The Impact of Air Pollution on Population Health

Katharina Janke

Lancaster University

April 2019

Types of evidence

- Toxicology
- Epidemiology
    - Time-series studies
    - Cohort studies

Hybrid research design

HEALTH ECONOMICS
Health Econ. **18**: 1031–1055 (2009)
Published online 7 April 2009 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hec.1475

DO CURRENT LEVELS OF AIR POLLUTION KILL? THE IMPACT OF AIR POLLUTION ON POPULATION MORTALITY IN ENGLAND

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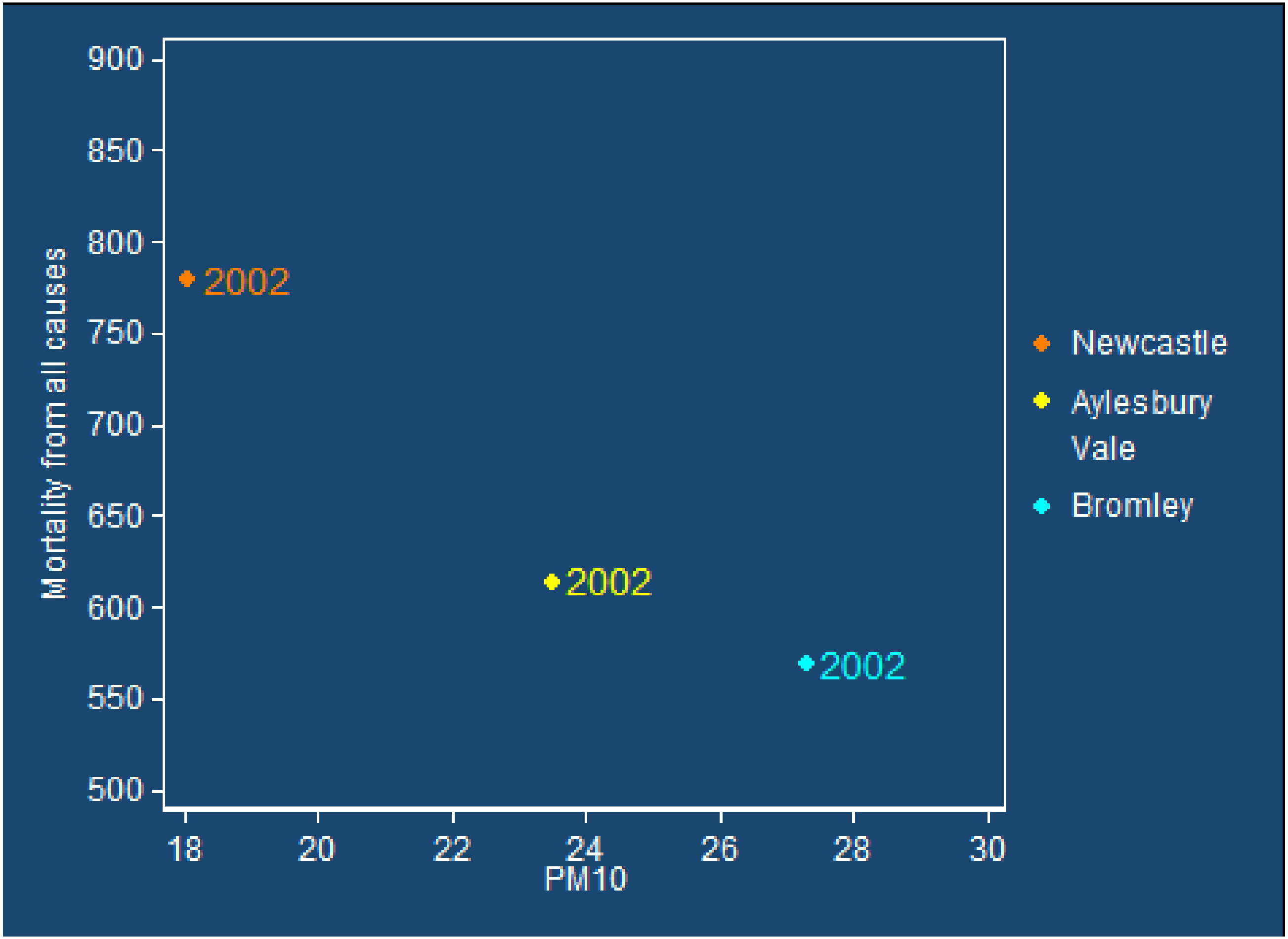
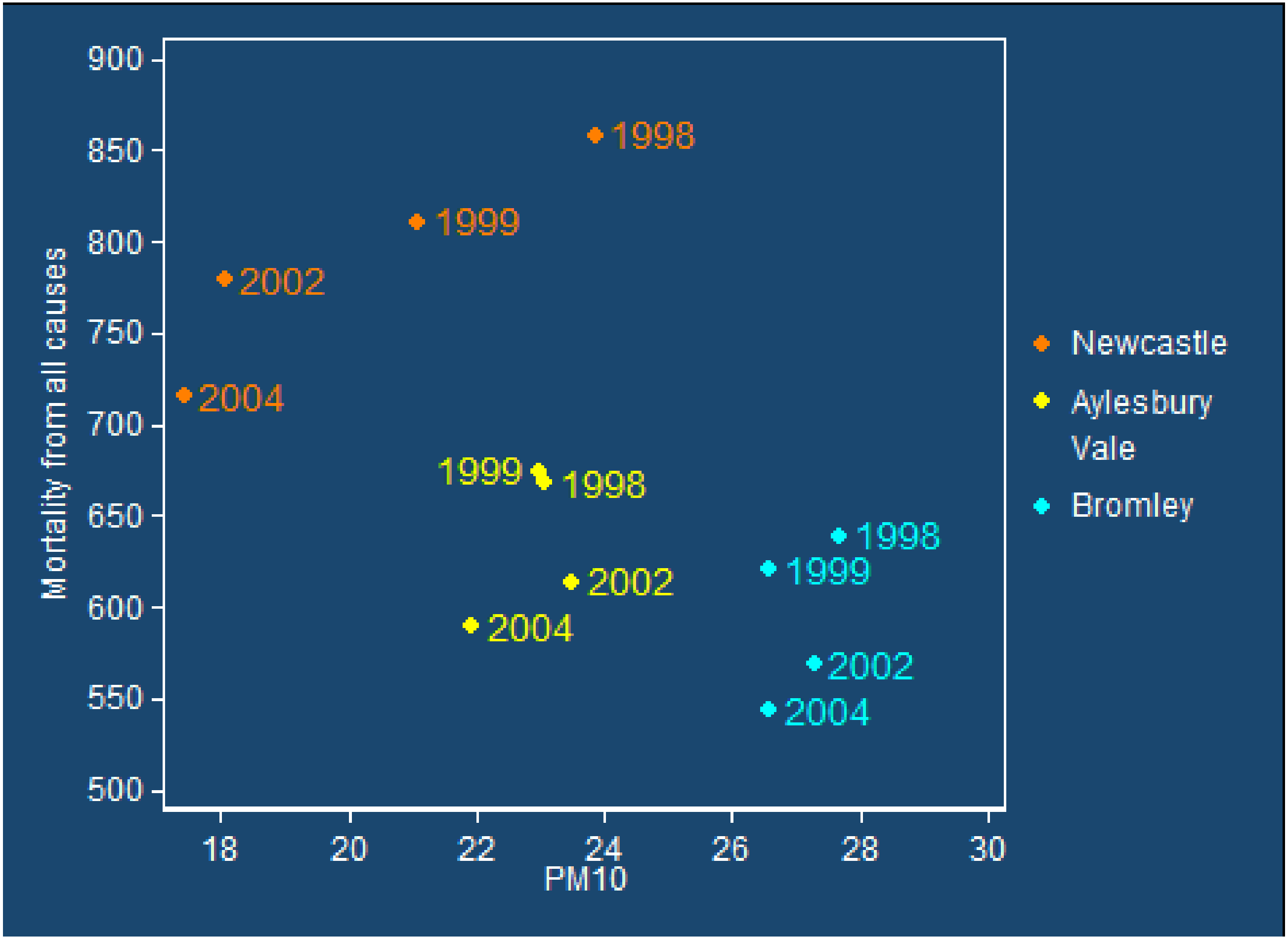
SUMMARY

The current air quality limit values for airborne pollutants in the UK are low by historical standards and are at levels that are believed not to harm health. We assess whether this view is correct. We examine the relationship between common sources of airborne pollution and population mortality for England. We use data at local authority level for 1998–2005 to examine whether current levels of airborne pollution, as measured by annual mean concentrations of carbon monoxide, nitrogen dioxide, particulate matter less than 10 μm in diameter (PM_{10}) and ozone, are associated with excess deaths. We examine all-cause mortality and deaths from specific cardiovascular and respiratory causes that are known to be exacerbated by air pollution. The panel nature of our data allows us to control for any unobserved time-invariant associations at local authority level between high levels of air pollution and poor population health and for common time trends. We estimate multi-pollutant models to allow for the fact that three of the pollutants are closely correlated. We find that higher levels of PM_{10} and ozone are associated with higher mortality rates, and the effect sizes are considerably larger than previously estimated from the primarily time series studies for England.

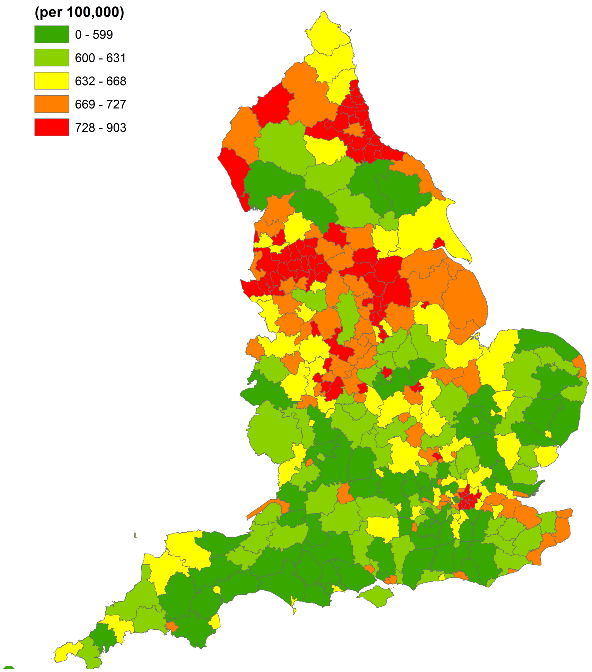
Unobserved local area effects

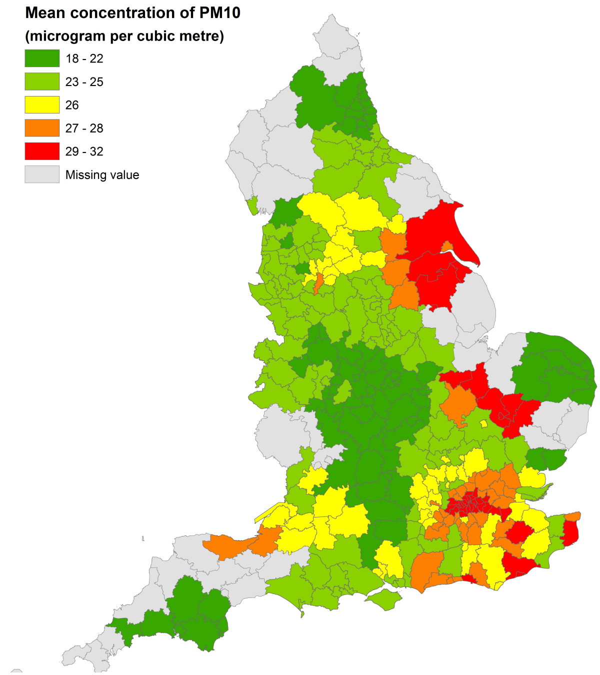


Unobserved local area effects

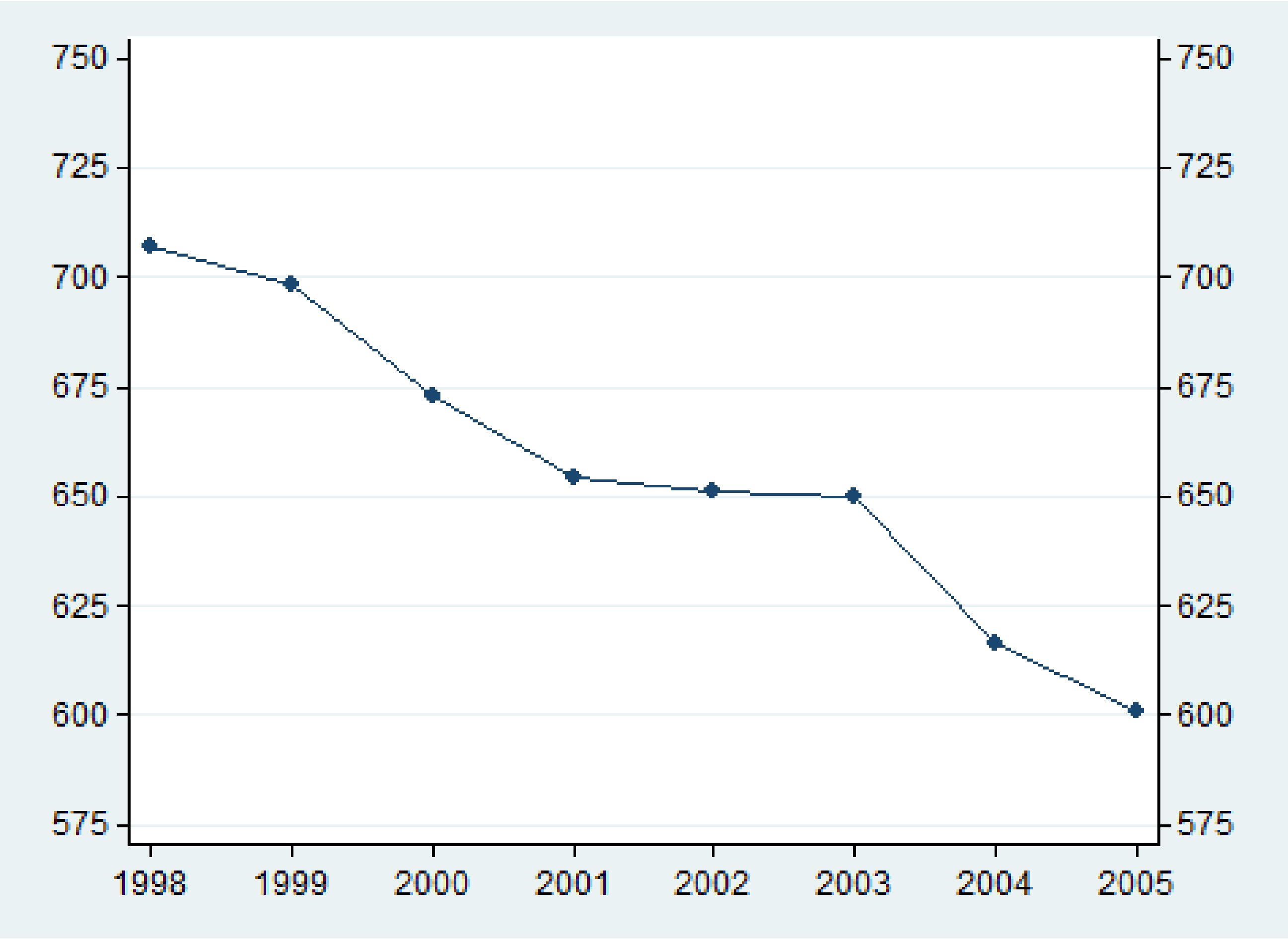


Cross-sectional distribution of mortality and PM_{10}





Annual means of mortality from all causes (per 100,000)



Results for all-cause mortality

	OLS	Within area
CO	0.45	−0.34
	(1.63)	(0.69)
$NO_2/10$	−2.82***	0.34
	(0.94)	(0.28)
$PM_{10}/10$	1.85	2.74***
	(1.92)	(0.51)
$O_3/10$	−6.60***	0.80***
	(0.80)	(0.29)
Degree qual. rate		−0.06*
		(0.03)
Summer temperature		0.90***
		(0.20)

Standard errors in (brackets). 2,338 observations in 312 groups. Coefficients are percentage changes in all-cause mortality per 1 mg/m^3 increase in CO, per 10 $\mu g/m^3$ increase in NO_2, PM_{10}, O_3.

Results for specific causes of mortality

	All causes	Circulatory diseases	Bronchitis, emphysema and other COPD
CO	−0.34	−0.02	−3.82
	(0.69)	(1.53)	(3.51)
$NO_2/10$	0.34	0.34	1.91
	(0.28)	(0.49)	(1.27)
$PM_{10}/10$	2.74***	4.38***	1.80
	(0.51)	(0.78)	(2.49)
$O_3/10$	0.80***	−0.01	2.40*
	(0.29)	(0.54)	(1.23)

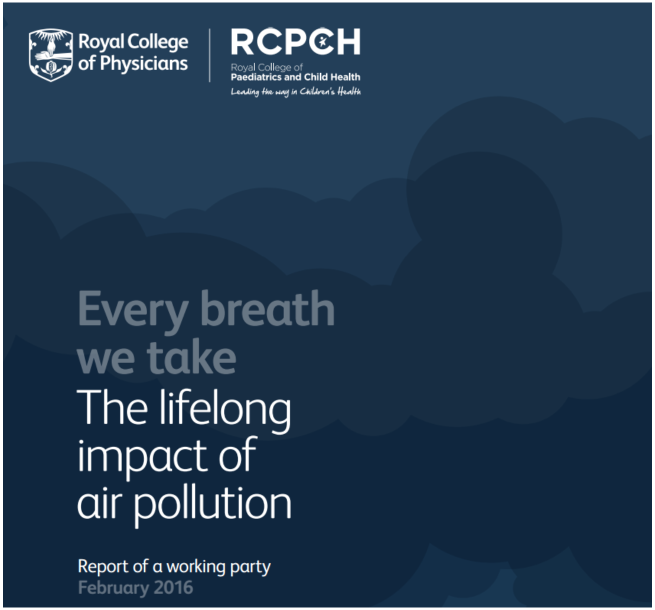
Standard errors in (brackets). 2,338 observations in 312 groups. Coefficients are percentage changes in all-cause mortality per 1 mg/m^3 increase in CO, per 10 $\mu g/m^3$ increase in NO_2, PM_{10}, O_3.

Comparison with other approaches

Our results	10 μg/m^3 PM_{10} $\downarrow$ 2.7%	10 μg/m^3 O_3 $\downarrow$ 0.8%
ACS cohort study	10 μg/m^3 $PM_{2.5}$ $\downarrow$ 6%	≈ 0
Time-series studies	10 μg/m^3 PM_{10} $\downarrow$ 0.6%	10 μg/m^3 O_3 $\downarrow$ 0.3%

Empowering people through information?

13 **Develop new technologies to improve air pollution monitoring.** We need better, more accurate and wider-ranging monitoring programmes so that we can track population-level exposure to air pollution. We also need to develop adaptable monitoring techniques to measure emerging new pollutants, and known pollutants that occur below current concentration limits. We must develop practical technology – such as wearable 'smart' monitors – that empower individuals to check their exposure and take action to protect their health.



Hospital emergency admissions and avoidance behaviour

Journal of Health Economics 38 (2014) 23–42

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Air pollution, avoidance behaviour and children's respiratory health: Evidence from England

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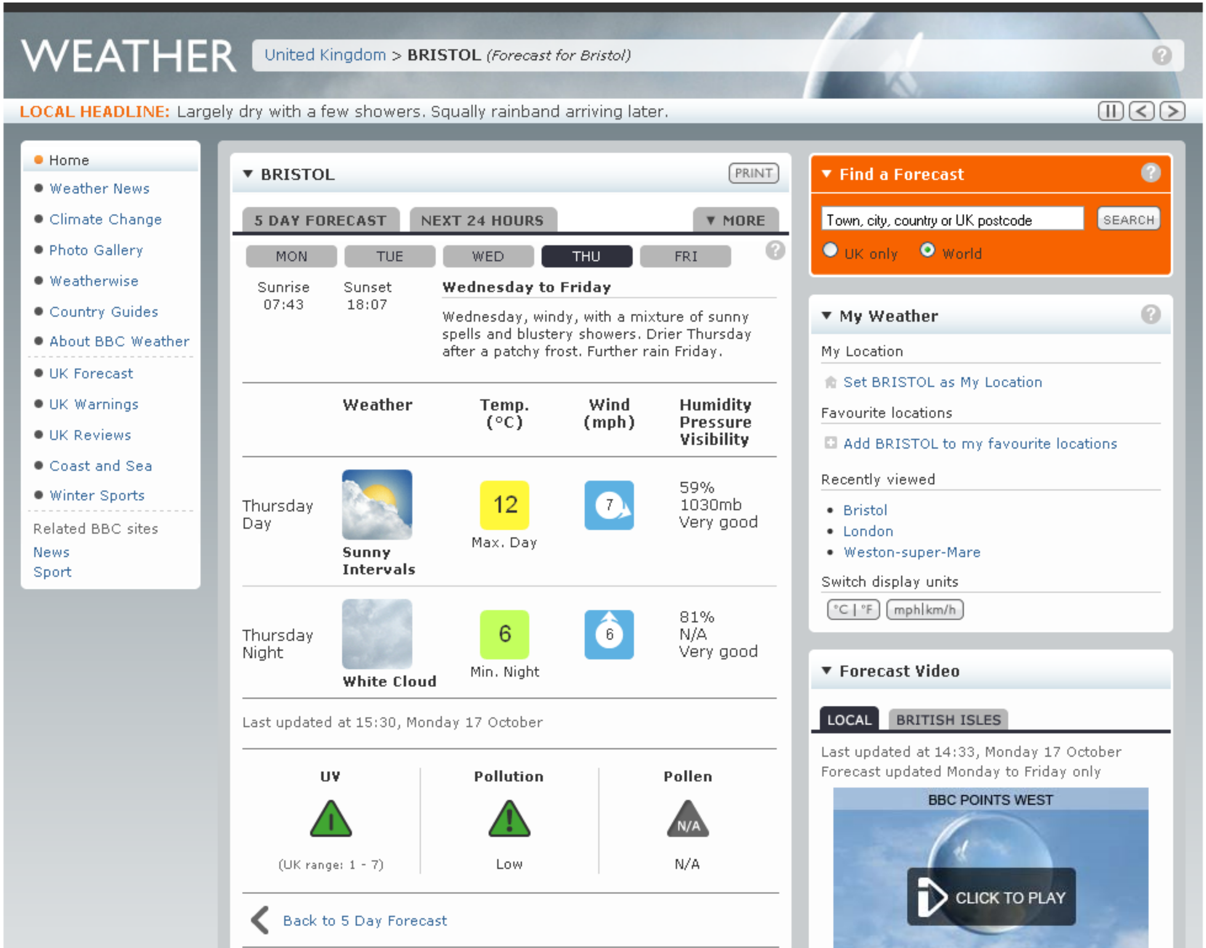
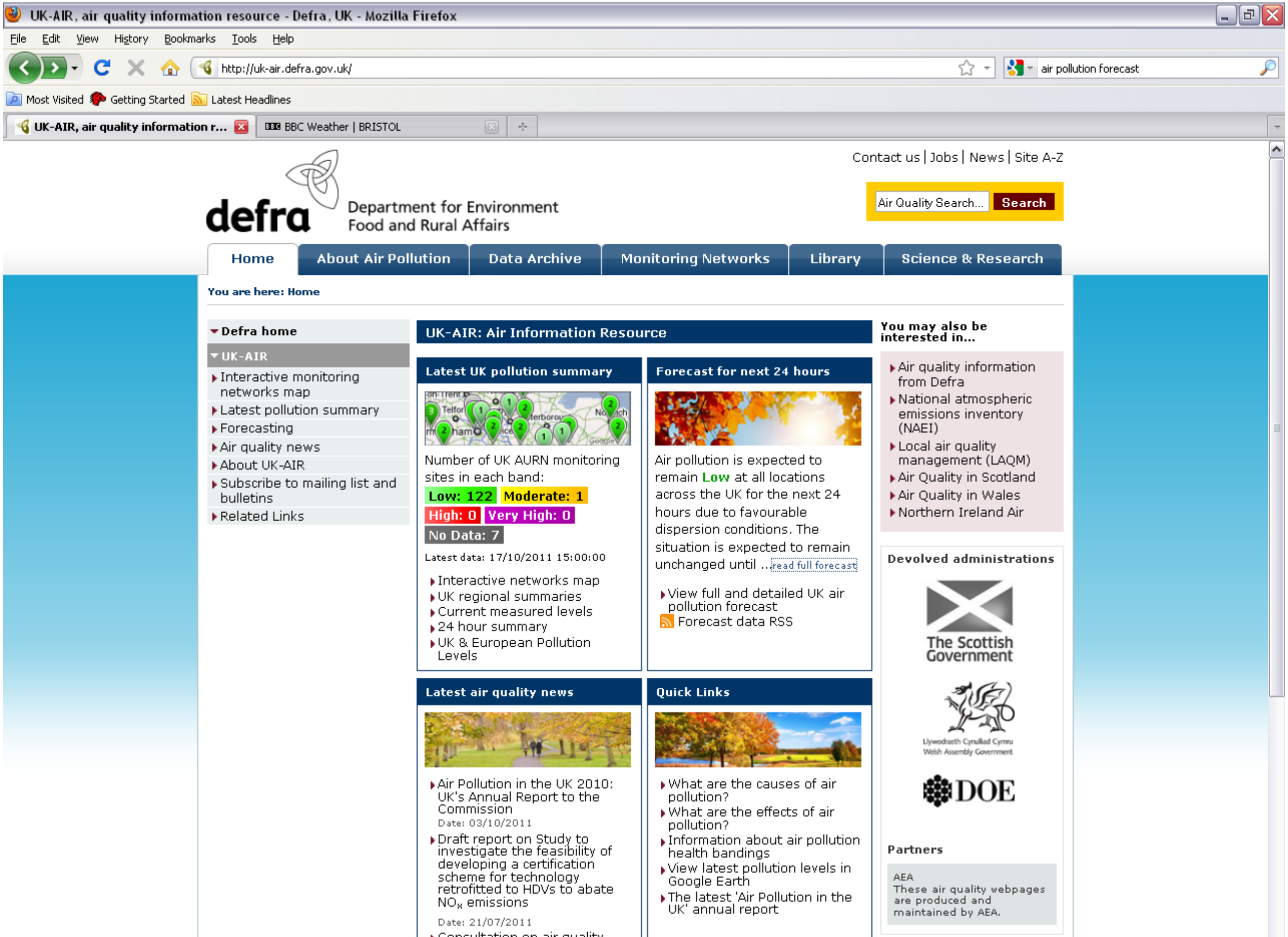
ABSTRACT

Despite progress in air pollution control, concerns remain over the health impact of poor air quality. Governments increasingly issue air quality information to enable vulnerable groups to avoid exposure. Avoidance behaviour potentially biases estimates of the health effects of air pollutants. But avoidance behaviour imposes a cost on individuals and therefore may not be taken in all circumstances. This paper exploits panel data at the English local authority level to estimate the relationship between children's daily hospital emergency admissions for respiratory diseases and common air pollutants, while allowing for avoidance behaviour in response to air pollution warnings. A 1% increase in nitrogen dioxide or ozone concentrations increases hospital admissions by 0.1%. For the subset of asthma admissions – where avoidance is less costly – there is evidence of avoidance behaviour. Ignoring avoidance behaviour, however, does not result in statistically significant underestimation of the health effect of air pollution.

Avoidance behaviour



Avoidance behaviour



Air pollution forecast bandings

Air Pollution Health Bandings

The table below outlines the air pollution health bandings and the potential impact on the health of people who are sensitive to air pollution.

Banding	Index	Health Descriptor
Low	1, 2, or 3	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
Moderate	4, 5, or 6	Mild effects, unlikely to require action, may be noticed amongst sensitive individuals.
High	7, 8, or 9	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung.
Very High	10	The effects on sensitive individuals described for 'High' levels of pollution may worsen.

Boundaries Between Index Points for Each Pollutant

Use the tabs below to view the bandings for each pollutant.

Ozone | Nitrogen Dioxide | Sulphur Dioxide | Carbon Monoxide | PM10 Particles

Ozone

Based on the running 8-hourly or hourly mean. For ozone, the maximum of the 8-hourly and hourly mean is used to calculate the index value.

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
µg/m³	0-33	34-65	66-99	100-125	126-153	154-179	180-239	240-299	300-359	360+
ppb	0-16	17-32	33-49	50-62	63-76	77-89	90-119	120-149	150-179	180+

You may also be interested in:

- Glossary of common terms used in the context of air pollution
- World Health Organisation - air pollution topic page
- UK Health Protection Agency
- Committee on the Medical Effects of Air Pollutants (COMEAP)

Page last modified: 21 February 2011

Results for all respiratory diseases

	Full specification	No warning
$NO_2/10$	0.036^{***}	0.034^{***}
	(0.008)	(0.008)
$O_3/10$	0.026^{***}	0.025^{***}
	(0.007)	(0.007)
Air pollution warning	-0.029	
	(0.039)	
	[-2.15]	

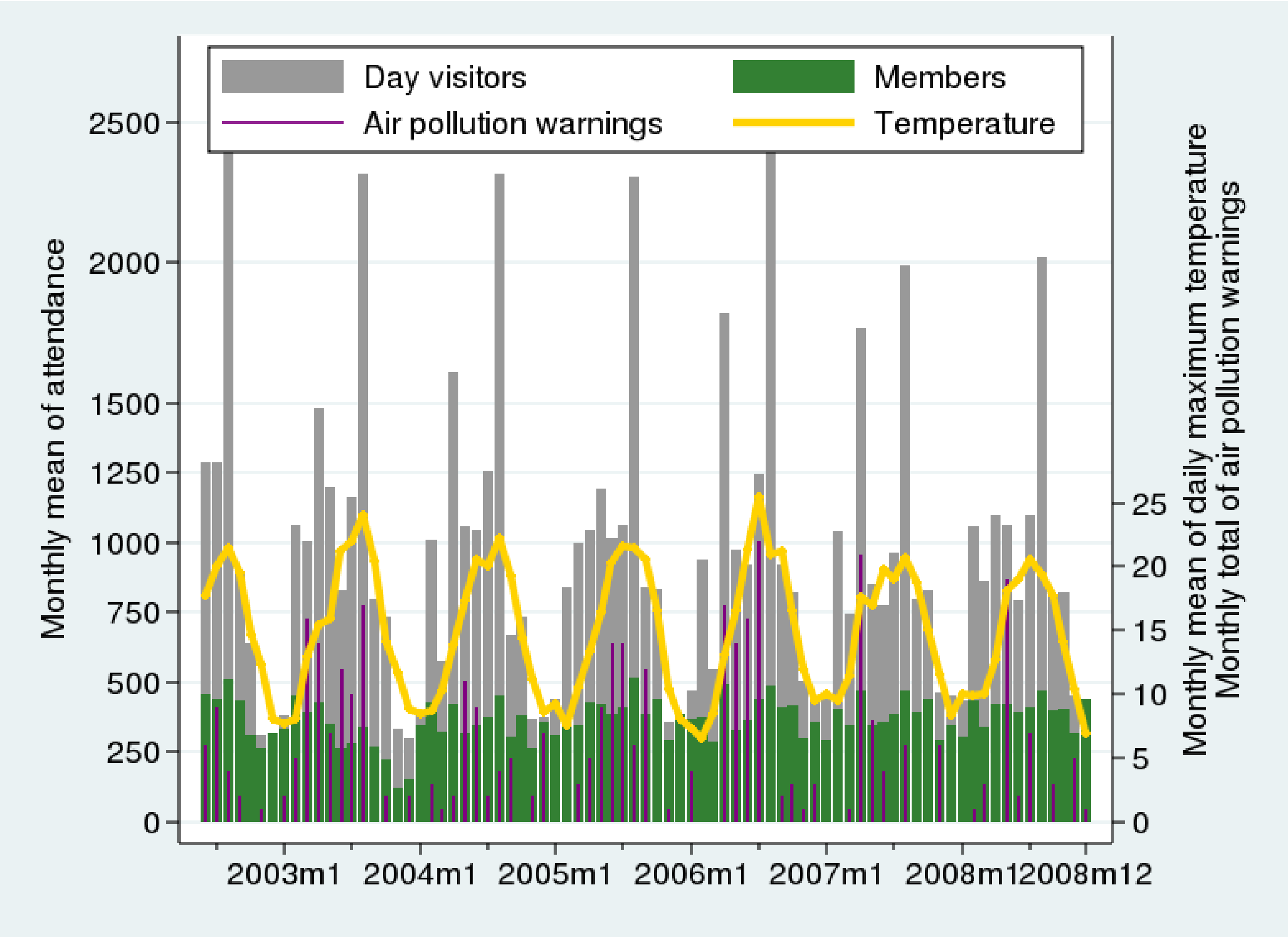
Standard errors in (brackets). Percent change in admission rate evaluated at the mean for discrete change in Air pollution warning from 0 to 1 in [square brackets]. 148,210 observations in 89 local authorities

Results for subset of asthma admissions

	Full specification	No warning
$NO_2/10$	0.013	0.011
	(0.007)	(0.006)
$O_3/10$	0.006	0.005
	(0.003)	(0.003)
Air pollution warning	-0.033^{***}	
	(0.010)	
	[-7.84]	

Standard errors in (brackets). Percent change in admission rate evaluated at the mean for discrete change in Air pollution warning from 0 to 1 in [square brackets]. 148,210 observations in 89 local authorities

Visitor data from Bristol Zoo



Daily visitor counts (Bristol Zoo)

	Day visitors	Members
Air pollution alert	0.029	-0.061^{**}
	(0.030)	(0.028)
Rain	-0.015^{***}	-0.014^{***}
	(0.002)	(0.002)
Max. temperature	0.029^{***}	0.026^{***}
	(0.006)	(0.005)
Min. temperature	-0.017^{***}	-0.017^{***}
	(0.005)	(0.005)
Wind speed	-0.018^{***}	-0.021^{***}
	(0.003)	(0.003)

Newey-West standard errors allowing for autocorrelation up to lag 10 in (brackets). Regressions include year-month dummies as well as dummies for day of week, public holidays and school holidays. 2,382 observations.

Air pollution a cause of Alzheimer's disease?

Magnetite pollution nanoparticles in the human brain

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Edited by Yinon Rudich, Weizmann Institute of Science, Rehovot, Israel, and accepted by Editorial Board Member A. R. Ravishankara July 25, 2016 (received for review April 13, 2016)

Biologically formed nanoparticles of the strongly magnetic mineral, magnetite, were first detected in the human brain over 20 y ago [Kirschvink JL, Kobayashi-Kirschvink A, Woodford BJ (1992) *Proc Natl Acad Sci USA* 89(16):7683–7687]. Magnetite can have potentially large impacts on the brain due to its unique combination of redox activity, surface charge, and strongly magnetic behavior. We used magnetic analyses and electron microscopy to identify the abundant presence in the brain of magnetite nanoparticles that are consistent with high-temperature formation, suggesting, therefore, an external, not internal, source. Comprising a separate nanoparticle population from the euhedral particles ascribed to endogenous sources, these brain magnetites are often found with other transition metal nanoparticles, and they display rounded crystal morphologies and fused surface textures, reflecting crystallization upon cooling from an initially heated, iron-bearing source material. Such high-temperature magnetite nanospheres are ubiquitous and abundant in airborne particulate matter pollution. They arise as combustion-derived, iron-rich particles, often associated with other transition metal particles, which condense and/or oxidize upon airborne release. Those magnetite pollutant particles which are <~200 nm in diameter can enter the brain directly via the olfactory bulb. Their presence proves that externally sourced iron-bearing nanoparticles, rather than their soluble compounds, can be transported directly into the brain, where they may pose hazard to human health.

We used magnetometry, high-resolution transmission electron microscopy (HRTEM), electron energy loss spectroscopy (EELS), and energy dispersive X-ray (EDX) analysis to examine the mineralogy, morphology, and composition of magnetic nanoparticles in and from the frontal cortex of 37 human brain samples, obtained from subjects who lived in Mexico City (14) (29 cases; ages 3 to 85 y; two females) and in Manchester, UK (8 cases; ages 62 to 92 y; five females; Tables S1 and S2). These brain magnetites display compelling similarity with the magnetite nanospheres formed by combustion, which are ubiquitous and prolific in urban, airborne particulate matter (PM) (15–19). We report here identification of the presence in human brain tissue of magnetite nanoparticles with an external, rather than an endogenous, source.

Results

To quantify brain magnetic content, a cryogenic magnetometer was used to measure, at room and low temperature (77 K), the saturation magnetic remanence (SIRM) of frontal tissue samples, initially fresh-frozen and subsequently freeze-dried. The SIRM 77 K captures the magnetic contribution of ferrimagnetic grains that are so small (<~20 nm) as to be magnetically unstable (superparamagnetic) at room temperature. The magnetic brain particles were then examined directly, by HRTEM and EDX analyses both of ultrathin tissue sections and of magnetically

Epidemiological evidence

American Journal of Epidemiology

Vol. 180, No. 4
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Original Contribution

Fine Particulate Matter Air Pollution and Cognitive Function Among Older US Adults

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Initially submitted October 6, 2013; accepted for publication April 4, 2014.

Existing research on the adverse health effects of exposure to pollution has devoted relatively little attention to the potential impact of ambient air pollution on cognitive function in older adults. We examined the cross-sectional association between residential concentrations of particulate matter with aerodynamic diameter of 2.5 μm or less ($PM_{2.5}$) and cognitive function in older adults. Using hierarchical linear modeling, we analyzed data from the 2004 Health and Retirement Study, a large, nationally representative sample of US adults aged 50 years or older. We linked participant data with 2000 US Census tract data and 2004 census tract–level annual average $PM_{2.5}$ concentrations. Older adults living in areas with higher $PM_{2.5}$ concentrations had worse cognitive function ($\beta = -0.26$, 95% confidence interval: −0.47, −0.05) even after adjustment for community- and individual-level social and economic characteristics. Results suggest that the association is strongest for the episodic memory component of cognitive function. This study adds to a growing body of research highlighting the importance of air pollution to cognitive function in older adults. Improving air quality in large metropolitan areas, where much of the aging US population resides, may be an important mechanism for reducing age-related cognitive decline.

Economic evidence

American Economic Journal: Applied Economics 2016, 8(4): 36–65
http://dx.doi.org/10.1257/app.20150213

The Long-Run Economic Consequences of High-Stakes Examinations: Evidence from Transitory Variation in Pollution†

By Avraham Ebenstein, Victor Lavy, and Sefi Roth*

Cognitive performance during high-stakes exams can be affected by random disturbances that, even if transitory, may have permanent consequences. We evaluate this hypothesis among Israeli students who took a series of matriculation exams between 2000 and 2002. Exploiting variation across the same student taking multiple exams, we find that transitory $PM_{2.5}$ exposure is associated with a significant decline in student performance. We then examine these students in 2010 and find that $PM_{2.5}$ exposure during exams is negatively associated with postsecondary educational attainment and earnings. The results highlight how reliance on noisy signals of student quality can lead to allocative inefficiency. (*JEL* I21, I23, I26, J24, J31, Q51, Q53)

Long-term impacts

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What Doesn't Kill You Makes You Weaker

Prenatal Pollution Exposure and Educational Outcomes

Nicholas J. Sanders

Abstract

I examine the impact of prenatal total suspended particulate (TSP) exposure on educational outcomes using county-level variation in the timing and severity of the industrial recession of the early 1980s as a shock to ambient TSPs (similar to Chay and Greenstone 2003b). I then instrument for pollution levels using county-level changes in relative manufacturing employment. A standard deviation decrease in TSPs in a student's year of birth is associated with 2 percent of a standard deviation increase in high school test scores for OLS and 6 percent for IV. I also consider how migration and selection into motherhood relate to my results.

Received July 2011.
Accepted October 2011.

Very long-term impacts

Every Breath You Take—Every Dollar You'll Make: The Long-Term Consequences of the Clean Air Act of 1970

Adam Isen

Office of Tax Analysis, Department of the Treasury

Maya Rossin-Slater

University of California Santa Barbara, National Bureau of Economic Research, and Institute for the Study of Labor (IZA)

W. Reed Walker

University of California Berkeley, National Bureau of Economic Research, and Institute for the Study of Labor (IZA)

This paper examines the long-term impacts of early childhood exposure to air pollution on adult outcomes using US administrative data. We exploit changes in air pollution driven by the 1970 Clean Air Act to analyze the difference in outcomes between cohorts born in counties before and after large improvements in air pollution relative to those same cohorts born in counties that had no improvements. We find a significant relationship between pollution exposure in the year of birth and later-life outcomes. A higher pollution level in the year of birth is associated with lower labor force participation and lower earnings at age 30.

This paper has been previously circulated under the title "Does Improved Air Quality at Birth Lead to Better Long-Term Outcomes? Evidence from the Clean Air Act of 1970." We would like to thank Doug Almond, Michael Anderson, David Card, Janet Currie, Lucas Davis, Olivier Deschenes, Will Dow, Ilyana Kuziemko, Matt Neidell, Yona Rubinstein, four anonymous referees, as well as seminar participants at Columbia, Georgia State, Texas A&M, University of Calgary, University of California Berkeley, National Bureau of Economic Research Summer Institute, Census Bureau, the Institute for the Study of Labor (IZA), the

Electronically published May 1, 2017
[*Journal of Political Economy*, 2017, vol. 125, no. 3]

Effects on productivity

American Economic Journal: Economic Policy 2016, 8(3): 141–169
http://dx.doi.org/10.1257/pol.20150085

Particulate Pollution and the Productivity of Pear Packers†

By Tom Chang, Joshua Graff Zivin, Tal Gross, and Matthew Neidell*

We study the effect of outdoor air pollution on the productivity of indoor workers at a pear-packing factory. Increases in fine particulate matter ($PM_{2.5}$), a pollutant that readily penetrates indoors, leads to significant decreases in productivity, with effects arising at levels below air quality standards. In contrast, pollutants that do not travel indoors, such as ozone, have little, if any, effect on productivity. This effect of outdoor pollution on indoor worker productivity suggests an overlooked consequence of pollution. Back-of-the-envelope calculations suggest the labor savings from nationwide reductions in $PM_{2.5}$ generated a sizable fraction of total welfare benefits. (*JEL* D24, J24, L66, Q13, Q51, Q53)

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Environment

Toxic air will shorten children's lives by 20 months, study reveals

Global air pollution crisis is taking its greatest toll on children in south Asia

Fiona Harvey *Environment correspondent*
Wed 3 Apr 2019 04.01 BST

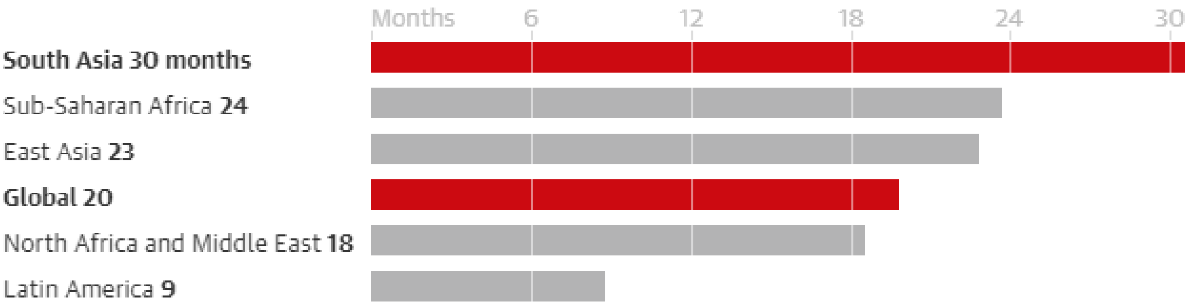
1,678

▲ Toxic air can cause stunted lung development in children. Photograph: VCG via Getty Images

The Figures

governments should be taking action."

Air pollution reduces life expectancy by 20 months on average worldwide, and more than 30 months in south Asia

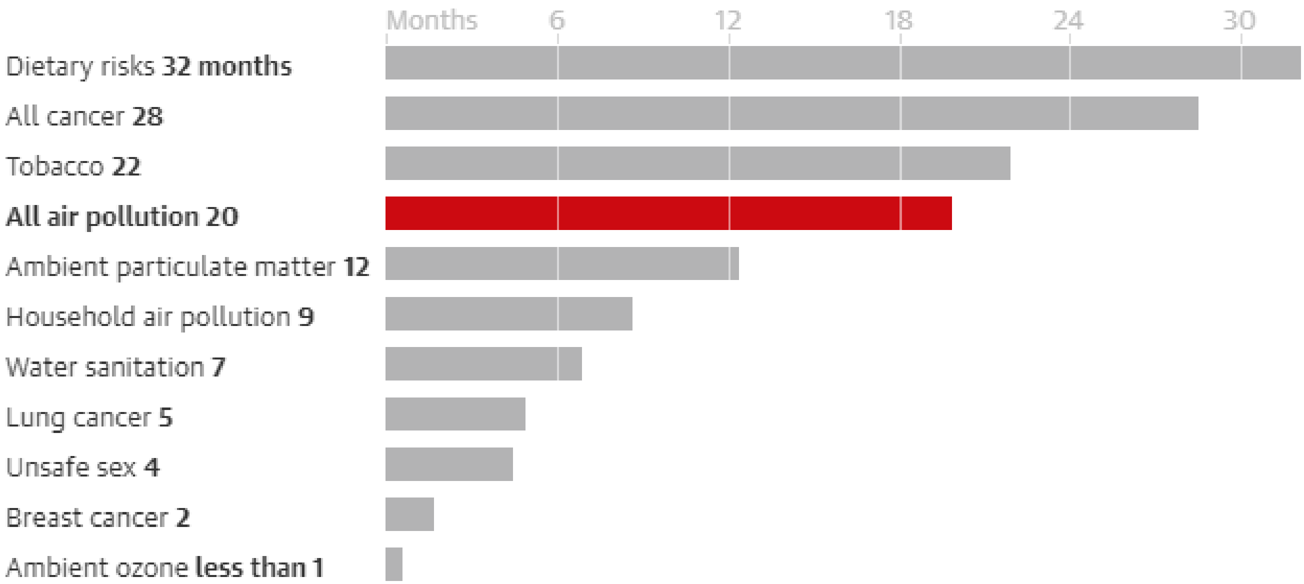


Guardian graphic | Source: State of Global Air 2019 Report

Alastair Harper, the head of campaigns and advocacy at Unicef UK, which has warned repeatedly of the threat to children's health, said: "This adds to a bleak picture of how polluted air impacts the health of society's most vulnerable groups, particularly children. Evidence continues to mount

The Figures

Air pollution is responsible for more early deaths than many better known health risks



Guardian graphic | Source: State of Global Air 2019 Report. Ambient particulate matter is for 2.5 micrometres or less

Attributable deaths

Table 7.2: Effect on mortality in 2008 of anthropogenic $PM_{2.5}$ air pollution in the UK population. UK totals are aggregates from the individual results presented

Pollution included	Country	Population-weighted mean concentration	Number of 'attributable' deaths	Number of 'attributable' deaths per 100,000 people aged 30 years and over
All anthropogenic	England and Wales	9.46 µg/m³	26,799	79
	Scotland	4.97 µg/m³	1,560	47
	Northern Ireland	6.02 µg/m³	502	48
	UK total	**8.97 µg/m³**	**28,861**	**75**
Anthropogenic >7 µg/m³	England and Wales	3.90 µg/m³	11,228	33
	Scotland	0.21 µg/m³	67	2
	Northern Ireland	0.91 µg/m³	77	7
	UK total	**3.50 µg/m³**	**11,372**	**30**

Calculation

Table 7.1: Baseline 2008 population data

Country	Total deaths in the population	Total deaths in the population aged 30 years and over	Life expectancy (years)	
			Males	Females
England and Wales combined	506,791	499,701	78.17	82.12
Scotland	55,532	54,647	75.46	80.14
Northern Ireland	14,669	14,322	76.71	81.44
UK	576,992	568,680	N/A	N/A

xiii Our recommendations for the individual coefficients that express the relative risks associated with a 10 μg/m³ increase in $PM_{2.5}$ are:

For all-cause mortality:

Best estimate 1.06 with 95% confidence interval (CI) 1.02–1.11.

6% per 10 $\mu g/m^3$ increase $\Rightarrow$ 5.38% per 8.97 $\mu g/m^3$ $PM_{2.5}$

568,680 deaths = 105.38% $\Rightarrow$ 539,647 = 100%

568,680 - 539,647 = 29,033

Interpretation

Pollution included	Country	Population-weighted mean concentration	Burden on total survival (life-years lost)
All anthropogenic	England and Wales	9.46 µg/m³	315,000
	Scotland	4.97 µg/m³	19,000
	Northern Ireland	6.02 µg/m³	6,000
	UK total	**8.97 µg/m³**	**340,000**

Hypothetical population affected	Number affected	Hypothetical average loss of life expectancy
Whole population (ages 30+)	38,348,000	3 days
All deaths (ages 30+)	569,000	½ year
50% of deaths (30+)	290,000	1 year
Deaths from CV causes (30+)	191,000	2 years
20% of deaths (30+)	116,000	3 years
10% of deaths (30+)	58,000	6 years
7% of deaths (30+)	40,000	8½ years
'Attributable' deaths (30+)	29,000	11½ years