Should we be concerned about the health effects from ozone?

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Overview

1. Climate change and health research at HPA
2. Health effects of ozone
3. Epidemiological evidence
   I. Short-term exposure effects
   II. Long-term exposure effects
4. Health impact assessments
5. Climate change and ozone
6. Conclusions and research gaps
Research interests and activities

1. Epidemiological studies on the effects of temperature and ozone on human health
2. Climate Change Risk Assessment
3. Urban heat island effects and indoor/outdoor environment interactions
4. Atmospheric modelling for population exposure assessment
HPA and Department of Health reports (2002 and 2008)

- Multi-authored reports on the health effects of climate change on the UK population
- Health impact of climate change due to changes in air pollution (mainly ozone)
Ozone trends

O_3 rural

O_3 urban

PM_{10} roadside

PM_{10} urban

www.airquality.co.uk
2003 Heatwave

- Temperatures reached 38.5°C in Kent in Aug 2003
- >2000 excess deaths in the UK
- Around 600 excess deaths were due to the elevated ozone (Stedman, 2004)
Health Effects of Ozone

Respiratory
• Increased airway inflammation
• Reduced lung function
• Exacerbation of asthma

Cardiovascular
• Vasoconstriction
• Systemic arterial hypertension
• Arrhythmia
Epidemiological Evidence

• Short-term exposure effects

Time-series studies

<table>
<thead>
<tr>
<th>Multi-city studies</th>
<th>Increase in daily mortality/10ppb O3</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 European cities</td>
<td><strong>2.84%</strong> (95% CI, 0.95-4.77%)</td>
<td>Touloumi et al. 1997</td>
</tr>
<tr>
<td>7 Spanish cities</td>
<td><strong>0.61%</strong> (95% CI, 0.38-1.60%)</td>
<td>Saez et al. 2002</td>
</tr>
<tr>
<td>6 French cities</td>
<td><strong>1.40%</strong> (95% CI, 0.68-2.12%)</td>
<td>Le Tertre et al. 2002</td>
</tr>
<tr>
<td>80 US urban centres</td>
<td><strong>0.43%</strong> (95% CI, 0.23-0.63%)</td>
<td>HEI, 2003</td>
</tr>
<tr>
<td>95 US urban centres</td>
<td><strong>0.52%</strong> (95% CI, 0.27-0.77%)</td>
<td>Bell et al. 2004</td>
</tr>
</tbody>
</table>

Different ozone metrics used (1-h max, 8-h max, daily mean)
Geographic Heterogeneity – USA (Bell et al. 2004)

10 ppb increase in the previous week’s ozone was associated with a 0.52% increase in total daily mortality and a 0.64% increase in cardiovascular and respiratory mortality.

Community-specific estimates of air pollution effects may be heterogeneous because of:

- City-specific differences in pollution characteristics
- Use of air conditioning
- Time spent indoors vs. outdoors
- Socioeconomic factors (Bell et al. 2004)
Geographic Heterogeneity – Europe (APHEA-2, Gryparis et al. 2004)

- 0.66% (95% CI, 0.34-1.04) increase in the total daily mortality associated with an increase of 10 ppb O3
- 2.26% (95% CI, 1.24-2.96) in respiratory deaths
- 0.90% (95% CI, 0.44-1.38) in cardiovascular deaths

- Ozone effects on cardiovascular mortality are larger on average in southern European cities, where the concentrations are higher.
Temporal Pattern: Lag models (Bell et al. 2004)

Percentage Change in Daily Mortality for a 10-ppb Increase in Ozone for Total and Cardiovascular Mortality, for Single-Lag and Distributed-Lag Models (Bell et al. 2004)
Temporal Pattern of Ozone Mortality (APHEA-2, Samoli et al. 2009)

• Temporal pattern of effects up to 21 days of summertime O$_3$ in total, cardiovascular and respiratory mortality.

• O3 effects are more prolonged for respiratory compared with cardiovascular deaths.

• A 10 ppb increase in O3 was associated with an increase in respiratory deaths:
  • 0.72% (95%CI: -0.42, 1.88) for lag 0
  • 6.70% (95% CI: 3.80, 9.66) for lags 0-20

• Studies on acute health effects of O3 using single day exposures may have overestimated the effects on total and cardiovascular mortality, but underestimated the effects on respiratory mortality.
Ozone, Heat and Mortality: Acute effects in 15 British conurbations (Pattenden et al. 2010)

- Robust effects of heat on summer mortality, but estimates of ozone effects depend on the modelling of temperature.
- Some evidence that ozone effects are worse on hot days.
Long-term ozone exposure and mortality (Jerrett et al. 2009)

- Large cohort study (American Cancer Society data from 96 US metropolitan statistical areas)
- Did not show association of ozone with all cause or cardiovascular mortality
- Significant positive association of ozone with respiratory mortality, RR=1.04 (CI: 95%, 1.01-1.07) for 10 ppb increment
- PM$_{2.5}$ did not modify the effect of ozone

<table>
<thead>
<tr>
<th>External Temperature (°C)</th>
<th>% of Subjects</th>
<th>RR (95% CI)</th>
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</thead>
<tbody>
<tr>
<td>&lt;23.3</td>
<td>24</td>
<td>0.96 (0.90–1.01)</td>
</tr>
<tr>
<td>&gt;23.3 to &lt;25.4</td>
<td>29</td>
<td>0.97 (0.87–1.08)</td>
</tr>
<tr>
<td>&gt;25.4 to &lt;28.7</td>
<td>22</td>
<td>1.04 (0.92–1.16)</td>
</tr>
<tr>
<td>&gt;28.7</td>
<td>25</td>
<td>1.05 (1.03–1.08)</td>
</tr>
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COMEAP (1998):

Short-term exposure to ozone

<table>
<thead>
<tr>
<th>Health Outcome</th>
<th>Increase /10ppb 8-hour O3</th>
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<tbody>
<tr>
<td>All cause deaths</td>
<td>1.20%</td>
</tr>
<tr>
<td>Resp. Hospital Adm.</td>
<td>1.40%</td>
</tr>
</tbody>
</table>

COMEAP (2009):

No recommendations in favour of quantifying the effects of long-term exposure to ozone

WHO (2005):

0.6-1.0% increase in daily mortality for 10 ppb 8-hour ozone
Health Impact Assessment

\[ \Delta H = \left( \frac{P}{100,000} \right) \times M \times \beta \times \Delta O_3 \]

\[ \Delta H \] excess mortality or morbidity
\[ P \] population exposed
\[ M \] background mortality or morbidity
\[ \beta \] concentration-response slope
\[ \Delta O_3 \] ozone above threshold
Ozone Metrics

Annual mean of the daily maximum of the running 8-h mean ozone concentration (µgm⁻³) (Stedman and Kent, 2008)
Deaths brought forward

Respiratory hospital admissions

<table>
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<tr>
<th>Ozone Thresholds</th>
<th>Deaths</th>
<th>Respiratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ppb</td>
<td>100</td>
<td>230</td>
</tr>
<tr>
<td>35 ppb</td>
<td>939</td>
<td>2169</td>
</tr>
<tr>
<td>50 ppb</td>
<td>10,283</td>
<td>23,751</td>
</tr>
</tbody>
</table>

Stedman and Kent (2008)
NY metropolitan study (Knowlton et al, 2004)
Modelled changes in O₃ (GCM/MM5/CMAQ) and associated summertime mortality in the 2050s compared with the 1990s
Future Ozone Levels – UK

Business-as-usual / current legislation:

Increases in annual mean $O_3$ of $\sim 7.2 \ \mu g m^{-3}$ in south and 
$\sim 3.6 \ \mu g m^{-3}$ in north.

*Dentener et al. (2005) broadly in agreement with Athanassiadou et al. (2010)*

Maximum Feasible Reduction (MFR) scenario:

Reductions in annual mean $O_3$ of $\sim 7.4 \ \mu g m^{-3}$ in south and 
$\sim 2.6 \ \mu g m^{-3}$ in the north.

*Dentener et al. (2005)*
Adaptation in Ozone Mortality

The mortality effects of ozone appear diminished later in the ozone season, reaching the null effect previously reported in winter by September (Zanobetti and Schwartz, 2008)
Research Gaps

• Effect modification (temperature, co-pollutants, etc.)
• Threshold effects
• Long-term exposure effects
• Time-lags
• Adaptation

• NERC funded 4-year project (LSHTM, Univ. Edinburgh, etc)
Air Pollution and Weather-related Health Impacts: Methodological Study Based on Spatio-temporally Disaggregated Multi-pollutant Models for Present-day and Future (Doherty et al. 2009)
Conclusions

• Ozone episodes may become more frequent (but less severe?) in the UK over the 21\textsuperscript{st} century.

• Climate change is likely to cause an increase in ground-level ozone concentrations and associated mortality for a BAU emission scenario.

• Short-term exposure effects of ozone on all cause mortality and respiratory morbidity well documented, though time-series study results are heterogeneous.

• Emerging evidence of long-term exposure effects on respiratory mortality at high ambient temperatures.

• More research needed on ozone thresholds, time-lags and effect modification, and physiological and planned adaptation.


References – 2


Saez, M., F. Ballester, et al. (2002). "A Combined Analysis of the Short-Term Effects of Photochemical Air Pollutants on Mortality within the EMECAM Project." Environ Health Perspect 110(3).


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