Air Pollution Regulations: The Health Perspective

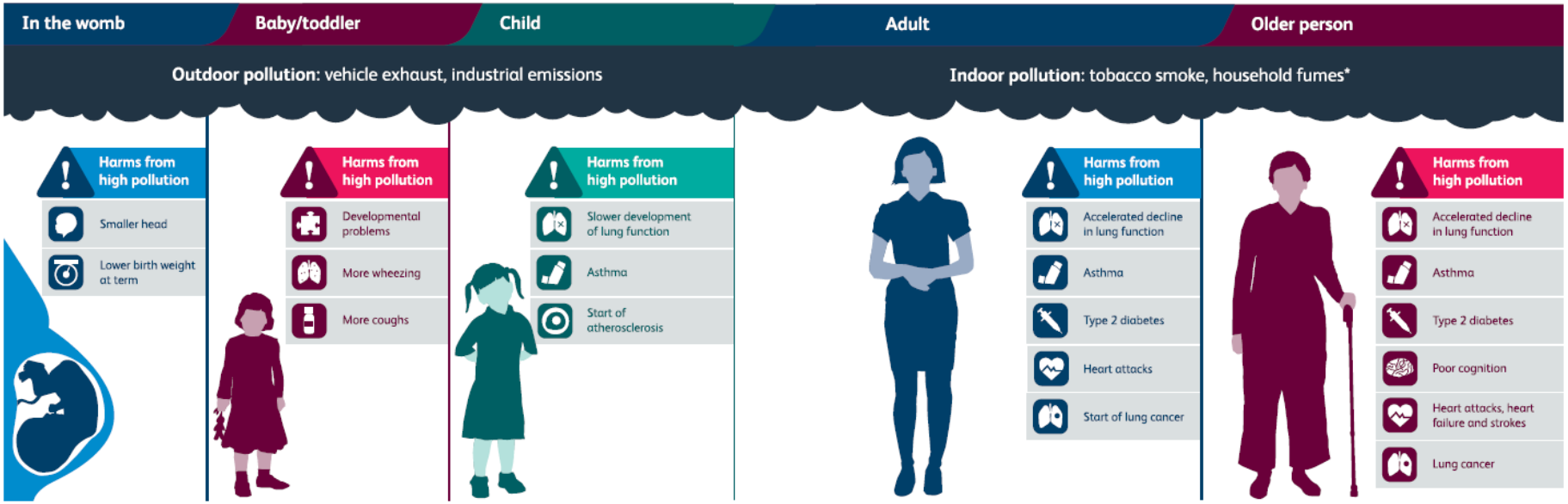
Dr Matt Loxham

Faculty of Medicine

University of Southampton

m.loxham@soton.ac.uk

Health Effects of Air Pollution



Royal College of Physicians (2016) Every Breath We Take

UK Emissions Legislation

- 1853 – Smoke Nuisance (Abatement) Act
- 1863 + 1874 – Alkali Act
  - Designed to reduce HCl emissions from industry
- 1956 + 1968 – Clean Air Act
  - Designed to reduce smoke emissions
  - Grants to householders to switch to cleaner fuels
  - Allowed (mandated) clean air zones

EU Pollution Legislation

- 1980: Directive on air quality limit values and guide values for SO2 and PM (80/779/EEC)
- 1982: Directive on limit values for lead in the air (82/884/EEC)
- 1985: Directive on air quality standards for NO2 (85/203/EEC)
- 1988: Directive limiting emissions of certain pollutants into the air fro large combustion plants (88/609/EEC)
- 1992: Directive on air pollution by ozone (92/72/EEC)
- 1996: Council Directive concerning integrated pollution prevention and control (96/61/EC)
- 1996: The Ambient Air Quality Assessment and Management Directive (96/62/EC)
- 1999: 1st Daughter Directive AQ limit for SO2, NO2, NOX, PM and lead (1999/30/EC)
- 2000: 2nd Daughter Directive relating to CO and benzene (2000/69/EC)
- 2001: Directive on the limitation of emissions of certain pollutants into the air from large combustion plants (2001/80/EC)
- 2002: 3rd Daughter Directive relating to O3 in ambient air (2002/3/EC)
- 2004: 4th Daughter Directive relating to As, Ni, PAH in ambient air (2004/107/EC)
- 2008: Directive of the European parliament and of the council on ambient air quality and cleaner air for Europe (2008/50/EC)

Pollution kills 1.7 million children every year, WHO reports

One out of every four deaths among young children is linked to environmental hazards, report finds

by Amar Toor | @amartoo | Mar 6, 2017, 3:23am EST

Air pollution 'causes 467,000 premature deaths a year in Europe'

23 November 2016 | Europe

Share

Air pollution 'kills 40,000 a year' in the UK, says report

Tuesday February 23 2016

Environment

Air pollution kills five million people per year, research finds

China and India are thought to be the worst affected countries

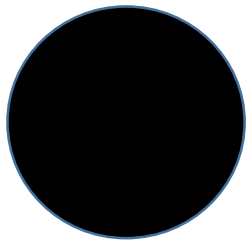
Siobhan Fenton | @siobhanfenton | Saturday 13 February 2016 09:54 GMT | 0 comments

GREEN 07/01/2016 07:04 am ET

Air Pollution Kills 6.5 Million People Every Year, And It Could Get Worse Unless We Act Now

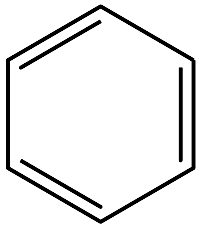
Poor air quality is now the fourth largest threat to our health, according to a new IEA report.

Currently Regulated Species

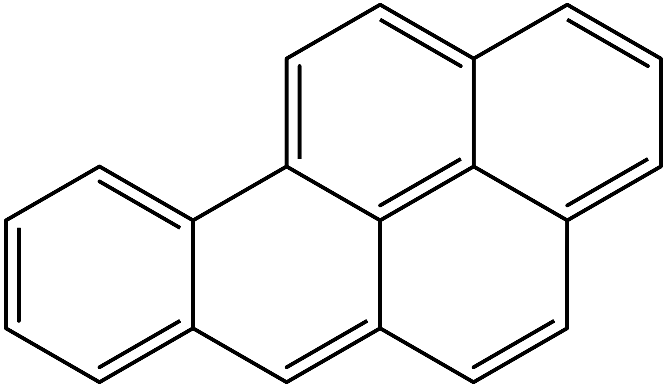


10µm

2.5µm

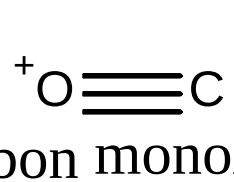


benzene

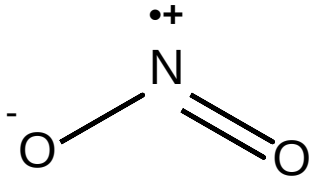


benz[a]pyrene

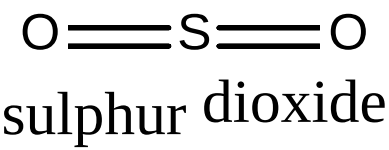
1,3-butadiene



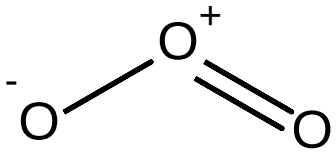
carbon monoxide



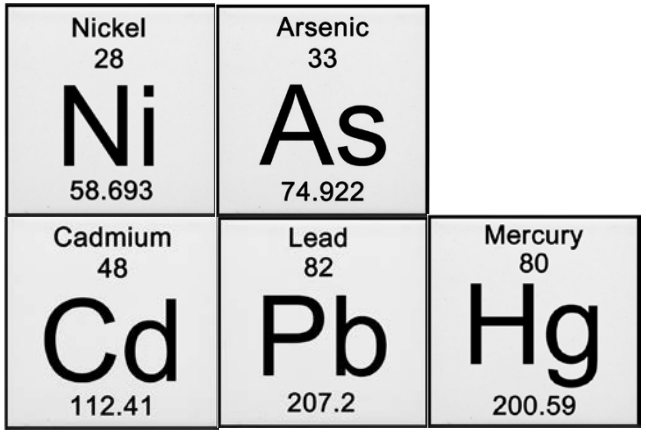
nitrogen dioxide



sulphur dioxide



ozone



Air Quality Guidelines Vary

Pollutant/Averaging Time	EU (AQS, 2011)	U.S. (U.S. EPA, 2012a)	WHO (WHO, 2006)
SO_2	ppb	ppb	ppb
1 hour mean	134	75	–
3 hour mean	–	500	–
24 hour mean	47	140	8
Annual mean	–	30	–
NO_2	ppb	ppb	ppb
1 hour mean	105	100	106
24 hour mean	–	–	–
Annual mean	21	53	21
PM_{10}	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
24 hour mean	50	150	50
Annual mean	40	–	20
$PM_{2.5}$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
24 hour mean	–	35	25
Annual mean	25	15	10
CO	ppb	ppb	ppb
8 hour mean	9 000	9 000	–
1 hour mean	–	35 000	–
Ozone	ppb	ppb	ppb
8 hour mean	40	75	50
1 hour mean	–	120	–
Benzene	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Annual	5	–	–
Lead	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Annual	0.5	0.15	–
PAH	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Benzo[*a*]pyrene	0.001	–	–

Kuklinska et al (2015) Atmos Poll Res 6:129

$PM_{2.5}$

1. PM = Particulate Matter - airborne dust
2. Under 2.5 µm in aerodynamic diameter
3. Predominantly from combustion sources
4. Most closely linked to health effects of all the pollutant species

Air Quality Guidelines Vary

Source	PM_{10} ($\mu g/m^3$)		$PM_{2.5}$ ($\mu g/m^3$)	
	1 year	24 hours	1 year	24 hours
WHO [2]	20	50	10	25
European Union	40	50	25	
United States	50	150	12	35
California	20	50	15	65
Japan		100	12	65
Brazil	50	150		
Mexico	50	120	15	65
South Africa	60	180	15	65
India (sensitive populations/ residential/industrial)	50/60/120			
China (Classes I/II/III)	40/100/150	50/150/250		35

Nemmar et al (2013) Biomed Res Int 279371

WHO (2006)

As thresholds have not been identified, and given that there is substantial inter-individual variability in exposure and in the response in a given exposure, it is unlikely that any standard or guideline value will lead to complete protection for every individual against all possible adverse health effects of particulate matter. Rather, the standard-setting process needs to aim at achieving the lowest concentrations possible in the context of local constraints, capabilities and public health priorities. Quantitative risk assessment offers one way of comparing alternative control scenarios and of estimating the residual risk associated with a particular guideline value.

NOAEL

No Observed Adverse Effect Level

Relative Risk (RR)

$$RR = \frac{P_{event\ when\ exposed}}{P_{event\ when\ not\ exposed}}$$

e.g. if 10% of people develop lung cancer when exposed to 1mg/m^3 $PM_{2.5}$, and 8% develop lung cancer where there is no air pollution:

$$RR = \frac{0.1}{0.08} = 1.25 \text{ (or a 25\% greater risk)}$$

Numbers in brackets – 1.25 (1.10-1.60) indicate the range of 95% confidence

The New England
Journal of Medicine

Volume 329 DECEMBER 9, 1993 Number 24

AN ASSOCIATION BETWEEN AIR POLLUTION AND MORTALITY IN SIX U.S. CITIES

DOUGLAS W. DOCKERY, SC.D., C. ARDEN POPE III, PH.D., XIPING XU, M.D., PH.D.,
JOHN D. SPENGLER, PH.D., JAMES H. WARE, PH.D., MARTHA E. FAY, M.P.H.,
BENJAMIN G. FERRIS, JR., M.D., AND FRANK E. SPEIZER, M.D.

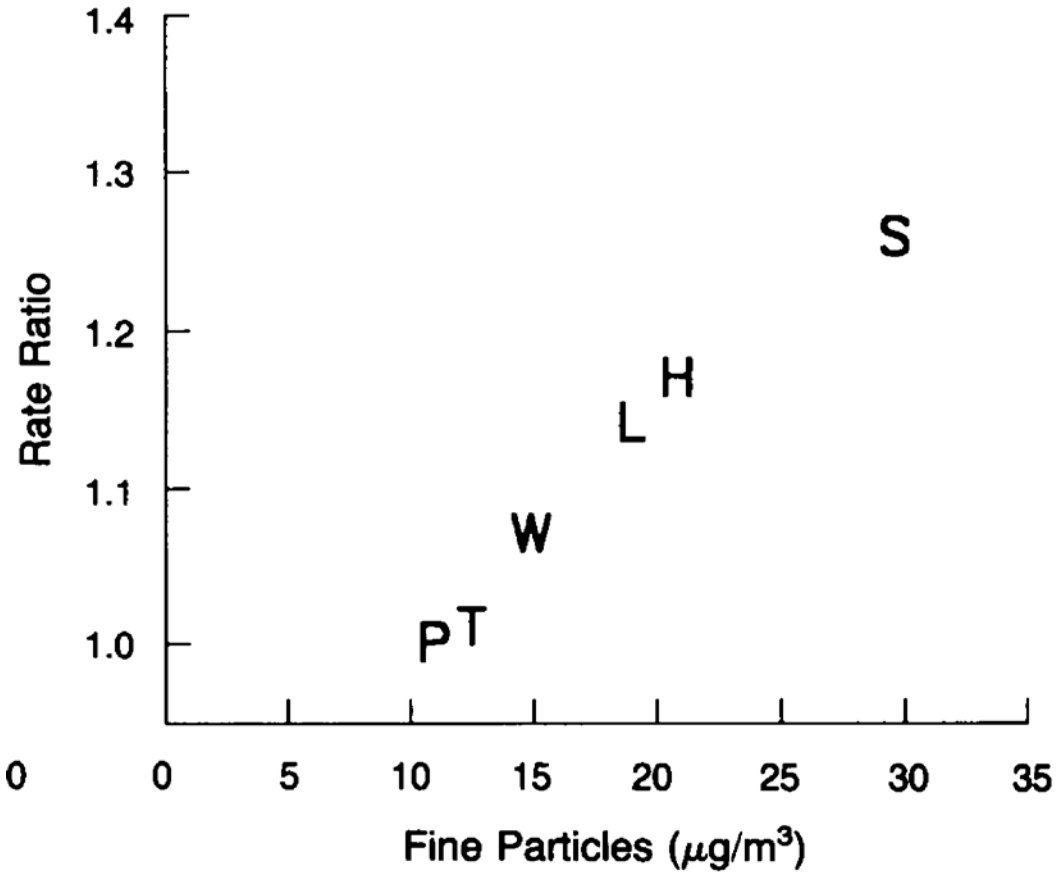
VARIABLE	ALL SUBJECTS
Current smoker	1.59 (1.31–1.92)
25 Pack-years of smoking	1.26 (1.16–1.38)
Former smoker	1.20 (1.01–1.43)
10 Pack-years of smoking	1.15 (1.08–1.23)
Less than high-school education	1.19 (1.06–1.33)
Body-mass index	1.08 (1.02–1.14)

The New England
Journal of Medicine

Volume 329 DECEMBER 9, 1993 Number 24

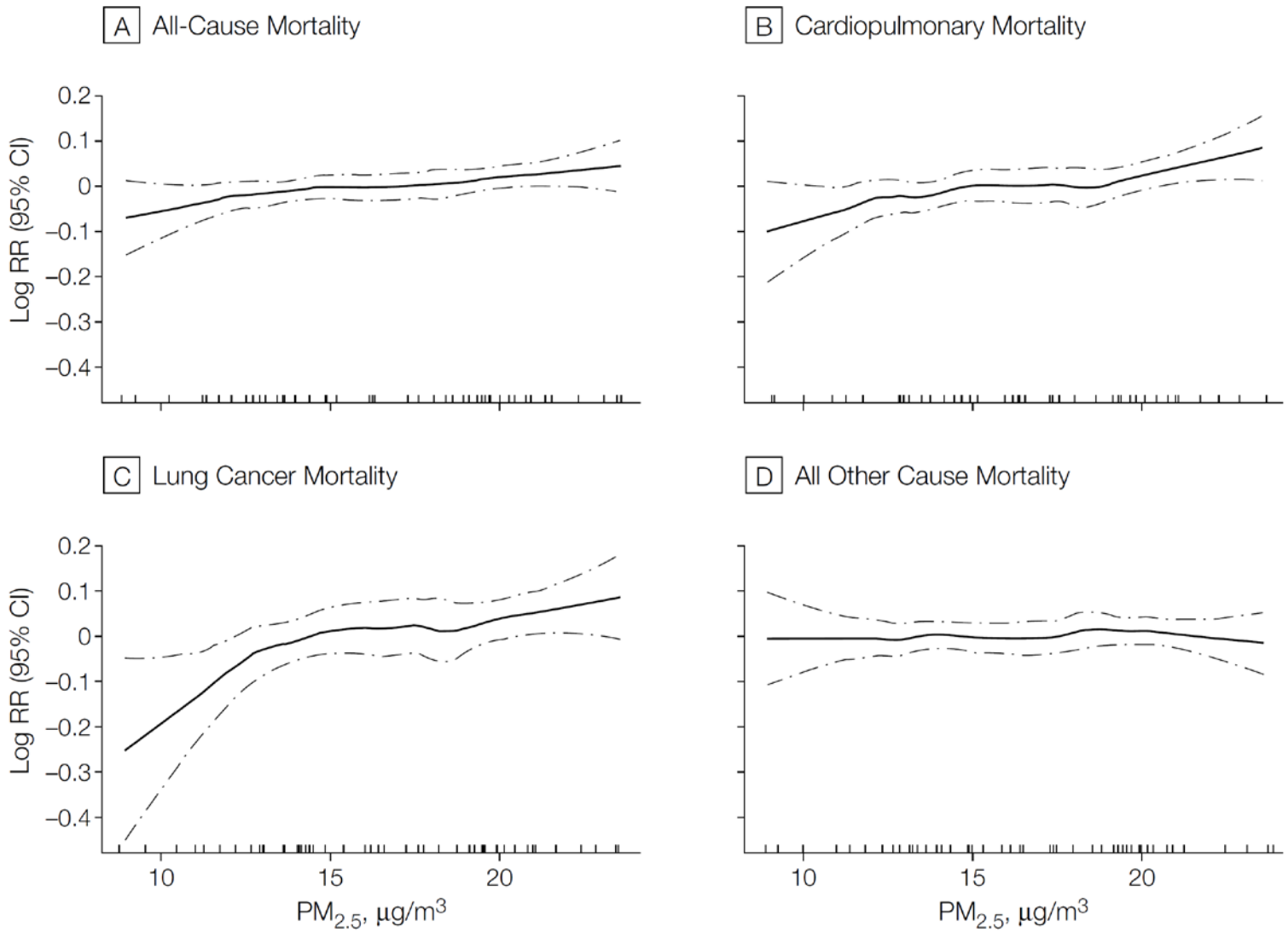
AN ASSOCIATION BETWEEN AIR POLLUTION AND MORTALITY IN SIX U.S. CITIES

DOUGLAS W. DOCKERY, SC.D., C. ARDEN POPE III, PH.D., XIPING XU, M.D., PH.D., JOHN D. SPENGLER, PH.D., JAMES H. WARE, PH.D., MARTHA E. FAY, M.P.H., BENJAMIN G. FERRIS, JR., M.D., AND FRANK E. SPEIZER, M.D.



Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution

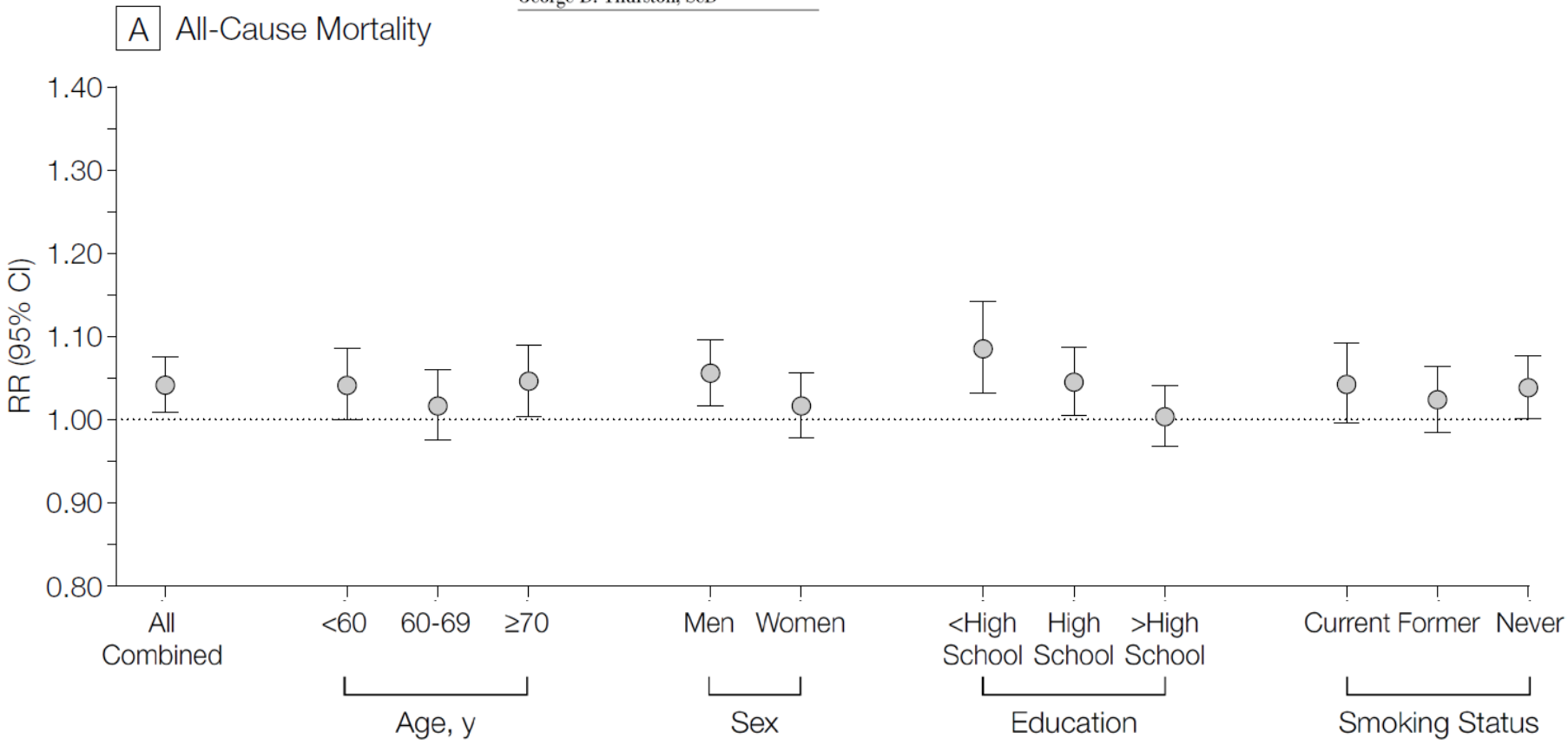
C. Arden Pope III, PhD
Richard T. Burnett, PhD
Michael J. Thun, MD
Eugenia E. Calle, PhD
Daniel Krewski, PhD
Kazuhiko Ito, PhD
George D. Thurston, ScD



Pope et al (2002) JAMA 287(9):1132-1141

Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution

C. Arden Pope III, PhD
Richard T. Burnett, PhD
Michael J. Thun, MD
Eugenia E. Calle, PhD
Daniel Krewski, PhD
Kazuhiko Ito, PhD
George D. Thurston, ScD



Pope et al (2002) JAMA 287(9):1132-1141

WHOair quality guidelines and interim targets for particulate matter: annual mean concentrations[a]

	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	Basis for the selected level
Iinterim target-1 (IT-1)	70	35	These levels are associated with about a 15% higher long-term mortality risk relative to the AQG level.
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% [2–11%] relative to theIT-1 level.
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% [2-11%] relative to the -IT-2 level.
Air quality guideline (AQG)	**20**	**10**	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to $PM_{2.5}$

WHO air quality guidelines and interim targets for particulate matter: 24-hour concentrations[a]

	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	Basis for the selected level
Interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over the AQG value).
Interim target-2 (IT-2)	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over the AQG value).
Interim target-3 (IT-3)*	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase in short-term mortality over the AQG value).
Air quality guideline (AQG)	**50**	**25**	Based on relationship between 24-hour and annual PM levels.

UK AQ Index

Band	Index	Ozone Running 8-hour mean (µg m^{-3})	Nitrogen dioxide 1-hour mean (µg m^{-3})	Sulphur dioxide 15-minute mean (µg m^{-3})	$PM_{2.5}$ particles 24-hour mean (µg m^{-3})	PM_{10} particles 24-hour mean (µg m^{-3})
Low	1	0–26	0–66	0–88	0–11	0–16
	2	27–53	67–133	89–176	12–23	17–33
	3	54–80	134–200	177–265	24–35	34–50
Moderate	4	81–107	201–267	266–354	36–41	51–58
	5	108–134	268–334	355–442	42–46	59–66
	6	135–160	335–400	443–531	47–53	67–75
High	7	161–187	401–467	532–708	54–58	76–83
	8	188–213	468–534	709–886	59–64	84–91
	9	214–240	535–600	887–1063	65–70	92–100
Very High	10	241 or more	601 or more	1064 or more	71 or more	101 or more

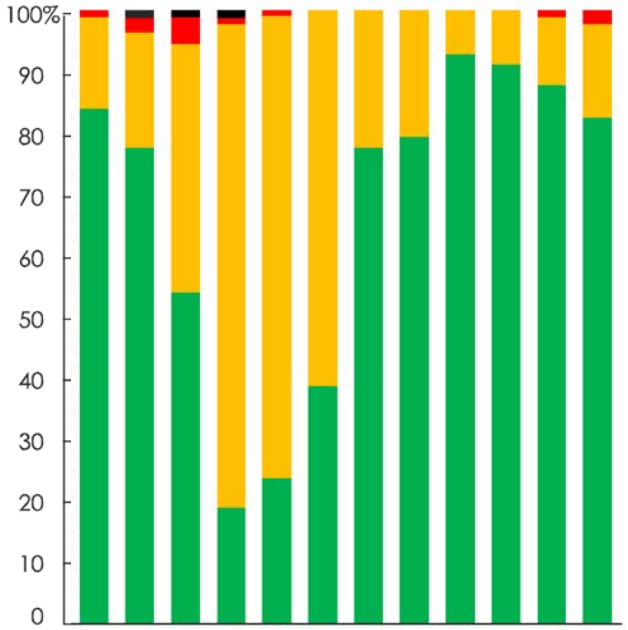
COMEAP (2011) Review of the UK Air Quality Index

AQ Advice

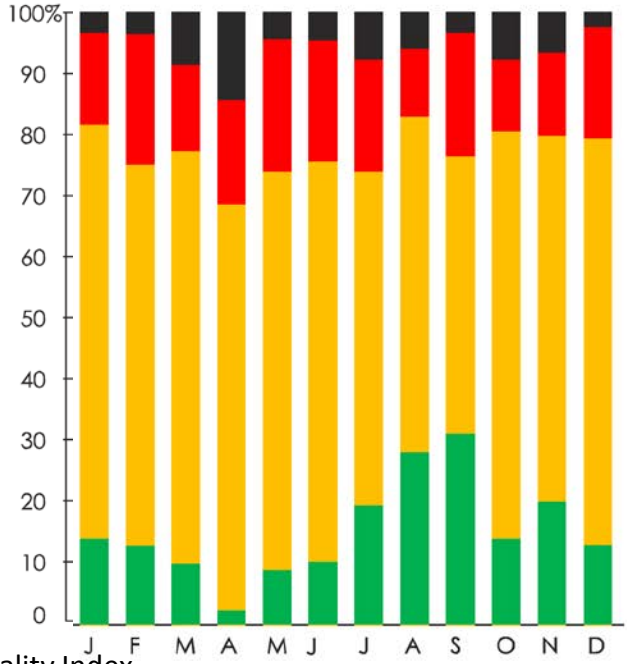
Index Banding	"At Risk"	General Population
Low	Enjoy usual outdoor activities	Enjoy usual outdoor activities
Moderate	Those with lung/heart problems who experience symptoms should reduce strenuous activity esp outdoors	Enjoy usual outdoor activities
High	Reduce strenuous extertion, esp outdoors. More mediation may be necessary	Reduce strenuous exercise outdoors if discomfort experienced
Very High	Avoid strenuous activity	Reduce physical exertion

COMEAP (2011) Review of the UK Air Quality Index

London Background



London Roadside

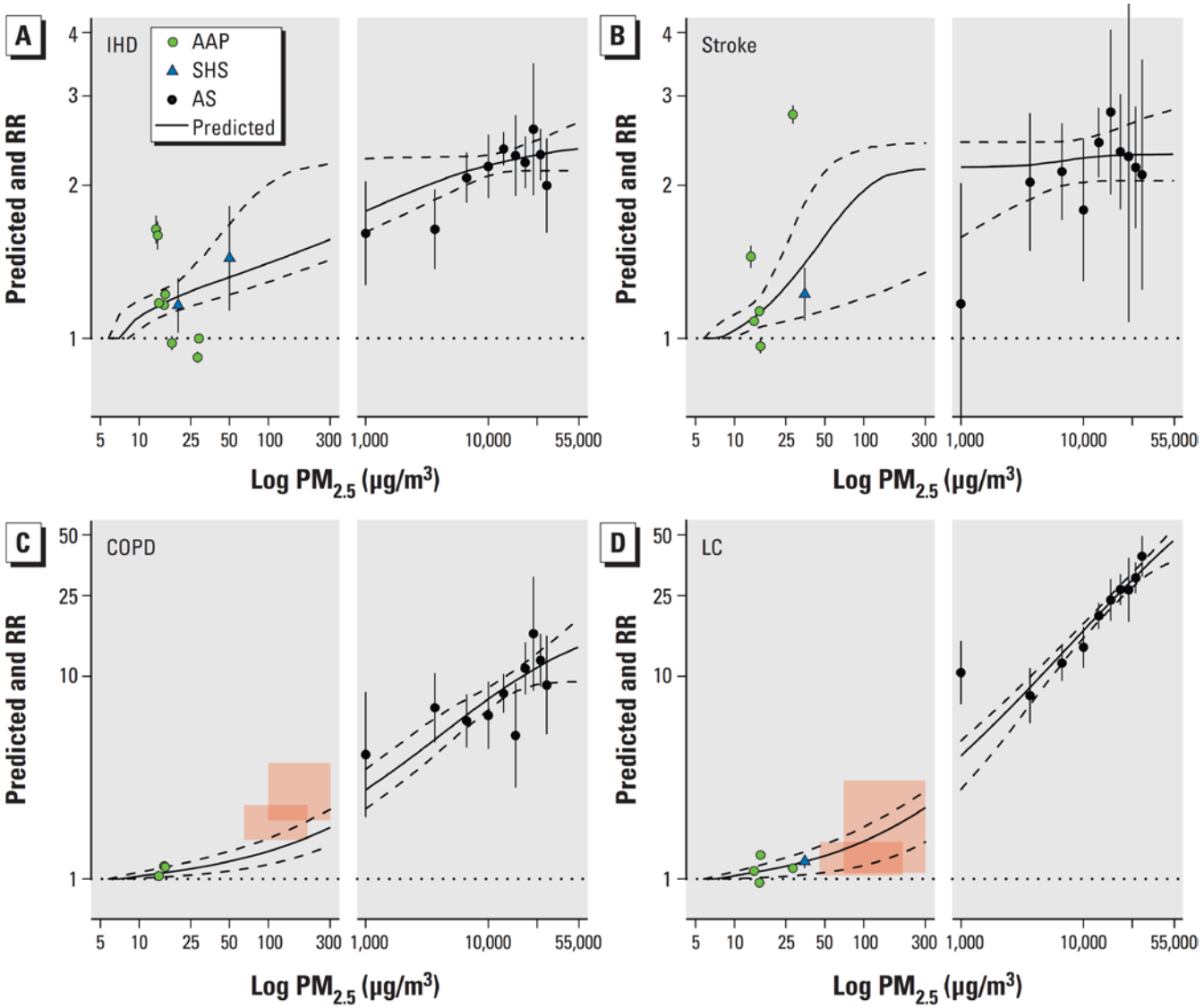


COMEAP (2011) Review of the UK Air Quality Index

Extending the Data

An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure

*Richard T. Burnett,[1] C. Arden Pope III,[2] Majid Ezzati,[3] Casey Olives,[4] Stephen S. Lim,[5] Sumi Mehta,[6] Hwashin H. Shin,[1] Gitanjali Singh,[7] Bryan Hubbell,[8] Michael Brauer,[9] H. Ross Anderson,[10] Kirk R. Smith,[11] John R. Balmes,[12,13] Nigel G. Bruce,[14] Haidong Kan,[15] Francine Laden,[16] Annette Prüss-Ustün,[17] Michelle C. Turner,[18] Susan M. Gapstur,[19] W. Ryan Diver,[19] and Aaron Cohen[20]**



Burnett et al (2014) Environmental Health Perspectives 122(4):397

RRs in Context

	All Cause	Cardiopulmonary	Lung Cancer
PM2.5 (per 10µg/m^3)	1.04	1.06	1.08

Average smoker (22/day over 33.5 years)	2.58 (all cause)	2.89 (cardiopulmonary)	14.80 (lung cancer)
BMI (all cause)	1.09 (26.5-28)	1.32 (30-32)	2.58 (>40)
Alcohol intake (all cause)	1.10 (15-21 units)	1.22 (22-34 units)	1.25 (>35 units)

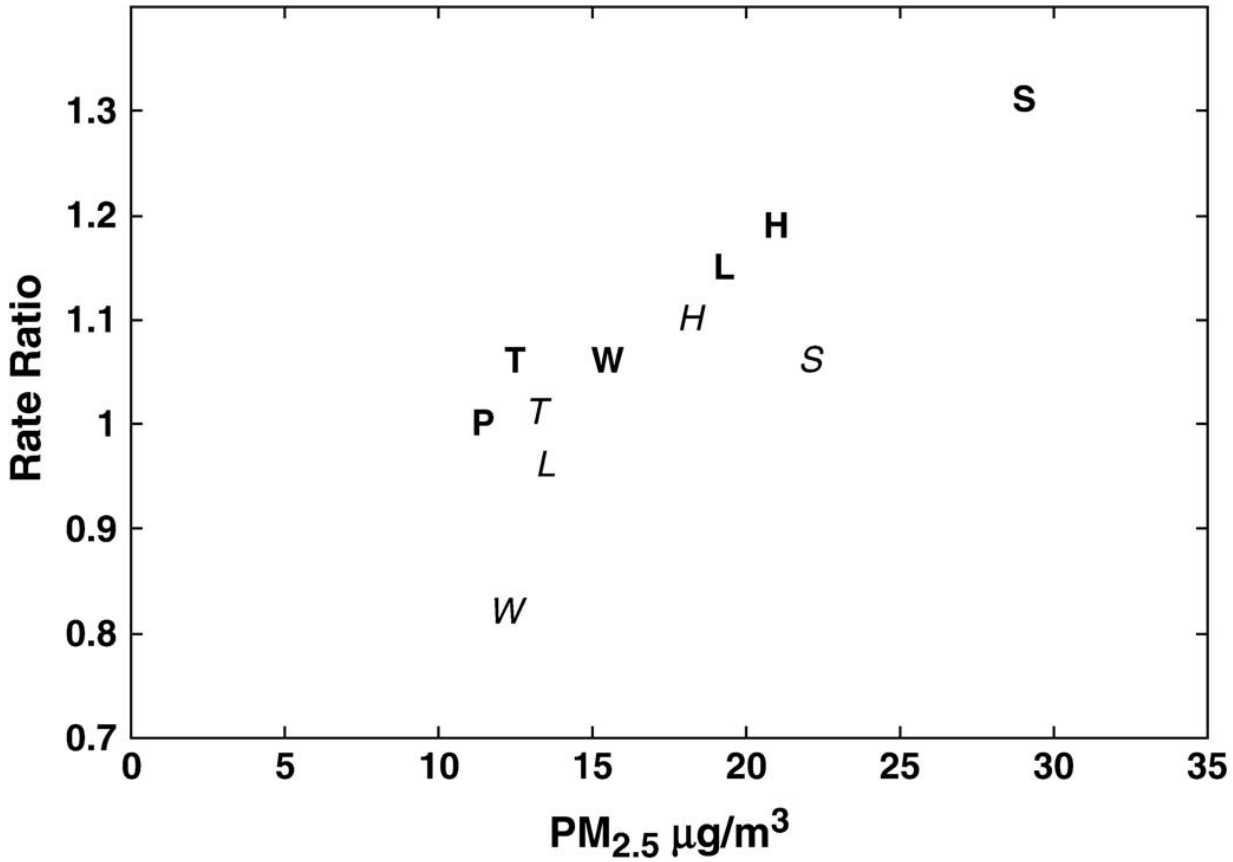
Pope et al (2002) JAMA 287(9):1132-1141
Calle et al (1999) N Engl J Med 341:1097-1105

Reduction in Fine Particulate Air Pollution and Mortality

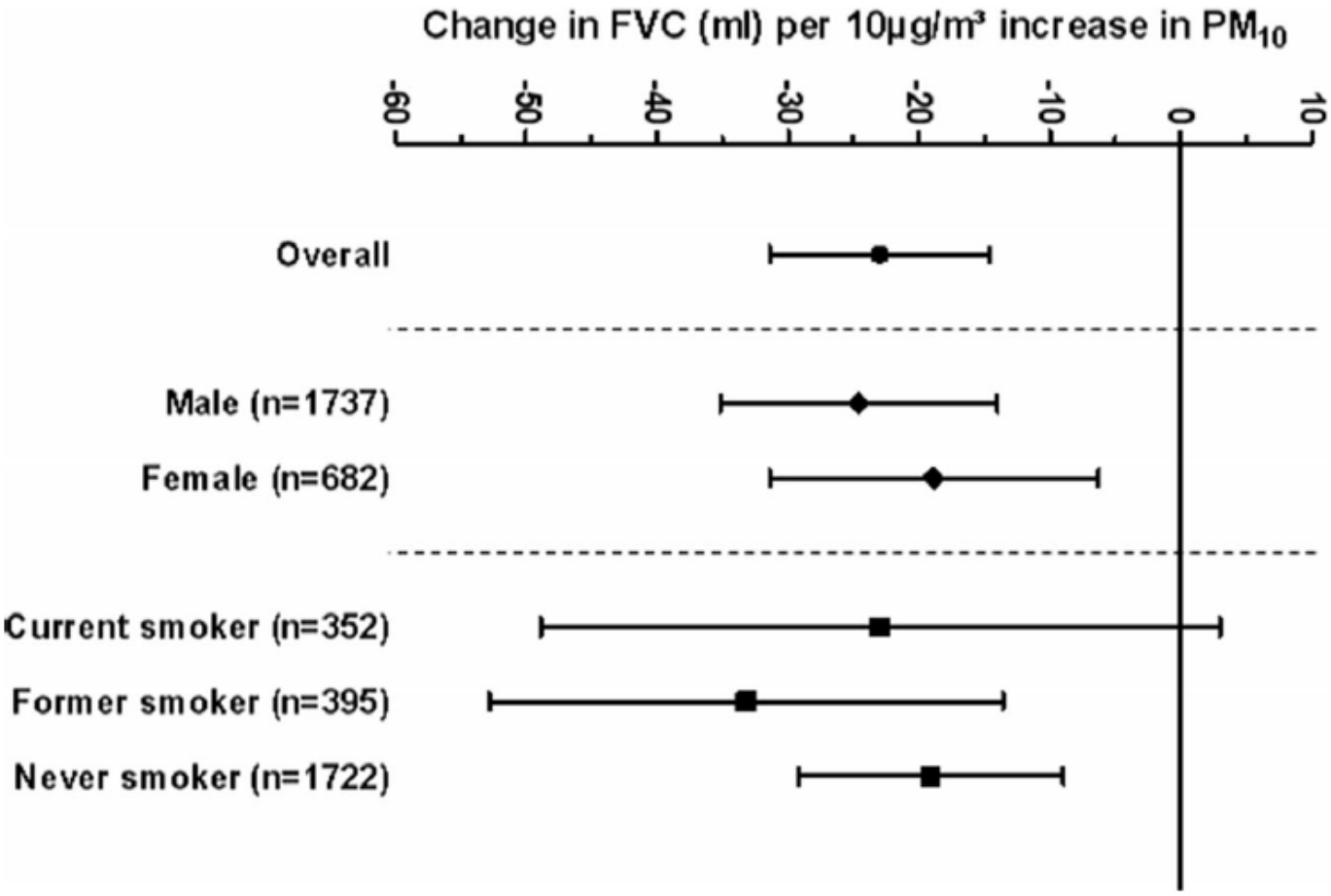
Extended Follow-up of the Harvard Six Cities Study

Francine Laden, Joel Schwartz, Frank E. Speizer, and Douglas W. Dockery

Exposure, Epidemiology, and Risk Program, Department of Environmental Health, Harvard School of Public Health; and Channing Laboratory, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts



Do AQ Limits Protect Us?



Int Panis et al. Environmental Health (2017) 16:60

How Certain are we of the Evidence?

Mortality	Relative Risk per 10 µg/m^3 $PM_{2.5}$
All cause	1.06 (1.02-1.11)
Cardiopulmonary	1.09 (1.03-1.16)
Lung cancer	1.08 (1.01-1.16)

	Coefficient (%)																	
Member	>0.99	>0	>1	>2	>3	>4	>5	>6	>7	>8	>9	>10	>11	>12	>13	>14	>15	>16	17
A		99	95	90	80	75	70	65	60	50	45	40	35	30	25	20	15	10	5
B		99	95	80	60	50	45	40	35	30	25	20	15	10	5	4	3	2	1
C		87	82	77	71	64	57	50	43	36	29	24	19	15	11	8	6	4	3
D		95	50	40	35	30	25	20	15	10	7.5	5	4	3	2	1.5	1	0.5	0
E		99	97	92	88	77	65	55	47	42	38	32	26	19	13	10	7	4	2
F	97.5*	95	92.5	75	60	45	30	15	12.5	10	7.5	5	2.5	0	0	0	0	0	0
G		98	95	90	85	75	60	50	40	30	20	15	15	10	5	2	2	2	0
Average probability (%) (arithmetic mean)		**96.0**	**86.6**	**77.7**	**68.4**	**59.4**	**50.3**	**42.1**	**36.1**	**29.7**	**24.6**	**20.1**	**16.6**	**12.4**	**8.7**	**6.5**	**4.9**	**3.2**	**1.6**
Median probability %		**98.0**	**95.0**	**80.0**	**71.0**	**64.0**	**57.0**	**50.0**	**40.0**	**30.0**	**25.0**	**20.0**	**15.0**	**10.0**	**5.0**	**4.0**	**3.0**	**2.0**	**1.0**

COMEAP (2009) Long-Term Exposure to Air Pollution: Effect on Mortality