Institution: St George's, University of London

Unit of Assessment: A2 Public Health, Health services and Primary Care

Title of case study: Effects of outdoor air pollutants on human health

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

A sustained programme of epidemiological research at St George's, spanning 20 years, has informed air pollution control policies in the UK and internationally. Time-series studies of the acute health effects of daily fluctuations in air pollutants, initially in London, were extended to Europe-wide collaborations, trans-Atlantic comparisons and studies in Asian cities. Publication bias has been explored systematically in meta-analyses of published time-series results, and the adverse effects of different particulate fractions compared in a UK setting. This evidence base has contributed substantially to the current UK Air Quality Strategy and informs ongoing debates about health impacts of shorter-lived "greenhouse" pollutants.

2. Underpinning research (indicative maximum 500 words)

In the early 1990s, the UK Department of Health convened an expert panel which developed into the Committee on the Medical Effects of Air Pollution (COMEAP). Three epidemiologists from St George's (Anderson, Atkinson and Strachan) have served at length on COMEAP and associated committees over the past two decades, a period which has seen outdoor air pollution re-emerge as a public health concern.

All three have been in continuous employment at St George's since 1993. Anderson has been professor of epidemiology and public health throughout. Atkinson was initially a research fellow working with Anderson and was promoted to senior lecturer in epidemiology in 2009. Strachan was initially senior lecturer in epidemiology and was promoted to professor in 1997.

An early stimulus to this renewed interest in air pollution was the observation that daily fluctuations in ambient levels of several pollutants were associated with short-term variations in both fatal and non-fatal health events at concentrations well below air quality standards of the time. Our studies of daily mortality in London during 1987-1992 [1] showed that ozone levels were associated with a significant increase in all cause mortality on the same day; black smoke concentrations on the previous day were significantly associated with all cause mortality; and significant but smaller adverse effects were observed for fluctuations in nitrogen dioxide and sulphur dioxide.

Embellishment of this approach and its extension to 12 European cities as part of the APHEA collaboration confirmed that, even at historically low ambient levels, airborne particles had detectable short term effects on mortality [2] and respiratory hospital admissions [3]. The consistency of the results across cities with wide differences in climate and environmental conditions suggested that these associations may be causal. As published evidence accumulated to support short-term associations between air pollution levels and adverse health effects, three methodological issues required investigation:

Firstly, whether developments of the time-series methodology through the 1990s could explain differences in the results obtained from various studies. This was addressed by the APHENA project which re-analysed, using a standardized methodology, the largest time-series studies of mortality from Europe and North America [4]. The findings obtained with the new standardized analysis were generally comparable to those obtained in the earlier studies, and were relatively robust to the data analysis method used. This led to greater confidence in their relevance to public policy on both sides of the Atlantic.

A second issue was whether selective publication and citation of "positive" results, or undue focus

on the most statistically significant lag period between pollution measurement and health outcome, could have overstated the epidemiological evidence. Our review of time series analyses published up to 2002 [5] concluded that publication bias is present in single-city time-series studies of ambient particles, and that differential selection of positive lags may also inflate estimates. However, short-term associations between particles and adverse health effects remained positive and significant after correcting statistically for publication bias.

A third issue of policy relevance was which components of the particulate mixture (size, number, source, toxicity) are most relevant to health. We investigated associations of a range of particle metrics with daily deaths and hospital admissions in London [6]. This is one of few studies to investigate particle numbers, rather than mass concentration, and found that particle numbers were associated with daily mortality and admissions, particularly for cardiovascular diseases whereas fluctuations in secondary particles (nitrate and sulphate) were more important for respiratory outcomes.

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

3.

[1] Anderson HR, Ponce de Leon A, Bland JM, Bower JS, Strachan DP. Air pollution and daily mortality in London: 1987-92. *Br Med J* 1996;312:665-9. PMID:8597732. *doi: http://dx.doi.org/10.1136/bmj.312.7032.665*

[2] Katsouyanni K, Touloumi G, Spix C, Schwartz J, Balducci F, Medina S, Rossi G, Wojtyniak B, Sunyer J, Bacharova L, Schouten JP, Ponka A, Anderson HR. Short-term effects of ambient sulphur dioxide and particulate matter on mortality in 12 European cities: results from time series data from the APHEA project. Air Pollution and Health: a European Approach. *Br Med J* 1997;314:1658-63. PMID:9180068. *doi: http://dx.doi.org/10.1136/bmj.314.7095.1658*

[3] Atkinson RW, Anderson HR, Sunyer J, Ayres J, Baccini M, Vonk JM, Boumghar A, Forastiere F, Forsberg B, Touloumi G, Schwartz J, Katsouyanni K. Acute effects of particulate air pollution on respiratory admissions: results from APHEA 2 project. Air Pollution and Health: a European Approach. *Am J Respir Crit Care Med* 2001;164:1860-6. PMID:11734437. doi: 10.1164/ajrccm.164.10.2010138

[4] Katsouyanni K, Samet JM, Anderson HR, Atkinson R, Le Tertre A, Medina S, Samoli E, Touloumi G, Burnett RT, Krewski D, Ramsay T, Dominici F, Peng RD, Schwartz J, Zanobetti A; HEI Health Review Committee. Air pollution and health: a European and North American approach (APHENA). *Res Rep Health Eff Inst* 2009;142:5-90. PMID: 20073322. No DOI available.

[5] Anderson HR, Atkinson RW, Peacock JL, Sweeting MJ, Marston L. Ambient particulate matter and health effects: publication bias in studies of short-term associations. *Epidemiology* 2005;16:155-63. PMID:15703529. DOI: 10.1097/01.ede.0000152528.22746.0f

[6] Atkinson RW, Fuller GW, Anderson HR, Harrison RM, Armstrong B. Urban ambient particle metrics and health: a time-series analysis. *Epidemiology* 2010;21:501-11. PMID: 20502338. doi: 10.1097/EDE.0b013e3181debc88

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

The European Union (EU) has designated 2013 to be the "Year of Air" during which a comprehensive review of the air quality policies has been undertaken. To inform this review, the REVIHAAP (Review of Evidence on Health Aspects of Air Pollution) project was co-funded by the EU DG ENVIRONMENT and WHO Regional Office for Europe, to answer 24 policy-related

questions about air pollution and health. Included in this review was consideration of whether new evidence was sufficient to revise the WHO 2005 Air Quality Guidelines, published in 2006 [A]. Anderson was a member of the REVIHAAP Scientific Advisory Committee and Atkinson was an expert advisor and contributor to the report, especially sections on ozone.

The following sections of the REVIHAAP July 2013 report [B] refer to the Air Pollution Epidemiology Database (APED) which is a systematic review facility established at St George's to provide continuously updated meta-analyses of time-series evidence, as described in document REF3a. APED incorporated the results of the underpinning time-series studies into a cumulative meta-analysis, commissioned specifically for the REVIHAAP report:

- Pages 52-55 & table 2: Use of ozone coefficients from APED, including APHENA [4]
- Pages 74-76 & table 5: Use of NO2 coefficients from APED
- Pages 145-149 & table 11: Use of SO2 coefficients from APED
- Pages 217-218: References (APED cited as Anderson HR *et al.* 2007, but see REF3a.)

Linked with REVIHAAP, and extending from it, the HRAPIE (Health Risks of Air Pollution in Europe) review [C] recommends concentration-response functions for cost-benefit analysis to guide future policies for air pollutant control. Anderson is a member of the Scientific Advisory Committee and Atkinson is an advisor and contributor of evidence to HRAPIE. Coefficients from time-series studies provide the key evidence base for estimating response functions and cost-benefit analyses for all gaseous pollutants.

Also, the observation that time-series analyses show similar effects of short-term fluctuations in PM on health outcomes worldwide [D] buttresses the argument that there is a causal association between respirable particulate exposures and diverse health outcomes, including non-respiratory mortality. This conclusion, linking time-series work with chronic effects of PM, was also reached by the UK Department of Health COMEAP in 2010 [E].

Results from time-series studies also underpin the 2011 COMEAP subgroup report on UK Air Quality Standards, on which Anderson was a committee member [F]. This used APED to update the WHO 2005 Air Quality Guidelines [A] from which was developed a Daily Air Quality Index (DAQI) with bandings indicating likely short-term health effects. The DAQI is now implemented as a public information system online [G] and during periods of high air pollutant levels, health warnings are incorporated into national weather forecasts for the UK.

Time-series methods have been extended to studies of the effects of heat waves and climate change. Although sulphate is a cooling agent, black carbon and ozone could together exert nearly half as much global warming as carbon dioxide. The complexity of these health and climate effects of shorter-lived greenhouse pollutants needs to be recognised in mitigation policies. Links between strategies to reduce greenhouse gases and public health outcomes were reviewed in 2009 by a consortium in which Anderson and Atkinson were involved [H].

Assessment of the relative importance of 67 risk factors, worldwide and by region, formed part of the Global Burden of Disease 2010 project (GBD). Anderson co-chaired the GBD subgroup assessing health effects of outdoor air pollution, which evaluated both ambient particulate pollution and ambient ozone [I]. An analysis of burden of disease due to air pollution in the UK found that this had fallen by over 50% between 1990 and 2010, reflecting mainly improvements in air quality over this time resulting from effective environmental policies [J].

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

[A] WHO. *Air Quality Guidelines, Global Update 2005. Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide.* World Health Organization, Copenhagen, 2006. ISBN: 92-890-2192-6.

[B] REVIHAAP report (2013). http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap [Downloaded to PDF 11 July 2013]

[C] HRAPIE report (2013). http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/health-risks-of-air-pollution-in-europe-hrapie-project.-new-emerging-risks-to-health-from-air-pollution-results-from-the-survey-of-experts [Downloaded to PDF 15 November 2013]

[D] Atkinson RW, Cohen A, Mehta S, Anderson HR. Systematic review and meta-analysis of epidemiological time-series studies on outdoor air pollution and health in Asia. *Air Quality Atmosphere and Health* 2012;5:383-91. doi:10.1007/s11869-010-0123-2.

[E] Committee on the Medical Effects of Air Pollutants. *The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom.* Health Protection Agency, 2010. ISBN 978-0-85951-685-3.

[F] Committee on the Medical Effects of Air Pollutants Standards Advisory Subgroup. *Review of the UK Air Quality Index.* Health Protection Agency, 2011. [PDF downloaded 11 July 2013] http://www.comeap.org.uk/images/stories/Documents/Reports/comeap%20review%20of%20the%20uk%20air%20quality%20index.pdf

[G] http://uk-air.defra.gov.uk/air-pollution/daqi [Downloaded to PDF 11 July 2013]

[H] Smith KR, Jerrett M, Anderson HR, Burnett RT, Stone V, Derwent R, Atkinson RW, Cohen A, Shonkoff SB, Krewski D, Pope CA 3rd, Thun MJ, Thurston G. Public health benefits of strategies to reduce greenhouse-gas emissions: health implications of short-lived greenhouse pollutants. *Lancet* 2009;374:2091-103. PMID: 19942276.

[I] Lim SS, Vos T, Flaxman AD, … Anderson HR, … Lopez AD, Murray CJ, Ezzati M. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380:2224-60. PMID: 23245609.

[J] Murray CJ, Richards MA, Newton JN, Fenton KA, Anderson HR, Atkinson C *et al*. UK health performance: findings of the Global Burden of Disease Study 2010. *Lancet* 2013;381:997-1020 PMID: 23668584.