Report

Baseline Projections of Air Quality in the UK for the 2006 Review of the Air Quality Strategy

Report to The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland

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Executive Summary

The UK Government and the devolved administrations published an Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS) in January 2000. It sets air quality standards and objectives for eight key pollutants to be achieved between 2003 and 2008. An addendum to the AQS was subsequently published in 2003. The UK Government and the devolved administrations are currently undertaking a review of the Air Quality Strategy. This review will assess progress towards the achievement of the AQS objectives and assess the costs and benefits of possible additional measures to improve air quality in the UK. The focus of this review of will be on the impact of measures on concentrations of particles, nitrogen dioxide and ozone, the pollutants for which the achievement of the objectives is likely to be the most challenging.

This report describes the GIS-based model predictions of baseline air quality carried out by netcen in support of the 2006 AQS review. These baseline predictions are our best estimate of the likely impact of current national and international air quality policies on the future concentrations of air pollutants. The results of our assessment of baseline air quality are presented in terms of the expected extent of exceedence of AQS objectives and population-weighted mean concentrations. Assessments have been carried out for the years for which the objectives have been set or for years under consideration within the review of possible additional measures (2010, 2015 and 2020). Baseline projections for NO_2 and PM_{10} have been calculated using base years of 2002 and 2003 in order to reflect the impact of different meteorology on predicted air quality. Projections for the other pollutants have been calculated from a base year of 2003.

Baseline projections of air quality for SO_2, NO_2, PM_{10}, benzene and CO are presented in this report along with a comparison of concentrations in future years with concentrations in 2003. There are currently no limit values or objectives for $PM_{2.5}$. It is however possible that limit values and objectives may be set in the future and an assessment of concentrations during 2003 and baseline projections for future years have therefore been calculated to support policy development. Our assessment of the 2003 concentrations of 1,3-butadiene is presented in this report.

The annual mean objective of 40 μg m^{-3} for NO_2 is expected to be met at all background locations across the UK by 2010 with only a small percentage (<1%) of total area assessed exceeding this value in 2003 and 2005 The objective is not expected to be met at all roadside locations under baseline conditions by 2020. However, percentage of total road length exceeding is expected to decline from 52.5% in 2003 to 8.5% in 2020.

For PM_{10} three objectives were assessed against. Exceedences of the annual mean objective of 40 μg m^{-3} at both background and roadside locations are expected to have been almost completely eliminated by 2010. An annual mean concentration of 31.5 μg m^{-3}, roughly equivalent to the AQS objective for 24-hour concentrations, is not predicted to be exceeded at any background locations. At roadside locations this concentrations is expected to be exceeded in some locations for all years with percentage of total road length exceedencing decreasing from 15.7% in 2003 to 0.3% in 2020. An annual mean concentration of 20 μg m^{-2} is predicted to be widely exceeded at both background and roadside locations for all years.

A comparison of modelling results and objectives for NO_2 and PM_{10} for a 2003 and a 2002 base year showed significantly fewer exceedences for these pollutants using a 2002 base year.

Objectives for benzene, CO and 1,3-butadiene are predicted to not be exceeded for relevant years. Exceedences of the 15-minute mean objective for SO_2 are predicted to remain in 2005 but be almost eliminated by 2010. A detailed investigation has not been carried out of the location of exceedences of all of the three the SO_2 objectives in 2003 adjacent to a single industrial plant. $PM_{2.5}$ has no limit values or objectives at present so no assessment of whether these have been met can be made.

This report describes our best estimates of future air quality for the baseline (current policies). An assessment of the impacts of a wide range of possible additional measures on future PM_{10}, NO_2 and $PM_{2.5}$ concentrations is presented in an accompanying technical report (Stedman et al, 2006). These reports do not estimate the health impacts of the baseline and additional policy measures. This is carried out elsewhere as part of the air quality strategy review. This report should be read in conjunction with the air quality strategy review consultation document (DEFRA et al, 2006a; DEFRA et al, 2006b) and An Economic Analysis to Inform the Air Quality Strategy Review Consultation: Third Report of the Interdepartmental Group on Costs and Benefits (DEFRA et al, 2006c) published simultaneously. Full details of the Cost Benefit analysis including an assessment of health impacts are included in the Economic Analysis document.

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1 Introduction

1.1 THE AIR QUALITY STRATEGY

The UK Government and the devolved administrations published an Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS) in 2000 (DETR et al, 2000). It sets air quality standards and objectives for eight key pollutants to be achieved between 2003 and 2008. For seven of these pollutants local authorities are charged with the task of working towards the objectives in a cost effective way. The standards and objectives are subject to regular review to take account of the latest information on the health effects of air pollution and technical and policy developments.

The AQS objectives for particles (PM_{10}), benzene and carbon monoxide were reviewed in 2000/01. An Addendum (Defra et al, 2003) was published in 2003 and incorporated tighter objectives for these pollutants and introduced an objective for polycyclic aromatic hydrocarbons.

The AQS aims to:

- Map out as far as possible future ambient air quality policy in the UK in the medium term
- Provide best practicable protection to human health by setting health-based objectives for air pollutants
- Contribute to the protection the natural environment through objectives for the protection of vegetation and ecosystems
- Describe current and future levels of air pollution
- Provide a framework to help identify what we can all do to improve air quality.

1.2 THE EU FRAMEWORK AND DAUGHTER DIRECTIVES

Directive 96/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive (Council Directive 96/62/EC)) establishes a framework under which the EU sets limit values or target values for the concentrations of specified air pollutants in ambient air.

The first Daughter Directive (Council Directive 1999/30/EC) sets the limit values to be achieved for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particles and lead. The second Daughter Directive (Council Directive 2000/69/EC) sets out the limit values to be achieved for benzene and carbon monoxide. The third Daughter Directive (Council Directive 2002/3/EC) sets target values and long-term objectives for ozone. The fourth Daughter Directive (Council Directive 2004/107/EC) sets target values for arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons.

1.3 2006 REVIEW OF THE AQS

The UK Government and the devolved administrations are currently undertaking a review of the Air Quality Strategy. This review will assess progress towards the achievement of the AQS objectives and assess the costs and benefits of possible additional measures to improve air quality in the UK. The focus of this review will be on the impact of measures on concentrations of particles, nitrogen dioxide and ozone, the pollutants for which the achievement of the objectives is likely to be the most challenging.

This report describes our best estimates of future air quality for the baseline (current policies). An assessment of the impacts of a wide range of possible additional measures on future PM_{10}, NO_2 and $PM_{2.5}$ concentrations is presented in an accompanying technical report (Stedman et al, 2006). These reports do not estimate the health impacts of the baseline and additional policy measures. This is carried out elsewhere as part of the air quality strategy review. This report should be read in conjunction with the air quality strategy review consultation document (DEFRA et al, 2006a; DEFRA et al, 2006b) and An Economic Analysis to Inform the Air Quality Strategy Review Consultation: Third Report of the Interdepartmental Group on Costs and Benefits (DEFRA et al, 2006c) published simultaneously. Full details of the Cost Benefit analysis including an assessment of health impacts are included in the Economic Analysis document.

1.4 BASELINE PROJECTIONS OF AIR QUALITY

This report describes the GIS-based model predictions of baseline air quality carried out by netcen in support of the 2006 AQS review. The baseline predictions are our best estimate of the likely impact of current national and international air quality policies on the future concentrations of air pollutants. The results of the assessment of baseline air quality are presented in terms of the expected extent of exceedence of AQS objectives and population-weighted mean concentrations. Assessments have been carried out for the years for which the objectives have been set or for years under consideration within the review of possible additional measures (2010, 2015 and 2020). Baseline projections for NO_2 and PM_{10} have been calculated using base years of 2002 and 2003 in order to reflect the impact of different meteorology on predicted air quality. Projections for the other pollutants have been calculated from a base year of 2003.

The emission projections used to calculate the predictions of future air quality are discussed in section 2.

Maps of the concentrations of pollutants covered by the first and second Daughter Directives (SO_2, NO_x and NO_2, PM_{10}, benzene and CO) during 2003 have been prepared and reported to the European Commission. The results of this air quality assessment and descriptions of the modelling methods used have been published (Stedman, et al 2005). The baseline projections of air quality for SO_2, NO_2, PM_{10}, benzene and CO are presented in sections 3, 4, 5, 7 and 8 of this report along with a comparison of concentrations in future years with concentrations in 2003.

There are currently no limit values or objectives for $PM_{2.5}$. It is however possible that limit values and objectives may be set in the future and an assessment of concentrations during 2003 and baseline projections for future years have therefore been calculated to support policy development. This assessment is described in section 6. Our assessment of the concentrations of 1,3-butadiene in 2003 is presented in section 9.

Assessments of the future concentrations of ozone (Hayman et al, 2006), polycyclic aromatic hydrocarbons (Vincent, 2006) and heavy metals (Vincent and Passant, 2006) are published in separate technical reports. Kent et al (2006) provides further information on the health based ozone metric used in the cost benefit analysis. There were no measured exceedences of the AQS objectives (0.5 and 0.25 $\mu g\ m^{-3}$ annual mean) or the limit value (0.5 $\mu g\ m^{-3}$ annual mean) for lead in 2003. Lead emissions are not expected to increase so exceedences in the future are not expected and further analysis has not been undertaken.

This report describes our best estimates of future air quality for a baseline (current policies) scenario. An assessment of the impacts of a wide range of possible additional measures on future PM_{10}, NO_2 and $PM_{2.5}$ concentrations is presented in an accompanying technical report (Stedman et al, 2006).

2 Emissions Projections

2.1 INTRODUCTION

Emissions projections estimates for years up to and including 2020 have been used in this report. Emissions maps from the 2002 National Atmospheric Emissions Inventory (NAEI) (Dore et al, 2004) have also been used.

2.2 BASELINE PROJECTIONS

The baseline projections used here have been calculated by the NAEI and represent the best estimates of emissions for a baseline scenario for the current policies including current and agreed policies for the future. More details on the methods used to derive the baseline emissions projections are provided in Appendix 1. A summary giving the UK totals for SO_2, NO_X, PM_{10}, $PM_{2.5}$ and benzene for key years is presented in table 2.1. The split into different sectors is largely based on the sector descriptions used for international reporting of emissions but some sectors have been subdivided to enable subsequent scenario calculations.

Table 2.1a Projections of UK total SO_2 emissions (ktonnes yr^{-1})

Source sector	2003	2005	2010	2015	2020
Power stations emission	675	490	204	113	65
(Number of power stations)	(23)	(23)	(12)	(10)	(5)
Other emission sources	322	342	315	316	323
Total Emission	997[1]	828	519	429	388

Table 2.1b Projections of UK total NO_X emissions (ktonnes yr^{-1})

Source sector	2002	2005	2010	2015	2020
Agriculture Forestry and land use change	0.3	0.3	0.3	0.3	0.3
Aircraft	22.0	23.7	24.9	28.3	31.6
Combustion in industry	149.4	151.6	148.5	155.5	163.9
Combustion in commercial	28.0	28.6	30.2	33.0	34.7
Combustion in domestic	73.6	67.9	66.5	67.6	70.4
Combustion in Energy production and transformation	474.4	452.2	361.5	332.3	223.2
Extraction and distribution of fossil fuels	0.7	1.1	1.1	1.2	1.3
Off road machinery	68.7	62.4	52.4	52.4	52.4
Production process	2.4	3.9	4.3	4.6	4.9
Railways	9.3	7.5	7.3	7.2	7.0
Ships	50.9	52.3	51.8	51.0	46.5
Waste treatment and disposal	4.1	5.5	5.9	6.3	6.8
Road transport	710.8	572.3	396.2	290.5	267.8
Total	1594.7	1429.3	1151.0	1030.3	910.7

[1] Value interpolated from the 2002 and 2005 emission totals.

Table 2.1c Projections of UK total PM_{10} emissions (ktonnes yr^{-1})

Source sector	2002	2005	2010	2015	2020
Agriculture Forestry and land use change	13.5	13.4	13.7	13.8	13.9
Aircraft	0.2	0.2	0.2	0.3	0.3
Brake and tyre wear	9.2	9.6	10.9	11.4	11.8
Combustion in industry	17.3	15.7	16.2	16.7	17.3
Combustion in commercial	4.4	3.4	3.4	3.4	3.5
Combustion in domestic	27.5	15.4	11.8	12.1	15.9
Combustion in Energy production and transformation	12.3	7.9	5.6	5.2	4.9
Construction	4.6	5.2	5.7	6.2	6.7
Off road machinery	6.7	5.8	4.4	4.4	4.4
Production process	11.5	13.8	14.8	15.7	16.7
Quarrying	20.6	29.3	26.1	28.3	30.7
Railways	0.5	0.4	0.4	0.4	0.4
Ships	1.0	1.0	1.0	1.0	0.9
Waste treatment and disposal	1.4	1.9	2.0	2.1	2.3
Road transport	29.8	25.4	18.7	14.5	14.0
Total	160.7	148.5	134.9	135.4	143.5

Table 2.1d Projections of UK total $PM_{2.5}$ emissions (ktonnes yr^{-1})

Source sector	2002	2005	2010	2015	2020
Agriculture Forestry and land use change	2.2	2.1	2.2	2.2	2.2
Aircraft	0.0	0.0	0.0	0.1	0.1
Brake and tyre wear	5.1	5.2	5.3	5.4	5.6
Combustion in commercial	3.0	2.0	2.1	2.1	2.1
Combustion in domestic	15.1	9.1	8.3	8.9	10.7
Combustion in Energy production and transformation	6.7	4.2	3.2	3.2	3.2
Combustion in industry	12.7	10.8	11.1	11.4	11.8
Construction	1.4	1.6	1.8	1.9	2.1
Off road machinery	5.2	4.5	3.4	3.4	3.4
Production process	6.3	7.6	8.1	8.6	9.1
Quarrying	6.0	8.5	7.6	8.2	8.9
Railways	0.5	0.4	0.4	0.4	0.4
Ships	7.3	6.5	5.3	5.3	5.3
Waste treatment and disposal	1.4	1.3	1.1	1.1	1.1
Road transport	26.8	22.9	16.8	13.1	12.6
Total	99.7	86.7	76.6	75.2	78.6

Table 2.1e Projections of UK total benzene emissions (ktonnes yr^{-1})

Source sector	2002	2005	2010	2015	2020
Aircraft	0.1	0.1	0.1	0.1	0.1
Combustion in industry	0.6	0.7	0.7	0.7	0.7
Combustion in commercial	0.1	0.1	0.2	0.2	0.2
Combustion in domestic	3.0	2.7	2.6	2.8	3.3
Combustion in Energy production and transformation	0.2	0.2	0.2	0.2	0.2
Extraction and distribution of fossil fuels	0.9	0.9	0.8	0.8	0.9
Off road machinery	1.6	1.2	1.0	1.0	1.0
Production process	1.3	1.4	1.5	1.5	1.6
Railways	0.0	0.0	0.0	0.0	0.0
Ships	0.4	0.4	0.4	0.4	0.4
Waste treatment and disposal	0.9	0.8	0.8	0.8	0.8
Road transport	4.5	2.9	1.9	1.4	1.3
Total	13.5	11.4	10.1	10.0	10.4

Emission projections from energy sectors were based upon the DTI's UEP12 energy forecasts and the 2002 NAEI. Road traffic emissions projections have been produced using the 2002 NAEI and DfT's September 2004, 10 year plan for transport which uses 10 area types representing the different traffic growth in different sizes of urban area. The emission projections show that there is a projected continuation in current trends of emission abatement resulting from current legislation. More details on the emissions projections are provided in Appendix 1.

2.3 MAPPING PROJECTIONS FROM NON-TRAFFIC SOURCES

1 x 1km area source emission maps from the NAEI (Dore et al, 2004) for 2002 have been used as a base for the projected emissions maps for 2005, 2010, 2015 and 2020. These maps have been scaled for the appropriate year and pollutant by the UK total emission projections for each sector in table 2.1.

For road transport area source emissions maps and point sources, a more complex method has been used as described in sections 2.4 and 2.5 respectively.

2.4 TRAFFIC PROJECTIONS

Roads transport projections have been handled separately to the stationary sources. This is because the NAEI includes a wealth of information on traffic emissions including the emissions from individual major road links split into different classes of vehicle (cars, HGVs, buses etc). Thus the calculation of emission projections can be carried out using this information on the traffic mix on each individual road link. This is important because the impact of measures to reduce emissions from road traffic may depend on traffic mix.

Emission estimates for major roads (motorways and A roads) for each road link for 2002 were used for modelling the roadside increment for 2003 (see Stedman et al, 2005). These have been scaled for the relevant projection years for NO_X and PM_{10} with fleet average emission factors by area and vehicle type. In Northern Ireland UK average emission factors by area and vehicle type have been used to scale road link emissions because these data were not available for Northern Ireland.

Area source road transport 1 x 1km maps for projected years (2005, 2010, 2015 and 2020) for NO_X and PM_{10} have been calculated by splitting road transport emissions into major road, minor road and cold start emissions maps. The 1 x 1km major road emissions map has been calculated by summing the projected link emissions in each grid square. Total minor road emissions are calculated as the UK total projected hot exhaust emissions minus the projected major roads total emission. To distribute this total across the UK, emissions have been assumed to be proportional to vehicle km across the UK, which have been scaled from 2002 to the projected years using area type based growth factors. Cold start emissions for projected years have been calculated as UK total emissions minus UK hot exhaust emissions. This total has been divided into 'home work', 'work based' and 'home to other' categories on the basis of the 2002 NAEI ratio of these categories and mapped using the 2002 NAEI distribution grids. Major, minor and cold start 1 x 1km maps have then been added together for NO_X and PM_{10} to give the total road projected area source road transport emissions map.

Area source benzene for 2010 and $PM_{2.5}$ maps for 2005, 2010, 2015 and 2020 have been generated by scaling the 2002 road transport emissions map for these pollutants from the 2002 NAEI using the ratio of UK total road transport emissions for 2002 and the relevant projected year.

2.5 POINT SOURCES

NAEI point source emission for 2002 (Dore et al, 2004) have been projected for future years using factors derived from baseline emission projections. Projection factors were defined for standard NAEI source classifications which do not differentiate between fuel types. Hence, emissions for a point source within a given sector were scaled according to the change in emissions for the whole sector, irrespective of fuel type.

3 SO_2

3.1 INTRODUCTION

Short-term average sulphur dioxide concentrations have been predicted for a number of future years using a mapping methodology developed by Abbott and Vincent (1999). The methodology involved modelling emissions from point and area sources separately using a dispersion model and compared the modelled concentrations to measured cncentrations at sampling sites located throughout the United Kingdom. At each sampling site the modelled concentrations were subtracted from the measured concentrations and the resulting values interpolated to produce a map of residual values. A fitting, or calibration, procedure was also used to ensure that the predicted concentration at a measurement site corresponded to the measured concentration at that site. Sulphur dioxide concentration maps for 2003, 2005, 2010, 2015 and 2020 were produced for each of the average times presented in Table 3.1.

Table 3.1: Short term average air quality objectives for sulphur dioxide and equivalent percentiles*

Air Quality Strategy Objective	**Averaging period**	**Equivalent percentile**
350 μg m-3, not to be exceeded more than 24 times a calendar year	1 hour	99.73 percentile of 1-hr mean
125 μg m-3, not to be exceeded more than 3 times a calendar year	24 hour	99.18 percentile of 24-hr mean
266 μg m-3, not to be exceeded more than 35 times a calendar year	15 minute	99.9 percentile of 15-minute mean

* Compliance with the objectives can also be assessed in terms of a percentile concentration. A 99.9 percentile of 15-minute mean SO_2 concentration of 266 $\mu g m^{-3}$ or less means that the objective of no more than 35 exceedences has been met

Concentrations for future years were predicted using the same calibration factors, meteorological data and concentration residual maps as used for the Daughter Directive Reporting Assessment (Stedman *et al.,* 2005). The only input parameter to change was the emission from power stations; emissions from all other point sources and area sources were assumed to remain constant. The dispersion model was then rerun for each of the forecast years.

The projected sulphur dioxide emission was the baseline scenario submitted to the European Union Commission as part of the Clean Air for Europe Programme. Table 3.2 shows the total sulphur dioxide emission from power stations and the remaining emission sources. Sulphur dioxide emissions from power stations are projected to decrease by an order of magnitude between 2003 and 2020. Table 3.2 also shows the number of power stations expected to be in operation for each of the forecast years- changes in power station emissions dominate the overall reduction in emission.

Table 3.2: Baseline sulphur dioxide emissions from power stations and other sources (ktonnes SO_2)

Source sector	2003	2005	2010	2015	2020
Power stations emission	675	490	204	113	65
(Number of coal/oil power stations)	(23)	(23)	(12)	(10)	(5)
Other emission sources	322	342	315	316	323
Total Emission	997[2]	828	519	429	388

3.2 DETAILED COMPARISON OF MODELLING RESULTS WITH OBJECTIVES

Stedman et al., 2005 showed that there was only one area of the United Kingdom that experienced an exceedence of the 1-hour and 24-hour Air Quality Strategy objectives - that was the 5 km x 5 km square in which a brick plant in Bedfordshire is located. This exceedence is projected to continue in the current model set up as emissions from non power stations sources were not changed.

However, for the 15-minute Air Quality Strategy objective there were a number of modelled exceedences in 2003. These occurred in the West Midlands – around Telford and in the Trent Valley. The 15-minute AQS objective was also exceeded at 4 non-national network monitoring sites in these areas.

Figure 3.1a to 3.1e shows the 99.9 percentile of 15 minute mean concentrations for 2003, 2005, 2010, 2015 and 2020. From 2003 to 2005 although sulphur dioxide emissions from power stations decreased by more than 25 %, the concentration map for 2005 shows that exceedences of the 15 minute standard are predicted to still occur. The area of the exceedence has moved north reflecting estimated changes in sulphur dioxide emissions from power stations in the Aire and Trent Valleys.

The high concentrations observed for the future scenarios in the West Midlands is an artefact of the residual map- the measured concentration at Telford Aqueduct was not modelled well in 2003 and a large residual value was produced for this region. This artefact was perpetuated through to the projected concentration maps but does not lead to any predicted exceedences beyond those in 2003.

The 'rayed' appearance of the SO_2 concentration maps is an artefact of the meteorological data used in the modelling. Wind direction in this data is given in 10° increments so the dispersion modelling is only done for 10° increments

[2] Value interpolated from the 2002 and 2005 emission totals.

Figure 3.1a to 3.1e. Maps showing the 99.9 percentile of 15 minute mean sulphur dioxide concentrations for 2003, 2005, 2010, 2015 and 2020.

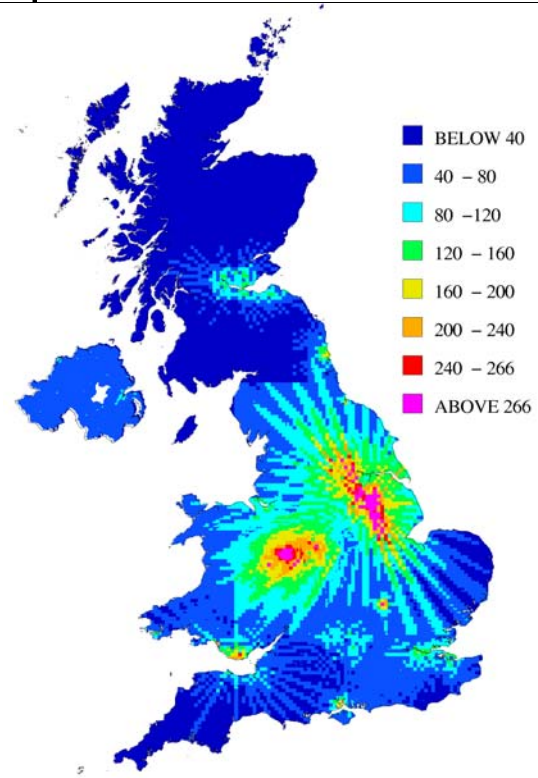


Figure 3.1a: 2003

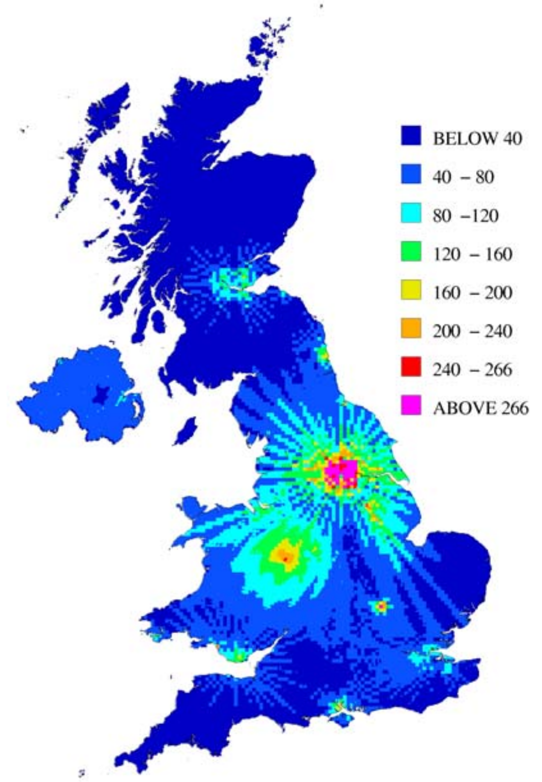


Figure 3.1b: 2005

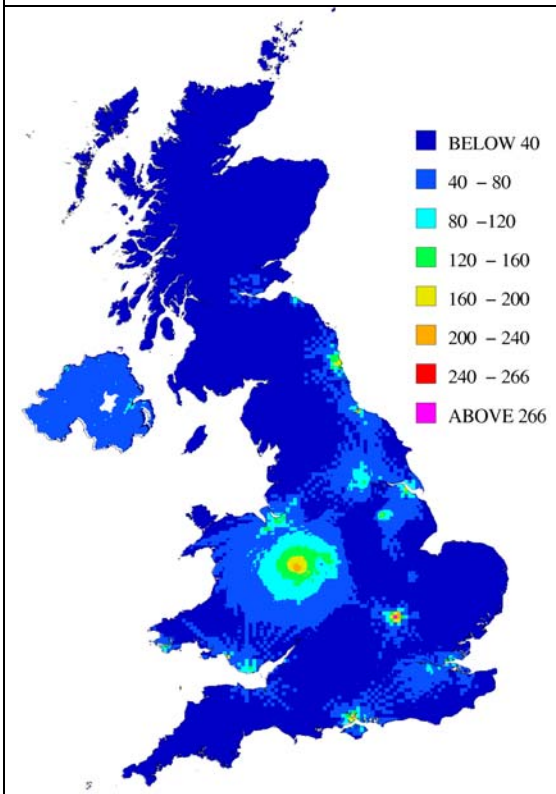


Figure 3.1c: 2010

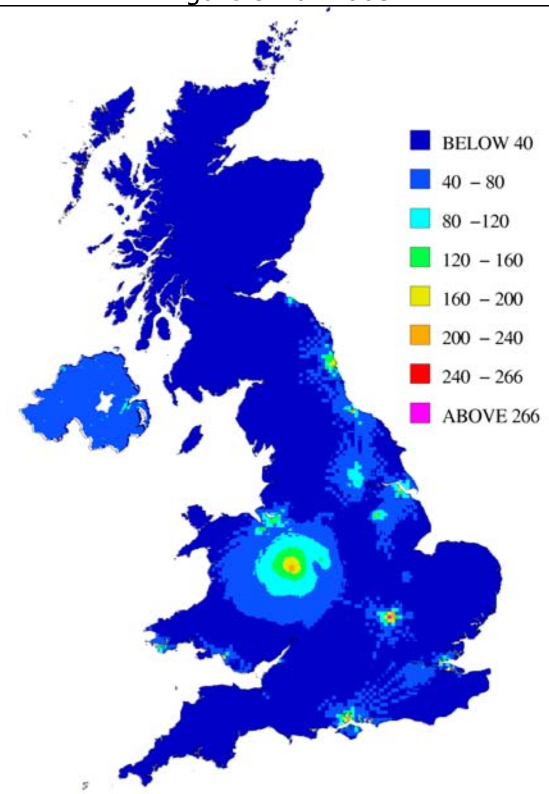


Figure 3.1d: 2015

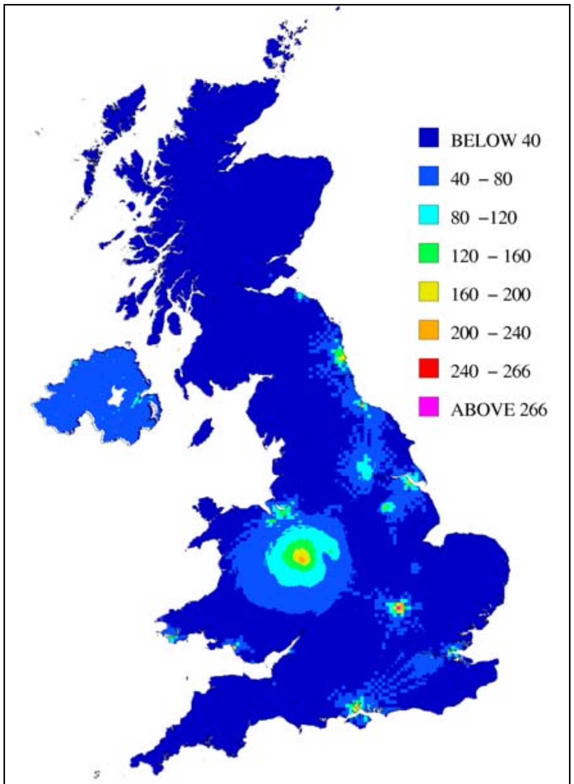


Figure 3.1e: 2020

Table 3.3 presents the area of the United Kingdom forecast to exceed the Air Quality Strategy objectives for 2003, 2005, 2010, 2015 and 2020. As discussed above there is no change to the extent of exceedence of the 1-hour and 24-hour objectives after 2003. For the 15-minute mean objective, the area of exceedence decreases slightly from 2003 to 2005. After 2005 the area of exceedence drops significantly reflecting the large reductions in emissions.

Table 3.4 shows the number of people exposed to the Air Quality Strategy objectives for 2003, 2005, 2010, 2015 and 2020. The number of people exposed to sulphur dioxide concentrations above the 15-minute mean Air Quality Strategy objective is forecast to increase from 2003 to 2005 reflecting that the predicted exceedence will occur in a more densely populated area. After 2005 the number of people exposed to concentrations exceeding the objective decreases significantly.

Table 3.3: Area (km^2) exceeding the AQS objectives for short-term average sulphur dioxide concentrations in 2003, 2005, 2010, 2015 and 2020 for a number of regions in the United Kingdom

	Region	2003	2005	2010	2015	2020
15 minute	London	0	0	0	0	0
	Rest of England	1566	1102	25	25	15
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	1566	1102	25	25	25
	% of UK	0.65	0.46	0.01	0.01	0.01
Daily and Hourly	London	0	0	0	0	0
	Rest of England	25	25	25	25	15
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	25	25	25	25	15
	% of UK	0.01	0.01	0.01	0.01	0.01

Table 3.4: Number of people exposed to sulphur dioxide concentrations exceeding the AQS objectives for short-term average concentrations in 2003, 2005, 2010, 2015 and 2020

	Region	2003	2005	2010	2015	2020
15 minute	London	0	0	0	0	0
	Rest of England	383,049	682,467	3,864	3,864	3,864
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	383,049	682,467	3,864	3,864	3,864
	% of UK	0.66	1.17	0.01	0.01	0.01
Daily and Hourly	London	0	0	0	0	0
	Rest of England	3,864	3,864	3,864	3,864	3,864
	Scotland	0	0	0	0	0
	Wales	0	0	0	0	0
	Northern Ireland	0	0	0	0	0
	Total	3,864	3,864	3,864	3,864	3,864
	% of UK	0.01	0.01	0.01	0.01	0.01

4 NO_2/NO_x

4.1 INTRODUCTION

Projected annual mean concentrations of NO_X and NO_2 have been modelled for 2005, 2010, 2015 and 2020. The modelling method used in estimating projected annual mean concentrations in these years closely follows the method used to estimate concentrations in 2003 for NO_X and NO_2 as described in Stedman et al (2005).

As in Stedman et al (2005), only annual mean concentrations for comparison with the annual mean objective have been modelled because this is expected to be the more stringent of the annual and one hour objective most of the time.

Background annual mean NO_X concentrations have been considered to be made up of contributions from

- Distant source (characterised by rural background concentrations)
- Large point sources
- Small point sources
- Local area sources

Therefore, projected NO_X concentrations away from busy roads can be modelled as:

Estimated background NO_X concentration (μgm^{-3}, as NO_2) = corrected rural NO_X concentration (μgm^{-3}, as NO_2) + contributions from large point sources (μgm^{-3}, as NO_2) + contributions from small point sources (μgm^{-3}, as NO_2) + contributions from area sources (μgm^{-3}, as NO_2)

The area source model calibration from 2003 for NO_X (Stedman et al, 2005) has been used for the projected years. Thus projections have been calculated assuming 2003 meteorology. Projections have also been calculated for 2002 meteorology (see section 4.8).

At locations close to busy roads an additional projected roadside contribution has been added to account to contributions to total NO_X from road traffic sources.

NO_2 concentrations have been estimated from modelled NO_X concentrations for projected years using the same method as used for 2003 (see Stedman et al, 2005).

4.2 EMPIRICAL RELATIONSHIPS BETWEEN NO_2 AND NO_X CONCENTRATIONS

The empirical relationship for estimating mean annual NO_2 concentrations from modelled NO_X concentrations in 2003 used the oxidant-partitioning model (Jenkins, 2004). This relationship has also been used to estimate projected annual mean NO_2 concentrations at background and roadside locations from projected NO_X concentrations. A full description of how this method has been implemented is given in Stedman et al (2005).

4.3 CONTRIBUTIONS FROM LARGE POINT SOURCES

Contributions to ground level annual mean NO_X concentrations from large point sources (those for which annual emissions were greater than 500 tonnes in the 2002 NAEI) were estimated by modelling each source explicitly using an atmospheric dispersion model.

For the baseline projections this has been done following the same method as that for the 2003 model described in Stedman et al (2005), but using projected emissions from each point source.

4.4 CONTRIBUTIONS FROM SMALL POINT SOURCES

Contributions to background NO_X from point sources with emissions in the 2002 NAEI of less than 500 tonnes were modelled using projected emissions (see section 2.5) and the dispersion kernel method described in Stedman et al (2005).

4.5 CONTRIBUTIONS FROM RURAL BACKGROUND CONCENTRATIONS

Estimation of contributions to NO_X from rural background concentrations for 2003 is described in Stedman et al (2005). This map has been scaled for projected years using the change in UK total baseline emissions of NO_X between 2003 and the projected years.

4.6 CONTRIBUTIONS FROM AREA SOURCES

The area source model applies an ADMS derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33 x 33km square (see Stedman et al, 2005). Emissions for projected years have been scaled for area source sectors using the projected UK emissions totals for these sectors presented in section 2.2. This has been calibrated using the dispersion coefficients derived from the 2003 modelling using 2003 measured annual mean NO_X concentrations minus modelled point sources and corrected rural NO_X at background sites (Stedman et al, 2005). The dispersion kernel constructed for 2003 using hourly sequential meteorological data from Heathrow has also been used here.

As for 2003, adjustment factors have been applied to emissions from aircraft and ships (see Stedman et al, 2005).

4.7 ROADSIDE CONCENTRATIONS

Annual mean concentrations of NO_X at roadside locations in 2003 were considered to be made up of two parts: background concentrations (see above) and a roadside increment (Stedman et al, 2005). This approach has also been taken here for the baseline projections:

Roadside NO_X concentration = background NO_X concentration + NO_X roadside increment

The roadside increment for projected years has been calculated by multiplying an adjusted road link emission for the projected years by an empirical dispersion coefficient determined using 2003 measurement data from roadside sites (see Stedman et al, 2005). To obtain projected road link emissions the UK major road link emissions have been projected forward using UK emissions projections as described in section 2.4.

4.8 2002 BASE YEAR MODELLING

The method outlined above used a 2003 base year for the projections. Modelling of annual mean NO_X and NO_2 has also been carried out using a 2002 base year. This follows the method set out above, with the following differences:

- 2002 measurement data has been used in the calibration of the area source and roadside increment models.
- The rural NO_X map has been based on 2002 measurement data
- Meteorological data from 2002 has been used for area source modelling

4.9 DETAILED COMPARISON OF MODELLING RESULTS WITH THE AIR QUALITY STRATEGY OBJECTIVE

Maps of mean projected NO_2 concentrations at background and roadside locations for 2010 and 2020 are presented in figures 4.1 - 4.4.

The modelling results for 2005, 2010, 2015 and 2020 using a 2003 base year, in terms of a comparison of modelled concentrations with the annual mean objective, are summarised in table 4.1. As with the 2003 modelling results described in Stedman et al (2005), estimates of area and population exposed have only been derived from the background maps. No attempt has been made to derive estimates using maps of roadside concentrations as these maps will only apply within approximately 10 metres from the road kerb.

Annual mean NO_2 concentrations were below 40 $\mu g\ m^{-3}$ across the majority of the UK in 2003 but this threshold was exceeded at a number of locations. Results from the national GIS-based models indicate that it was exceeded at background locations representing 4.0% of the UK population and at roadside locations alongside 52.5% of the length of urban major roads. In 2003 it was also exceeded at 30% of the national automatic monitoring sites. Central London had the greatest proportion of background exceedences compared with total area covered and 40 $\mu g\ m^{-3}$ was also exceeded alongside most of the major roads in London. The percentage of the land area of the UK with exceedences was much lower than the percentage of the population that this represents because concentrations are generally higher in more densely populated areas and lower in rural areas.

Reductions in NO_X emissions resulting from current policies are expected to lead to a reduction in ambient NO_2 concentrations and the extent of exceedences. The extent of exceedence at the roadside is predicted to decline to 41.3% of the length of urban major roads by 2005, reducing further to 18.2% by 2010 and 10.0% by 2015. By 2015 most of the exceedences are predicted to be confined to London and the rest of England.

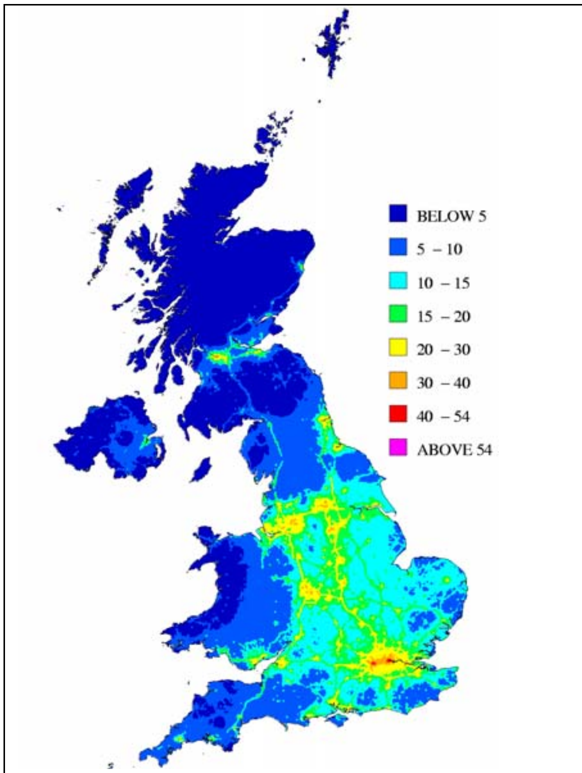


Figure 4.1 Annual mean background NO_2 concentration, 2010 ($\mu g\ m^{-3}$)

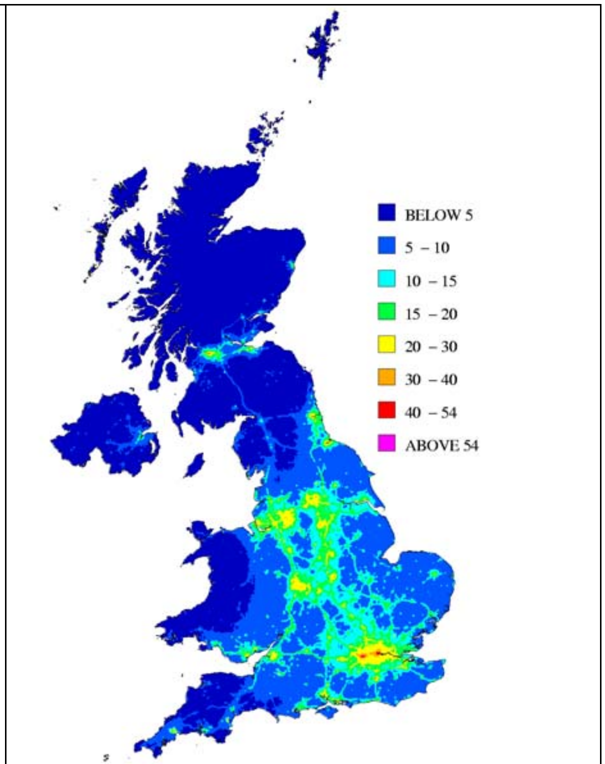


Figure 4.2 Annual mean background NO_2 concentration, 2020 ($\mu g\ m^{-3}$)

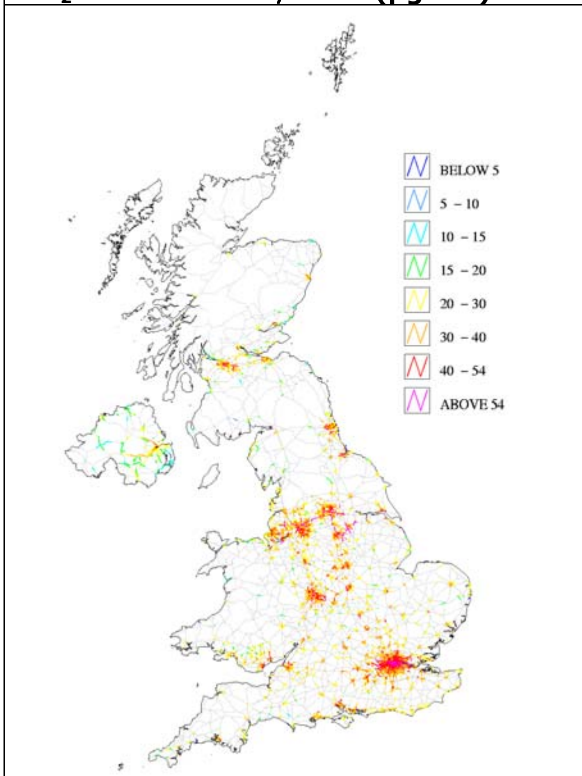


Figure 4.3 Urban major roads, annual mean roadside NO_2 concentration,

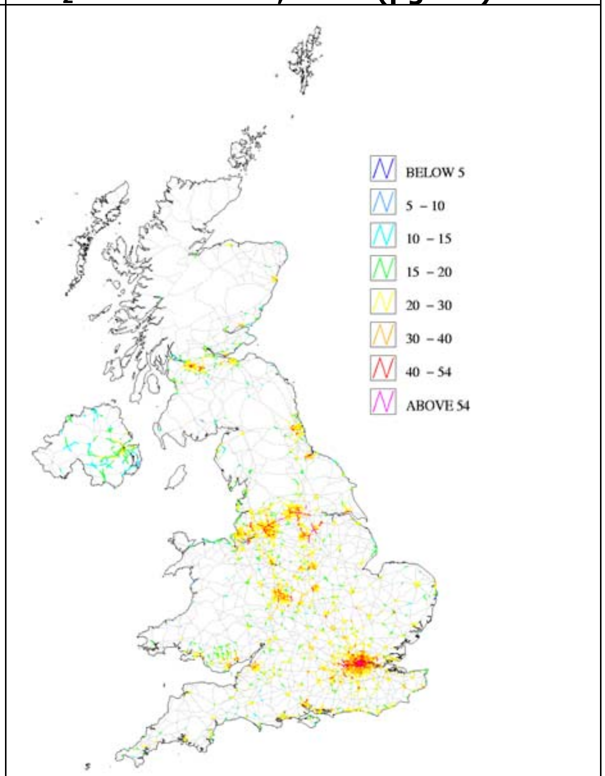


Figure 4.4 Urban major roads, annual mean roadside NO_2 concentration, 2020

2010 ($\mu g\ m^{-3}$)	($\mu g\ m^{-3}$)

Table 4.1 Summary statistics for UK baseline NO_2 projections using a 2003 base year

Total major road length (km) exceeding the annual mean objective of 40 $\mu g\ m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1886	1775	1625	1024	651	564
Rest of England	9430	4949	3686	1372	680	570
Scotland	1085	371	278	112	51	43
Wales	640	168	110	42	22	17
Northern Ireland	1044	131	114	18	0	0
Total	14084	7394	5813	2567	1405	1194
Percentage > 40 $\mu g\ m^{-3}$		52.5%	41.3%	18.2%	10.0%	8.5%
Total background area (km^2) exceeding the annual objective of 40 $\mu g\ m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1624	232	139	55	39	38
Rest of England	128770	269	147	19	12	15
Scotland	77791	15	11	2	0	0
Wales	20745	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0
Total	242248	516	297	76	51	53
Percentage > 40 $\mu g\ m^{-3}$		0.2%	0.1%	0.0%	0.0%	0.0%
Total population in area exceeding the annual mean objective of 40 $\mu g\ m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	1,772,254	1,062,428	319,019	156,502	154,748
Rest of England	41,011,137	467,832	229,142	17,395	5,946	6,071
Scotland	4,944,573	63,758	42,187	6,547	0	0
Wales	2,850,727	0	0	0	0	0
Northern Ireland	1,623,309	0	0	0	0	0
Total	58,160,071	2,303,843	1,333,757	342,961	162,448	160,819
Percentage > 40 $\mu g\ m^{-3}$		4.0%	2.3%	0.6%	0.3%	0.3%

Annual mean NO_2 concentrations for 2005, 2010, 2015 and 2020 have also been modelled using a 2002 base year. Summary results for this are presented in table 4.2

2003 was a year of unusually high air pollutant concentrations due to the unusual meteorological conditions. Annual mean NO_2 concentrations were lower in 2002. Results from the national GIS-based modelled indicate that 40 $\mu g\ m^{-3}$ was exceeded during 2002 at background locations representing 1.3% of the UK population and at roadside locations alongside 39.1% of the length of major urban roads. It was also exceeded at 27% of the national automatic monitoring sites. Predicted concentration derived from a 2002 base year are therefore lower than those derived from 2003. The extent of exceedence at the roadside is expected to decline to 25.1% of the length of major urban roads by 2005, reducing further to 11.8% by 2010 and 6.6% by 2015.

Table 4.2 Summary statistics for UK baseline NO_2 projections using a 2002 base year

Total major road length (km) exceeding the annual mean objective of 40 µg m^{-3}						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	1886	1580	1186	724	421	359
Rest of England	9430	3428	2071	834	465	385
Scotland	1085	278	159	62	31	21
Wales	640	104	71	27	15	13
Northern Ireland	1044	114	55	8	0	0
Total	14084	5504	3542	1655	932	777
Percentage > 40 µg m^{-3}		39.1%	25.1%	11.8%	6.6%	5.5%
Total background area (km^2) exceeding the annual mean objective of 40 µg m^{-3}						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	1624	89	49	30	24	24
Rest of England	128770	45	12	2	2	4
Scotland	77791	4	0	0	0	0
Wales	20745	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0
Total	242248	138	61	32	26	28
percentage > 40 µg m^{-3}		0.1%	0.0%	0.0%	0.0%	0.0%
Total population in area exceeding the annual mean objective of 40 µg m^{-3}						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	699,549	272,675	114,925	86,112	80,938
Rest of England	41,011,137	57,727	8,380	308	308	2,346
Scotland	4,944,573	13,426	0	0	0	0
Wales	2,850,727	0	0	0	0	0
Northern Ireland	1,623,309	0	0	0	0	0
Total	58,160,071	770,703	281,055	115,233	86,420	83,284
percentage > 40 µg m^{-3}		1.3%	0.5%	0.2%	0.1%	0.1%

Population-weighted annual mean NO_2 concentrations at background locations are also illustrated in Tables 4.3 and 4.4 for a 2003 and 2002 base year respectively. This statistic represents the average concentration exposure of the UK population and can be used to calculate the health impacts of air pollutants and the expected health benefits resulting from reductions in ambient concentrations. The population-weighted mean concentrations from a 2002 base year are predicted to be between 75 and 89% of the equivalent population-weighted mean concentrations from a 2003 base year.

Table 4.3 Population weighted mean NO_2 concentration using a 2003 base year (µg m^{-3})

	2003	**2005**	**2010**	**2015**	**2020**
Scotland	17.34	16.16	13.41	11.85	11.31
Wales	17.58	16.45	13.53	11.97	11.18
Northern Ireland	12.56	11.52	9.25	7.96	7.38
Inner London	41.31	38.76	34.02	31.59	30.93
Outer London	34.07	32.02	27.77	25.54	24.82
Rest of England	24.15	22.80	19.27	17.34	16.43
UK	24.45	23.02	19.52	17.61	16.78

Table 4.4 Population weighted mean NO_2 concentration using a 2002 base year ($\mu g\ m^{-3}$)

	2003	2005	2010	2015	2020
Scotland	15.09	13.55	11.26	10.00	9.57
Wales	15.40	13.93	11.46	10.14	9.47
Northern Ireland	10.00	8.79	6.98	6.02	5.64
Inner London	36.97	33.72	29.78	27.83	27.34
Outer London	30.15	27.51	24.06	22.28	21.75
Rest of England	21.03	19.21	16.30	14.70	13.94
UK	21.35	19.46	16.57	15.00	14.31

5 PM_{10}

5.1 INTRODUCTION

Projected annual mean PM_{10} concentrations have been modelled for 2005, 2010, 2015 and 2020. The modelling method used in estimating projected annual mean concentrations in these years closely follows the method used to estimate concentrations in 2003 PM_{10} as described in Stedman et al (2005).

The information on the source apportionment of ambient particle concentrations in the UK available from the APEG receptor model (APEG, 1999, Stedman et al, 2001a) has been applied to the calculation of maps of annual mean concentrations. A regression analysis has been carried out to divide measured daily average PM_{10} concentrations (as measured by TEOM or equivalent monitor at selected monitoring sites) into three components:

- primary combustion PM_{10} (from co-located NO_x measurements)
- secondary PM_{10} (from rural sulphate measurements)
- 'other' PM_{10} (the residual).

The regression analysis was carried out for the calendar year of monitoring data for each site to determine the coefficients A and B:

[measured PM_{10} ($\mu g\ m^{-3}$, TEOM)] = A [measured NO_x ($\mu g\ m^{-3}$, as NO_2)] + B [measured sulphate ($\mu g\ m^{-3}$)] + C ($\mu g\ m^{-3}$, TEOM)

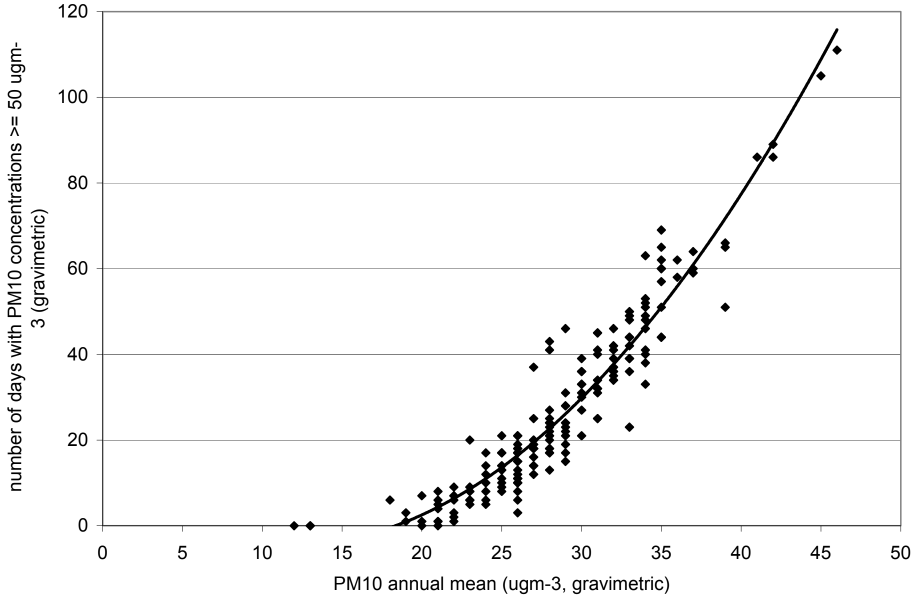
These coefficients can then be used to divide the measured concentration into the three components and the contributions from each component to the annual mean concentration can be calculated. The maps of background concentrations are made up of contributions from

- Large point sources of primary particles
- Small point sources of primary particles
- Area sources of primary particles
- Secondary particles
- Residual particle concentrations, not explicitly modelled.

An additional roadside increment is added for roadside locations.

24-hour mean concentrations have not been explicitly modelled for comparison with the 24-hour objective. An annual mean concentration of 31.5 $\mu g\ m^{-3}$, gravimetric has been taken to be equivalent to 35 days with 24-hour mean concentrations greater than 50 $\mu g\ m^{-3}$ gravimetric (the 24-hour objective). This equivalence is derived from an analysis of monitoring data (Stedman et al, 2001b) and is reproduced in Figure 4.5. The relationship between the number of days with concentrations greater than 50 $\mu g\ m^{-3}$, gravimetric and annual mean is less certain at lower numbers of exceedences and no attempt has been made to model exceedences of the indicative stage 2 24-hour limit value of 7 exceedences of 50 $\mu g\ m^{-3}$, gravimetric. In any case, the stage 2 annual mean limit value is expected to be as stringent as the stage 2 24-hour limit value (AQEG, 2005).

Figure 4.5. The relationship between the number of days with PM_{10} concentrations greater than or equal to 50 μg m^{-3} and annual mean concentration (1992 –1999)



The reference method for the limit values for PM_{10} is the use of a gravimetric instrument. The analysis presented here is based on TEOM (Tapered Element Oscillating Microbalance) instruments, which are currently widely used within the UK national monitoring networks. We have applied a scaling factor of 1.3 to all data before comparing with the limit value, as suggested by APEG (1999), and recommended as an interim measure by the EC Working Group set up to address the issue of scaling automatic PM_{10} measurements in advance of Member States undertaking their own detailed inter-comparisons with the Directive Reference Method. Measurements of PM_{10} concentrations using gravimetric instruments are now available for a number of sites in the UK. These measurements provide an additional independent verification of the model results.

5.2 SECONDARY PARTICLE CONTRIBUTIONS

In 2003, secondary particles were assumed to consist of sulphates and nitrates only. Maps of concentrations of sulphates and nitrates were then calculated using rural measurement data (Stedman et al, 2005). These maps have been scaled for projected years using EMEP model results for sulphate and nitrate for 2010 and 2020 using a 2000 base year. Values for 2005 and 2015 were calculated by interpolation.

5.3 CONTRIBUTIONS FROM LARGE POINT SOURCES

Contributions to ground level annual mean PM_{10} concentrations from large point sources (those for which annual emissions were greater than 200 tonnes in the 2002 NAEI) were estimated by modelling each source explicitly using an atmospheric dispersion model.

For the baseline projections this has been done following the same method as that for the 2003 model described in Stedman et al (2005), but using projected emissions from each point source.

5.4 CONTRIBUTIONS FROM SMALL POINT SOURCES

Contributions to background PM_{10} from point sources with emissions in the 2002 NAEI of less than 200 tonnes were modelled using projected emissions (see section 2.5) and the small points dispersion kernel method described in Stedman et al (2005).

5.5 CONTRIBUTIONS FROM AREA SOURCES

The contribution to area source at each monitoring site in 2003 was calculated by subtracting modelled large point sources, small point sources and mapped secondary PM_{10} from the measured annual mean concentration. This was compared with the modelled area source contribution to annual mean PM_{10} at each monitoring site to calibrate the area source model for 2003 (Stedman et al, 2005). The calibration for 2003 has been used in modelling the area source for projected years.

The area source model applies an ADMS derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33 x 33km square (see Stedman et al, 2005). Emissions for projected years have been scaled for area source sectors using the projected UK emissions totals for these sectors presented in section 2.2.

Similar to 2003, adjustment factors have been applied to emissions from aircraft and ships for projected years (see Stedman et al, 2005).

5.6 RESIDUAL PM_{10}

As in Stedman et al (2005) a constant residual particle concentration of 8.8 μ gm^{-3}, gravimetric (6.75 $\mu g\ m^{-3}$, TEOM) has been included in the modelled background PM_{10} concentration.

5.7 ROADSIDE CONCENTRATIONS

Annual mean PM_{10} concentration at a roadside location for projected years has been considered two consist of two components: the background concentration (see above) and a roadside increment:

Roadside PM_{10} concentration = background PM_{10} concentration + PM_{10} roadside increment

Emissions of PM_{10} for major road links in the UK for projected years have been estimated using UK emissions projections (Hobson, 2005) to scale 2002 road link emissions to emissions for the projection year (see section 2.4). Each road link emission has then been adjusted for annual average traffic flow (see Stedman et al, 2005). The roadside increment for projected years has then been calculated by multiplying this adjusted road link emission for the projected years by an empirical dispersion coefficient determined using 2003 measurement data from roadside sites (see Stedman et al, 2005).

5.8 2002 BASE YEAR MODELLING

The method outlined above used a 2003 base year for the projections. Modelling of annual mean PM_{10} has also been carried out using a 2002 base year. This follows the method set out above, with the following differences:

- 2002 measurement data has been used in the calibration of the area source and roadside increment models.
- The sulphate and nitrate maps have been based on 2002 measurement data
- Meteorological data from 2002 has been used for area source modelling

5.9 DETAILED COMPARISON OF MODELLING RESULTS WITH OBJECTIVES AND LIMIT VALUES

Maps at background and roadside locations for 2010 and 2020 are presented in figures 5.1 -5.4. Equivalent maps for 2003 are presented in Stedman et al (2005).

Modelling results using a 2003 base year, in terms of a comparison of modelled concentrations with an annual mean concentration of 31.5 µg m^{-3} (roughly equivalent to the 24-hour objective) are shown in table 5.1. Estimates of area and population exposure have been derived from the background maps only. No attempt has been made to derive estimates using maps of roadside concentrations as these maps only apply within approximately 10 metres of the road kerb.

Annual mean concentrations were below 31.5 μg m^{-3} across the majority of the UK in 2003 but this threshold was exceeded at a number of locations. The results indicate that it was exceeded at background locations representing less than 0.5% of the UK population and at roadside locations alongside 15.7% of the length of urban major roads. The roadside exceedences were mostly alongside major roads in London and the rest of England. The 24-hour objective was exceeded at 23% of the national automatic monitoring sites.

Reductions in PM_{10} concentrations resulting from current policies are expected to lead to a reduction in the extent of exceedences of 31.5 μg m^{-3}. The extent of exceedence at the roadside is expected to decline to 9.7% of the length of urban major roads by 2005, reducing further to 2.1% by 2010 and 0.5% by 2015. By 2015 most of the exceedences are predicted to be confined to London and the rest of England.

Exceedences of an annual mean concentration of 20 μg m^{-3} (the stage 2 indicative limit value and objective for England, exlcuding London, Wales and Northern Ireland) (table 5.1b) were much more extensive in 2003: at background locations representing 79.7% of the UK population and at roadside locations alongside 92.3% of the length of urban major roads. The extent of exceedences is expected to decline as a result of current policies but exceedences at background locations representing 36.0% of the UK population and at roadside locations alongside 67.3% of the length of urban major roads are expected to remain in 2015.

Predicted annual mean PM_{10} concentrations have been compared with a threshold of 20 µg m^{-3} in this report and in the accompanying report on the impact of measures (Stedman et al, 2006). This is the 2010 stage 2 indicative limit value and the AQS objective for England excluding London, Wales and Northern Ireland. The 2010 AQS objective for Scotland is 18 µg m^{-3} and the objective for London is 23 µg m^{-3}. A comparison of the baseline PM_{10} predictions with these objectives is listed in table 5.1c.

No results are shown for the annual mean objective of 40 µg m^{-3}. This is because annual mean PM_{10} concentrations were below 40 μg m^{-3} across almost all of the UK in 2003. 40 μg m^{-3} was not exceeded at background locations at all and only was exceeded at roadside locations alongside 1.7% of the length of urban major roads. The majority of the exceedences were in Central London. Exceedences of 40 μg m^{-3} at both background and roadside locations are expected to have been almost completely eliminated by 2010.

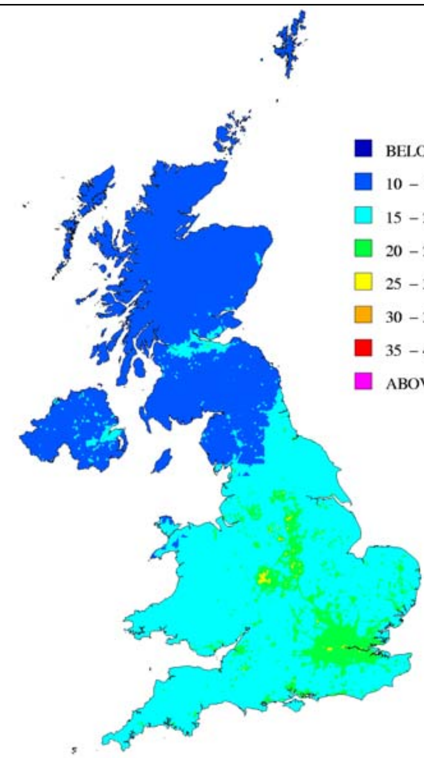


Figure 4.1 Annual mean background PM_{10} concentration, 2010 (µg m^{-3} gravimetric)

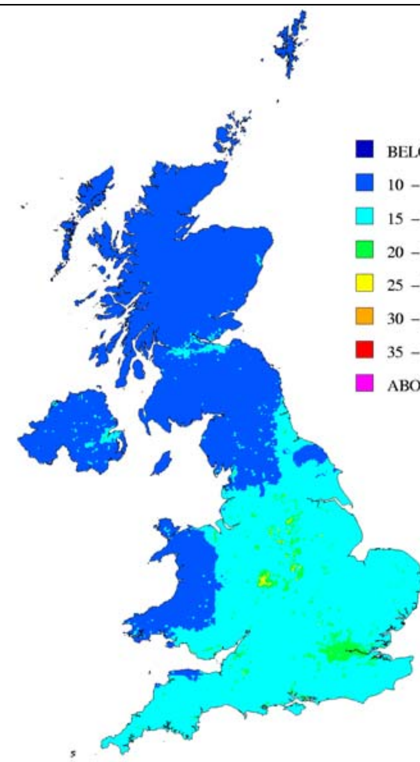


Figure 4.2 Annual mean background PM_{10} concentration, 2020 (µg m^{-3} gravimetric)

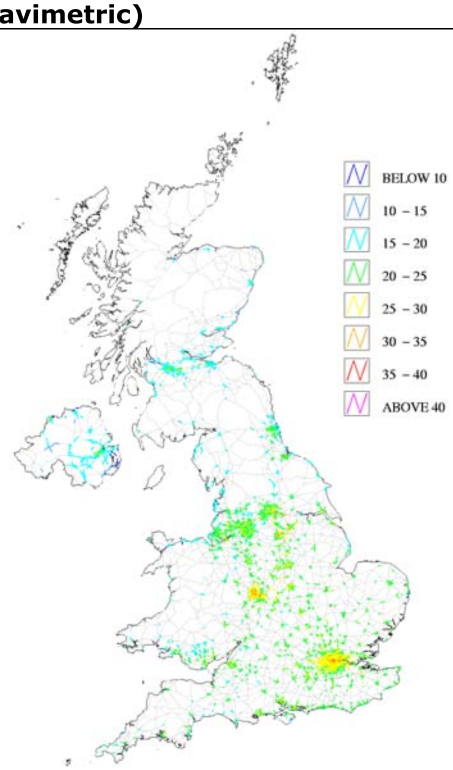


Figure 4.3 Urban major roads, annual mean roadside PM_{10} concentration,

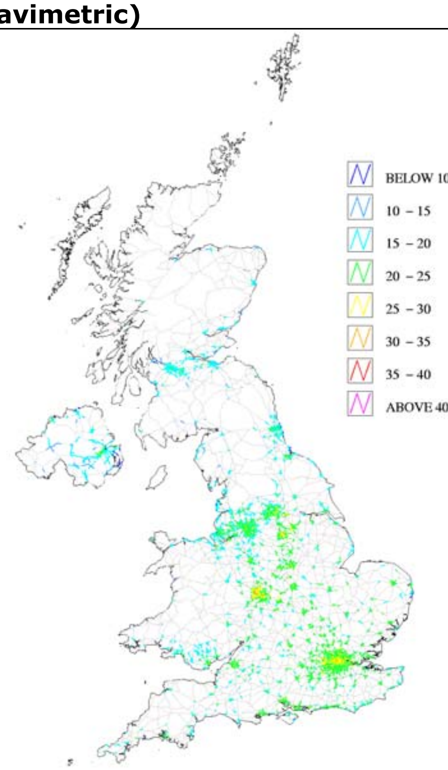


Figure 4.4 Urban major roads, annual mean roadside PM_{10} concentration,

2010 (µg m^{-3} gravimetirc)	2020 (µg m^{-3} gravimetric)

Table 5.1a Summary statistics for UK baseline PM_{10} projections comparison with 31.5 µg m^{-3}, using a 2003 base year

Total major road length (km) exceeding an annual mean value of 31.5 µg m^{-3}, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1886	935.9	513.8	139.9	31.1	20.6
Rest of England	9430	1225.8	825.5	158.1	40.6	27.7
Scotland	1085	27.4	8.0	2.8	0	0
Wales	640	23.8	21	0	0	0
Northern Ireland	1044	3.9	0	0	0	0
Total	14084	2216.7	1368.3	300.9	71.7	48.4
percentage > 31.5 µg m^{-3}, gravimetric		15.7%	9.7%	2.1%	0.5%	0.3%
Total background area (km^2) exceeding an annual mean value of 31.5 µg m^{-3}, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1624	0	0	0	0	0
Rest of England	128770	75	51	6	4	5
Scotland	77791	0	0	0	0	0
Wales	20745	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0
Total	242248	75	51	6	4	5
percentage > 31.5 µg m^{-3}, gravimetric		0.0%	0.0%	0.0%	0.0%	0.0%
Total population in area exceeding an annual mean value of 31.5 µg m^{-3}, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	0	0	0	0	0
Rest of England	41,011,137	83,469	56,673	10,242	3,477	5,306
Scotland	4,944,573	0	0	0	0	0
Wales	2,850,727	0	0	0	0	0
Northern Ireland	1,623,309	0	0	0	0	0
Total	58,160,071	83,469	56,673	10,242	3,477	5,306
percentage > 31.5 µg m^{-3}, gravimetric		0.1%	0.1%	0.0%	0.0%	0.0%

Table 5.1b Summary statistics for UK baseline PM_{10} projections comparison with 20 µg m^{-3}, using a 2003 base year

Total major road length (km) exceeding the annual mean limit value of 20 µg m^{-3}, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1886	1884.6	1884.6	1884.6	1884.6	1880.8
Rest of England	9430	9264.7	9152.3	8375.7	7202.7	6292.1
Scotland	1085	679.1	510.8	187.3	79.5	66.5
Wales	640	599.7	565.6	336.4	193.5	141.0
Northern Ireland	1044	567.9	378.8	148.9	119.3	146.0
Total	14084	12996.1	12492.1	10932.9	9479.6	8526.4
percentage > 20 µg m^{-3}, gravimetric		92.3%	88.7%	77.6%	67.3%	60.5%
Total background area (km^2) exceeding the annual mean limit value of 20 µg m^{-3}, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1624	1624	1624	1621	1523	1291
Rest of England	128770	76865	64570	17192	8207	4682
Scotland	77791	128	60	25	18	18
Wales	20745	1578	948	267	180	163
Northern Ireland	13318	271	98	19	10	32
Total	242248	80466	67300	19124	9938	6186
percentage > 20 µg m^{-3}, gravimetric		33.2%	27.8%	7.9%	4.1%	2.6%
Total population in area exceeding the annual mean limit value of 20 µg m^{-3}, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	7,730,326	7,730,326	7,727,768	7,544,505	6,919,180
Rest of England	41,011,137	36,113,795	33,078,917	20,904,147	13,140,915	8,313,678
Scotland	4,944,573	309,707	127,320	41,611	32,421	32,421
Wales	2,850,727	1,565,189	1,051,036	352,663	180,796	136,343
Northern Ireland	1,623,309	647,783	332,744	65,651	30,106	115,537
Total	58,160,071	46,366,799	42,320,343	29,091,840	20,928,742	15,517,158
percentage >20 µg m^{-3}, gravimetric		79.7%	72.8%	50.0%	36.0%	26.7%

Table 5.1c Summary statistics for UK baseline PM_{10} projections comparison with 2010 objectives for different regions of the UK, using a 2003 base year

Total major road length (km) exceeding the objective, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London (23 µg m^{-3} annual average)	1886	1885	1885	1854	1847	1858
Rest of England (not London, 20 µg.m^{-3} annual average)	9430	9265	9152	8376	7203	6292
Scotland (18 µg m^{-3} annual average)	1085	913	822	529	300	252
Wales (20 µg m^{-3} annual average)	640	600	566	336	193	141
Northern Ireland (20 µg m^{-3} annual average)	1044	568	379	149	119	146
Total background area (km^2) exceeding the objective, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London (23 µg m^{-3} annual average)	1624	1581	1509	564	155	66
Rest of England (not London, 20 µg.m^{-3} annual average)	128770	76865	64570	17192	8207	4682
Scotland (18 µg m^{-3} annual average)	77791	647	468	115	68	60
Wales (20 µg m^{-3} annual average)	20745	1578	948	267	180	163
Northern Ireland (20 µg m^{-3} annual average)	13318	271	98	19	10	32
Total population ($x10^3$) in area exceeding the objective, gravimetric						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London (23 µg m^{-3} annual average)	7,730	7,700	7,510	3,571	994	297
Rest of England (not London, 20 µg.m^{-3} annual average)	41,011	36,114	33,079	20,904	13,141	8,314
Scotland (18 µg m^{-3} annual average)	4,945	1,275	956	250	126	102
Wales (20 µg m^{-3} annual average)	2,851	1,565	1,051	353	181	136
Northern Ireland (20 µg m^{-3} annual average)	1,623	648	333	66	30	116

2003 was a year of unusually high air pollutant concentrations due to the unusual meteorological conditions. This was especially true for PM_{10}. Annual mean PM_{10} concentrations were much lower in 2002. Results from the national GIS-based model (table 5.2) indicate that an annual mean concentration of 31.5 μg m^{-3} was exceeded during 2002 at roadside locations alongside only 5.4% of the length of urban major roads. It was also exceeded at only 3% of the national automatic monitoring sites. Predicted concentration derived from a 2002 base year are therefore lower than those derived from 2003. The extent of exceedence of 31.5 μg m^{-3} at the roadside is expected to decline to 1.9% of the length of major urban roads by 2005, reducing further to 0.1% by 2010 and 0% by 2015.

Table 5.2a Summary statistics for UK baseline PM_{10} projections comparison with 31.5 µg m^{-3}, using a 2002 base year

Total major road length (km) exceeding an annual mean value of 31.5 µg m^{-3}, gravimetric						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	1886	270.9	86.2	8.0	0.8	0.8
Rest of England	9430	473.4	184.7	12.3	0.4	2.3
Scotland	1085	2.8	2.8	0.0	0	0
Wales	640	8.9	0	0	0	0
Northern Ireland	1044	0.0	0	0	0	0
Total	14084	756.0	273.8	20.2	1.2	3.1
percentage > 31.5 µg m^{-3}, gravimetric		5.4%	1.9%	0.1%	0.0%	0.0%
Total background area (km^2) exceeding an annual mean value of 31.5 µg m^{-3}, gravimetric						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	1624	0	0	0	0	0
Rest of England	128770	52	9	0	0	2
Scotland	77791	0	0	0	0	0
Wales	20745	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0
Total	242248	52	9	0	0	2
percentage > 31.5 µg m^{-3}, gravimetric		0.0%	0.0%	0.0%	0.0%	0.0%
Total population in area exceeding an annual mean value of 31.5 µg m^{-3}, gravimetric						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	0	0	0	0	0
Rest of England	41,011,137	45,902	5,871	0	0	671
Scotland	4,944,573	0	0	0	0	0
Wales	2,850,727	0	0	0	0	0
Northern Ireland	1,623,309	0	0	0	0	0
Total	58,160,071	45,902	5,871	0	0	671
percentage > 31.5 µg m^{-3}, gravimetric		0.1%	0.0%	0.0%	0.0%	0.0%

Table 5.2b Summary statistics for UK baseline PM_{10} projections comparison with 20 µg m^{-3}, using a 2002 base year

Total major road length (km) exceeding the annual mean limit value of 20 µg m^{-3}, gravimetric						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	1886	1884.6	1881.4	1828.2	1591.8	1388.5
Rest of England	9430	8543.1	7514.6	4550.7	2787.9	2315.5
Scotland	1085	355.3	173.1	56.4	31.7	31.7
Wales	640	369.1	229.8	81.4	56.9	56.0
Northern Ireland	1044	360.8	187.9	38.1	24.2	86.2
Total	14084	11512.9	9987.0	6554.8	4492.5	3877.9
percentage > 20 µg m^{-3}, gravimetric		81.7%	70.9%	46.5%	31.9%	27.5%
Total background area (km^2) exceeding the annual mean limit value of 20 µg m^{-3}, gravimetric						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	1624	1574	1396	612	233	147
Rest of England	128770	16078	7720	2131	1377	1206
Scotland	77791	38	20	8	8	7
Wales	20745	170	140	75	67	65
Northern Ireland	13318	180	24	1	0	8
Total	242248	18040	9300	2827	1685	1433
percentage > 20 µg m^{-3}, gravimetric		7.4%	3.8%	1.2%	0.7%	0.6%
Total population in area exceeding the annual mean limit value of 20 µg m^{-3}, gravimetric						
	Total assessed	**2002**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	7,653,612	7,252,808	3,891,107	1,627,515	990,805
Rest of England	41,011,137	20,539,904	12,258,353	4,053,831	2,560,282	2,212,135
Scotland	4,944,573	72,589	31,480	6,919	6,919	5,148
Wales	2,850,727	252,407	124,742	49,477	30,875	28,907
Northern Ireland	1,623,309	513,204	83,983	6,316	0	22,227
Total	58,160,071	29,031,717	19,751,366	8,007,649	4,225,590	3,259,222
percentage >20 µg m^{-3}, gravimetric		49.9%	34.0%	13.8%	7.3%	5.6%

Population-weighted annual mean PM_{10} concentrations at background locations for a 2003 and 2002 base year are illustrated in Table 5.3 and 5.4 respectively. This statistic represents the average concentration exposure of the UK population and can be used to calculate the health impacts of air pollutants and the expected health benefits resulting from reductions in ambient concentrations. The reduction in concentrations from 2002 or 2003 to 2010, 2015 and 2020 is clearly illustrated but note the important influence of the base year meteorology on the projections. The expected decline from 2002 or 2003 to 2020 is about 4 µg m^{-3} and the difference due to the weather in the different base years is about 2 µg m^{-3}.

The concentrations presented in tables 5.3 and 5.4 are given to a higher degree of precision than the modelling method warrants so that small differences in the model outputs can be seen. This is useful when comparing the baseline results with modelling for additional measures presented in Stedman et al (2006), where certain measures only result in small changes, for example in the 3rd decimal place.

Table 5.3 Population weighted mean PM_{10} concentration using a 2003 base year, ($\mu g\ m^{-3}$, gravimetric)

	2003	**2005**	**2010**	**2015**	**2020**
Scotland	17.178	16.529	15.479	15.021	14.794
Wales	20.159	19.445	17.991	17.347	16.886
Northern Ireland	19.248	17.603	16.239	15.889	16.110
Inner London	26.997	25.707	23.567	22.460	21.772
Outer London	25.779	24.731	22.697	21.647	20.920
Rest of England	22.683	21.851	20.143	19.326	18.742
UK	22.424	21.554	19.880	19.084	18.543

Table 5.4 Population weighted mean PM_{10} concentration using a 2002 base year ($\mu g\ m^{-3}$, gravimetric)

	2003	**2005**	**2010**	**2015**	**2020**
Scotland	15.757	14.972	14.145	13.810	13.709
Wales	17.643	16.850	15.771	15.333	15.088
Northern Ireland	18.094	16.015	14.871	14.649	15.010
Inner London	23.944	22.400	20.750	19.909	19.523
Outer London	22.564	21.333	19.795	19.016	18.587
Rest of England	20.075	19.107	17.794	17.193	16.835
UK	19.896	18.875	17.587	17.003	16.686

6 $PM_{2.5}$

6.1 INTRODUCTION

Maps of annual mean $PM_{2.5}$ at background and roadside locations for 2003 are presented in figures 6.1 and 6.2. $PM_{2.5}$ concentrations for 2003 have been calculated using a similar approach to that adopted for PM_{10} described in Stedman et al (2005).

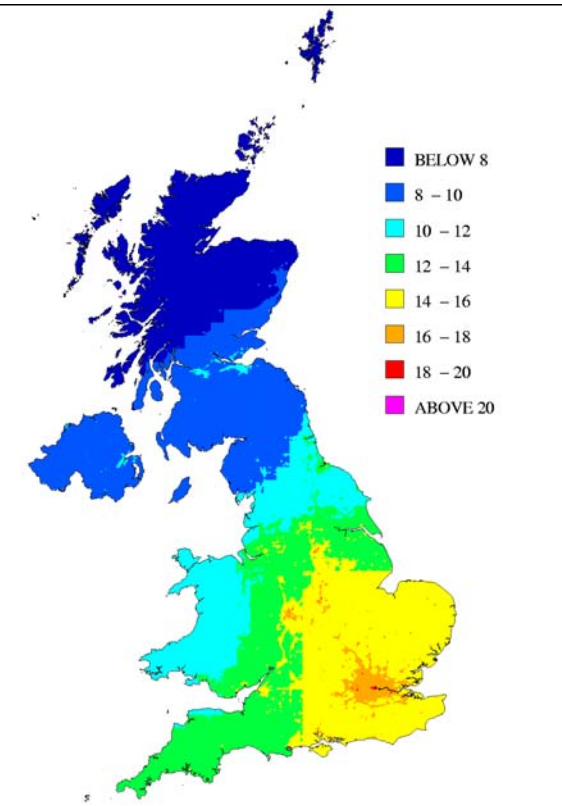


Figure 6.1 Annual mean background $PM_{2.5}$ concentration, 2003 (µg m^{-3}, gravimetric)

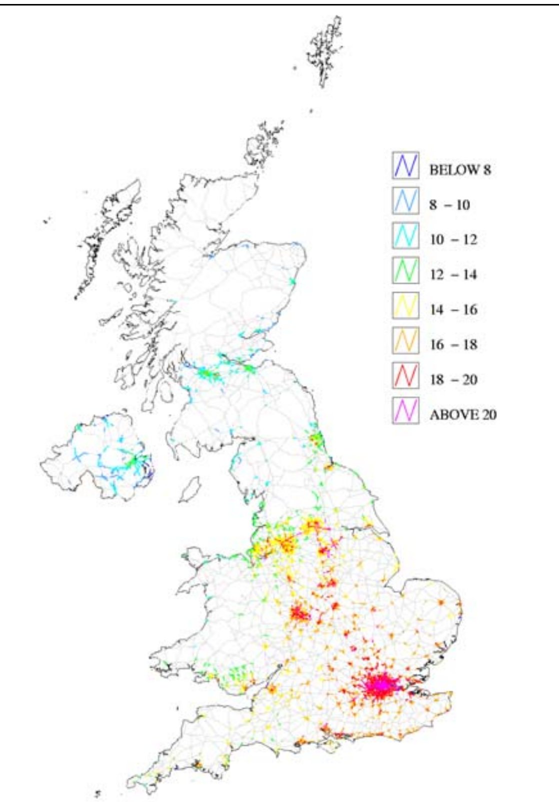


Figure 6.2 Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2003 (µg m^{-3}, gravimetric)

The monitoring of $PM_{2.5}$ concentrations is currently limited to very few sites in the UK. The differences between concentrations measured by TEOM and gravimetric monitoring is expected to be greater than for PM_{10} and no attempt has been made to scale TEOM measurements to a gravimetric equivalent concentrations. In contrast to PM_{10} we have therefore attempted to model gravimetric concentrations directly. The APEG receptor model has been used to assess the source apportionment of the limited gravimetric $PM_{2.5}$ measurement data available for 2003 in the UK. This provides the appropriate scaling factors to derive the secondary $PM_{2.5}$ concentrations from measurements of sulphate and nitrate and a value for the residual $PM_{2.5}$ concentration.

Projected annual mean $PM_{2.5}$ concentrations have been modelled for 2005, 2010, 2015 and 2020. Background and roadside maps for 2010 and 2020 are presented in figures 6.3 to 6.6. The method for projecting $PM_{2.5}$ closely follows that adopted for PM_{10}.

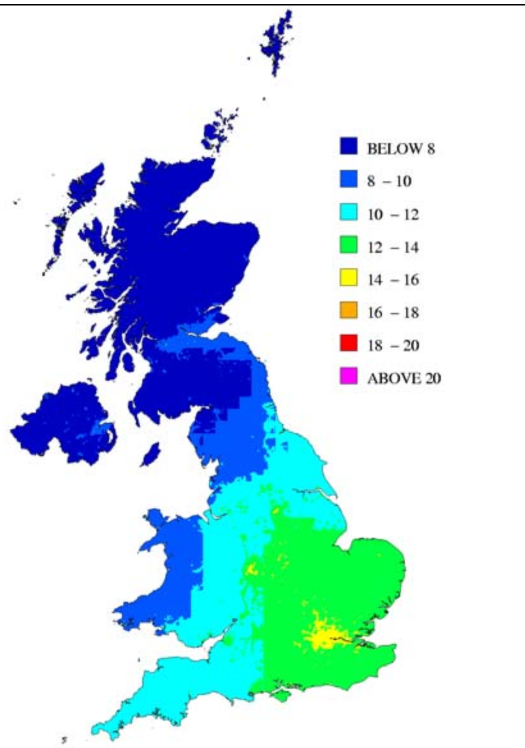


Figure 6.3 Annual mean background $PM_{2.5}$ concentration, 2010 ($\mu g\ m^{-3}$, gravimetric)

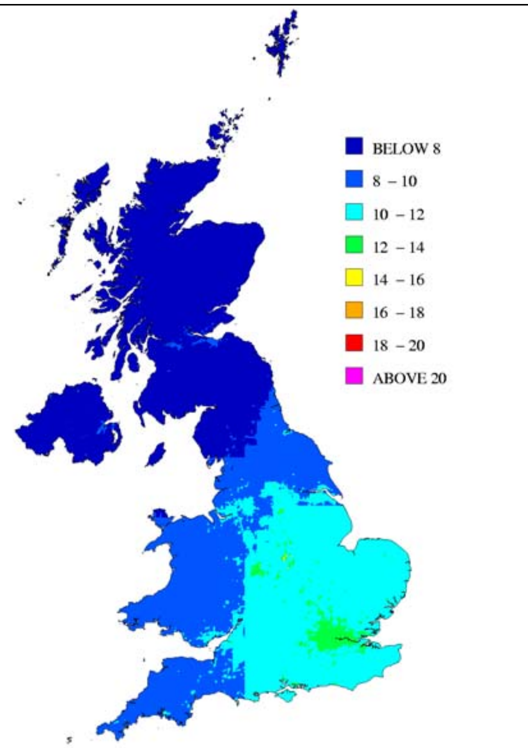


Figure 6.4 Annual mean background $PM_{2.5}$ concentration, 2020 ($\mu g\ m^{-3}$, gravimetric)

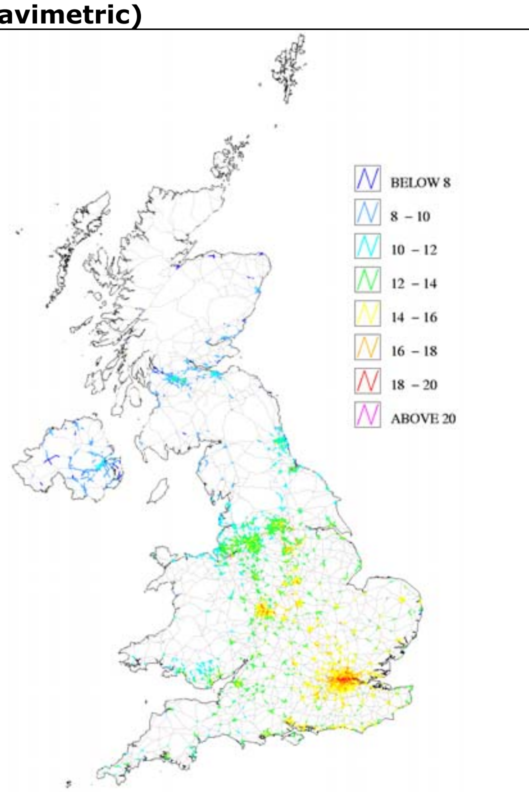


Figure 6.5 Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2010 ($\mu g\ m^{-3}$, gravimetric)

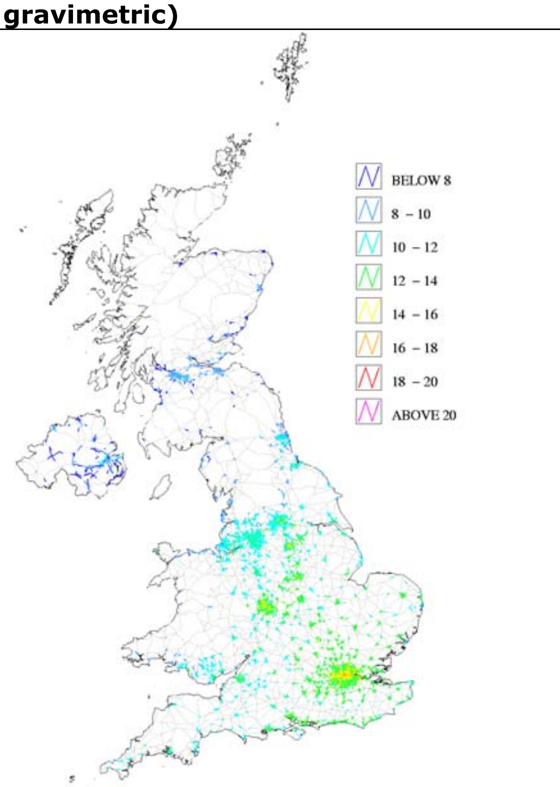


Figure 6.6 Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2020 ($\mu g\ m^{-3}$, gravimetric)

6.2 SECONDARY PARTICLE CONTRIBUTIONS

For 2003 modelling, secondary particles were assumed to consist of sulphates and nitrates only. Maps of concentrations of sulphates and nitrates were then calculated using rural measurement data (Stedman et al, 2005). These maps have been scaled for $PM_{2.5}$ for 2003 modelling using a scaling factor for nitrate of 1.419 derived from the APEG receptor modelling results for gravimetric $PM_{2.5}$. This is higher that the scaling factor of 1 used for TEOM PM_{10} (Stedman et al, 2005) but lower than would be expected for gravimetric PM_{10}. This is because $PM_{2.5}$ measured using a gravimetric instrument will not suffer from the same losses of ammonium nitrate as a TEOM instrument. It is likely, however, that some nitrate is associated with particles larger than included in the $PM_{2.5}$ fraction.

The sulphate and nitrate maps used in modelling $PM_{2.5}$ concentrations in 2003 have been scaled for projected years using EMEP model results for sulphate and nitrate for 2010 and 2020 using a 2000 base year. Values for 2005 and 2015 were calculated by interpolation.

6.3 CONTRIBUTIONS FROM LARGE POINT SOURCES

Contributions to ground level annual mean $PM_{2.5}$ concentrations from large point sources (those for which annual emissions were greater than 200 tonnes in the 2002 NAEI) in 2003 have been estimated by modelling each source explicitly using an atmospheric dispersion model. This has been done following the same method as that used for PM_{10} described in Stedman et al (2005).

Contributions from large point sources have been projected forward for 2005, 2010, 2015 and 2020 using the same method, but using projected emissions of $PM_{2.5}$ from each point source.

6.4 CONTRIBUTIONS FROM SMALL POINT SOURCES

Contributions to background $PM_{2.5}$ from point sources with emissions in the 2002 NAEI of less than 200 tonnes were modelled using projected emissions (see section 2.5) and the small points method described in Stedman et al (2005).

6.5 CONTRIBUTIONS FROM AREA SOURCES

The area source model for $PM_{2.5}$ is exactly the same as for PM_{10} except that $PM_{2.5}$ emissions maps from the NAEI and projected scaling factors are used and because of the small number of monitoring sites, calibration coefficients from the 2003 NO_X model have been adopted.

6.6 RESIDUAL $PM_{2.5}$

A constant residual particle contribution has been included in the modelled background $PM_{2.5}$ concentration. This contribution has been set at 3.37 $\mu g\ m^{-3}$ for all years.

6.7 ROADSIDE CONCENTRATIONS

As for PM_{10}, roadside concentrations of $PM_{2.5}$ have been considered to be made up of two parts: the background concentration (see above) and a roadside increment.

The roadside increment has been modelled using the same method as for PM_{10}. However, because of insufficient monitoring data, the NO_X calibration coefficients from Stedman et al (2005) have been used.

Emissions of $PM_{2.5}$ on individual road links have been estimated as PM_{10} road link emissions scaled by a factor of 0.9 as recommended by AQEG (AQEG, 2005).

6.8 VERIFICATION OF MAPPED VALUES

Figure 6.7 shows the comparison of modelled and measured annual mean $PM_{2.5}$ concentrations in 2003 at background and roadside national network monitoring site locations. Lines representing y = x + 50% and y = x – 50% are shown.

Summary statistics for comparison between modelled and measured $PM_{2.5}$ concentrations are presented in tables 6.1 and 6.2.

Figure 6.7 Verification of background and roadside annual mean gravimetric $PM_{2.5}$ model 2003

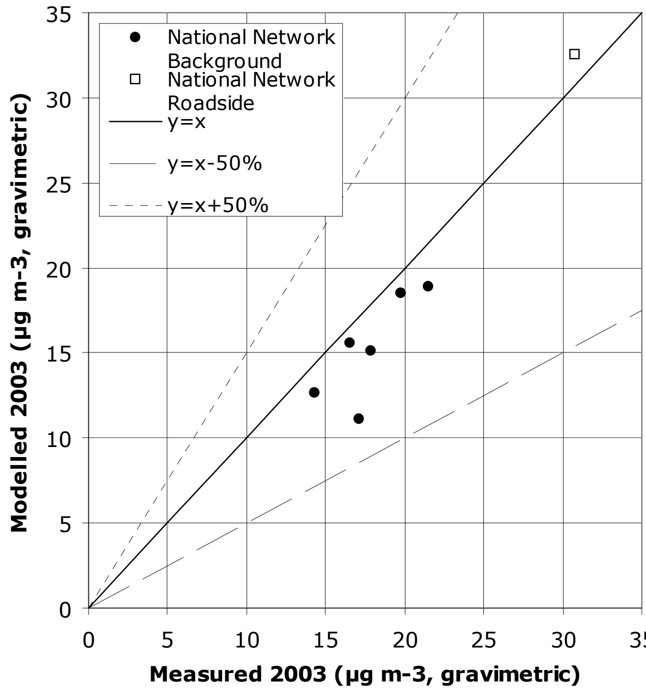


Table 6.1. Summary statistics for comparison between modelled and measured $PM_{2.5}$ concentrations at background sites

	Mean of measurements (µg m^{-3} gravimetric)	Mean of model estimates (µg m^{-3} gravimetric)	r^2	Number of sites
National Network	17.8	15.3	0.64	6

Table 6.2. Summary statistics for comparison between modelled and measured $PM_{2.5}$ concentrations at roadside sites

	Mean of measurements ($\mu g\ m^{-3}$, gravimetric)	Mean of model estimates ($\mu g\ m^{-3}$ gravimetric)	Number of sites
National Network	30.8	32.6	1

6.9 DETAILED COMPARISON OF MODELLING RESULTS WITH THRESHOLD CONCENTRATIONS

Modelling Results using a 2003 base year, in terms of a comparison of modelled gravimetric concentrations with annual mean concentrations of 20, 16 and 12$\mu g\ m^{-3}$ are presented in table 6.3. There are currently no limit values or objectives for $PM_{2.5}$. Therefore these threshold concentrations have been chosen to illustrate the changes in predicted concentration in different years.

Table 6.3a Summary statistics for UK baseline $PM_{2.5}$ projections comparison with 20 $\mu g\ m^{-3}$,using a 2003 base year

Total major road length (km) exceeding an annual mean value of 20 $\mu g\ m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1886	716	333	22	1	0
Rest of England	9430	527	267	3	0	0
Scotland	1085	3	0	0	0	0
Wales	640	13	4	0	0	0
Northern Ireland	1044	0	0	0	0	0
Total	14084	1260	603	24	1	0
percentage > 20 $\mu g\ m^{-3}$		8.9%	4.3%	0.2%	0.0%	0.0%
Total background area (km^2) exceeding an annual mean value of 20 $\mu g\ m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1624	0	0	0	0	0
Rest of England	128770	1	0	0	0	0
Scotland	77791	0	0	0	0	0
Wales	20745	0	0	0	0	0
Northern Ireland	13318	0	0	0	0	0
Total	242248	1	0	0	0	0
percentage > 20 $\mu g\ m^{-3}$		0.0%	0.0%	0.0%	0.0%	0.0%
Total population in area exceeding an annual mean value of 20 $\mu g\ m^{-3}$						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	0	0	0	0	0
Rest of England	41,011,137	16	0	0	0	0
Scotland	4,944,573	0	0	0	0	0
Wales	2,850,727	0	0	0	0	0
Northern Ireland	1,623,309	0	0	0	0	0
Total	58,160,071	16	0	0	0	0
percentage > 20 $\mu g\ m^{-3}$		0.0%	0.0%	0.0%	0.0%	0.0%

Table 6.3b Summary statistics for UK baseline $PM_{2.5}$ projections comparison with 16 µg m^{-3},using a 2003 base year

Total major road length (km) exceeding an annual mean value of 16 µg m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1886	1885	1879	943	257	105
Rest of England	9430	5491	4028	587	73	26
Scotland	1085	29	7	0	0	0
Wales	640	73	40	6	0	0
Northern Ireland	1044	0	0	0	0	0
Total	14084	7478	5954	1536	330	131
percentage > 16 µg m^{-3}		53.1%	42.3%	10.9%	2.3%	0.9%
Total background area (km^2) exceeding an annual mean value of 16 µg m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1624	1533	980	2	0	0
Rest of England	128770	3736	839	21	3	2
Scotland	77791	0	0	0	0	0
Wales	20745	2	1	0	0	0
Northern Ireland	13318	0	0	0	0	0
Total	242248	5271	1820	23	3	2
percentage > 16 µg m^{-3}		2.2%	0.8%	0.0%	0.0%	0.0%
Total population in area exceeding an annual mean value of 16 µg m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	7,564,587	5,687,809	9,814	0	0
Rest of England	41,011,137	6,059,674	1,356,092	24,332	1,751	1,735
Scotland	4,944,573	0	0	0	0	0
Wales	2,850,727	375	130	0	0	0
Northern Ireland	1,623,309	0	0	0	0	0
Total	58,160,071	13,624,636	7,044,031	34,146	1,751	1,735
percentage > 16 µg m^{-3}		23.4%	12.1%	0.1%	0.0%	0.0%

Table 6.3c Summary statistics for UK baseline $PM_{2.5}$ projections comparison with 12 μg m^{-3}, using a 2003 base year

Total major road length (km) exceeding an annual mean value of 12 μg m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1886	1885	1885	1885	1885	1882
Rest of England	9430	9139	9042	8029	6274	4647
Scotland	1085	336	166	38	5	4
Wales	640	611	560	234	92	50
Northern Ireland	1044	0	0	0	0	0
Total	14084	11971	11653	10185	8256	6583
percentage > 12 μg m^{-3}		85.0%	82.7%	72.3%	58.6%	46.7%
Total background area (km^2) exceeding an annual mean value of 12 μg m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	1624	1624	1624	1624	1624	1468
Rest of England	128770	101687	87973	57524	21866	3510
Scotland	77791	6	2	0	0	0
Wales	20745	3554	1954	93	25	13
Northern Ireland	13318	7	2	0	0	0
Total	242248	106878	91555	59241	23515	4991
percentage > 12 μg m^{-3}		44.1%	37.8%	24.5%	9.7%	2.1%
Total population in area exceeding an annual mean value of 12 μg m^{-3}						
	Total assessed	**2003**	**2005**	**2010**	**2015**	**2020**
London	7,730,326	7,730,326	7,730,326	7,730,326	7,730,326	7,422,172
Rest of England	41,011,137	37,964,637	35,897,165	24,995,661	17,266,493	6,146,668
Scotland	4,944,573	13,560	1,892	0	0	0
Wales	2,850,727	1,890,793	1,444,426	206,009	32,847	10,010
Northern Ireland	1,623,309	20,002	7,201	0	0	0
Total	58,160,071	47,619,318	45,081,010	32,931,996	25,029,665	13,578,851
percentage > 12 μg m^{-3}		81.9%	77.5%	56.6%	43.0%	23.3%

Annual mean $PM_{2.5}$ concentrations were below 20 μg m^{-3} across much of the UK in 2003 the results indicate that it was not exceeded at background locations but it was exceeded at roadside locations alongside 9.0% of the length of urban major roads.

Annual mean concentrations were below 16 μg m^{-3} across much of the UK in 2003 but this threshold was exceeded at a number of locations. Results from the national GIS-based models indicate that it was exceeded at background locations representing 23.4% of the UK population and at roadside locations alongside 53.1% of the length of urban major roads. Reductions in $PM_{2.5}$ concentrations resulting from current policies are expected to lead to a reduction in the extent of exceedences of 16 μg m^{-3}. The extent of exceedence at the roadside is expected to decline to 10.9% of the length of urban major roads by 2010, reducing further to 2.3% by 2015 and 0.9% by 2020. Exceedences at background locations are expected to be almost eliminated by 2010.

Exceedences of an annual mean concentration of 12 μg m^{-3} were much more extensive in 2003: at background locations representing 81.9% of the UK population and at roadside locations alongside 85.0% of the length of urban major roads. The extent of exceedences is expected to decline as a result of current policies but exceedences at background locations representing 43.0% of the UK population and at roadside locations alongside 58.6% of the length of urban major roads are expected to remain in 2015.

Overall the statistics for $PM_{2.5}$ tend to show a steeper decline in the extent of exceedences for the baseline scenario than similar statistics for PM_{10}.

Population weighted mean concentrations of $PM_{2.5}$ are presented in Table 6.4. These data are given to a higher degree of precision than the modelling method warrants so that small differences in the model outputs can be seen. This is useful when comparing the baseline results with modelling for additional measures presented in Stedman et al (2006), where certain measures only result in small changes, for example in the 3rd decimal place.

Table 6.4 Population weighted mean $PM_{2.5}$ concentration (μg m^{-3}, gravimetric)

	2003	**2005**	**2010**	**2015**	**2020**
Scotland	9.457	9.136	8.256	7.846	7.520
Wales	12.412	11.941	10.724	10.109	9.551
Northern Ireland	9.704	9.412	8.349	8.014	7.798
Inner London	17.368	16.600	14.642	13.617	12.799
Outer London	16.903	16.176	14.332	13.357	12.533
Rest of England	14.398	13.824	12.349	11.587	10.914
UK	14.074	13.514	12.064	11.322	10.680

7 Benzene

7.1 INTRODUCTION

Maps of mean projected benzene concentrations at background and roadside locations for 2010 are presented in figures 7.1 and 7.2. The modelling method used in estimating projected annual mean concentrations in these years closely follows the method used to estimate concentrations in 2003 for benzene as described in Stedman et al (2005).

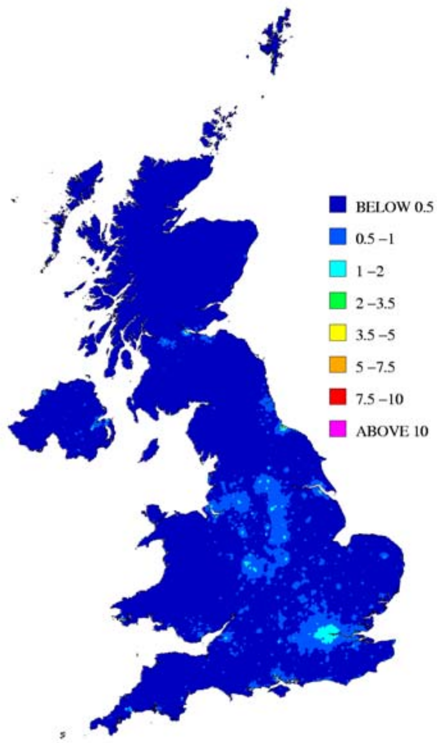


Figure 7.1 Annual mean background benzene concentration, 2010 (µg m^{-3})

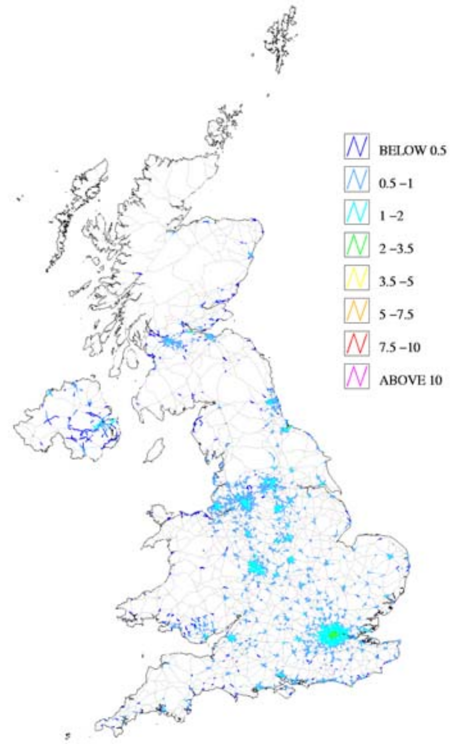


Figure 7.2 Urban major roads, annual mean roadside benzene concentration, 2010 (µg m^{-3})

As for 2003 (see Stedman et al, 2005), annual mean background concentration for 2010 has been considered to consist of contributions from

- Distant sources (characterised by an estimate of rural background concentration)
- Combustion point sources
- Fugitive and process point sources
- Local area sources.

Model calibration from 2003 based on national network monitoring data has been used in the 2010 model.

At locations close to urban major roads an additional roadside contribution has been added to take into account contributions from road traffic sources.

7.2 CONTRIBUTIONS FROM COMBUSTION POINT SOURCES

Contributions to ground level annual mean benzene concentrations from large combustion related point sources (those for which annual emissions were greater than 5 tonnes in the 2002 NAEI) were estimated by modelling each source explicitly using an atmospheric dispersion model.

For the baseline projections this has been done following the same method as that for the 2003 model described in Stedman et al (2005), but using projected emissions of benzene from each point source.

7.3 CONTRIBUTIONS FROM FUGITIVE AND PROCESS POINT SOURCES

Contributions to background benzene concentrations from fugitive and process point sources with emissions in the 2002 NAEI of less than 5 tonnes were modelled using projected emissions (see section 2.5) and the modified version of the small points model as described in Stedman et al (2005). As with the 2003 model, a GIS mask has been applied because of significant model over estimation close to refineries. No attempt has been made to model concentrations close to these locations.

7.4 CONTRIBUTIONS FROM RURAL BACKGROUND CONCENTRATIONS

Regional rural benzene concentrations have been estimated for 2010 by scaling the 2003 map of rural benzene (see Stedman et al, 2005) by the ratio of the total UK emissions of benzene in these years.

7.5 CONTRIBUTIONS FROM AREA SOURCES

The calibration of the area source model for 2003 (see Stedman et al, 2005) has been used for area source model projections for 2010 for benzene. The approach used to model area sources involves applying an ADMS derived dispersion kernel to calculate the contribution to ambient concentrations at a central receptor location from area source emissions within a 33 x 33 km square. The dispersion kernel constructed for 2003 using hourly sequential meteorological data from Heathrow has also been used here. Emissions maps to which the dispersion kernel has been applied for 2010 have been estimated by scaling 2002 emissions by the NAEI emission projections (see section 2.2).

As with 2003 area source modelling, adjustment factors have been applied to emissions from aircraft and shipping sectors (see Stedman et al, 2005 for details).

7.6 ROADSIDE CONCENTRATIONS

Annual mean concentration of benzene near roadside locations has been considered to consist of the background concentration (see above) and a roadside increment. The calibration coefficient used in the 2003 modelling for the roadside increment (see Stedman et al, 2005) has also been applied to the projected roadside increment in 2010. As with 2003 modelling, emissions were adjusted for average annual daily traffic flow.

7.7 DETAILED COMPARISON OF MODELLING RESULTS WITH OBJECTIVES AND LIMIT VALUES

The modelling results for 2010 in terms of a comparison of modelled concentrations with the annual mean objective for England and Wales, are summarised in table 7.1. As with the 2003 results (see Stedman et al, 2005), estimates of area and population exposed have only been derived from the background maps. No attempt has been made to derive estimates using maps of roadside concentrations as these maps will only apply within approximately 10 metres from the road kerb.

Table 7.1 Summary statistics for UK baseline benzene projections using a 2003 base year

Total major road length (km) exceeding the annual mean objective of 5 µg m^{-3}			
	Total assessed	**2003**	**2010**
London	1886	71	0
Rest of England	9430	0	0
Scotland	1085	0	0
Wales	640	0	0
Northern Ireland	1044	0	0
Total	14084	71	0
percentage > 5 µg m^{-3}		1%	0%
Total background area (km^2) exceeding the annual mean limit value of 5 µg m^{-3}			
	Total assessed	**2003**	**2010**
London	1624	0	0
Rest of England	128770	0	0
Scotland	77791	0	0
Wales	20745	0	0
Northern Ireland	13318	0	0
Total	242248	0	0
percentage > 5 µg m^{-3}		0%	0%
Total population in area exceeding the annual mean limit value of 5 µg m^{-3}			
	Total assessed	**2003**	**2010**
London	7,730,326	0	0
Rest of England	41,011,137	0	0
Scotland	4,944,573	0	0
Wales	2,850,727	0	0
Northern Ireland	1,623,309	0	0
Total	58,160,071	0	0
percentage > 5 µg m^{-3}		0%	0%

Concentrations in background locations were below the objective of 5 µg m^{-3} across the whole of the UK in 2003 and this threshold was only exceeded at a small number of roadside locations in London. A continued decline in benzene emissions from road traffic sources is expected between 2003 and 2010. Thus no excedeences of 5 µg m^{-3} are predicted for 2010.

The 2010 AQS objective is 5 µg m^{-3} as an annual mean in England and Wales. The objective in Scotland and Northern Ireland is 3.25 µg m^{-3} measured as the maximum running annual mean. The GIS-based modelling does not predict any exceedences of this objective in 2003 or 2010 in Scotland or Northern Ireland.

8 CO

8.1 INTRODUCTION

No projections have been produced for this pollutant. This is because the 2003 modelling (Stedman et al, 2005) and measurements showed that there were no exceedences of the AQS objective for 2003, which is the same as the limit value for 2005. Emissions projections for future years show that the main source of CO, road traffic emissions, are likely to continue to decline and so modelled exceedences of the objective in future years are improbable.

9 1,3-butadiene

9.1 INTRODUCTION

Maps of annual mean 1,3-butadiene at background and roadside locations are presented in figures 9.1 and 9.2. 1,3-butadiene concentrations have been calculated using a similar approach to that adopted for benzene described in Stedman et al (2005).

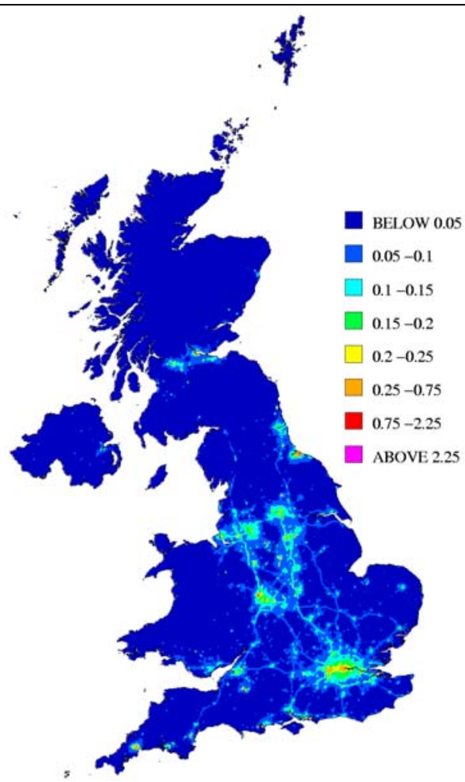


Figure 9.1 Annual mean background 1,3-butadiene concentration, 2003 (µgm-3)

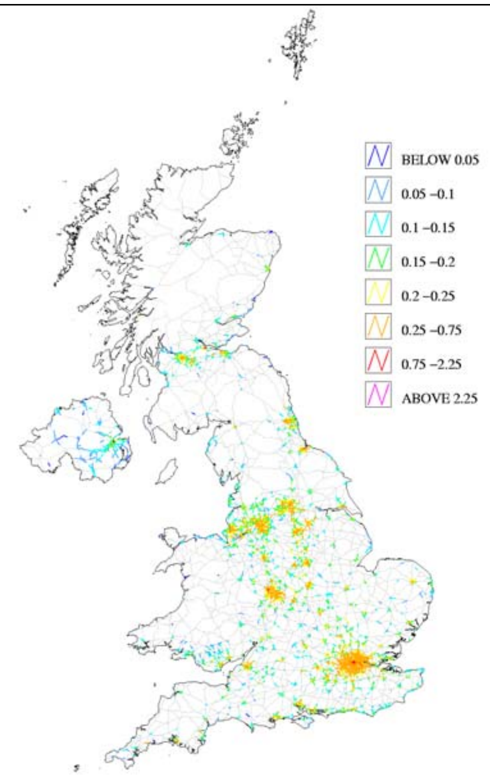


Figure 9.2. Urban major roads, annual mean roadside 1,3-butadiene concentration, 2003 (µgm-3)

Projections have not been produced for 1,3-butadiene. This is because there are no exceedences of the AQS objective for 2003 and emissions are expected to decline in the future, so modelled exceedences in future years are unlikely.

Annual mean background 1,3 butadiene concentrations have been consider to consist of contributions from:

- Distant sources (characterised by an estimate of rural background concentration)
- Point sources
- Local area sources

Because of insufficient numbers of national network monitoring stations for 1,3-butadiene, the area source model has been calibrated with the NO_X calibration coefficients given in Stedman et al (2005).

At locations close to major roads in built up areas an additional roadside contribution was added to account for contributions to total 1,3-butadiene from road traffic sources.

9.2 CONTRIBUTIONS FROM SMALL POINT SOURCES

Contributions from 1,3-butadiene have been modelled using the small points model described in Stedman et al (2005). As with modelling contributions from fugitive and process point sources for benzene in 2003 (see Stedman et al, 2005), problems have been identified with modelling emissions from refineries. Therefore a GIS mask has been applied to the locations of refineries in the final background map and no attempt has been made to estimate concentrations in these locations.

9.3 CONTRIBUTIONS FROM RURAL BACKGROUND CONCENTRATIONS

Regional rural 1,3-butadiene concentrations have been estimated from the map of rural NO_X concentrations described in Stedman et al (2005). A factor of the ratio of annual mean 1,3-butadiene and NO_X concentrations at the rural Harwell monitoring site was applied to this map.

9.4 CONTRIBUTIONS FROM AREA SOURCES

There are only two national network monitoring stations in background locations for 1,3-butadiene. This means any coefficient produced in calibrating the area source model using monitoring data is not robust. Therefore the empirical coefficients derived for the NO_X area source model in Stedman et al (2005) have been used for 1,3-butadiene.

As for other pollutants in 2003 adjustment factors were applied to emissions from selected sources. A full description of this is given in Stedman et al (2005).

9.5 ROADSIDE CONCENTRATIONS

Annual mean concentrations of 1,3-butadiene at roadside locations have been considered to be made up of two parts: the background concentration (see above) and a roadside increment. There are only two national network sites at roadside locations for which 1,3-butadiene is measured so there is insufficient data to calibrate the roadside increment model. To deal with this problem when calibrating the area source model, the area source NO_X calibration coefficient was used. For the roadside increment model however, the roadside NO_X calibration coefficient was found to over predict compared to data from the two monitors there are. Therefore a calibration coefficient of 3.0×10^{-6} was chosen which gave a reasonable agreement with the available monitoring data.

As with other pollutants, emissions have been adjusted for average annual traffic flow using the method described in Stedman et al (2005).

9.6 VERIFICATION OF MAPPED VALUES

Figures 9.3 and 9.4 show comparisons of the modelled and measured annual mean 1,3-butadiene concentrations for background and roadside locations. Line showing y = x – 50% and y = x + 50% are included in these charts.

Figure 9.3. Verification of background annual mean 1,3-butadiene model 2003

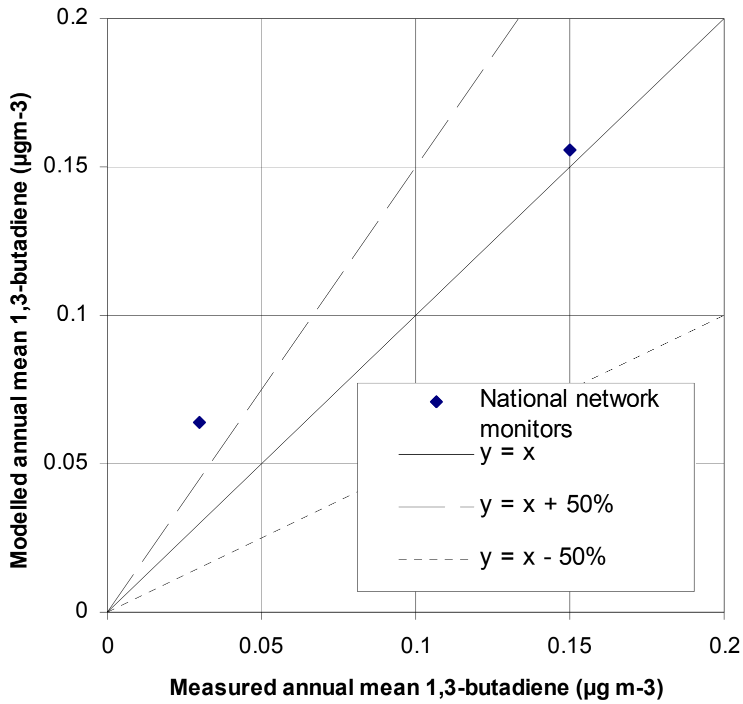
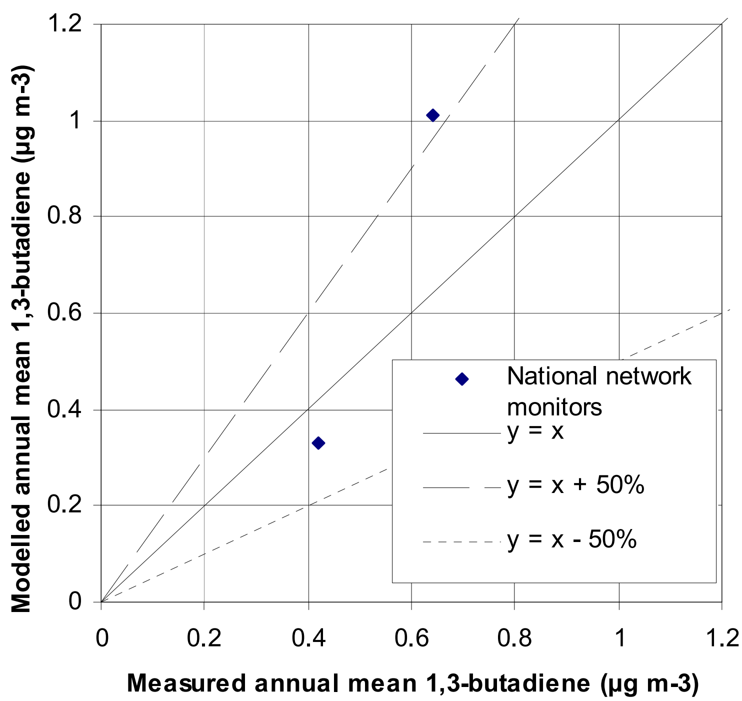


Figure 9.4 Verification of roadside annual mean model 2003



Summary statistics for the comparison between modelled and measured 1,3-butadiene concentrations are listed in Tables 9.1 and 9.2. No r^2 values are given because this statistic requires more than two measurements to be meaningful.

Table 9.1. Summary statistics for comparison between modelled and measured 1,3-butadiene concentrations at background sites

	Mean of measurements ($\mu g\ m^{-3}$)	**Mean of model estimates ($\mu g\ m^{-3}$)**	**Number of sites**
National network	0.09	0.11	2

Table 9.2. Summary statistics for comparison between modelled and measured 1,3-butadiene concentrations at roadside sites

	Mean of measurements ($\mu g\ m^{-3}$)	**Mean of model estimates ($\mu g\ m^{-3}$)**	**Number of sites**
National network	0.53	0.67	2

9.7 DETAILED COMPARISON OF MODELLING RESULTS WITH OBJECTIVE

A comparison of modelling results with the AQS objective concentration of 2.25$\mu g\ m^{-3}$ for 2003 shows there are no modelled background or roadside exceedences for this pollutant for 2003.

10 Conclusions

GIS-based modelling predictions of air quality using baseline conditions (i.e. under current policies) have been produced for SO_2, NO_X and NO_2, PM_{10}, benzene, CO, $PM_{2.5}$ and 1,3-butadiene for a range of years. A summary of the percentage of modelled exceedences of relevant AQS objectives/ thresholds for each pollutant is presented in table 10.1.

Table 10.1 Summary of total exceedences using a 2003 base year

Percentage of total urban major major road length exceeding (%)						
Pollutant	**Threshold**	**2003**	**2005**	**2010**	**2015**	**2020**
SO_2	15-minute mean objective	N/A	N/A	N/A	N/A	N/A
	1-hour and 24-hour objective	N/A	N/A	N/A	N/A	N/A
NO_2	Annual mean >40 μgm^{-3}	52.5	41.3	18.2	10.0	8.5
PM_{10}	Annual mean >31.5 μgm^{-3}	15.7	9.7	2.1	0.5	0.3
	Annual mean >20 μgm^{-3}	92.3	88.7	77.6	67.3	60.5
$PM_{2.5}$	Annual mean >20 μgm^{-3}	9.0	4.3	0.2	0.0	0.0
	Annual mean >16 μgm^{-3}	53.1	42.3	10.9	2.3	0.9
	Annual mean >12 μgm^{-3}	85.0	82.7	72.3	58.6	46.7
Benzene	Annual mean > 5 μgm^{-3}	1.0	-	0.0	-	-
CO	8-hour mean > 10 μgm^{-3}	0.0	-	-	-	-
1-3, butadiene	Annual mean > 2.25 μgm^{-3}	0.0	-	-	-	-
Percentage of total background area exceeding (%)						
Pollutant	**Threshold**	**2003**	**2005**	**2010**	**2015**	**2020**
SO_2	15-minute mean objective	0.65	0.46	0.01	0.01	0.01
	1-hour and 24-hour objective	0.01	0.01	0.01	0.01	0.01
NO_2	Annual mean >40 μgm^{-3}	0.2	0.1	0.0	0.0	0.0
PM_{10}	Annual mean >31.5 μgm^{-3}	0.0	0.0	0.0	0.0	0.0
	Annual mean >20 μgm^{-3}	33.2	27.8	7.9	4.1	2.6
$PM_{2.5}$	Annual mean >20 μgm^{-3}	0.0	0.0	0.0	0.0	0.0
	Annual mean >16 μgm^{-3}	2.2	0.8	0.0	0.0	0.0
	Annual mean >12 μgm^{-3}	44.1	37.8	24.5	9.7	2.1
Benzene	Annual mean > 5 μgm^{-3}	0.0	-	0.0	-	-
CO	8-hour mean > 10 μgm^{-3}	0.0	-	-	-	-
1-3, butadiene	Annual mean > 2.25 μgm^{-3}	0.0	-	-	-	-
Percentage of total population in the area exceeding (%)						
Pollutant	**Threshold**	**2003**	**2005**	**2010**	**2015**	**2020**
SO_2	15-minute mean objective	0.66	1.17	0.01	0.01	0.01
	1-hour and 24-hour objective	0.01	0.01	0.01	0.01	0.01
NO_2	Annual mean >40 μgm^{-3}	4.0	2.3	0.6	0.3	0.3
PM_{10}	Annual mean >31.5 μgm^{-3}	0.1	0.1	0.0	0.0	0.0
	Annual mean >20 μgm^{-3}	79.9	72.8	50.0	36.0	26.7
$PM_{2.5}$	Annual mean >20 μgm^{-3}	0.0	0.0	0.0	0.0	0.0
	Annual mean >16 μgm^{-3}	23.4	12.1	0.1	0.0	0.0
	Annual mean >12 μgm^{-3}	81.9	77.5	56.6	43.0	23.3
Benzene	Annual mean > 5 μgm^{-3}	0.0	-	0.0	-	-
CO	8-hour mean > 10 μgm^{-3}	0.0	-	-	-	-
1-3, butadiene	Annual mean > 2.25 μgm^{-3}	0.0	-	-	-	-

Exceedences of the 15-minute mean objective for SO_2 are predicted to remain in 2005 but be almost eliminated by 2010. Exceedences of the SO_2 1-hour and 24-hour objective are limited to the vicinity of one industrial plant. Further work will be undertaken to assess the likelihood of the objectives being met at this location.

The annual mean objective of 40 µg m^{-3} for NO_2 is expected to be met at all background locations across the UK by 2010 with only a small percentage (<1%) of total area assessed exceeding this value in 2003 and 2005. The objective is not expected to be met at all roadside locations under baseline conditions by 2020. However, percentage of total major road length exceeding is expected to decline from 52.5% in 2003 to 8.5% in 2020.

For PM_{10} three limit values and objectives were assessed against. Exceedences of 40 µg m^{-3} objective at both background and roadside locations are expected to have been almost completely eliminated by 2010. An annual mean concentration of 31.5 µg m^{-2} (roughly equivalent to the 24-hour objective) is not predicted to be exceeded at any background locations. At roadside locations this concentrations is expected to be exceeded in some locations for all years with percentage of total road length exceedencing decreasing from 15.7% in 2003 to 0.3% in 2020. An annual mean concentration of 20 µg m^{-2} is predicted to be exceeded at both background and roadside locations for all years and therefore this indicative limit value is not expected to be met.

Table 10.1 contains a summary of results for a 2003 base year. A comparison of modelling results and limit values for NO_2 and PM_{10} for a 2002 base year (see sections 4.9 and 5.9) showed significantly fewer exceedences for projections derived from this base year.

$PM_{2.5}$ thresholds were set to illustrate changes in predicted concentrations in different years. No background exceedences of an annual mean of 20 µg m^{-3} are predicted and roadside exceedences of this concentration are expected to have been eliminated by 2015. Background exceedences of an annual mean of 16 µg m^{-3} are expected to have been eliminated by 2010. Roadside exceedences are expected for all years. Background and roadside exceedences of an annual mean concentration of 12 µg m^{-3} are predicted for all years.

Benzene projections show that the annual mean objective of 5 µg m^{-3} for England and Wales is expected to be met at all background and roadside locations in 2010. The 2010 objective in Scotland and Northern Ireland is also expected to be met.

No CO projections have been produced for comparison with the objective. This is because there were no modelled or measured exceedences in 2003 and emissions from the main sources of CO are expected to decrease. Therefore no exceedences of CO are expected in future years and the objective is expected to continue to be met.

Modelling of 1,3-butadiene for 2003 showed no predicted exceedences of the objective. Therefore projections have not been produced because emissions are expected to decline in the future, so the objective is expected to continue to be met.

11 Acknowledgements

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12 References

Abbott J and Vincent K (1999). Annual average sulphur dioxide concentration maps derived by dispersion modelling. AEA Technology, National Environmental Technology Centre. Report AEAT - 4629
http://www.aeat.co.uk/netcen/airqual/reports/kvann1/so2ann.html

Airborne Particles Expert Group (APEG). Source Apportionment of Airborne Particulate Matter in the United Kingdom. ISBN 0-7058-1771-7, January 1999.
http://www.defra.gov.uk/environment/airquality/airbornepm/index.htm

Air Quality Expert Group (AQEG, 2004). Nitrogen Dioxide in the United Kingdom.
http://www.defra.gov.uk/environment/airquality/aqeg/nitrogen-dioxide/index.htm

Air Quality Expert Group (AQEG, 2005). Particulate Matter in the United Kingdom,
http://www.defra.gov.uk/environment/airquality/aqeg/particulate-matter/index.htm

The Carbon Trust and DTI (2004). The carbon trust & DTI's renewables network impact study.
http://www.thecarbontrust.co.uk/carbontrust/about/publications/Renewables%20Network%20Impact%20Study%20Final.pdf

Council Directive 96/62/EC, of 27 September 1996. On ambient air quality assessment and management (The Framework Directive). From the Official Journal of the European Communities, 21.11.1996, En Series, L296/55.

Council Directive 1999/30/EC, of 22 April 1999 Relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (The First Daughter Directive). From the Official Journal of the European Communities, 29.6.1999, En Series, L163/41.

Council Directive 2000/69/EC, of 16 November 2000 Relating to limit values for benzene and carbon monoxide in ambient air (The Second Daughter Directive). From the Official Journal of the European Communities, 13.12.2000, En Series, L313/12.

Council Directive 2002/3/EC, of 12 February 2002 Relating to ozone in ambient air (The Third Daughter Directive). From the Official Journal of the European Communities, 9.3.2002, En Series, L67/14.

Council Directive 2004/107/EC, of 15 December 2004 Relating to arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons in ambient air (The Fourth Daughter Directive). From the Official Journal of the European Communities, 26.1.2005, En Series, L23/3.

DEFRA et al (2003). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland: Addendum. February 2003.

DEFRA et al (2006a). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. The Air Quality Strategy for England, Scotkland, Wales and Northern Ireland. Volume 1: A consultation document on options for further improvements in air quality;

DEFRA et al (2006b). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. The Air Quality Strategy for England, Scotkland, Wales and Northern Ireland. Volume 2: Technical Annex and Regulatory Impact Assessment

DEFRA et al (2006c). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. An Economic Analysis to Inform the Air Quality Strategy Review Consultation: Third Report of the Interdepartmental Group on Costs and Benefits

DETR *et al* (2000) Department of the Environment, Transport and the Regions, The Scottish Executive, The National Assembly for Wales and The Department of the Environment in Northern Ireland. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. January 2000.

DfT (2003) The Future of Air Transport - White Paper and the Civil Aviation Bill http://www.dft.gov.uk/stellent/groups/dft_aviation/documents/divisionhomepage/029650.hcsp

DfT (2004) The Future of Transport - White paper CM 6234 http://www.dft.gov.uk/stellent/groups/dft_about/documents/divisionhomepage/031259.hcsp

DTI (2004) Department of Trade and Industry updated emissions projections. Final projections to inform the National Allocation Plan (NAP). http://www.dti.gov.uk/energy/sepn/uep2004.pdf?pubpdfload=04%F2099

Dore, C J, Watterson, JD, Goodwin, JWL et al (2004). UK Emissions of Air Pollutants 1970 to 2002 August 2004. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre.

Hayman, G, Abbott, J, Thomson, C et al (2005). Modelling of Tropospheric Ozone. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1858

Hayman, G., Thomson, C., Abbott, J. and Bush, A. (2006) Ozone Modelling for the Review of the Air Quality Strategy. A report produced for the Department for Environment, Food and Rural Affairs, the Scottish Executive, Welsh Assembly Government and the Department of the Environment Northern Ireland by AEA Technology plc AEAT/ENV/R/2092 Issue 1

Kent, A., Thompson, C. L., Grice, S., & Stedman, J. R. 2006, Comparison of health based metrics and modelling methods for ozone in the UK National Atmospheric Emissions Inventory. Report AEAT/ENV/R/1935 issue 2, AEA Technology, National Environmental Technology Centre.

Jenkin, M E. (2004). Analysis of sources and partitioning of oxidant in the UK—Part 1: the NOX-dependence of annual mean concentrations of nitrogen dioxide and ozone. *Atmospheric Environment* **38** 5117–5129.

Stedman, J R, Linehan E and Conlan B (2001a). Receptor Modelling of PM_{10} Concentrations at a United Kingdom National Network Monitoring Site in Central London. *Atmospheric Environment,* **35**, 297-304.

Stedman, J R, Bush, T J, Murrells, T P and King, K (2001b). Baseline PM_{10} and NO_x projections for PM_{10} objective analysis. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/0726.
http://www.aeat.co.uk/netcen/airqual/reports/naqs2001/aeat-env-r-0726.pdf

Stedman, J R, Bush, T J, Vincent, K J, Kent, A J, Grice, S, Abbott, J (2005) UK air quality modelling for annual reporting 2003 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1790.

Stedman, J R, Grice, S, Bush, T J, Murrells, T P and Hobson, M (2006) Projections of air quality in the UK for additional measures scenarios for the 2006 review of the air quality strategy. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1986.

Vincent K J (2006a) Assessment of benzo[a]pyrene concentrations in the United Kingdom in 2003 AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1861.

Vincent, K J and Passant, N (2006b) Assessment of heavy metal concentrations in the United Kingdom. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/2013

Appendix 1 Emission Projections

A1 METHODOLOGY

The NAEI method follows the methodology outlined in the UNECE Task Force on Emission Inventories and projections (TFEIP) Guidebook (3rd Edition, June 2002).

In order to establish consistency between historic and projected emissions, emission inventories and emission projections should be based on the same structure. Therefore a similar method to that used to calculate historic emissions has been used to estimate future emissions. Historical emissions are calculated by combining an emission factor with an activity statistic.
For example:

E2002 = A2002 * EF2002

where E = emission, A = activity and EF = emission factor in 2002.

For projected emissions:

E2010 = A2010 * EF2010

Where E = emission, A = activity and EF = emission factor in 2010.

A1.1 ACTIVITY

To produce a projection each activity is linked to an activity driver. Examples of drivers include forecasts of fuel use, vehicle kilometres and GDP. The latest activity statistics are obtained from a number of sources including Oxford economic forecasting and UEP12 produced by DTI. The UEP12 forecasts incorporate climate change programme measures that are considered firm or are considered likely to become firm by Defra. Carbon pricing has not been taken into account in the energy forecasts.

For road transport, a fairly detailed emission forecasting approach is used, adopting the latest traffic forecasts reflecting current Government policies on transport, fleet turnover and the penetration of vehicles meeting the tougher European vehicle emission Directives.

A1.2 EMISSION FACTORS

In addition to changes in activity influencing emissions, improvements in abatement measures will reduce emissions. The implementation of more stringent abatement measures, often the result of legal requirements must be considered when estimating future emissions. Therefore the emission factors where relevant have been varied to account for this. Regulations that have been taken into account are:

- The large combustion plant Directive
- IPPC Directive
- The Solvent Emissions Directive
- Marpol VI
- Sulphur content of liquid fuels regulations, and
- European directives on vehicle emissions and fuel quality.

These are discussed in more detail in this appendix.

The EPEP (Expert panel on emission projections), part of the TFEIP suggests that the years, 2005 & 2010 are covered as projection years and that the emission projections should be reported using the updated source category split (snap level split). As projected activity statistics up to 2020 were available for the majority of sectors in the UK, emissions have been projected to this year. However, in a few cases emission estimates are very uncertain beyond 2010. When this is the case emissions have been kept constant beyond 2010.

A1.3 GENERAL ASSUMPTIONS

In general the projections are based on a number of assumptions:

- that measures are introduced when required by legislation and not earlier and that all operators comply with this legislation.
- there is no improvement in environmental efficiency other than in response to legislation.

In a few cases in the coatings emission projections, some alteration in product formulations maybe included which are not required by legislation, for example changes in DIY paints. However, this is probably the only example and generally we have not tried to model voluntary reductions.

Therefore the projections produced tend to be conservative and are likely to over estimate the actual emissions.

A2 DETAILS FOR INDIVIDUAL SECTORS

A2.1 ENERGY, INDUSTRY AND SERVICES

DTI have issued revised energy projections known as UEP12 (DTI, 2004). UEP12 provides projections up to 2020 and is based on the updated energy projections for the EU Emissions Trading Scheme. The projections are based on an analysis of historical trends in energy use and its relationship to such factors as economic growth and fuel prices. They also take into account the impact of existing government policies on energy and the environment. Assumptions about fossil fuel prices, economic growth and other relevant factors are used in the model to investigate possible scenarios for UK energy demand and supply. Various energy demand scenarios are examined in UEP12. The NAEI projections from a 2002 base year are based on the UEP12 forecasts with firm or expected to be firm climate change measures.

Total activity in the renewable energy sector was provided in UEP12. An estimate of the fuel split in 2010 was however provided by Defra. To estimate activity by source in 2005 the numbers have been interpolated between 2000 & 2010. Post 2010 the activity by each emitting source has assumed to grow in line with the forecasts provided in a Mott MacDonald study (The Carbon Trust and DTI, 2004). Emissions from “biomass” have been assumed to be similar to emissions from power stations burning poultry litter due to no other information being available.

In the past DTI provided economic projections by industry sector, which are used to predict activity in the non fuel combustion sectors. Nine of these have recently been updated by DTI and combined with those previously provided for other sectors. Therefore the latest projections are based on a mixture of old and new economic projections.

A2.2 ROAD TRANSPORT

The assumptions behind the activity data in the road transport emission projections contained in the latest emission forecasts are as follows:

- Central traffic forecasts for GB from DfT (DfT, 2004), by area and vehicle type, taking account of the Ten Year Plan for Transport. The DfT figures are for 2010, 2015, 2025 from ITEA Division using their FORGE model.

- Fleet Turnover - The rate at which new vehicles penetrate the fleet and old ones are taken out are calculated by a fleet turnover model based on average survival rates and figures from DfT's Vehicle Market Model (VMM) on new car sales. The survival rates are based on averages of historical survival rates over the last 10 years.

- Diesel car sales assumed to grow to 42% by 2010.

- The dates that the Euro III and IV standards come into effect are largely based on the regulatory implementation dates. However, the early introduction of new petrol cars meeting the Euro IV standard has been assumed, as advised by TET Division of DfT in 2001. Also, the penetration of new diesel cars fitted with particulate traps and the retrofitting of some heavy duty vehicles with particulate traps are assumed, again according to figures provided by TET.

  The assumptions assumed are shown in the following table

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008+
Proportion of Euro IV cars in the new petrol car market	0%	15%	29%	43%	62%	81%	100%	100%	100%
Proportion of new diesel cars with particulate traps	0%	5%	10%	15%	20%	20%	20%	20%	20%
Cumulative number of heavy duty vehicles retrofitted with particulate traps	4000	6000	8000	10000	12000	14000	14000	14000	14000

The following assumptions are made concerning the introduction of new vehicle emission standards:

- ***Petrol cars:***

  - Euro III (98/69/EC) – 10% in 2000 (balance are Euro II's)
  - Euro IV (98/69/EC) – as in table

- ***Diesel cars:***

  - Euro III (98/69/EC) - 10% in 2000 (balance are Euro II's). 100% from 1 January 2001 to 2005
  - Euro IV (98/69/EC) – 100% from 1 January 2006

- ***LGVs (petrol and diesel):***

    - Euro III (98/69/EC) – 100% from 1 January 2002 (2001 for small LGVs)
    - Euro IV (98/69/EC) – 100% from 1 January 2006

- ***HGVs and buses:***

    - Euro III (1999/96/EC) – 100% from 1 October 2001
    - Euro IV (1999/96/EC) – 100% from 1 October 2006 (standards for NOx introduced in 2 stages, second stage from 1 October 2008)

- London-specific bus fleet projections data from TfL are incorporated into the national NAEI model, taking account of measures introduced by LT Buses to reduce emissions from the bus fleet in London.

- The NAEI projections take account of the early introduction of ULS petrol and diesel in the UK market (by 2001). It also takes account of the introduction of sulphur-free fuels (SFP/D), required under the Directive 2003/17/EC. The Directive requires their introduction by 1 January 2009, but the NAEI projections assume their penetration into the UK market sooner than this. It is now assumed that these fuels will reach 70% of petrol sales and 93% of diesel sales in the UK by 2005, rising to 100% by 2009.

- The effect of these sulphur-free fuels on emissions is based on recommendations of DfT TET Division to NETCEN in 2001 and studies by SENCO.

The emission factor assumptions in the road transport projections are as follows:

- Hot exhaust emission factors are based on speed-emission functions published by TRL from their review of measured emission factors in 2001 for vehicles up to Euro II standards.

- Emission factors for Euro III, IV vehicles were estimated by applying scaling factors to the Euro II factors. They are based on the extent that current emissions from Euro II vehicles will need to be reduced to just meet the Euro III, IV limit values. However, consideration is given to a) the fact that the test cycle for Euro III, IV light duty vehicles includes a period soon after start up when the engine is cold and b) the emission durability requirements of the Directives, so that the emission factor for light duty vehicles when new are lower than required to meet the limit values, but are allowed to degrade to factors consistent with the limit values at rates defined by the Directives. Scaling factors for heavy duty vehicles and motorcycles taken from COPERT II.

- Variable catalyst failure rates assumed, with lower failure rates for more modern catalyst-equipped vehicles and Euro standards:
  The failure rates now adopted are:
  Euro I cars: 5% per annum
  Euro II cars: 1.5% per annum
  Euro III-IV cars: 0.5% per annum

- A modification to the method for calculating evaporative emissions of NMVOCs from vehicles. Monthly fuel volatility and ambient temperature are now used to calculate evaporative emissions on a monthly basis, then summed over a whole year, rather than annual average volatility and temperature data. Annual variations in temperature data for each year are taken into account using actual Met data records. Better account has been made of modern systems to control evaporative emissions from cars to comply with European Directives.

- PM emission factors for tyre and brake wear revised, based on a review of PM emissions from these sources carried out for the UNECE Task Force on Emission Inventories and the CORINAIR Emission Inventory Guidebook (http://vergina.eng.auth.gr/mech/lat/PM10). For both tyre and brake wear, the UNECE method provides emission factors for different vehicle types and provides speed correction factors. These imply higher emissions per km at lower speeds than at high speeds. For heavy duty vehicles, a load correction factor is also provided and tyre wear emissions depend on the number of axles.

A2.3 OTHER TRANSPORT

For aviation, the projected growth has not been taken from UEP12. Instead figures have been used which are consistent with the aviation white paper (DfT, 2003)

A2.4 THE REVISED LARGE COMBUSTION PLANT DIRECTIVE (LCPD, 2001/80/EC)

The revised large combustion plant directive applies to combustion plants with a thermal input equal to or greater than 50MW. The plants must also comply with the IPPC Directive (96/91/EC). While new combustion plants must meet the emission limit values (ELVs) given in the LCPD, member states can choose to meet obligations for existing plants (those in operation pre 1987) by:

(a) Complying with ELVs for NOx, SO_2 and particles, or
(b) Operating within a national emissions reduction plan (NERP) that would set a ceiling for each pollutant.

Individual plants may 'opt out' and instead accept a limit on their operating hours for the period 2008 – 2015 provided that they made a declaration to do so by 30th June 2004.

At the present time the government has not taken final decisions on the implementation route in the UK. It is exploring with the European Commission implementation by means of a combined approach with ELVs for the electricity supply industry (ESI) and a NERP for the non ESI. The UEP12 projections are broadly consistent with the ELV approach. UEP12 provides emissions of SO_2 and NOx from power stations. This data has been used in the projections. For PM_{10}, future emissions have been estimated based on 2002 implied emission factors for FGD and non FGD plant.

A2.5 RENEWABLE FUELS CONSUMED BY POWER STATIONS.

Information on future landfill gas activity levels has been provided by the Environment Agency. For other combustion renewables, information has been taken from The carbon trust & DTI's renewables network impact study (The carbon trust and DTI, 2004). It has been assumed that the difference between DTI's forecast of total renewable energy consumption and that derived from the The carbon trust and DTI (2004) study will be provided by non combustion renewables.

A2.6 SULPHUR CONTENT OF LIQUID FUELS REGULATIONS 2000 (1999/32/EC)

It has been assumed that the Sulphur in Liquid Fuels Directive will be met by all non marine consumers. For gas oil a sulphur content of no more than 0.2% now is required and by 2008 no more than 0.1%. For fuel oil the requirement is that from 2003 the sulphur content must be less than 1%.

A2.7 MARPOL VI

It has been assumed that all ships will comply with the Marpol VI agreement requiring marine fuel oil to have no higher than 1.5% sulphur content in 2005 & beyond. Alternatively, ships must fit an exhaust gas cleaning system or use any other technological method to limit SO_2 emissions. Whilst legally Marpol VI will only apply to ships in the North Sea (as this has been designated a SO_2 emission control area) it has been assumed that ships in other UK waters will also meet this standard due to no data on the split between fuel consumption by ships in the north sea against other areas being readily available. SO_2 emissions from this source are small.

A2.8 IRON & STEEL

Prospective activity in the iron & steel combustion and sinter sector on a fuel by fuel basis has been predicted from UEP12. Operations in the iron & steel blast furnaces sector have been forecast based on generic growth in the iron and steel sector obtained from UEP12. Activity in the iron & steel foundries sector was obtained by using the projected growth of the castings industry supplied by UEP12.

PM_{10} emission factors from iron and steel sinter plant have been assumed to be reduced by 10% between 2000 and 2010 as a result of introducing moving electrode ESP for PPC. PM_{10} emission factors from foundries have been reduced by 25% as a result of introducing fume control and fabric filters for PPC (Source: Entec, Feb 04). The 2000 starting point is based on emissions data and activity data from the iron and steel industry and the Environment Agency's pollution inventory.

For all other pollutants and other iron and steel sectors historic emission factors have been used when making future forecasts on emissions from this source and therefore assume no additional abatement from the current reported years emissions (currently 2002).

A2.9 CEMENT PRODUCTION

Projected growth in the construction industry (provided by OEF) is the driver of cement production. This sector is forecast to increase levels of activity between 2000 and 2010 by ~30%. Emission factors have been varied following discussions with Entec (Feb 04). For NO_x, an emission factor reduction of 44% between 2000 and 2010 has been applied to account for increasing use of alternative fuels and low NO_x burners to comply with IPPC and WID requirements. For PM_{10}, an emission factor reduction of 7% between 2000 and 2010 has been applied as a result of introducing additional upgrades to ESPs/fabric filters under WID and PPC. For SO_2, an emission factor reduction of 23% between 2000 and 2010 has been applied as a result of introducing a wet scrubber at one plant (as required for LAQM/PPC).

Despite the reduction in the PM_{10} & SO_2 emission factors in future years an increase in emissions is seen in this sector between 2001 and 2010. This is due to the large increase in activity in this sector outweighing any decreases in emission factor.

For NOx, PM_{10} & SO_2 post 2010, emission factors have been held at 2010 predicted levels.

Estimated emissions in Ktonnes from the cement sector.

Pollutant	2002	2010
NO_x	31.6	30.2
SO_2	23.1	29.3
PM_{10}	1.4	2.8

A2.10 PETROLEUM COKE CONSUMED IN REFINERIES

SO_2 emission factors from petroleum coke consumed in refineries have been reduced by 15% between 2000 and 2010. This is as a result of tail gas clean up at one plant, to meet LAQM and PPC (source: Entec, Feb 2004). For other pollutants the emissions have been kept constant in future years despite changes in activity levels (DTI).

A2.11 SULPHURIC ACID MANUFACTURE

SO_2 emission factors from sulphuric acid manufacture have been reduced by 22% between 2000 and 2010. This is as a result of installing a hydrogen peroxide tail gas scrubber to meet PPC requirements and reducing capacity at one of the UK's three plants. This reduction in capacity was included as part of the emission factor measures as the reductions achievable at this plant were not separated into those from the scrubber and those from the reduction in capacity.

A2.12 QUARRYING

Fugitive PM_{10} emission factors from quarrying have been reduced by 31% between 2000 and 2010. This is due to actions being taken including enclosure, paving, water sprays etc.

A2.13 OFF ROAD MACHINERY

Future emissions from the house and garden machinery sector have been taken from the following report: Emission factors programme Task 8 –Emission estimates for UK non-road mobile machinery in the lawn and garden sector (AEAT/ENV/R/1421) November 2003. The report suggests improved emission factors for this sector and provides future estimates of emissions taking into account EU Directive 2002/88/EC, which contains new emission limits for spark ignition internal combustion engines in the non-road mobile machinery sector.