Modelling the air quality health impact of the 2006 UK heatwave

Andrew Kent
John Stedman
Heather Walton
Susannah Grice
David Green

16th May 2007
Introduction

• An assessment of the number of deaths brought forward as a result of increased air pollution concentrations during the extended heatwave in June-July 2006.

• The study developed methodology used in an analysis of the 2003 heatwave, undertaken by John Stedman.

• Pollutants under investigation were ozone, PM$_{10}$ and SO$_2$.

• Study conducted on behalf of Defra (Air & Environmental Quality division).

• Collaboration between AEA Energy & Environment, HPA and ERG.
Methodology (1)

• Health impact was measured in terms of ‘deaths brought forward’.

• Dose response functions used to estimate the impact of changing concentrations on health.

<table>
<thead>
<tr>
<th></th>
<th>Ozone</th>
<th>PM$_{10}$*</th>
<th>SO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline death rate (per 100 000 people per annum)</td>
<td>989.7</td>
<td>989.7</td>
<td>989.7</td>
</tr>
<tr>
<td>Concentration response function</td>
<td>0.6 (COMEAP, 1998)</td>
<td>0.75</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>0.3 (WHO, 2004)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* For particle concentrations measured using a Tapered Element Oscillating Microbalance (TEOM) instrument

• Coefficients are expressed as a percentage change in mortality rate for a specified change in pollutant concentration (e.g. 0.6% per 10 µg m$^{-3}$).
Methodology (2)

- Principle was to apply dose response coefficients to measured concentrations and population data for the heatwave period:

  Zone/agglomeration mean * dose response function * baseline mortality rate * population

- Thresholds used for ozone calculations at:

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 µg m(^{-3}) (no threshold)</td>
<td>COMEAP (1998)</td>
</tr>
<tr>
<td>70 µg m(^{-3})</td>
<td>WHO/UNECE (2004)</td>
</tr>
<tr>
<td>100 µg m(^{-3})</td>
<td>COMEAP (1998)</td>
</tr>
</tbody>
</table>

- An equivalent period in 2004 was used to provide a non-heatwave baseline to find the excess deaths associated with the heatwave.
Area and time period

• Calculations performed for each of 43 zones and agglomerations (defined under first air quality Daughter Directive).

• Calculations at the zone and agglomeration level allowed aggregation into their respective countries using population-weighted means to provide statistics for each Devolved Administration.

• Results were calculated for:
  • the whole of June and July.
  • two episodes (27th June - 7th July and 13th - 23rd July) – defined by concentrations.
  • two ONS ‘hot periods’ (1st - 7th July and 16th - 28th July) – defined by temperature.

• Focus of this presentation will be the two ONS hot periods.
UK zones, agglomerations and AURN monitoring sites

Zones and Agglomerations

Ozone sites

PM$_{10}$ (TEOM) sites
Ozone concentrations over time

Time series chart of population-weighted mean concentrations for maximum daily running 8-hour ozone (µg m⁻³) for the UK compared with baseline 2004 and temperature (°C), June and July 2006

- 1st selected episode (27 June - 7 July)
- 2nd selected episode (13 - 23 July)
- 1st ONS 'Hot Period' (1 - 7 July)
- 2nd ONS 'Hot Period' (16 - 28 July)
- SO² episode period
- SO² episode period

Central England Temperature (°C)

Population-weighted mean concentration (µg m⁻³)

Date

$\text{PM}_{10}$ concentrations over time

Time series chart of population-weighted mean concentrations for daily mean $\text{PM}_{10}$ (TEOM, $\mu g$ m$^{-3}$) for the UK compared with baseline 2004 and temperature ($^\circ$C), June and July 2006.
SO$_2$ methodology (1)

- Elevated SO$_2$ levels were an unexpected feature of the heatwave and one of the most interesting aspects.

- Area under assessment was limited to Greater London where the elevated concentrations were measured.

- Episode days used in the calculations:
  - 25$^{th}$ June - 6$^{th}$ July
  - 16$^{th}$ - 19$^{th}$ July
  - 24$^{th}$ - 25$^{th}$ July

- Baseline of 5 µg m$^{-3}$ was used to represent the equivalent period without the influence of heatwave conditions.
**SO₂ methodology (2)**

- The spatial variability of SO₂ concentrations required an alternative method of modelling.

- Concentrations across AURN, LAQN, Kent & Medway, Hertfordshire & Bedfordshire monitoring networks were used.

- Inverse distance weighted interpolation was used to estimate concentrations across the area on a 1km grid which were then calculated as population-weighted means for each grid square.

- Calculations were performed on a 1km grid square basis and aggregated to the Greater London area.
SO$_2$ concentrations over time

Population-weighted mean SO$_2$ for London and daily maximum 15-minute concentrations for London and south east England and temperature (°C)

Date

Population-weighted mean concentration (µg m$^{-3}$) and Central England Temperature (°C)

Network max 15-minute mean concentration (µg m$^{-3}$)

SO$_2$ episode period

Central England Temperature 2006

Network maximum 15-minute concentration 2006

SO$_2$ episode period
## Results – Ozone and PM$_{10}$ (ONS 1$^{\text{st}}$ Hot Period)

Predicted number of deaths brought forward due to ozone and PM$_{10}$ concentrations, 1$^{\text{st}}$ to 7$^{\text{th}}$ July, 1$^{\text{st}}$ ONS ‘Hot Period’ (7 days) (compared with 2004 baseline)

<table>
<thead>
<tr>
<th>Region</th>
<th>Deaths brought forward</th>
<th>Ozone</th>
<th>PM$_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Coefficient 0.3% per 10 µg m$^{-3}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No threshold</td>
<td>70 µg m$^{-3}$ threshold</td>
</tr>
<tr>
<td>England and Wales</td>
<td></td>
<td>166</td>
<td>148</td>
</tr>
</tbody>
</table>

- England and Wales only.
- Most realistic range – ozone using 0.3% coefficient and 70 µg m$^{-3}$ threshold and no threshold plus PM$_{10}$.
- ONS estimated excess deaths brought forward = 0
- Modelled deaths brought forward = 229-247
Results – Ozone and PM$_{10}$ (ONS 2$^{\text{nd}}$ Hot Period)

Predicted number of deaths brought forward due to ozone and PM$_{10}$ concentrations, 16$^{\text{th}}$ to 28$^{\text{th}}$ July, 2$^{\text{nd}}$ ONS ‘Hot Period’ (13 days) (compared with 2004 baseline)

<table>
<thead>
<tr>
<th>Region</th>
<th>Deaths brought forward</th>
<th>Ozone</th>
<th>PM$_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient 0.3% per 10 µg m$^{-3}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No threshold</td>
<td>70 µg m$^{-3}$ threshold</td>
<td>100 µg m$^{-3}$ threshold</td>
</tr>
<tr>
<td>England and Wales</td>
<td>272</td>
<td>224</td>
<td>120</td>
</tr>
</tbody>
</table>

- ONS estimated excess deaths brought forward = 680
- Modelled deaths brought forward = 354-402 (52-59% of total).
- This is a higher percentage of total estimated excess deaths than was modelled for the 2003 heatwave (21-38% of total excess deaths).
Comparing with ONS daily mortality figures

- The ONS figures are also only estimates and contain their own uncertainties.

- The 1\textsuperscript{st} hot period (1\textsuperscript{st} - 7\textsuperscript{th} July) did show a positive number of excess deaths in the oldest (most sensitive) cohort (75+).

- Uncertainty over an ozone threshold – if the threshold is higher than the 70 \(\mu\text{g m}^{-3}\) presented here, then excess deaths would be lower.

- High proportion of our predicted excess deaths due to air pollution compared with ONS total excess deaths:
  - Residual confounding of effects of temperature.
  - Possible impact of Government’s Heat Wave Plan (HWP).
Results – SO$_2$

Predicted number of deaths brought forward due to SO$_2$ in Greater London relative to ozone and PM$_{10}$ during episode days

<table>
<thead>
<tr>
<th>Region</th>
<th>SO$_2$</th>
<th>PM$_{10}$</th>
<th>Ozone*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater London</td>
<td>17</td>
<td>25</td>
<td>40-53</td>
</tr>
</tbody>
</table>

* based on the range using a 0.3% coefficient and 70 µg m$^{-3}$ threshold and no threshold

- Total number of deaths brought forward associated with heatwave in London = 82-95.
- Assumes that deaths associated with SO$_2$ and PM$_{10}$ are additional.
Comparison with 2003 heatwave (1)

- Comparison was made by recalculating the 2006 heatwave using the dose-response coefficients and thresholds for ozone and PM$_{10}$ used in the 2003 assessment.

Comparison of 2003 heatwave episode with the two selected 2006 episode periods

<table>
<thead>
<tr>
<th></th>
<th>Deaths brought forward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of days in episode</td>
<td>11</td>
</tr>
<tr>
<td>Ozone 0.6% coefficient, 100 µg m$^{-3}$ threshold</td>
<td>191</td>
</tr>
<tr>
<td>Ozone 0.6% coefficient, no threshold</td>
<td>432</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>108</td>
</tr>
<tr>
<td>Total</td>
<td>299 - 540</td>
</tr>
</tbody>
</table>
• The 2006 heatwave was lower intensity, longer duration event than the 2003 heatwave.

• Each of the two episodes in 2006 resulted in fewer predicted deaths brought forward than the 2003 episode but combined they exceeded the 2003 episode.

• Due to the different lengths of episode periods in 2006 and 2003 it is better to compare number of excess deaths per day:
  • similar or higher for ozone in 2006 than in 2003.
  • lower for PM$_{10}$ in 2006 than 2003.
Conclusions

- 2003 ozone and PM$_{10}$ analysis predicted 21-38% of total excess deaths were due to air pollution. In 2006 a similar analysis predicted 52%-59%.

- 2006 analysis resulted in inconsistent results with ONS estimates, predicting a significant number of deaths when ONS estimated zero during the 1$^{st}$ hot period and predicting a high percentage of air pollution related deaths during the 2$^{nd}$ hot period.

- The number of SO$_2$ and PM$_{10}$ related deaths were similar. Ozone and PM$_{10}$ due to unusual weather conditions but SO$_2$ levels resulted from unusual weather and unusual emission patterns which themselves due to the heatwave.

- Individual episode periods in 2006 resulted in a lower number of deaths than the 2003 heatwave but the combined event exceeded deaths in 2003 heatwave.

- Future heatwaves - climate change trends → more frequent, longer duration events like 2006?
and finally…

…thank you for your attention.

Any further questions: andrew.kent@aeat.co.uk