,000
Urban outdoor air	799,000	487,000
Indoor air	1,619,000	1,025,000
Lead	234,000	88,000

Cohen et al. 2005



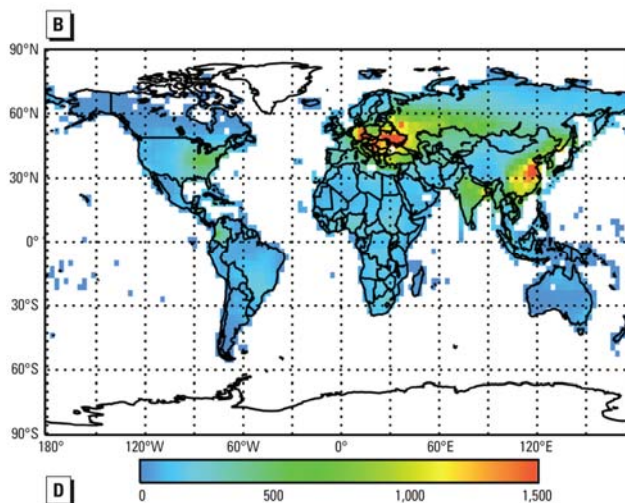
Estimated Annual Global Deaths Attributable to Outdoor Air Pollution

Table 5. Estimated annual global PM_{2.5} mortalities (mean \pm 1 SD) using alternative CRFs with and without LCTs and HCTs ($\times 1,000$).

	Mortality		
	All causes	Cardiopulmonary	Lung cancer
Krewski et al. (2009)	3,381 \pm 986	3,499 \pm 864	222 \pm 80
LCT = 5.8 $\mu\text{g}/\text{m}^3$	2,378 \pm 876 (-29.7%)	2,506 \pm 816 (-28.4%)	164 \pm 68 (-26.1%)
LCT = 7.5 $\mu\text{g}/\text{m}^3$	2,077 \pm 822 (-38.6%)	2,201 \pm 780 (-37.1%)	146 \pm 64 (-34.2%)
HCT = 30 $\mu\text{g}/\text{m}^3$	3,059 \pm 774 (-9.5%)	3,205 \pm 676 (-8.4%)	201 \pm 68 (-9.5%)
HCT = 50 $\mu\text{g}/\text{m}^3$	3,338 \pm 940 (-1.3%)	3,464 \pm 826 (-1.0%)	219 \pm 78 (-1.4%)
Pope et al. (2002), 1979–1983 ^a	2,333 \pm 1,196 (-31.0%)	1,800 \pm 742 (-48.6%)	139 \pm 72 (-37.4%)
Laden et al. (2006) ^b	7,714 \pm 2,736 (+128.2%)	4,549 \pm 1,439 (+30.0%)	336 \pm 198 (+51.4%)

Anenberg et al. *EHP* 2010

Estimated Annual Excess Cardiopulmonary Mortality Rate Attributable to PM_{2.5}



Anenberg et al.
EHP 2010

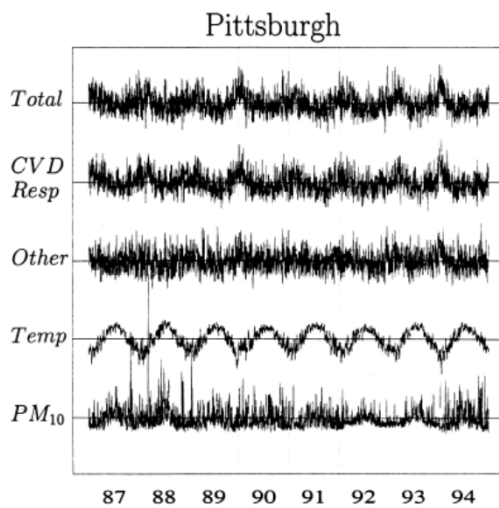
What Are People Dying Of?

Cause of death	Percent of total deaths	Estimated RR per 50 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$	Percent of excess deaths due to PM exposure
All Causes	100	1.07	100
Respiratory	8	1.25	28
Cardiovascular	45	1.11	69
Other	47	1.04	3

Pope *EHP* 2000

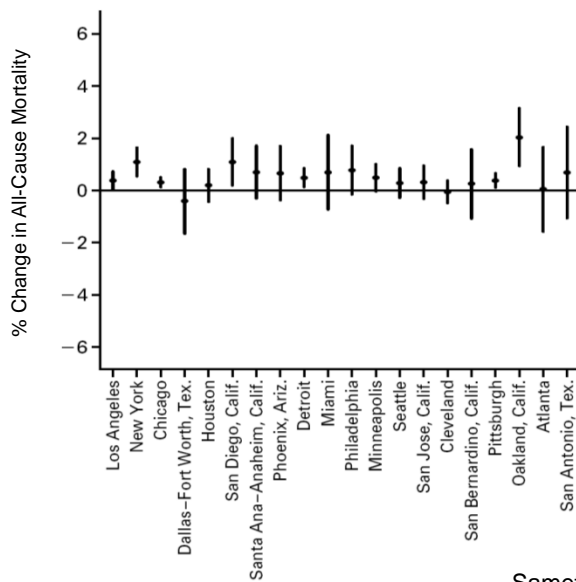
Cardiovascular Effects of Short-Term Exposure

The Problem



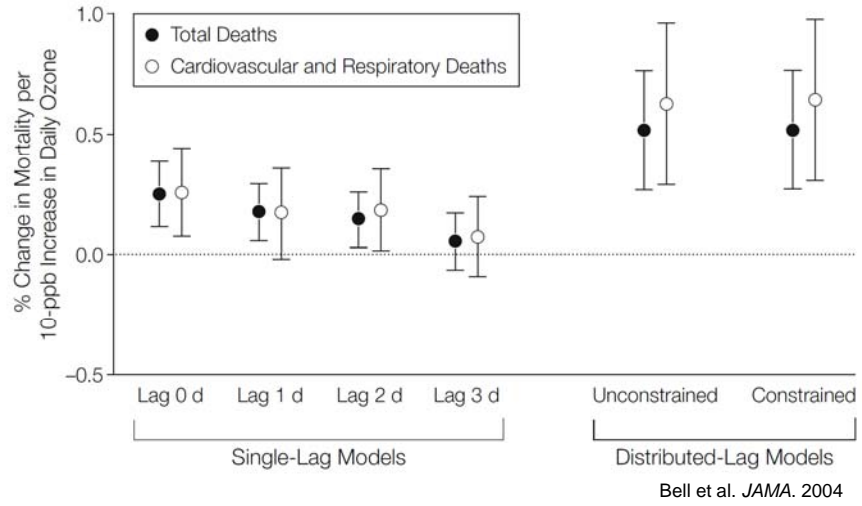
Dominici et al. *AJE* 2003

PM₁₀ and All-Cause Mortality in 20 US Cities

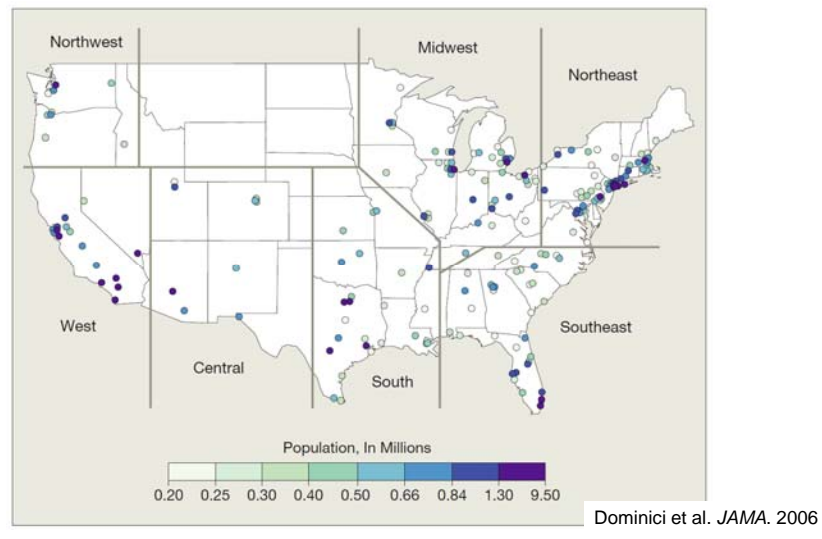


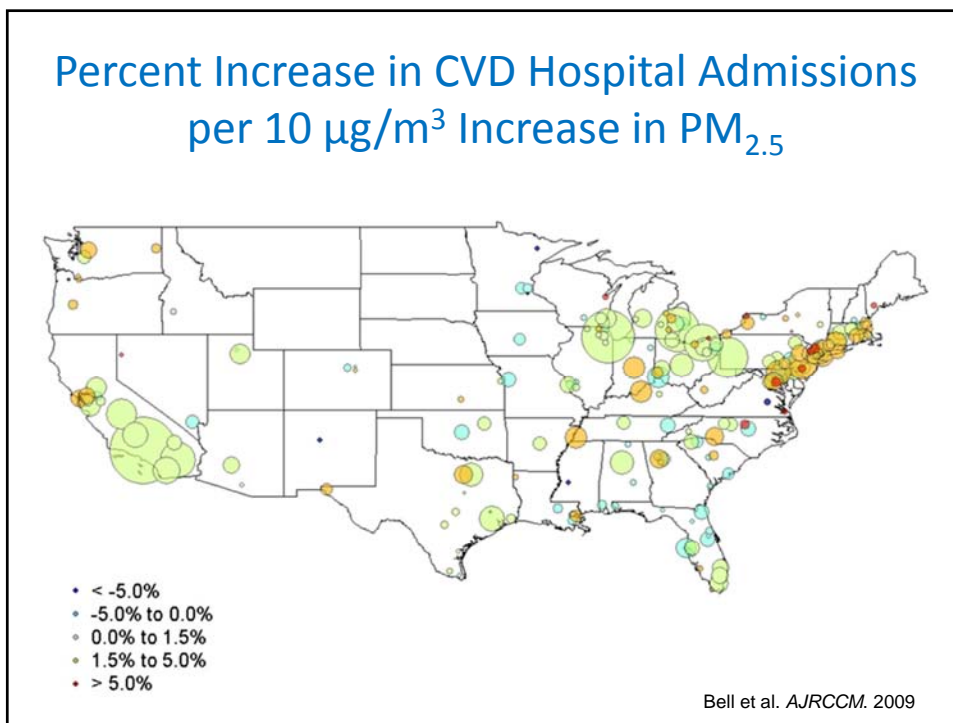
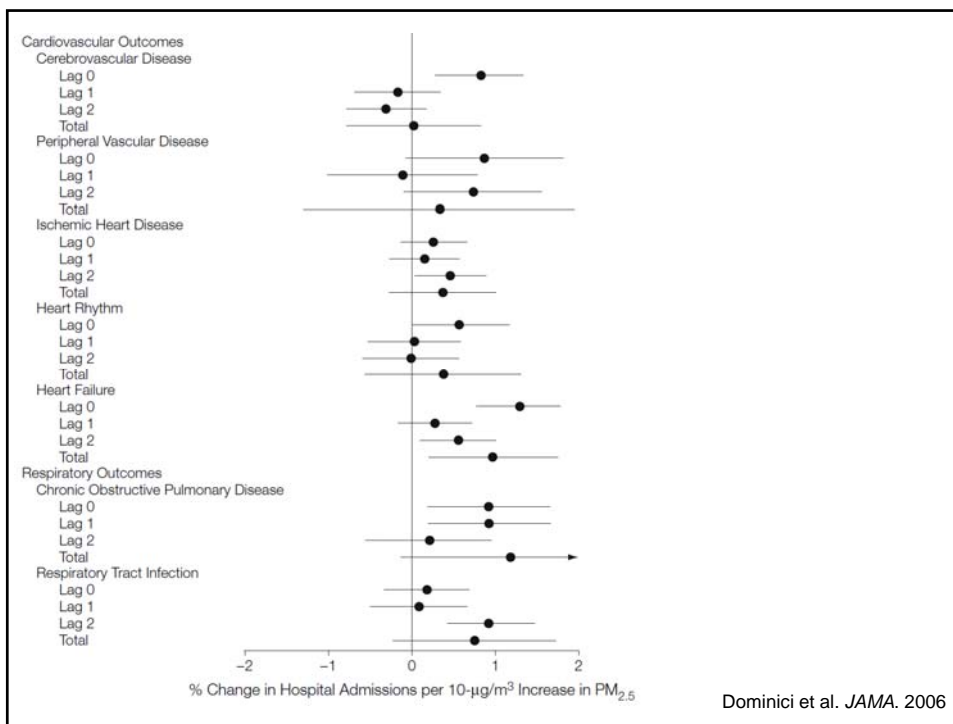
Samet et al. *NEJM* 2000

NMMAPS: Percent Change in Daily Mortality for a 10-ppb Increase in O₃

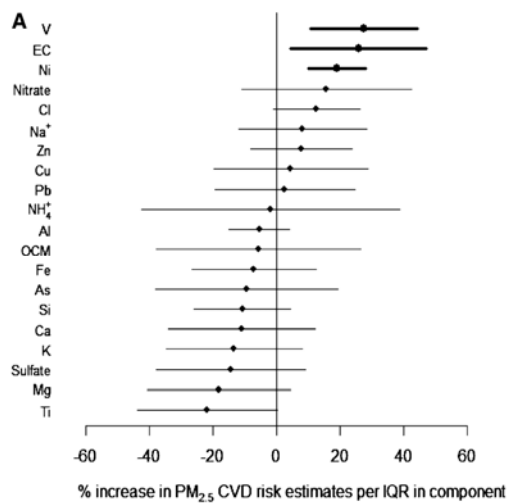


Medicare Cohort Air Pollution Study (MCAPS), 1999–2002





Percent Increase in CVD Hospital Admissions per IQR Increase in Each Component



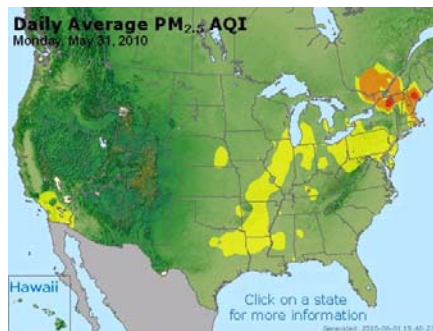
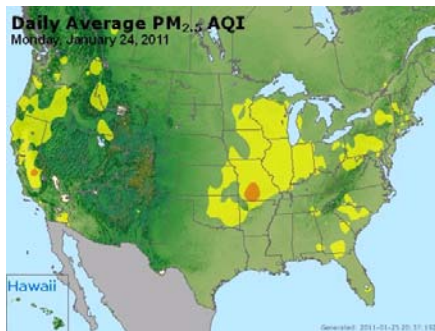
Bell et al. *AJRCCM*. 2009

Air Quality Guide for Particle Pollution

Air Quality	Air Quality Index	Health Advisory
Good	0-50	None.
Moderate	51-100	Unusually sensitive people should consider reducing prolonged or heavy exertion.
Unhealthy for Sensitive Groups	101-150	People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.
Unhealthy	151-200	People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion.
Very Unhealthy	201-300	People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.

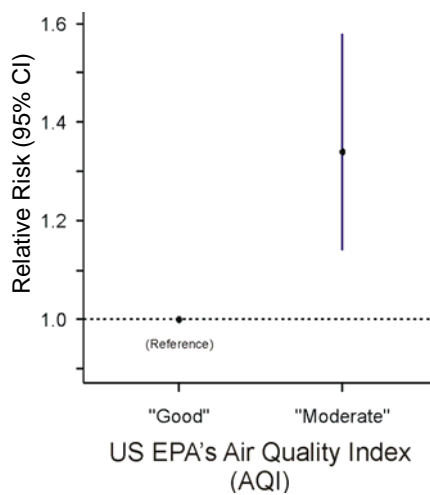
www.airnow.gov

Air Quality Index for PM_{2.5}



www.airnow.gov

AQI and Risk of Ischemic Stroke Onset



Wellenius et al. *Arch Intern Med* 2012

Public health importance of triggers of myocardial infarction: a comparative risk assessment

Tim S Nawrot, Laura Perez, Nino Künzli, Elke Munters, Benoit Nemery

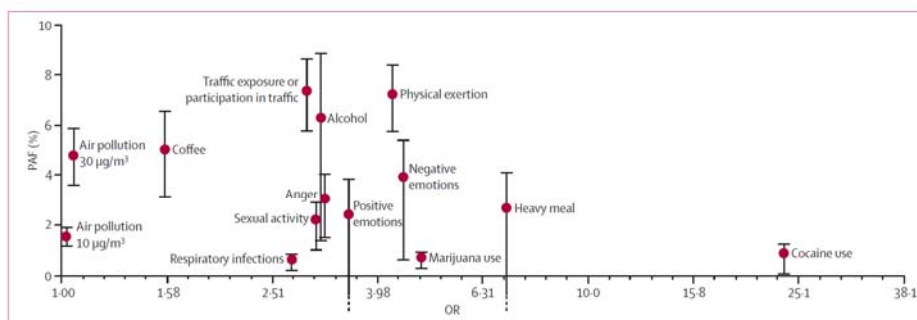


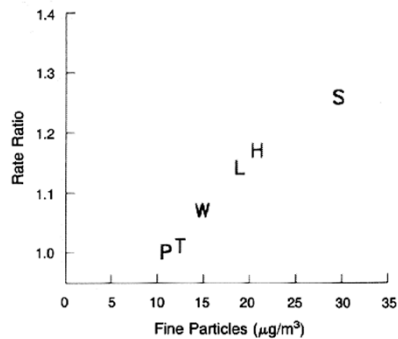
Figure 2: Relation between OR and the PAF for each studies trigger

PAFs were calculated and reported with their 95% CI (error bars). Not significant triggers show 95% CIs that are lower than 0%. X-axis is log scale, and ORs are given as anti-logs. OR=odds ratio. PAF=population attributable fraction.

Nawrot et al. *Lancet*. 2011

Cardiovascular Effects of Long-Term Exposure

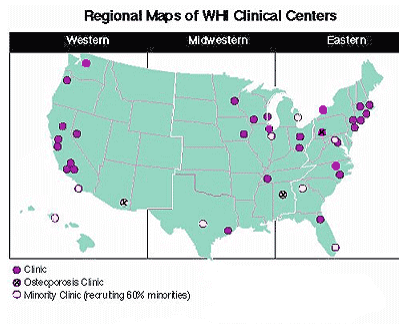
Harvard Six-Cities Study



- 8111 adults in 6 cities recruited between 1974 and 1977
- 14-16 year follow-up for mortality

Dockery *NEJM* 1993

Women's Health Initiative



- 65,000 women recruited from 49 centers in 36 US Metropolitan areas between 1994 and 1998
- Followed prospectively through 2002
- Exposure estimated based on average $\text{PM}_{2.5}$ levels in 2000 at nearest EPA monitor

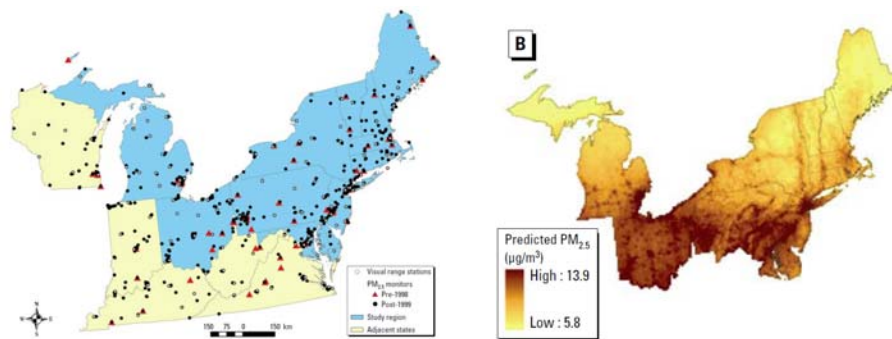
Women's Health Initiative

Table 3. Estimated Hazard Ratios for the Time to the First Cardiovascular Event or Death Associated with an Exposure Increase of 10 μg per Cubic Meter in the Level of Fine Particulate Matter ($\text{PM}_{2.5}$).^{a,b}

Outcome	No. of Events	Hazard Ratio (95% CI)		
		Overall	Between Cities	Within Cities
First cardiovascular event				
Any cardiovascular event ^c	1816	1.24 (1.09–1.41)	1.15 (0.99–1.32)	1.64 (1.24–2.18)
Coronary heart disease ^d	1268	1.21 (1.04–1.42)	1.13 (0.95–1.35)	1.56 (1.11–2.19)
Cerebrovascular disease ^e	600	1.35 (1.08–1.68)	1.20 (0.94–1.54)	2.08 (1.28–3.40)
Myocardial infarction	584	1.06 (0.85–1.34)	0.97 (0.75–1.25)	1.52 (0.91–2.51)
Coronary revascularization	949	1.20 (1.00–1.43)	1.14 (0.93–1.39)	1.45 (0.98–2.16)
Stroke	554	1.28 (1.02–1.61)	1.12 (0.87–1.45)	2.08 (1.25–3.48)
Death from cardiovascular cause				
Any death from cardiovascular cause	261	1.76 (1.25–2.47)	1.63 (1.10–2.40)	2.28 (1.10–4.75)
Coronary heart disease				
Definite diagnosis	80	2.21 (1.17–4.16)	2.22 (1.06–4.62)	2.17 (0.60–7.89)
Possible diagnosis	59	1.26 (0.62–2.56)	1.20 (0.54–2.63)	1.57 (0.29–8.51)
Cerebrovascular disease	122	1.83 (1.11–3.00)	1.58 (0.90–2.78)	2.93 (1.03–8.38)

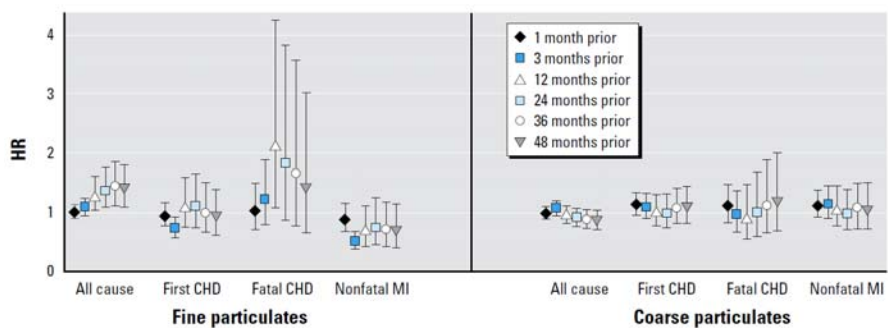
Miller et al. *NEJM*. 2007

Nurses' Health Study



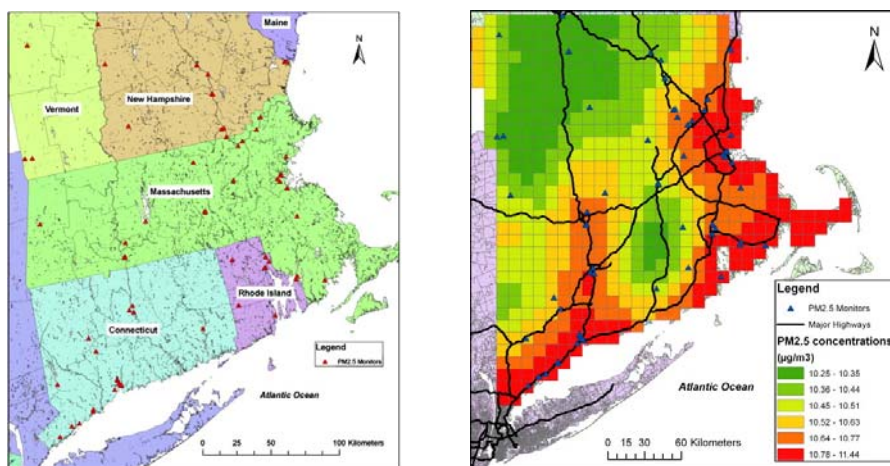
Yanosky et al. *Env Health Perspect*. 2008

Nurses' Health Study



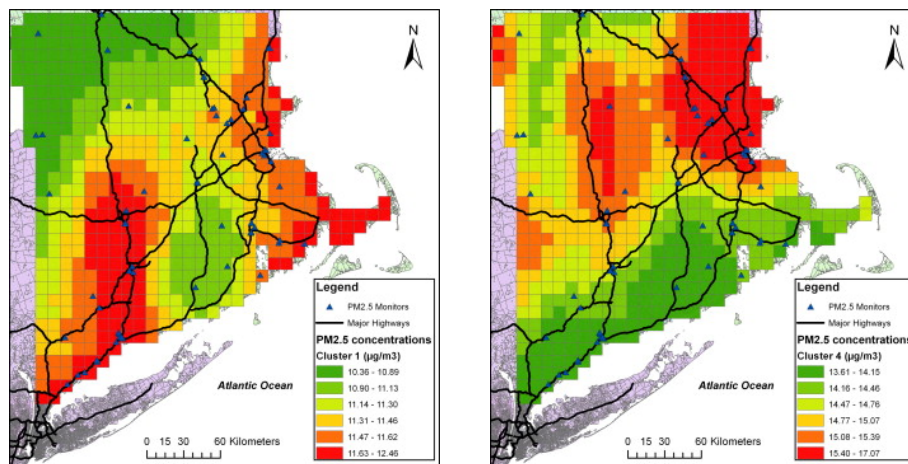
Puett et al. *Env Health Perspect.* 2009

Combining Ground and Satellite Data



Lee et al. *Environ Res.* 2012

Combining Ground and Satellite Data



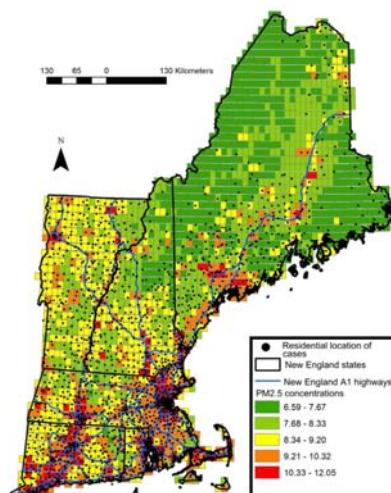
Lee et al. *Environ Res.* 2012

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PLOS one

Acute and Chronic Effects of Particles on Hospital Admissions in New-England

Itai Kloog^{1*}, Brent A. Coull², Antonella Zanobetti¹, Petros Koutrakis¹, Joel D. Schwartz¹



Kloog et al. *PLoS One.* 2012

Acute and Chronic Effects of Particles on Hospital Admissions in New-England

Itai Kloog^{1*}, Brent A. Coull², Antonella Zanobetti¹, Petros Koutrakis¹, Joel D. Schwartz¹

PM _{2.5} exposure type	All Respiratory	CVD
	Percent increase ^a	Percent increase ^a
Short term PM _{2.5} exposure	0.70 (0.35–0.52)	1.03 (0.69–0.45)
Long term PM _{2.5} exposure	4.22(1.06–4.75)	3.12(0.30–4.29)

Note: ^aValues are percent.
doi:10.1371/journal.pone.0034664.t003

Kloog et al. *PLoS One*. 2012

Cardiovascular Health Effects of Particulate Air Pollution

Chronic effects

- Clinical events
- Atherosclerosis
- Hemodynamics
- Oxidative stress
- Inflammation

Acute effects

- Clinical events
- Autonomic nervous system function
- Hemodynamics
- Inflammation
- Oxidative stress
- Hemostasis
- Endothelial cell function

Connection to Policy

Summary of NAAQS Promulgated for PM, 1971-2006

Year (Final Rule)	Indicator	Avg Time	Level	Form
1971 (36 FR 8186)	TSP (Total Suspended Particulates)	24 h	260 µg/m ³ (primary) 150 µg/m ³ (secondary)	Not to be exceeded more than once per yr
		Annual	75 µg/m ³ (primary)	Annual geometric mean
1987 (52 FR 24634)	PM ₁₀	24 h	150 µg/m ³	Not to be exceeded more than once per yr on average over a 3-yr period
		Annual	50 µg/m ³	Annual arithmetic mean, averaged over 3 yr
1997 (62 FR 38652)	PM _{2.5}	24 h	65 µg/m ³	98th percentile, averaged over 3 yr
		Annual	15 µg/m ³	Annual arithmetic mean, averaged over 3 yr ¹
	PM ₁₀	24 h	150 µg/m ³	Initially promulgated 99th percentile, averaged over 3 yr; when 1997 standards were vacated in 1999, the form of 1987 standards remained in place (not to be exceeded more than once per yr on average over a 3-yr period)
		Annual	50 µg/m ³	Annual arithmetic mean, averaged over 3 yr
2006 (71 FR 61144)	PM _{2.5}	24 h	35 µg/m ³	98th percentile, averaged over 3 yr
		Annual	15 µg/m ³	Annual arithmetic mean, averaged over 3 yr ²
	PM ₁₀	24 h	150 µg/m ³	Not to be exceeded more than once per yr on average over a 3-yr period

Note: When not specified, primary and secondary standards are identical.

38990

Federal Register / Vol. 77, No. 126 / Friday, June 29, 2012 / Proposed Rules

ENVIRONMENTAL PROTECTION AGENCY
40 CFR Parts 50, 51, 52, 53, and 58
EPA-HQ-OAR-2007-0402; FRL-9682-9|
RIN 2060-AG-07

National Ambient Air Quality Standards for Particulate Matter

Agency: Environmental Protection Agency (EPA).
 ACTION: Proposed rule.

SUMMARY: Based on its review of the air quality criteria and the national ambient air quality standards (NAAQS) for particulate matter (PM), the EPA proposes to make revisions to the primary and secondary NAAQS for PM to provide requisite protection of public health and welfare, respectively, and to make corresponding revisions to the data handling conventions for PM and ambient air monitoring, reporting, and network design requirements. The EPA also proposes revisions to the prevention of significant deterioration (PSD) permitting program with respect to the proposed NAAQS revisions. With regard to primary standards for fine particles (generally referring to particles less than or equal to 2.5 micrometers (µm) in diameter, PM_{2.5}), the EPA proposes to revise the annual PM_{2.5} standard by lowering the level to within a range of 12.0 to 13.0 micrograms per cubic meter (µg/m³), so as to provide increased protection against health effects associated with long- and short-term exposures (including premature mortality, increased hospital admissions and emergency department visits, and development of chronic respiratory disease) and to retain the 24-hour PM_{2.5} standard. The EPA proposes changes to the Air Quality Index (AQI) for PM_{2.5} to be consistent with the proposed primary PM_{2.5} standards. With regard to the primary standard for particulate matter less than or equal to 10 µm in diameter (PM₁₀), the EPA proposes to retain the current 24-hour PM₁₀ standard to continue to provide protection against effects associated with short-term exposure to chronic coarse particles (i.e., PM_{10-2.5}). With regard to the secondary PM standards, the EPA proposes to revise the suite of secondary PM standards by adding a distance standard for PM_{2.5} to address PM-related visibility impairment and to retain the current standards generally to address non-visibility welfare effects. The proposed distance secondary standard would be defined in terms of a PM_{2.5} visibility index, which would use specified PM_{2.5} mass concentrations

and relative humidity data to calculate PM_{2.5} light extinction, translated to the deciview (dv) scale, similar to the Regional Haze Program's 24-hour averaging time; a 90th percentile form averaged over 3 years; and a level set at one of two options—either 30 dv or 28 dv.

DATES: Comments must be received on or before August 31, 2012. **Public Hearings:** The EPA intends to hold public hearings on this proposed rule in July 2012. These will be announced in a separate **Federal Register** notice that provides details, including specific dates, times, addresses, and contact information for these hearings.

ADDRESSES: Submit your comments, identified by Docket ID No. EPA-HQ-OAR-2007-0402 by one of the following methods:

- **www.regulations.gov:** Follow the on-line instructions for submitting comments.
- **Email:** rand-docket@epa.gov.
- **Fax:** 202-566-0744.

• **Mail:** Docket No. EPA-HQ-OAR-2007-0402, Environmental Protection Agency, Mail code 6102T, 1200 Pennsylvania Ave., NW, Washington, DC 20460. Please include a total of two copies.

• **Hand Delivery:** Docket No. EPA-HQ-OAR-2007-0402, Environmental Protection Agency, EPA West, Room 3334, 1301 Constitution Ave., NW, Washington, DC. Such deliveries are only accepted during the Docket's normal hours of operation, and special arrangements should be made for deliveries of boxed information.

Instructions: Direct your comments to Docket ID No. EPA-HQ-OAR-2007-0402. The EPA's policy is that all comments received will be included in the public docket without change and may be made available online at www.regulations.gov, including any personal information provided, unless the comment includes information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Do not submit information that you consider to be CBI or otherwise protected through www.regulations.gov or email. The www.regulations.gov Web site is an "anonymous access" system, which means the EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an email comment directly to the EPA without going through www.regulations.gov, your email address will be automatically captured and included as part of the comment that is placed in the public

docket and made available on the Internet. If you submit an electronic comment, the EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD-ROM you submit. If the EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, the EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses. For additional information about EPA's public docket visit the EPA Docket Center homepage at <http://www.epa.gov/epahome/dockets.htm>.

Docket: All documents in the docket are listed on the www.regulations.gov Web site. This includes documents in the rulemaking docket (Docket ID No. EPA-HQ-OAR-2007-0402) and a separate docket, established for 2009 Integrated Science Assessment (Docket No. EPA-HQ-ORD-2007-0517), that has been incorporated by reference into the rulemaking docket. All documents in these dockets are listed on the www.regulations.gov Web site.

Although listed in the index, some information is not publicly available, e.g., CBI or other information whose disclosure is restricted by statute.

Certain other material, such as copyrighted material, is not placed on the Internet and may be viewed, with prior arrangement, at the EPA Docket Center. Publicly available docket materials are available either electronically in www.regulations.gov or in hard copy at the Air and Radiation Docket and Information Center, EPA/DC, EPA West, Room 3334, 1301 Constitution Ave., NW, Washington, DC. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566-1744 and the telephone number for the Air and Radiation Docket and Information Center is (202) 566-1742.

FOR FURTHER INFORMATION CONTACT: Ms. Beth M. Hassett-Sipple, Health and Environmental Impacts Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Mail code C204-06, Research Triangle Park, NC 27711; telephone: (919) 541-4600; fax: (919) 541-4237; email: hassett-sipple@epa.gov.

SUPPLEMENTARY INFORMATION:

38890 Federal Register / Vol. 77, No. 126 / Friday, June 29, 2012 / Proposed Rules

ENVIRONMENTAL PROTECTION AGENCY
40 CFR Parts 50, 51, 52, 53, and 58
EPA-HQ-OAR-2007-0492; FRL-9682-9]
RIN 2060-AO47

National Ambient Air Quality Standards for Particulate Matter

AGENCY: Environmental Protection Agency (EPA).
ACTION: Proposed rule.

SUMMARY: Based on its review of quality criteria and the national air quality standards (NAAQ) for particulate matter (PM), the Agency proposes to revise its primary and secondary NAAQS to provide requisite protection of health and welfare, respect to make corresponding revisions to data handling conventions for ambient air monitoring, reporting network design requirements and proposed revisions to the prevention of significant deterioration (PSD) permitting program in the proposed NAAQS revision regard to primary standards for particulate matter (generally referring to particles with a diameter less than or equal to 2.5 micrometers in diameter, PM_{2.5}), the Agency proposes to revise the annual standard by lowering the level a range of 12.0 to 13.0 micrograms per cubic meter (µg/m³), so as to increase protection against effects associated with long-term exposures (including mortality, increased hospitalizations and emergency department development of chronic respiratory disease) and to retain the 24-hour standard. The EPA proposes the Air Quality Index (AQI) be consistent with the proposed PM_{2.5} standards. With respect to the primary standard for particulate matter less than or equal to 10 micrometers (PM₁₀), the EPA proposes to continue to provide protection against effects associated with short-term exposures to chronic disease (i.e., PM_{10-2.5}). With respect to secondary PM standards, the Agency proposes to revise the suite of PM standards by adding a standard for PM₁₀ to address PM-related visibility impairment and to retain the current standards generally to address non-visibility welfare effects. The proposed distinct secondary standard would be defined in terms of a PM_{2.5} visibility index, which would use specified PM_{2.5} mass concentrations and relative humidity data to calculate PM_{2.5} light extinction, translated to the deciview (dv) scale, similar to the Regional Haze Program, a 24-hour averaging time, a 90th percentile form averaged over 3 years, and a level set at 0.05 dv km (0.03 dv mi) at 50% relative humidity.

ENVIRONMENTAL PROTECTION AGENCY
40 CFR Parts 50, 51, 52, 53, and 58
[EPA-HQ-OAR-2007-0492; FRL-9682-9]
RIN 2060-AO47

National Ambient Air Quality Standards for Particulate Matter

AGENCY: Environmental Protection Agency (EPA).
ACTION: Proposed rule.

U.S. Environmental Protection Agency,
 Mail code C204-06, Research Triangle Park, NC 27711; telephone: (919) 341-4600; fax: (919) 341-4237; email: insent-eppa@epa.gov.
SUPPLEMENTARY INFORMATION:

do not include your identity or contact information unless you provide it in the body of your comment. If you send an email comment directly to the EPA without going through www.regulations.gov, your email address will be automatically captured and included in part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, the EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD-ROM

Connection to Policy

TABLE 4—TOTAL COSTS, MONETIZED BENEFITS AND NET BENEFITS IN 2020^a (MILLIONS OF 2006\$)^b FULL ATTAINMENT

Alternate PM _{2.5} standards (annual/24-hour, µg/m ³)	Total costs		Monetized benefits ^b		Net benefits ^b	
	3% Discount rate	7% Discount rate	3% Discount rate	7% Discount rate	3% Discount rate ^c	7% Discount rate
13/35	\$2.9	\$2.9	\$88 to \$220	\$79 to \$200	\$85 to \$220	\$76 to \$200
12/35	69	69	2,300 to \$5,900	2,100 to \$5,400	2,300 to \$5,900	2,000 to \$5,300
11/35	270	270	9,200 to \$23,000	8,300 to \$21,000	8,900 to \$23,000	8,000 to \$21,000
11/30	390	390	14,000 to \$36,000	13,000 to \$33,000	14,000 to \$36,000	13,000 to \$33,000

Open Research Questions

- Who is most susceptible to these effects?
- Other health effects?
- What are the key components or sources of PM_{2.5} that elicit these effects?
- Interactions with other pollutants?
- Interactions with meteorological factors?
- Interactions with population/housing characteristics?
- Many more....

Summary

- Ambient PM_{2.5} is associated with a wide range of adverse cardiovascular health effects
- Many important research questions remain unanswered
- This research has direct relevance to public policy and public health
- EPA's ambient air quality data has been (and will continue to be) central to health effects research

Thank You!