Institution: EaStCHEM

Unit of Assessment: 8; Chemistry

Title of case study: Air Quality; measurement, standardisation, and quantification of airborne contaminants

1. Summary of the impact

Impact type: Public Policy

Significance: The research provided evidence for formulation of government policies to ameliorate poor air quality, to which fine particulate matter ($PM_{2.5}$), O_3 and NO_2 are the most important contributors; $PM_{2.5}$ alone reduces average life expectancy in the UK by 6 months and costs £9bn-£20bn a year. The research has been incorporated into UK national guidance and policy-evidence documents for Defra, the Health Protection Agency, and the Environment Agencies.

Beneficiaries are the public and the environment.

Research; date; attribution: EaStCHEM research (1995-2011) (a) established reliable techniques to measure NO_2 for a national protocol, and (b) quantified the impact of pollutant emissions on $PM_{2.5}$ and O_3 concentrations, and on hospital admissions and deaths. Heal (EaStCHEM) led the research and wrote, collaboratively in some cases, the reports and the work cited.

Reach: UK wide.

2. Underpinning research

Background: Air pollution is the environmental factor with the greatest impact on health in the EU, with 16-30% and 15-17% of the EU urban pollution estimated to be exposed to levels of $PM_{2.5}$ and O_3 greater than the EU limit values.[EEA, 2012]. Air quality in Europe - 2012 report. EEA Report No 4/2012, European Environment Agency] In the UK, poor air quality is estimated to reduce average life expectancy by ~6 months [COMEAP, 2010]. The mortality effects of long-term exposure to particulate air pollution in the United Kingdom, UK Department of Health Committee on the Medical Effects of Air Pollution] and cost £9bn-£20bn in adverse human health impacts alone.[EAC, 2010].'Air Quality' House of Commons Environmental Audit Committee, 5th report] NO_2 is the pollutant causing the greatest number of failures of air quality standards in the UK.
Heal's group (EaStCHEM) has led air pollution research on all three of the most important air pollutants; NO_2, $PM_{2.5}$ and O_3.

(A) Measurement of ambient NO_2 by passive diffusion tube; improved accuracy and quantification of errors

Measurement of ambient NO_2 by passive diffusion tube is widely used in the UK as part of air quality assessments required by law. From 1995 onwards, research led by the Heal group (EaStCHEM) showed that this method is subject to inaccuracies, in particular overestimation caused by the within-tube reaction between co-diffusing NO and O_3 to form additional NO_2, and an effective shortening of the assumed diffusion path length caused by wind turbulence across the entrance of the tube. Through field deployments and numerical modelling these biases were quantified for locations of varying ambient chemical and meteorological conditions.[1,2] Parallel research defined optimal methods for the adsorbent preparation and post-exposure chemical analysis.[3] This research was initiated in collaboration with Prof. Cape of the NERC Centre for Ecology & Hydrology and Honorary EaStCHEM professor but was subsequently carried out entirely in the Heal group. The work led to more accurate and reliable measurements of atmospheric NO_2 concentration and Heal's methods are now incorporated into protocols applied to measurements of NO_2 for statutory air quality assessments in all urban areas in the UK (estimated >139,000 NO_2 measurements costing £0.5 M annually).[S1]

(B) Characterisation of sources of airborne particulate matter (PM)

Research led by the Heal group (EaStCHEM) in 2007-09 quantified the proportions of contemporary and fossil carbon in samples of $PM_{2.5}$ via accelerator mass spectrometric determination of the carbon-14 radioisotope. A key finding was that around half the carbon was shown to be contemporary rather than fossil, which was higher than anticipated.[4] This finding has been important for informing $PM_{2.5}$ reduction policy actions.
Research carried out in 2012 for the Scottish Environment Protection Agency, SEPA, (in

collaboration with Dr Vieno from the Centre for Ecology & Hydrology) used an atmospheric chemistry transport model to quantify the sensitivity of components of $PM_{2.5}$ in Scotland to reductions of primary $PM_{2.5}$ or gaseous inorganic precursors (SO_2, NO_x, NH_3) from industry and shipping within or outside of Scotland.[5] A key finding is that reductions in these components are most sensitive to reductions in ammonia emissions regionally but that the greatest reductions in population exposure are achieved nationally by reductions in primary $PM_{2.5}$ emissions. These results are being used by SEPA and the Scottish Government to develop policy on reduction of $PM_{2.5}$ in Scotland.

(C) Quantification of the current and potential future UK health burden from exposure to ambient ozone

Research led by the Heal group in 2011 used an atmospheric chemistry transport model to produce time-series of hourly surface O_3 concentrations at 5 km spatial resolution across the UK for the present-day and for possible future scenarios of different precursor emissions and increased temperatures from climate change. The O_3 concentrations were used to calculate numbers of regionally-disaggregated deaths and hospital admissions that may be attributable to O_3 currently and in the future.[6] The research shows that over a time horizon of a few decades policy actions that reduce man-made emissions to the atmosphere can have substantially greater health benefits than adverse impacts through O_3 via climate change but that the O_3 health benefits are extremely sensitive to the exact trends in the man-made emissions that are followed.

People:

Heal, M. R.: PI who led the research in EaStCHEM, Sept. 1994 to date.
Hamilton, R.P, O'Donoghue, M.A.; PhD students in the Heal group.
Doherty, R.D., Stevenson, D.S.; Naysmith, P., Cook, G. T., Xu, S., Raventos, D. T., Harrison, R. M., Bigg, M.; collaborating staff in other departments and UK academic institutions.
Cape, J.N., Vieno. M.; staff at the Centre for Ecology and Hydrology, Edinburgh (CEH) (Cape was also an Honorary Professor in EaStCHEM (now retired)).
Laxen, D., Laxen, K., Heaviside, C., Vardoulakis, S.; staff at non-HEI institutions (consultancy and public sector).

3. References to the research

Underpinning research has been published in international, high-quality, peer reviewed, journals and reports, and receives citations from across the research area: Atmospheric Environment *is one of the top journals in the field of air quality research.*

[1] * Heal, M. R., Cape, J. N. (1997) A numerical evaluation of chemical interferences in the measurement of ambient nitrogen dioxide by passive diffusion samplers, Atmospheric Environment 31, 1911-1923. doi:10.1016/S1352-2310(97)00025-3. [34 cits, JIF 3.1]

[2] * Heal, M. R., O'Donoghue, M. A., Cape, J. N. (1999) Overestimation of urban nitrogen dioxide by passive diffusion tubes: a comparative exposure and model study, Atmospheric Environment 33, 513-524. doi:10.1016/S1352-2310(98)00290-8. [39 cits, JIF 3.1]

[3] Hamilton, R. P., Heal, M. R. (2004) Evaluation of method of preparation of passive diffusion tubes for measurement of ambient nitrogen dioxide, Journal of Environmental Monitoring 6, 12-17. doi:10.1039/b311869j. [6 cits, JIF 2.00]

[4] * Heal, M. R., Naysmith, P., Cook, G. T., Xu, S., Raventos, D. T. and Harrison, R. M. (2011) Application of ^{14}C analyses to source apportionment of carbonaceous $PM_{2.5}$ in the UK, Atmospheric Environment 45, 2341-2348. doi:10.1016/j.atmosenv.2011.02.029. [18 cits, JIF 3.1]

[5] Laxen, D., Laxen, K., Heal, M. R., Vieno, M., Bigg, M. (2012) $PM_{2.5}$ in Scotland. A report for the Scottish Environment Protection Agency. http://www.sepa.org.uk/air/idoc.ashx?docid=56d39371-fccd-4a80-8389-30e109d22c01&version=-1 [The output of a consultancy contract awarded to the author team through competitive tender].

[6] Heal, M. R., Doherty, R. M., Heaviside, C., Vieno, M., Stevenson, D. S., Vardoulakis, S. (2012) Health effects due to changes in air pollution under future scenarios, in Health Effects of Climate Change in the UK 2012: Current evidence, recommendations and research gaps, (ed. Vardoulakis, S. and Heaviside, C.), Health Protection Agency, UK. ISBN 978-0-85951-723-2.

http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317135969235. [An anonymously peer-reviewed chapter; 4 reviewers selected by the HPA.]

4. Details of the impact

Public Policy: Air quality and climate change science and policy actions have complex linkages. The research above provided both the sound scientific evidence base and expert interpretation of that science for the UK government and regulatory agencies to establish air quality measurement standards and policy actions.[S1]

NO_2 The research in Section 2(A) underpinned major parts of the standardisation and improvement in protocols for the measurement of NO_2 by passive diffusion tube in the UK. Heal was an invited member on the working group for 'Harmonisation of Diffusion Tube Methods' and references [1-3] are cited in the 2008 Defra report. 'Diffusion tubes for ambient NO_2 monitoring: practical guidance for laboratories and users.'[S2]
The beneficiaries are Defra and the Local Authorities which are required to measure ambient NO_2 in their areas under the legal framework of the UK Air Quality Strategy, and the commercial laboratories contracted to provide these measurements for the Local Authorities. These procedures are now compulsory for air quality reviews to be accepted by Defra.
The 2011 AEA group report [S3] indicates that the implementation of these standardised procedures is slowly making improvements to the measurement of NO_2 by passive diffusion tube.
The impact of Heal's research is testified by the Senior Air Quality Consultant at AEA Technology plc a corroborating letter [F1] which also states:
"Dr Heal was an active and productive member of the working group. In particular, Dr Heal's research findings in this field were important contributions to the desired impact of harmonised protocols for application by users of NO2 passive sampler measurement across the UK...
The measurement results often feed into potentially expensive decisions (such as declaration of an Air Quality Management Area). It is therefore important that the results of these measurements are consistent and reliable…Dr Heal's ongoing research in this field (in particular, the effects of meteorological factors on diffusion tube performance) continues to provide important input to the scientific community's understanding of this much-used measurement technique…"

$PM_{2.5}$ The research quantifying sources of carbon in $PM_{2.5}$ described in Section 2(B), and ref 5 (section 3) is cited in the report 'Fine particulate matter ($PM_{2.5}$) in the United Kingdom' 2012, PB13837,[S4] written for Defra for assessment and recommendations on the concentrations, sources and trends of $PM_{2.5}$ in the UK. The research is also part of evidence contained within the 2010 report commissioned by the UK environment agencies (EA, SEPA and DENI) '$PM_{2.5}$ in the UK'.[S5] The research described in Section 2(B) on emission sources potentially controllable within Scotland is part of the 2012 report '$PM_{2.5}$ in Scotland' presented to SEPA which analyses potential policy levers available to SEPA for amelioration of $PM_{2.5}$.[S6] SEPA is currently considering this report; SEPA's Local Air Quality Management Specialist states in a supporting letter [F2] " *this kind of research helps SEPA to carry out its duties (such as protecting and improving the environment)…We are also pleased to see that sections of the $PM_{2.5}$ in Scotland report have been referenced in several internal and external reports."*

O_3 The research (sect 2(C), [6]) has led to new public health recommendations to raise public awareness of the adverse health effects of surface O_3, and to strengthen warning systems with targeted ozone alerts for high risk groups. It forms part of the evidence presented in 2012 to the Dept of Health and the Health Protection Agency for their plans for preparedness and mitigation of health effects from air pollution and climate change.[S6] Air Pollution and Climate Change Group Leader at Public Health England confirmed, in a supporting letter "*The Health Protection Agency…commissioned the research presented … The research showed that present-day ozone-related mortality in the UK is estimated to be up to around 11,900 premature deaths per year, and … increase of around 500 additional premature deaths due to increasing surface ozone in a higher-temperature future…The output and recommendations in this report are helping inform policy options and preparedness actions for the future impacts of ozone on the population…Dr Heal led a team that carried out this excellent research work …"*[F3]

5. Sources to corroborate the impact

[S1] Heal's research underpins his membership of the UK government's Air Quality Expert Group in 2001-2009 and 2012-current. http://archive.defra.gov.uk/environment/quality/air/airquality/panels/aqeg/publications/membership-aqeg.pdf.

NO_2

[F1] A corroborating letter is provided by the Senior Air Quality Consultant, AEA Technology plc., Gemini Building, Harwell, Didcot, OX11 0QR.

[S2] Measurement recommendations: *Diffusion tubes for ambient NO_2 monitoring: practical guidance for laboratories and users*. report no. AEAT/ENV/R/2504, 2008, by the Defra Working Group (of which Heal was an invited member). AEA Energy & Environment, Didcot, UK. http://uk-air.defra.gov.uk/reports/cat05/0802141004_NO2_WG_PracticalGuidance_Issue1a.pdf. Heal was also acknowledged particularly for input on diffusion tube analysis (p37).

[S3] The effect of improved measurements: *Investigation of the effects of harmonising diffusion tube methodology*, Report no. AEAT/ENV/R/3122, 2011. Loader, A., Willis, P. And Targa, J., AEA Group, Didcot, UK. http://uk-air.defra.gov.uk/reports/cat05/1108030957_Harmonisation_Follow-Up_Report_issue_2.pdf.

$PM_{2.5}$

[S4] *Fine particulate matter ($PM_{2.5}$) in the United Kingdom.* 2012, report no. PB13837. A report by the Air Quality Expert Group, prepared for Department for Environment, Food and Rural Affairs, Scottish Government, Welsh Government and Department for Environment Northern Ireland http://uk-air.defra.gov.uk/library/reports?report_id=727.

[S5] *$PM_{2.5}$ in the UK*, ER12, 2010. Laxen, D., Moorcroft, S., Marner, B., Laxen, K., Boulter, P., Barlow, T., Harrison, R.M., and Heal, M.R. Scotland & Northern Ireland Forum for Environmental Research Report ER12. pp.212. http://www.sniffer.org.uk/Resources/ER12/Layout_Default/0.aspx?backurl=http.

[S6] *$PM_{2.5}$ in Scotland*. Laxen, D., Laxen, K., Heal, M.R., Vieno, M., and Bigg, M. A report for the Scottish Environment Protection Agency, 2012. http://www.sepa.org.uk/air/idoc.ashx?docid=56d39371-fccd-4a80-8389-30e109d22c01&version=-1.

[F2] Corroborating evidence of expert advice provision to the environment agencies in letter from The Local Air Quality Management Specialist, Scottish Environment Protection Agency.

O_3 and public health

[S7] *Health effects due to changes in air pollution under future scenarios,* Heal, M. R., Doherty, R. M., Heaviside, C., Vieno, M., Stevenson, D. S. and Vardoulakis, S.. Chapter 3 in *Health Effects of Climate Change in the UK 2012: Current evidence, recommendations and research gaps*, ed. Vardoulakis, S. and Heaviside, C., Health Protection Agency, UK. ISBN 978-0-85951-723-2. 2012. http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317135969235.

[F3] *Corroboration of expert advice provision on the potential current and future health effects of O_3 in the UK:*, Group Leader, Air Pollution and Climate Change, Public Health England.