Institution: St George's, University of London

Unit of Assessment: 2 Public Health, Health Services and Primary Care

Title of case study: Outdoor air pollution and mortality: systematic reviews supporting the UK Government Air Quality Strategy

Period when the underpinning research was undertaken: 2004 to 2018

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Richard Atkinson	Professor of Epidemiology Reader in Epidemiology Senior Lecturer in Epidemiology Senior Research Fellow Research Fellow	2018 – 2020 (present) 2014 – 2018 2009 – 2014 2008 – 2009 1994 – 2008
Barbara Butland	Senior Lecturer in Medical Statistics Lecturer in Medical Statistics	2019 – 2020 (present) 1991 – 2019
Peijue Huangfu	Research Fellow	2015 – 2020 (present)
Ross Anderson	Emeritus Professor Professor of Epidemiology	2014 – 2020 (present) 1983 – 2014
David Strachan	Professor of Epidemiology Reader in Epidemiology Senior Lecturer in Epidemiology	1997 – 2020 (present) 1995 – 1997 1990 – 1995
Inga Mills	External PhD Student	2010 – 2015
Stephen Bremner	Research Assistant	2000 – 2006
Joanne Carrington	Research Statistician	2005 – 2006
Janet Peacock	Reader in Medical Statistics	1983 – 2004

Period when the claimed impact occurred: 2017 to 2018

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

Among outdoor air pollution components, long-term nitrogen dioxide (NO_2) exposure is implicated as an important health hazard. At the UK Government's request, Atkinson and Butland assessed the association between long-term NO_2 concentrations and mortality risk, conducting a systematic review and meta-analysis of prospective epidemiological studies and showing that an increase of 10μg/m^3 in NO_2 concentration was associated with an increase of 2.3% in mortality risk. This estimate was used by the Department of Food, Environment and Rural Affairs (DEFRA) to calculate health benefits of different policy options for reducing UK NO_2 emissions to meet European Union air quality limits. It also underpinned the UK Government's subsequent Air Quality Strategy (2019).

2. Underpinning research (indicative maximum 500 words)

Defining the epidemiology of air pollution and its impact on populations

Outdoor air pollution is a major environmental human health hazard and a cause of mortality and morbidity worldwide. In the UK, the major source of particulate and gaseous air pollution is combustion of fossil fuels, particularly from traffic. Atkinson and St George's colleagues have studied the health effects of air pollution since 1996, including using large, linked population databases and strengthening the evidence for associations between long-term ambient air pollution exposure and all-cause mortality rates. They have pioneered the use of systematic review and meta-analysis to synthesize available evidence, emphasizing their value in air pollution epidemiology where individual risks are small.

Their internationally recognised expertise has led them to conduct systematic reviews of the health effects of outdoor air pollution exposure for the Department of Health [1] and the US Health Effects Institute (HEI) [2] and to assess the health effects of pollutant mixtures [3]. These reviews have informed the understanding of national and international agencies of the health effects of air pollution. Atkinson and Anderson have been long-standing members of the UK Government's Committee on the Medical Effects of Air Pollutants (COMEAP) (2009-2019 and 1995-2016 respectively).

Quantifying the mortality benefits of reducing NO_2 pollution

In 2015, the UK Government sought to quantify the mortality benefits of reducing long-term ambient concentrations of NO_2 in response to a Supreme Court order requiring it to submit to the European Commission new air quality plans for achievement of EU NO_2 limit values. In developing these plans, the Department for Food and Rural Affairs (DEFRA) sought advice from COMEAP on how best to quantify the mortality benefits of reducing long-term ambient concentrations of NO_2. To quantify the potential health benefits of policy options to reduce ambient NO_2 concentrations, DEFRA required an estimate, with guidance on its interpretation, for the effect of NO_2 on mortality based upon the most recent scientific evidence.

To underpin COMEAP's advice, Atkinson and Butland planned and conducted a new systematic review and meta-analysis of epidemiological cohort studies of long-term average concentrations of NO_2 and all-cause mortality [4]. This work, funded by DEFRA, included the most up-to-date evidence available, maximising the precision of the results, and assessing the independence from co-pollutants. The systematic review was substantially more comprehensive than previous reports, being based on 20 cohort studies and included large administrative cohorts (including one analysed and reported by Atkinson, Anderson and colleagues). A summary coefficient of 1.023 (95%CI: 1.008, 1.037) was obtained, denoting the increase in the relative risk of death associated with an increase of 10μg/m^3 in average NO_2 long-term concentrations. Thus, a location with an average concentration of NO_2 10μg/m^3 higher than another location has an estimated increase of 2.3% in risk of death, although the uncertainty around this estimate means the change in risk may be as low as 0.8% or as high as 3.7%. The review assessed the literature in relation to closely correlated pollutants and provided advice to DEFRA on how to interpret the evidence for health policy.

A subsequent updated and expanded systematic review was also undertaken by Atkinson and Butland and published in the journal *Epidemiology* documented current evidence on the prospective association between NO_2 and mortality rates [5]. More recently, Huangfu and Atkinson conducted a systematic review of the association between NO_2 (and ozone, another pollutant) and mortality rates on behalf of the World Health Organisation, in support of their programme of work on air quality guidelines. [6]

3. References to the research (indicative maximum of six references)

1. Anderson HR, Atkinson RW, Bremner SA, Carrington J, Peacock J. Quantitative systematic review of short-term associations between ambient air pollution (particulate matter, ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide), and mortality and morbidity. Department of Health, UK; 2007.

https://www.gov.uk/government/publications/quantitative-systematic-review-of-short-term-associations-between-ambient-air-pollution-particulate-matter-ozone-nitrogen-dioxide-sulphur-dioxide-and-carbon-monoxide-and-mortality-and-morbidity
Report commissioned by UK Department of Health. Atkinson contributed to the design of the review, statistical methodology and to the writing of the report.

2. Anderson HR, Atkinson RW, Chen,B Cohen,A, Greenbaum D, Hedley AJ, Huang,W, Pande JN, Bhartia S, Pope A, Smith KR.
Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review. 2004. Report No.: Special Report 15.
https://www.healtheffects.org/system/files/SpecialReport15.pdf
Review commissioned by the US Health Effects Institute. Atkinson designed, conducted and wrote the section on systematic review of short-term exposure studies. Pages 43-73

3. Mills IC, Atkinson RW, Anderson HR, Maynard RL, Strachan DP. Distinguishing the associations between daily mortality and hospital admissions and nitrogen dioxide from those of particulate matter: a systematic review and meta-analysis. BMJ Open. 2016;6(7):e010751. DOI: 10.1136/bmjopen-2015-010751. Systematic review cited 27 times (WOS 03.02.2021).

4. Atkinson RW, Butland BK. Committee on the Medical Effects of Air Pollutants (COMEAP). Associations of long-term average concentrations of nitrogen dioxide with mortality. © Crown copyright 2018 PHE publishing gateway number: 2018238. Systematic review and meta-analysis.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734802/COMEAP_NO2_Working_Paper_1.pdf Published 2018

5. Atkinson RW, Butland BK, Anderson HR, Maynard RL. Long-term Concentrations of Nitrogen Dioxide and Mortality: A Meta-analysis of Cohort Studies. Epidemiology. 2018;29(4):460-72. DOI: 10.1097/EDE.0000000000000847.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5991178/ Journal article cited 40 times (WOS 03.02.2021).

6. Huangfu P, Atkinson R. Long-term exposure to NO2 and O3 and all-cause and respiratory mortality: A systematic review and meta-analysis. Environment International. 2020;144:105998. DOI: 10.1016/j.envint.2020.105998. Journal article cited 1 time (WOS 28.02.2021).

4. Details of the impact (indicative maximum 750 words)

Health and economic impacts of decreasing NO_2 emissions and influence on recommendations

Population exposure to outdoor air pollution is widespread. The formulation of Government policy and detailed plans to reduce population exposure require development of appropriate emission control strategies supported by cost-benefit analyses. Emission reduction strategies should lead to an increase in life expectancy.

To determine the reduction in years of life lost as a result of air pollution exposure, a coefficient describing the relationship between a change in the concentration of a pollutant and risk of death is required. The increase in life expectancy can then be calculated and monetised using a valuation on years of life lost derived from a consideration of individuals' or society's willingness to pay for an increase in life expectancy. The immediate impact of a systematic review to provide a coefficient to Government policy makers therefore is the calculation, and hence monetisation, of health benefits arising from a proposed air quality management plan.

The research by Atkinson and Butland produced a coefficient representing the increase in mortality risk (2.3%, 95%CI: 0.8%, 3.7%) associated with an increase of 10μg/m^3 in NO_2 long-term average concentrations) [A]. COMEAP used this coefficient to estimate that in the UK population of 64,000,000, a decrease of 1μg/m^3 in NO_2 would yield a saving of between about

420,000 and 903,000 life years in the UK over the next 106 years, associated with an average increase in life expectancy (at birth) of around 2 to 5 days [B]. COMEAP recommended the use of this coefficient (and CI) to DEFRA in a letter to the Parliamentary Under Secretary of State for the Environment and Rural Life Opportunities, Department for Environment, Food & Rural Affairs [C]. DEFRA used this coefficient and associated confidence interval [D] to calculate (using the method outlined above) the monetary benefits of increased life expectancy associated with the Government's plans for Clean Air Zones (CAZ) to be GBP400,000,000 (low estimate GBP2,800,000, high estimate GBP2,400,000,000) [E]. These monetary benefits enabled DEFRA to model the impacts of road use charging and introduction in CAZs as a means to achieve statutory NO_2 limit values in towns and cities in the shortest possible time. The review by Atkinson and Butland therefore provided DEFRA policy makers with the most up-to-date assessment of the impact of NO_2 reduction on mortality rates available. Without this review and the coefficient provided, DEFRA would have had to rely upon previously published reviews containing older evidence (and therefore less relevant to the current air pollution situation) and those with fewer studies included; and would have lacked studies from the UK (the only national cohort study of NO_2 and mortality in the UK was published in 2013).

Implementation of strategies to reduce NO_2 levels

Atkinson and Butland's research also provided advice on the interpretation of this evidence covering assessment of potential biases, confounding by other outdoor pollutants and interpretation of the meta-analyses results [A]. This advice was considered in detail by COMEAP. The subsequent detailed discussions and opinions of COMEAP, including the views presented by Atkinson and Butland, were summarised in the COMEAP statement to DEFRA [B] and documented more fully in the resulting COMEAP report [F]. These recommendations played a key role in the evaluation of the Clean Air Zone strategy as the preferred, and only option costed, by DEFRA. These policy options were discussed in detail in the technical report [G], part of the full DEFRA report which included an overview and detailed plan for reducing roadside NO_2 concentrations [H].

Following publication of the DEFRA report [H] and the subsequent public consultation, the government has legally directed 33 local authorities to design local plans to reduce emissions of NO_2 in 81 road links (sections of a road, usually between two junctions) where pollution levels remained high [I]. Execution of these local plans to reduce NO_2 levels will involve implementation of non-charging Clean Air Zones using measures including reductions in speed limits; transport fleet upgrades; and pedestrian and traffic signal optimisation (all currently being evaluated by DEFRA) and potentially also more stringent actions including charging Clean Air Zones [G]). These interventions aim to reduce concentrations of NO_2 at all previously identified non-compliant road links, enabling the UK Government to comply with European limit values and potentially realise some of the expected improvements in life expectancy across the whole UK population.

The proposed reductions in NO_2 emissions and the associated health benefits likely to arise were also incorporated in the UK Government's 2019 air quality strategy [J] which directly referenced the COMEAP report [F] based upon the systematic review and advice provided by Atkinson and Butland [A].

The review undertaken for the World Health Organization is likely to have significant future impact as it is currently informing the deliberations of the WHO Guideline Development Group, which is considering revisions to WHO Air Quality Guidelines.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734802/COMEAP_NO2_Working_Paper_1.pdf
Published 2018

B.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf
Published 2018
Output from Atkinson & Butland used in impact calculation in Section 9.1.1 of report.

C.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/632916/air-quality-plan-technical-report.pdf
Published 2017
Annex A contains letter from COMEAP recommending use of coefficient from research by Atkinson & Butland

D.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/632916/air-quality-plan-technical-report.pdf
Published 2017
Section 2.2.1 quotes results of research from Atkinson & Butland.

E.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/632916/air-quality-plan-technical-report.pdf
Published 2017
Section 3.2.2 & Table 3.8 give costs derived using results of research from Atkinson & Butland

F.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf
Published 2018
Research by Atkinson & Butland informed COMEAP's thinking on interpretation of evidence – see Sections 3.2, 3.3, Chapters 7 & 10

G.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/632916/air-quality-plan-technical-report.pdf
Published 2017
Research by Atkinson & Butland led to COMEAP's recommendation of coefficients adjusted for other pollutants used in sensitivity analyses - Section 4.2.5

Ha. Overview:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633269/air-quality-plan-overview.pdf Published 2017
b. Detailed plan:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633270/air-quality-plan-detail.pdf Published 2017
This report influenced by item F, which was informed by Atkinson and Butland's research

I. https://uk-air.defra.gov.uk/library/no2ten/2018-la-tfs-documents
Published 2018
This report influenced by item F, which was informed by Atkinson and Butland's research

J.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770715/clean-air-strategy-2019.pdf
Published 2019
COMEAP report containing research by Atkinson & Butland referenced in Section 2.1