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Quantification of the Health Effects of Air Pollution in the UK for the Review of the National Air Quality Strategy.

A report produced for The Department of the Environment, Transport and the Regions

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Executive Summary

The UK National Air Quality Strategy (NAQS, DoE, 1997) sets objectives for reductions in the concentrations of eight major pollutants to be achieved by the year 2005. The Department of the Environment, Transport and the Regions (DETR)-led Interdepartmental Group on Costs and Benefits (IGCB) was charged with the responsibility for carrying out an economic analysis of the additional measures that would be required to achieve the objectives and has prepared an interim report (DETR, 1999). The purpose of the interim report, which forms part of the wider review of the NAQS, was to explain how the IGCB have conducted the economic analysis of the NAQS objectives and to present preliminary results.

Air pollution damages health and one of the major purposes of the NAQS is to ensure a high degree of protection against risks to public health from air pollution. An assessment of the health benefits that are likely to result from the reductions in air pollutant concentrations as a result of the implementation of existing policies is therefore an important component of an economic analysis of the NAQS. In some instances it has also been possible to assess the health benefits that could be expected to result from additional measures on top of those that are expected to result from current policies.

The health benefit calculations that are presented in the IGCB report (DETR, 1999) were undertaken at the AEA Technology National Environmental Technology Centre (NETCEN) and this report provides additional details of the methods and assumptions underlying these calculations.

Contents

1 Introduction

The UK National Air Quality Strategy (NAQS, DoE, 1997) sets objectives for reductions in the concentrations of eight major pollutants to be achieved by the year 2005. When the objectives were set, the Government gave a commitment to undertake a formal economic analysis of the additional measures that would be required to achieve the objectives. The Department of the Environment, Transport and the Regions (DETR)-led Interdepartmental Group on Costs and Benefits (IGCB) was charged with the responsibility for fulfilling this commitment and has prepared an interim report (DETR, 1999). The purpose of the interim report, which forms part of the wider review of the NAQS, was to explain how the IGCB has conducted the economic analysis of the NAQS objectives and to present preliminary results.

Air pollution damages health and one of the major purposes of the NAQS is to ensure a high degree of protection against risks to public health from air pollution. Healthy individuals are not thought to be at significant risk from current levels of air pollution in the UK, but studies have indicated associations which persist at relatively low levels, between daily variations in levels of some pollutants and daily variations in mortality and hospital admissions for acute respiratory conditions. In some cases the mechanisms are not yet known, but the Department of Health's Committee on the Medical Effects of Air Pollutants has advised that it would be imprudent not to regard the associations as causal. An assessment of the health benefits that are likely to result from the reductions in air pollutant concentrations as a result of the implementation of existing policies is therefore an important component of an economic analysis of the NAQS. In some instances it has also been possible to assess the health benefits that could be expected to result from additional measures on top of those that are expected to result from current policies.

The health benefit calculations that are presented in the IGCB report (DETR, 1999) were undertaken at the AEA Technology National Environmental Technology Centre (NETCEN) and this report provides additional details of the methods and assumptions underlying these calculations. Details of the methods that were used to calculate the maps of estimated pollutant concentration for both current and future years that are required for the health benefit calculations are given in the following NETCEN reports: Nitrogen Dioxide (NO_2) - Stedman, Bush and King (1998), Particles (PM_{10}) - Stedman, Linehan *et al* (1998) and SO_2 - Abbott and Vincent (1999). The methods that have been used to map summer ozone concentrations are described in Stedman *et al* (1997).

Our general approach to estimating the magnitude of the health impacts of air pollutant concentrations is given in section 2. Details of the health benefits calculations that have been carried out for each pollutant for the review of the NAQS are described in subsequent sections.

2 General Approach

2.1 INTRODUCTION

The approach that we have adopted in the health benefit calculations for the review of the NAQS is consistent with the approach adopted in the report published by the Department of Health's Committee on the Medical Effects of Air Pollutants early in 1998 (Quantification of the Effects of Air Pollution on Health in the United Kingdom, COMEAP, 1998). The results of this type of calculation are a refinement of the crude estimates that might be produced by assuming that all the population is exposed to some national average concentration of pollutants. A method that is equivalent to assessing the population weighted mean concentrations of air pollutants across the country is required because both the concentrations air pollutants and the population density are variable across the country.

The method adopted by COMEAP (1998) can be summarised as follows.

1. The country has been divided into 1 km grid squares and the annual average concentration of pollutants and resident population has been estimated for each square. The former has been derived from the national mapping of the UK pollution climate undertaken at NETCEN and the latter from census data .
2. A baseline level of the given health-related and pollution affected events e.g., daily deaths, hospital admissions for the treatment of respiratory diseases has been assigned to each grid square.
3. By combining the data from (1) and (2) and applying a coefficient linking pollutant concentrations with the relevant effects the estimated health impact of each pollutant can be calculated for each grid square.
4. Summing the results obtained in (3) gives the relevant totals for the UK.

The results presented for particles, SO_2 and NO_2 by COMEAP were based on the population in urban areas only because the epidemiological studies on which the dose response coefficients were based, were done in cities. The calculations for ozone included both the urban and rural populations but were performed for the summer only. This was because ozone concentrations are generally higher in rural than in urban areas and concentrations are also higher in the summer. The health benefit calculations for the review of the NAQS have followed these conventions.

2.2 DOSE RESPONSE COEFFICIENTS

The literature on the effects of air pollutants on health is extensive and was not reviewed for the IGCB report. This was felt to be unnecessary as the COMEAP report had examined the relevant evidence and had produced a series of dose-response coefficients linking concentrations of three major pollutants with effects on health. The exposure (dose)-response coefficients used in the current analysis are the same as those used by COMEAP (1998) and are presented in Table 2.1.

Table 2.1. Dose Response Coefficients

Pollutant	Health Outcome	Dose-response coefficient
PM_{10}	Deaths brought forward (all causes) Respiratory hospital admissions	+ 0.75% per 10 µg/m^3 (24 hour mean) + 0.80% per 10 µg/m^3 (24 hour mean)
Sulphur dioxide	Deaths brought forward (all causes) Respiratory hospital admissions	+ 0.6% per 10 µg/m^3 (24 hour mean) + 0.5% per 10 µg/m^3 (24 hour mean)
Ozone	Deaths brought forward (all causes) Respiratory hospital admissions	+ 0.6% per 10 µg/m^3 (8 hour mean) +0.7 % per 10 µg/m^3 (8 hour mean)
NO_2	See note below	See note below
Notes: For NO_2 a coefficient of 0.5% per 10 µg/m^3 was used to estimate the effect on respiratory hospital admissions in a sensitivity analysis.		
Source: COMEAP (1998)		

Table 2.1 shows that dose-response coefficients were specified for particulate matter, ozone and sulphur dioxide. The Committee also examined nitrogen dioxide and carbon monoxide but felt that the evidence was not sufficiently strong to allow firm estimates of total effects on health to be made. In the case of nitrogen dioxide, a dose-response coefficient was, however, defined for respiratory hospital admissions and this coefficient can be used for a sensitivity analysis (see EAHEAP (1999) for more information on the implications of this).

The health effects that were considered were daily deaths and admissions to hospital for the treatment of respiratory diseases. In both cases the COMEAP report made clear that the numbers of events calculated as related to exposure to air pollution, could not be simply interpreted as extra events. Deaths are brought forward and hospital admissions may be either brought forward or caused *de novo*. The extent of advancement of deaths and hospital admissions cannot yet be calculated and estimates from a few days or weeks to a year have been produced. This inability to calculate the extent of advancement of these events is due to the time-series nature of the epidemiological studies upon which the estimates are based.

2.3 BASELINE RATES FOR DEATHS BROUGHT FORWARD AND RESPIRATORY HOSPITAL ADMISSIONS

The baseline rates of deaths brought forward and respiratory hospital admissions used in the current work have been updated from those used in COMEAP (1998). They are listed in Table 2.2 along with the ones used by COMEAP for comparison. The baseline rates that are used should match those used in the studies generating the dose response coefficients. For example, most studies of air pollution and mortality have excluded accidents. Revised baseline rates, as recommended by EAHEAP (1999), have been used in order to take this into account.

Table 2.2. Baseline death rates and respiratory hospital admissions rates per 100,000 people (Figure in brackets are those used by COMEAP, 1998)

Pollutants	Deaths	Respiratory hospital admissions
Particles, SO_2 (and NO_2)	1074[1] (1106.4)[5]	830[2] (1342.3)[6]
Ozone	491.8[3] (506.8)[7]	360[4] (345)[8]
Notes [1] deaths excluding external causes, per year, 1995 [2] emergency respiratory admissions, per year, 1994/5 [3] deaths excluding external causes, per summer (April to September 1995) [4] emergency respiratory admissions, per summer (April to September 1995) [5] deaths including external causes, per year, 1995 [6] respiratory admissions, per year, 1994/5 [7] deaths including external causes, per summer (April to September 1995) [8] emergency respiratory admissions, per summer (April to September 1993)		

2.4 POPULATION STATISTICS

The population statistics used in the COMEAP report were based on the 1981 census and included people living in Great Britain only. The urban population represented within this census data was estimated by assigning areas as urban if the sum of urban and suburban land cover classes within the Land Cover Map of Great Britain (Fuller *et al*, 1994) for a given 1 km square was greater than 20%. This gave an urban population of 42,500,000. We have used data from the 1991 census for the whole of the UK for the calculations presented in this report and the urban population represented within this dataset is 40,700,000. The change in urban population between the 1981 and 1991 based datasets may be due, at least in part, to differences in the way that the census data has been aggregated from enumeration district to grid square totals.

3 Nitrogen Dioxide

3.1 POLLUTANT CONCENTRATION MAPS

Maps of estimated annual mean background NO_2 concentration have been calculated for 1996 and 2005. Full details of the methods used to calculate the 1996 map are given in Stedman (1998). A brief description of these methods is provided in Stedman, Bush and King (1998) along with a description of the methods used and assumption that have been made in order to project this map forward to provide estimates for 2005.

Maps for 1996 were calculated from a combination of a map of rural NO_2 concentration and estimates of low level NO_x emissions on a 1 km square basis from the National Atmospheric Emissions Inventory (NAEI, Salway *et al*, 1997, Goodwin *et al*, 1997). The relationship between ambient annual mean NO_2 concentration and emission rates was calibrated using data from the DETR national monitoring networks (Broughton *et al*, 1998).

A map for 2005 was then calculated for comparison with the NAQS annual mean objective for NO_2 of 21 ppb. NO_2 is a secondary pollutant and is therefore not expected to respond in a simple linear fashion to the reductions in urban road traffic NO_x emissions that are expect to result from the implementation of current policies. A non-linear relationship between the reductions in NO_x emissions that are expected for this 'business as usual' scenario and the resulting ambient NO_2 concentrations was therefore adopted, as suggested by Derwent (*pers comm).*

3.2 HEALTH BENEFITS RESULTING FROM CURRENT POLICIES

The estimated health benefits that are expected to result from the implementation of current national policy measures between 1996 and 2005 are listed in Table 3.1. The first column shows the number of admissions that has been calculated for the individual years for which maps have been calculated. The second column shows the cumulative reduction in hospital admissions calculated by adding up the marginal benefits between 1996 and 2005.

Table 3.1 Numbers of respiratory hospital admissions after predicted reductions in levels of NO_2 resulting from business as usual (UK Urban population).

Pollutant	Deaths Brought Forward		Emergency Respiratory Hospital Admissions (additional or brought forward)	
NO_2	In named year	Total reduction (from 1996 baseline)	In named year	Total reduction (from 1996 baseline)
1996	-		*5160*	
2005	-	-	*3505*	*8255*

Notes
Values have been rounded to the nearest 5.
Hospital admission estimates are provided for NO_2 as a sensitivity analysis (italics indicate the greater uncertainty for this pollutant, see EAHEAP, 1999).

3.3 HEALTH BENEFITS RESULTING FROM ADDITIONAL MEASURES

The national modelling of NO_2 that has been carried out for the review of the NAQS (Stedman, Bush and King, 1998) has shown that the annual NO_2 objective is expected to be met at all background locations except inner London and at most roadside locations in 2005. Several alternative emissions reduction scenarios for NO_x have been investigated within both national and local modelling studies in order to assess the impact of these measures on the policy gap between the concentrations of NO_2 at roadside and urban background locations which current policies are likely to deliver and the NAQS objective. The marginal health benefits that are expected to result from these additional reductions in emissions have also been calculated.

The alternative emissions reduction scenarios that have been examined are listed in Table 3.2. Marginal health benefits have been calculated for two scenarios for which emission reductions are targeted to London and are listed in Table 3.3. The cumulative total additional health benefits listed in Table 3.3 have been calculated on the basis of a linear additional reduction in admissions between 1996 and 2005. If measures were fully implemented at the start of 2005, rather than introduced gradually over the period between 1996 and 2005, then there would be no cumulative health benefits over this period relative to business as usual. The additional health benefits would be limited to those in 2005 and subsequent years.

Table 3.2 Alternative emissions reduction scenarios for 2005 , relative to 2005 business as usual

scenario	emission reduction compared with business as usual
hl	30% less emissions from road traffic in inner London 10% less emissions from road traffic in outer London business as usual in the rest of the country
il	30% less emissions from cars in inner London 10% less emissions from cars in outer London business as usual in the rest of the country

Table 3.3. The impact of additional emissions reduction measures on additional and brought forward hospital admissions attributable to NO_2.

scenario	Marginal benefit in 2005	cumulative total benefit relative to business as usual
hl	*62*	*310*
il	*19*	*95*

4 Particles

4.1 POLLUTANT CONCENTRATION MAPS

Maps of estimated annual mean background PM_{10} concentration have been calculated for 1995, 1996, 2000, 2004 and 2005. Details of the methods used to calculate these maps are given in Stedman, Linehan *et al* (1998).

While maps of current annual mean PM_{10} concentrations have been previously presented by Stedman (1998), maps of annual means and number of exceedance days, for comparison with the existing PM_{10} NAQS objective and European Union 'Daughter Directive' 24-hour and annual limit values for both current and future years have been calculated by Stedman, Linehan *et al*

(1998). The daily PM_{10} receptor modelling methods developed for the Airborne Particles Expert Group report (APEG, 1999) and annual mean mapping methods of Stedman (1998) have been combined to produce daily maps of background PM_{10} concentrations.

Daily mean maps for the UK were calculated every day for both 1995 and 1996 by combining maps of secondary particles (derived from interpolated daily rural sulphate data), coarse particle maps (derived from an interpolation of the daily estimates of coarse particles at urban sites) and primary particle maps consisting of both long range transported primary particles and local primary particles (derived from black smoke measurements and emissions data). The daily maps were then summed to produce an annual mean map for both 1995 and 1996. Projections to 2000, 2004, and 2005 were undertaken, on the basis of current policies, using both of these years as a starting point, in order to assess the influence of different types of meteorology on future concentrations.

4.2 HEALTH BENEFITS RESULTING FROM CURRENT POLICIES

The estimated health benefits that are expected to result from the implementation of current national policy measures between 1995/1996 and 2005 are listed in Table 4.1. The first column shows the number of deaths or admissions that has been calculated for the individual years for which maps have been calculated. The second column shows the cumulative reduction in deaths hospital admissions calculated by adding up the marginal benefits between 1996 and 2005. Cumulative benefits were calculated by assuming linear changes in health outcomes between 1995/1996 and 2000 and between 2000 and 2005. The benefits in each year relative to 1995/1996 were then summed to give the total benefit over the period.

Table 4.1 Numbers of deaths and respiratory hospital admissions after predicted reductions in levels of PM_{10} resulting from business as usual (UK Urban population).

Pollutant	**Deaths Brought Forward**		**Emergency Respiratory Hospital Admissions (additional or brought forward)**	
PM_{10}	In named year	Total reduction (from 1995 or 1996 baseline)	In named year	Total reduction (from 1995 or 1996 baseline)
Baseline 1995				
1995	7060		5820	
2000	6570		5415	
2004	6250		5150	
2005	6170	5120	5090	4225
Baseline 1996				
1996	7390		6090	
2000	6910		5695	
2004	6585		5410	
2005	6480	4860	5345	4015
Notes				

Values have been rounded to the nearest 5.

4.3 HEALTH BENEFITS RESULTING FROM ADDITIONAL MEASURES

The marginal health benefits due to reductions is PM_{10} concentration have also been calculated for the alternative emissions reduction scenarios listed in Table 3.2 and the results are listed in Table 4.2. Once again the cumulative total benefits have been calculated on the assumption that the additional emission reduction measures are introduced gradually over the period between 1996 and 2005.

Table 4.2. The impact of additional emissions reduction measures on deaths and hospital admissions attributable to PM_{10}.

scenario	Marginal benefit in named year		cumulative total benefit relative to business as usual	
	deaths	admissions	deaths	admissions
hl	28	23	140	115
il	9	8	45	40
Notes Marginal benefits in 2005 and cumulative marginal benefits between 1996 and 2005 compared with 2005 business as usual scenario. Base year is 1996 for all calculations				

5 Sulphur Dioxide

5.1 POLLUTANT CONCENTRATION MAPS

Maps of estimated annual mean background SO_2 concentration in Great Britain have been calculated for 1996 and 2005. Full details of the methods used to calculate these maps are given in Abbott and Vincent (1999).

Maps for 1996 were calculated from a combination of dispersion modelling of major point sources (Part A emissions), box modelling of local low level sources and interpolation of the residual rural concentration. A business as usual scenario has been examined for 2005: the emissions projections in this scenario assume a complete upgrade of Part A processes and the implementation of the ‘Sulphur content of liquid fuels’ EU Directive.

5.2 HEALTH BENEFITS RESULTING FROM CURRENT POLICIES

The estimated health benefits that are expected to result from the implementation of current national policy measures are listed in Table 5.1. The first column shows the number of deaths or admissions that has been calculated for the individual years for which maps have been calculated. The second column shows the cumulative reduction in deaths or hospital admissions calculated by adding up the marginal benefits between 1996 and 2005. Estimates are shown for both of the scenarios for 2005.

Table 5.1 Numbers of deaths and respiratory hospital admissions after predicted reductions in levels of SO_2 (Great Britain Urban population).

Pollutant	**Deaths Brought Forward**		**Emergency Respiratory Hospital Admissions (additional or brought forward)**	
SO_2	In named year	Total reduction (from 1996 baseline)	In named year	Total reduction (from 1996 baseline)
1996	3305		2125	
2005a	1370	9675	880	6230
Notes Values have been rounded to the nearest 5. Sulphur dioxide maps exclude Northern Ireland.				

6 Ozone

6.1 INTRODUCTION

The health benefits calculations that been carried out within the review of the NAQS for ozone are less complete than for the other pollutants because there are a number of complicating factors which are unique to this pollutant.

- The health outcome calculations in the COMEAP quantification report (COMEAP, 1998) were calculated using two different approaches:
    - a threshold for health impact of 50 ppb
    - no threshold
- peak ozone concentrations during photochemical episodes are expected to reduce in future years due to reductions in emissions of the precursors of ozone on European scale.
- long term mean ozone concentrations in cities are expected to increase in future years as urban NO_x emissions reduce.

The methods that have been used previously to map daily ozone concentrations and calculate the resulting health impacts for the summer of 1995 are described in COMEAP (1998) and in some detail in Stedman *et al* (1997). Maps of maximum running 8-hour mean were calculated for each day during the summer of 1995 and health impacts for ozone concentrations greater than a 50 ppb threshold for the GB population were then calculated. A map of the summer mean of the daily maximum of running 8-hour mean ozone concentration for 1995 was also calculated and used for the no-threshold health impact calculation (this is mathematically the same as carrying out the no-threshold calculation on a daily basis and summing the results). The estimated health impacts due to ozone during the summer of 1995 calculated for the review of the NAQS used the same maps of ozone concentrations as used by COMEAP (1998) and Stedman *et al* (1997), the baseline rates listed in Table 2.2 and 1991 UK census data. The resulting numbers of deaths and hospital admissions in 1995 due to ozone are therefore different from those published previously.

The modelling work that has been undertaken to quantify the likely effects of emission reductions on peak and long term mean ozone concentrations is briefly described in sections 6.2 and 6.3. The results of the modelling work for peak ozone concentrations has enabled 50 ppb threshold health benefit calculations to be completed for a range of different scenarios and these results are listed in section 6.4. Health benefit calculations for the no-threshold case have not been completed and the reasons why this has not been done are given in section 6.5.

6.2 MODELLING PEAK CONCENTRATIONS IN 2010

Modelling of ozone concentrations on a European scale is currently being carried out in the UNECE, as part of the preliminary stages of the negotiations on the so-called Multi-Protocol, and within the EU as part of the development of the combined ozone and acidification strategies and the draft ozone directive. The emissions from each Member State which deliver the environmental goals of the strategies will be embodied in the National Emissions Ceilings Directive, a draft of which the Commission intends to produce in February 1999. The modelling is being carried out by IIASA in both fora, using the integrated assessment model, RAINS, which incorporates the EMEP atmospheric models transfer matrices, abatement cost and efficiency information, and critical loads and levels data for the ecosystems in the countries concerned. As well as this European scale modelling, more detailed modelling of ozone is being carried out for DETR by the Meteorological Office and the Universities of Edinburgh and Lancaster. This latter modelling is concentrating on ozone in the UK at a more detailed spatial level than the RAINS model is currently capable of handling. It deals with regional scale ozone concentrations in the UK, at a spatial resolution of 100 km.

The results of the European and UK scale modelling studies have been combined to produce Table 6.1, which lists the ozone reduction factors that each scenario is likely to deliver on days with photochemical ozone episodes (current ozone concentrations greater 40 ppb). The reference scenario refers to the expected emissions in 2010 resulting from the implementation of current policies. The F1 scenario is a set of emission ceilings for the EU-15 following the cost optimal attainment of environmental targets for acidification and ozone across the EU.

Table 6.1 Photochemical ozone reduction factors relative to 1995 concentrations.

scenario	description	factor
1995		1.000
2010 reference	current policies	0.799
2010 F1		0.774
2010 MFR	Maximum feasible reductions	0.662

6.3 MODELLING LONG TERM URBAN OZONE CONCENTRATIONS IN 2010

Unlike the European scale modelling referred to above, UK modelling has begun the more difficult task of estimating ozone concentrations in urban areas, at a spatial resolution of 1 km. Preliminary results for London (Derwent, *pers comm*, 1998) suggest that for reductions in NO_x emissions of 50-60%, annual mean ozone concentrations will increase by about 3-4 ppb from current levels of around 10-15 ppb. The functions listed in Table 6.2 have been suggested for predicting the change in annual mean ozone concentration for 60% NO_x control (which is roughly business as usual for 2010, relative to 1995).

Table 6.2 Function for predicting change in annual mean ozone concentration (Derwent, *pers comm*, 1998)

ozone concentration in 1995	ozone concentration in 2010
< 10 ppb	add 4.2 ppb
10 - 26 ppb	add 4.2 - (0.25*(ozone - 10))
> 26 ppb	no change

6.4 HEALTH BENEFITS FOR A 50 PPB THRESHOLD CALCULATION

The ozone reduction factors listed in Table 6.1 have been used to scale the daily maps of ozone concentrations for the summer of 1995 and the resulting health benefits for each scenario are listed in Table 6.3. A linear reduction in deaths and admissions between 1995 and 2010 has been assumed in the calculations of the cumulative benefits.

Table 6.3 Numbers of deaths and respiratory hospital admissions due to ozone for a range of scenarios UK Urban and Rural population, 50 ppb threshold).

Pollutant	**Deaths Brought Forward**		**Emergency Respiratory Hospital Admissions (additional or brought forward)**	
ozone	In named year	Total reduction (from 1995 baseline)	In named year	Total reduction (from 1995 baseline)
1995	720		615	

2010 reference	235	3890	200	3320
2010 F1	190	4250	160	3625
2010 MFR	25	5550	20	4745
Notes Values have been rounded to the nearest 5.				

6.5 HEALTH BENEFITS FOR A NO-THRESHOLD CALCULATION

The calculation of the numbers of deaths and hospital admissions due to ozone for the no-threshold case is relatively straight forward for 1995 and the results are listed in Table 6.4.

Table 6.4 Numbers of deaths and respiratory hospital admissions due to ozone for a no-threshold calculation (UK Urban and Rural population).

Pollutant	**Deaths Brought Forward**		**Emergency Respiratory Hospital Admissions (additional or brought forward)**	
ozone	In named year	difference relative to 1995	In named year	difference relative to 1995
1995	12240		10455	
2010 effect of reduction in peak concentration	*11455*	*-790*	*9780*	*-675*
2010 effect of increase in mean concentrations in urban areas	*12600*	*+360*	*10760*	*+305*
Notes Values have been rounded to the nearest 5. Italics indicate the greater uncertainty associated with these values				

For 2010 it is expected that peak concentrations will reduce relative to 1995 but non-episode concentrations in urban areas are likely to increase. Current modelling methods are not sufficiently advanced to enable a full no-threshold calculation of the health outcomes in 2010. The influences of the changes in peak and changes in urban ozone concentrations between 1995 and 2010 have been calculated separately.

For the reduction in peak values we have applied an ozone reduction factor for the reference scenario listed in Table 6.1 on a daily basis to 8-hour ozone concentrations greater than 40 ppb (values above 50 ppb were multiplied by 0.799 and values between 40 and 50 were set to 40 ppb). This results in the reductions in numbers of deaths and admissions which are listed in the second row of Table 6.4.

In order to apply the function for predicting changes in annual mean ozone to the daily maximum of running 8-hour ozone concentrations we calculated a map of the summer mean of the daily maximum of running 8-hour ozone for 1995 and examined the relationship between this statistic and annual mean:

*summer mean of daily maximum of running 8-hour ozone = 0.884 * annual mean + 16.328 (r^2 = 0.78).*

This relationship was then used to calculate a map of predicted summer mean of the daily maximum of running 8-hour ozone for 2010 in which the concentrations have been adjusted to take the likely changes in long term mean ozone concentrations in urban areas into account. This results in the increases in numbers of deaths and admissions as listed in the third row of Table 6.4.

Thus the likely reduction in admissions and deaths due to reducing peak levels of ozone is larger than the likely increase due to increases in urban areas. The results of this preliminary calculation are not very robust and firm conclusions will need to await more detailed analysis of the combined effects the emissions changes on future ozone concentrations. It is reasonable to note, however, that the likely reductions in health effects due to the reduction in peak ozone may be offset by the increase in urban ozone for a no-threshold calculation.

7 Acknowledgement

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