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Predicting PM_{10} concentrations in the UK

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

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Executive Summary

The UK National Air Quality Strategy (NAQS) gives the following objective for PM_{10} to be achieved by the end of 2005:

- 24-hour running mean of 50 μgm^{-3}, measured as the 99th percentile.

The European Union 'Daughter Directive' gives the following limit values for PM_{10}:

- Stage 1, to be achieved by 1 January 2005: annual mean limit value of 40 μgm^{-3} and 24-hour limit value of 50μgm^{-3}, not to be exceeded more than 35 times a year (approximately equivalent to a 90th percentile of 50μgm^{-3}).
- Stage 2, to be achieved by 1 January 2010: annual mean limit value of 20 μgm^{-3} and 24-hour limit value of 50μgm^{-3}, not to be exceeded more than 7 times a year (approximately equivalent to a 98th percentile of 50μgm^{-3}).

The stage 2 limit values are indicative and will be reviewed in the light of information on health and environmental effects, technical feasibility and experience in the application of Stage 1 limit values in Member States.

The source apportionment of airborne particulate matter in the United Kingdom has recently been comprehensively reviewed by the Airborne Particle Expert Group in their first report. A new receptor modelling technique has been developed which has given new quantitative insights into the sources of PM_{10} in the UK. The receptor modelling technique was extended to provide forecasts of concentrations for comparison with the NAQS objective and EU 'Daughter Directive' limit values for PM_{10}. Projections of PM_{10} concentrations for 2005 were calculated by multiplying the individual contributions to daily particle concentrations by emissions reduction factors derived from model studies. The forecasts of emissions changes presented within the APEG report were for a 'business as usual' scenario, defined as the likely impact of current national and international policies on current emissions.

This report describes the further development of these receptor modelling and forecasting methods that has been carried out by air quality experts at AEA Technology Environment on behalf of the Department of the Environment Transport and the regions.

The projections that have been calculated for a business as usual scenario indicate that significant exceedences of the National Air Quality Strategy objective for PM_{10} are likely in 2005. Projected 99th percentiles are well in excess of 50 μgm^{-3} for urban background monitoring site locations in major cities and concentrations are also likely to be in excess of the objective in many smaller urban areas, particularly for years with elevated secondary particle concentrations, such as 1996.

The picture is similar for the EU 'Daughter Directive' indicative Stage 2 limit values for 2009, with exceedences in many areas likely with the business as usual scenario. Projected concentrations in 2004 are expected to be lower than the EU 'Daughter Directive' Stage 1 limit values at most urban background locations, with the possible exception of central London.

Concentrations at the roadside are expected to be higher than at nearby background locations. Concentrations higher than the EU Stage 1 limit value are therefore expected at the roadside of heavily trafficked roads in urban areas in 2004. Concentrations at sites with significant industrial source contributions to measured ambient PM_{10} concentrations are also expected to be at risk of exceeding this limit value.

Contents

1 Introduction

The UK National Air Quality Strategy (NAQS) gives the following objective for PM_{10} to be achieved by the end of 2005:

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The stage 2 limit values are indicative and will be reviewed in the light of information on health and environmental effects, technical feasibility and experience in the application of Stage 1 limit values in Member States.

The source apportionment of airborne particulate matter in the United Kingdom has recently been comprehensively reviewed by the Airborne Particle Expert Group in their first report (APEG, 1998). A new receptor modelling technique has been developed which has given new quantitative insights into the sources of PM_{10} in the UK. The receptor modelling technique was extended to provide forecasts of concentrations for comparison with the NAQS objective and EU 'Daughter Directive' limit values for PM_{10}. Projections of PM_{10} concentrations for 2005 were calculated by multiplying the individual contributions to daily particle concentrations by emissions reduction factors derived from model studies. The forecasts of emissions changes presented within the APEG report were for a 'business as usual' scenario, defined as the likely impact of current national and international policies on current emissions.

This report describes the further development of these receptor modelling and forecasting methods that has been carried out by air quality experts at AEA Technology Environment on behalf of the Department of the Environment Transport and the Regions.

Section 2 provides a brief summary of the receptor modelling technique and projection results presented in the APEG report. Projections for a 'business as usual' were calculated for eight city centre monitoring site locations based on both 1995 and 1996 measurement data. Similar projections based on 1995 and 1996 data for additional monitoring site locations are presented in section 3. Section 4 provides a detailed analysis of the PM_{10} concentrations that are likely to result from a range of alternative emissions reduction scenarios. These projections show the relative lack of sensitivity of the forecast concentrations to extreme changes in emissions.

The receptor modelling methods have also been applied to 1997 monitoring data and section 5 provides a comprehensive review of projections based on this data and a comparison with the projections based on 1995 and 1996 data. Methods for projecting concentrations at roadside and industrial sites are presented in sections 6 and 7. Some alternative emission reduction scenarios have been examined for sites that are likely to exceed the EU Stage 1 24-hour limit value in 2004 for the business as usual scenario. These are listed in section 9. Projections of both PM_{10} and $PM_{2.5}$ are presented in section 9. These are based on approximately one year of monitoring data at the four sites at which $PM_{2.5}$ measurements commenced during the summer of 1997.

The majority of the national modelling of future PM_{10} concentrations carried out by AEA Technology Environment has been done on an individual monitoring site basis. This enables the receptor modelling and projections to be firmly based on actual observations of current PM_{10} concentrations. Maps of both current and projected PM_{10} concentrations are however required for the quantification of health impacts similar to those presented by COMEAP (1998). While maps of annual mean PM_{10} concentrations have been presented by Stedman (1998), this report provides the first maps of annual means and numbers of exceedence days for comparison with PM_{10} objectives and limit values. The daily PM_{10} mapping methods that have been developed are presented in section 10. The use of these mapping methods does, however, increase the uncertainty of the projections compared with those for individual sites.

2 Summary of PM_{10} projections presented in the APEG report

2.1 RECEPTOR MODELLING

A receptor modelling technique has been developed which enables the measured daily mean PM_{10} concentration at a monitoring site to be divided into three components (APEG, 1998, Stedman, 1997):

- primary combustion particles
- secondary particles
- ‘other’ particles

A multiple regression analysis is carried out to determine the coefficients *A* and *B* for primary combustion and secondary particle concentrations. Either black smoke measurements or oxides of nitrogen (NO_x) measurements are used as an indicator for primary combustion particles and rural sulphate measurements are used as an indicator for secondary particles:

$$[measured\ PM_{10}] = A_{bs}\ [measured\ black\ smoke] + B\ [measured\ sulphate] + C$$

or

$$[measured\ PM_{10}] = A_{NOx}\ [measured\ NO_x] + B\ [measured\ sulphate] + C$$

The daily mean concentration of 'other' particles is determined by difference.

2.2 NAQS PROJECTIONS FOR 8 SITES BASED ON 1995 AND 1996 DATA

The PM_{10} receptor model that has been developed enables us to make relatively sophisticated estimates of both annual mean and high percentile PM_{10} concentrations for future years. The key advantage of this method is that the PM_{10} concentrations have been separated into their component parts and appropriate reductions can be applied to these components, based on an understanding of the likely impact of current policies on future levels. The emission reduction factors that have been used to calculate the predictions based on 1996 data are summarised in Table 2.1. The factors for 1995 are slightly different.

Table 2.1. Emission reduction factors used to calculate projections for 2005 and 2010, relative to 1996 values.

Year	Urban traffic exhaust	Other Urban prim ary	Urban primary combustion, GB	Urban primary combustion, NI	Secondary particles	'other' particles
2005	0.51	1.00	0.63	0.75	0.81	1.00
2010	0.37	1.00	0.53	0.69	0.70	1.00

Projections for urban road traffic exhaust emissions of PM_{10} within the UK National Atmospheric Emissions Inventory (NAEI) show that these emissions are expected to reduce to approximately half their 1996 values by 2005 (Salway *et al*, 1997, Goodwin *et al*, 1997, Murrells, 1998). We have assumed that 75% of 1996 primary emissions in UK cities were from traffic exhaust and 25% from other local sources and the latter emissions were assumed to remain at 1996 levels in 2005 and 2010. This 75% is an average of the split between traffic and other sources across major cities in Great Britain. Across all of the urban areas in Great Britain the split is 67% whereas in London 91% of primary emissions is from traffic exhausts sources. Coal use currently contributes substantially more to primary particle concentrations in urban areas of Northern Ireland (NI) than is generally the case in urban areas in GB. We have assumed that non-traffic exhaust emissions contributed 50% of the total of urban emissions in 1996 in NI and that these emissions will remain at 1996 levels.

The factors for secondary particle concentrations future years in the UK have been based on the results of the EMEP modelling of secondary particles over Europe (Tarrason and Tsyro, 1998), which showed that levels in 2010 are likely to be about 70% of 1996 levels on the basis of current policies. It has been assumed that this reduction up to 2010 will be linear, leading to an estimate of concentration in 2005 being equal to 0.81 times the current values.

It has been assumed that the 'other' particle concentration will remain at 1996 levels in all future years.

This analysis directly provides an estimate of the 99th percentile of daily mean PM_{10} concentrations, so one additional step is required to provide an estimate of the value required for comparison with the NAQS objective. The 99th percentile of the daily maximum of running 24-hour mean PM_{10} concentration (NAQS 99th percentile) is generally slightly higher than the 99th percentile of daily values, by a factor of about 1.16 (Figure 2.1). This is largely due to primary particle episodes, which are generally of shorter duration than secondary particle episodes causing daily maximum 24-hour running mean concentrations to be higher than fixed daily means. This factor of 1.16 tends to overestimate the NAQS 99^{th} percentile in years dominated by secondary particle episodes such as 1996, while underestimating values in years such as 1995, where high percentiles were less dominated by secondary particle episodes. It should also be noted that this factor of 1.16 is unlikely to remain constant in future years and may reduce as the traffic exhaust contribution to urban PM_{10} becomes smaller. This therefore increases the uncertainty of the estimates of NAQS 99th percentiles presented in this report. The number of days per year with running 24-hour PM_{10} concentrations greater than 50 μgm^{-3} (NAQS days) is also greater than the number of days with fixed daily means above this threshold. The number of NAQS days is currently approximately 1.8 times the number of fixed days above 50 μgm^{-3}. Since this is a large correction factor and it is likely to change in future years, we have not applied it to the number of days with concentrations above 50 μgm^{-3} presented in this report and have presented a value for fixed daily means only.

The estimated PM_{10} concentrations for 2005 and 2010 presented in the APEG report for the business as usual scenario are reproduced in Table 2.2. This table shows predictions for comparison with the NAQS objective.

The estimated NAQS 99^{th} percentiles for 2005 based on both 1996 and 1995 meteorology are higher than 50 $\mu g\ m^{-3}$ (much higher than 50 $\mu g\ m^{-3}$ for 1996 meteorology) indicating that current policies are unlikely to deliver compliance with the objective for 2005 at city centre locations.

Table 2.2. Estimated annual means and 99th percentiles of PM_{10} concentrations including predictions for 2005 and 2010 (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
Annual mean								
1996	30	25	26	26	23	24	19	25
1995	28	23	24	-	22	24	20	27
NAQS 99th percentile								
1996	100	94	87	85	100	94	62	86
1995	80	77	70	-	71	95	61	72
Fixed daily means above 50μgm^{-3}								
1996	37	20	18	21	14	18	6	22
1995	24	11	11	-	9	13	8	28
Annual mean								
2005 estimate based on 1996	25	20	22	22	19	21	17	21
2005 estimate based on 1995	23	19	19	-	18	21	18	22
2010 estimate based on 1996	23	18	20	20	18	20	16	19
2010 estimate based on 1995	21	17	18	-	16	20	17	21
NAQS 99th percentile								
2005 estimate based on 1996	82	76	70	71	82	76	55	70
2005 estimate based on 1995	69	65	57	-	57	82	57	63
2010 estimate based on 1996	76	69	64	65	72	70	53	64
2010 estimate based on 1995	65	58	52	-	52	79	55	61
Fixed daily means above 50μgm^{-3}								
2005 estimate based on 1996	11	13	7	8	10	9	4	10
2005 estimate based on 1995	9	6	2	-	2	8	3	9
2010 estimate based on 1996	9	7	6	6	7	6	2	7
2010 estimate based on 1995	9	3	0	-	2	8	2	6

2.3 EU DAUGHTER DIRECTIVE PROJECTIONS FOR 8 SITES BASED IN 1995 AND 1996 DATA

The estimates of PM_{10} concentrations presented in Table 2.3 and 2.4 have been multiplied by 1.3 for comparison with the EU limit values. This is to take into account the difference between TEOM (Tapered Element Oscillating Microbalance) measurements of PM_{10} and the EU reference gravimetric method. While there is considerable uncertainty to the exact relationship between TEOM and gravimetric measurements, we have chosen to use a factor of 1.3 as a conservative approach.

In contrast to the projections calculated for comparison with the NAQS objective, the projections of percentiles and numbers of days above 50 μgm^{-3} can be calculated directly from the results of the receptor models because the limit value is for fixed daily means. The EU Stage 1 and Stage 2 limit values will apply for 1 January 2005 and 1 January 2010 respectively. Projections for comparison with these limit values should therefore ideally be calculated for 2004 and 2009, rather than 2005 and 2010. Projections for 2005 and 2010 for comparison with the EU limit values were, however, presented in the APEG report for easy of computation and consistency with the NAQS projections. We have therefore adopted this approach for all of the 1996 and 1995 base year projections presented in this report. Projections based on 1997 data have been calculated for 2005 for comparison with the NAQS and for 2004 and 2009 for comparison with the EU limit values.

Table 2.3 PM_{10} concentrations 1996 and 1995 (μgm^{-3}) for comparison with EU 'Daughter' Directive limit values

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
1996	39	33	34	34	30	31	25	33
1995	36	30	31	-	29	31	26	35
				Stage 1 EU 90th percentile of fixed daily means				
1996	68	52	57	55	51	55	39	55
1995	60	48	55	-	46	50	42	62
				Stage 2 EU 98th percentile of fixed daily means				
1996	91	86	81	84	86	81	61	87
1995	83	72	74	-	70	77	67	76
				Fixed daily means above 50 μgm^{-3}				
1996	65	38	40	39	39	44	14	48
1995	58	30	33	-	25	35	19	60

Predictions of PM_{10} concentrations for 2005 and 2010 for comparison with the 'Daughter Directive' have been made based on 1995 and 1996 analysis. A "business as usual" primary emissions reduction scenario, blanket reduction of secondary particle concentrations using EMEP coefficients have been used in the calculations. Current national policies are likely to deliver concentrations lower than the Stage 1 90th percentile limit value except possibly in central

London. For Stage 2 the 98th percentile and the annual limit value are likely to be exceeded at all sites (Table 2.4).

Table 2.4 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis ($\mu g m^{-3}$)

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
Annual mean								
2005 estimate based on 1996	33	26	29	29	25	27	22	27
2005 estimate based on 1995	30	25	25	-	23	27	23	29
2010 estimate based on 1996	30	23	26	26	23	26	21	25
2010 estimate based on 1995	27	22	23	-	21	26	22	27
Stage 1 EU 90th percentile of fixed daily means								
2005 estimate based on 1996	54	42	45	46	42	47	35	45
2005 estimate based on 1995	49	40	43	-	37	44	36	51
2010 estimate based on 1996	50	39	43	42	37	43	33	41
2010 estimate based on 1995	45	38	39	-	34	42	35	46
Stage 2 EU 98th percentile of fixed daily means								
2005 estimate based on 1996	80	72	67	70	69	67	53	69
2005 estimate based on 1995	72	60	59	-	57	70	55	66
2010 estimate based on 1996	73	65	61	61	61	62	50	62
2010 estimate based on 1995	67	56	56	-	51	67	52	62
Fixed daily means above 50$\mu g m^{-3}$								
2005 estimate based on 1996	42	23	23	23	18	27	8	22
2005 estimate based on 1995	33	14	18	-	12	22	12	34
2010 estimate based on 1996	31	19	15	14	12	19	6	19
2010 estimate based on 1995	27	9	12	-	8	21	9	27

2.4 UNCERTAINTIES IN THE RECEPTOR MODELLING OF THE 'OTHER' PARTICLE CONCENTRATION

It was noted in the APEG report that all of the 8 cities for which projections were calculated had several days with estimated daily mean 'other' particle concentrations in the range of 25 - 30 µg m^{-3} in both 1995 and 1996. It is impossible to know if these days are coarse particle episodes or are due to an underestimate of the primary or secondary contribution. For projections to 2005 or 2010 these days can have a significant influence on the 99th percentile. This is important because the other particle concentrations are assumed to remain unchanged between now and 2005 and 2010, while the contributions from the other sources are expected to reduce.

Table 2.5 lists the maximum and 99th percentile of fixed daily mean 'other' particle concentrations within the model.

Table 2.5 Maximum and 99th percentile of fixed daily mean 'other' particle concentrations within the model (µg m^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpoo l Centre
1996 max	47	50	66	54	43	30	36	50
1996 99%ile	28	29	31	26	20	26	21	29
1995 max	44	45	29	-	41	44	44	44
1995 99%ile	37	33	33	-	23	35	34	42

These can be compared with the coarse particle concentration derived from the difference between co-located PM_{10} and $PM_{2.5}$ measurements (Table 2.6).

Table 2.6 Maximum and 99th percentile of fixed daily mean coarse particle concentrations from co-located PM_{10} and $PM_{2.5}$ measurements (µg m^{-3})

	London Bloomsbury 19/6/97-27/8/98	Rochester 21/5/97-27/8/98	Marylebone Road 17/7/97-27/8/98	Birmingham Hodge Hill 1/1/95-31/12/95	Birmingham Hodge Hill 1/1/96-30/9/96
max	39	44	29	57	20
99%ile	21	20	27	27	19

The measured coarse particle 99th percentile concentrations look perhaps 10 µg m^{-3} lower than the 99th percentile 'other' particle concentration in the model, although it is not possible to make a direct comparison.

This uncertainty in the daily variation of the 'other' particle concentration within the receptor modelling applies to all of the projections presented in the APEG report and in this current report.

2.5 ALTERNATIVE MODEL OF DAILY PM_{10} CONCENTRATIONS USING NO_X MEASUREMENTS

One of the limitations of the method that has been used to assign the contributions to daily PM_{10} concentrations from different sources is that the concentration of particles that are neither primary combustion related or secondary has been calculated as the difference between the measured PM_{10} concentration and the estimated total of primary and secondary. Any contribution to measured PM_{10} concentrations that does not exhibit a similar temporal variation to either black smoke or sulphate is therefore included as ‘other’ particles.

An alternative regression model of daily PM_{10} concentrations, which utilises NO_x measurements instead of black smoke measurements as an indicator for the primary particles was also presented in the APEG report. This has the advantage that the NO_x measurements are directly co-located with the PM_{10} measurements but an implicit assumption in this model is of common sources for NO_x and primary PM_{10}. While the black smoke monitoring method includes greater uncertainties than NO_x measurements, it has the advantage of more directly sampling the atmospheric particle concentration.

The regression coefficients for this NO_x-based model are compared with the black smoke based model in Tables 2.7 and 2.8. The correlation coefficients are very similar. The intercept, C, is generally several $\mu g\ m^{-3}$ lower than for NO_x than for the black smoke-based regressions; the difference being PM_{10} that has now been assigned to either primary or secondary instead of ‘other’. Estimates of PM_{10} concentrations for 2005 and 2010 have also been calculated using this NO_x based model and were found to be very similar to those listed in Table 2.2. The similarity of the predictions based on the black smoke and NO_x based models increases our confidence in the projections and also enables the calculation of projections based on either black smoke or NO_x as the indicator for combustion primary PM_{10}.

Table 2.7 Regression coefficients for Black Smoke and Sulphate receptor modelling of 1996 PM_{10} data

	Smoke coefficient, A	SO_4 coefficient, B	Intercept, C	r^2
London Bloomsbury	0.64	2.26	10.96	0.78
Birmingham Centre	0.59	2.41	8.30	0.71
Bristol Centre	1.03	2.35	10.83	0.70
Manchester Piccadilly	0.60	2.46	9.77	0.74
Newcastle Centre	0.66	3.13	7.73	0.84
Belfast Centre	0.71	2.30	9.21	0.79
Edinburgh Centre	0.59	2.46	9.85	0.61
Liverpool Centre	0.92	2.46	9.79	0.76

Table 2.8 Regression coefficients for NO_x and Sulphate receptor modelling of 1996 PM_{10} data (NO_x concentration expressed in ppb)

	NO_x coefficient, A	SO_4 coefficient, B	Intercept C	r^2
London Bloomsbury	0.112	2.55	9.29	0.74
Birmingham Centre	0.207	2.29	6.52	0.72
Bristol Centre	0.145	2.62	7.97	0.76
Manchester Piccadilly	0.160	2.95	7.69	0.74
Newcastle Centre	0.155	3.48	5.66	0.83
Belfast Centre	0.302	2.65	5.91	0.85
Edinburgh Centre	0.122	2.99	6.42	0.67
Liverpool Centre	0.187	2.56	7.57	0.76

3 PM_{10} Projections for 12 additional sites based on 1995 and 1996 data

3.1 PROJECTIONS FOR COMPARISON WITH NAQS OBJECTIVE

Projections for comparison with the NAQS objective have been calculated for an additional 12 monitoring sites using PM_{10} measurement data for 1996 and 1995 (where available) and these projections are shown in tables 3.1 and 3.2. A receptor model using daily mean NO_x and sulphate concentrations has been used along with a business as usual emissions scenario. The projected NAQS 99th percentile is greater than 50 μgm^{-3} for all projections based on 1996 data. The 99th percentiles predicted on the basis of 1995 are just below 50 μgm^{-3} for Leicester Centre and Southampton Centre.

3.2 EU DAUGHTER DIRECTIVE PROJECTIONS

Projections for comparison with the EU Daughter Directive limit values have also been calculated for these additional 12 sites and are shown in tables 3.3 and 3.4. The Stage 1 24-hour limit value is seen to be at risk of being exceeded at Swansea and Sheffield centre site for the business as usual scenario. The Stage 2 limit value is likely to be exceeded at most sites. As before, the TEOM PM_{10} measurements have been multiplied by a factor of 1.3 for comparison with the EU limit values.

Table 3.1 PM_{10} concentrations 1996 and 1995 (μgm^{-3})

	Rochester	Cardiff Centre	Leeds Centre	Birmingham East	Hull Centre	Leicester Centre	Southampton Centre	London Bexley	Swansea	Middlesbrough	Sheffield Centre	Wolverhampton Centre
							Annual mean					
1996	23	26	27	23	25	22	23	25	24	21	28	26
1995	-	25	25	22	24	20	22	24	27	-	-	-
							NAQS 99th percentile					
1996	88	83	87	88	94	82	81	93	76	78	102	103
1995	-	65	83	84	73	59	61	83	75	-	-	-
							Fixed daily means above $50\mu gm^{-3}$					
1996	16	18	28	15	21	12	12	22	11	13	33	18
1995	-	12	20	9	12	4	8	16	21	-	-	-

Table 3.2 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, nitrogen oxides and sulphate data, "business as usual" primary and secondary emissions reduction scenario (μgm^{-3})

	Rochester	Cardiff Centre	Leeds Centre	Birmingham East	Hull Centre	Leiceste r Centre	Southampton Centre	London Bexley	Swansea	Middlesbrough	Sheffield Centre	Wolverhampton Centre
							Annual mean					
2005 estimate based on 1996	19	22	21	18	20	18	19	20	21	19	21	20
2005 estimate based on 1995	-	20	19	18	19	16	17	20	24	-	-	-
2010 estimate based on 1996	17	20	18	17	19	16	17	18	20	17	19	18
2010 estimate based on 1995	-	18	17	16	18	15	15	19	22	-	-	-
							NAQS 99th percentile					
2005 estimate based on 1996	74	71	72	72	76	69	67	78	68	67	86	81
2005 estimate based on 1995	-	57	65	62	63	49	49	73	67	-	-	-
2010 estimate based on 1996	66	67	66	64	67	64	61	70	65	61	78	71
2010 estimate based on 1995	-	53	59	57	57	45	46	69	67	-	-	-
							Fixed daily means above $50\mu gm^{-3}$					
2005 estimate based on 1996	8	9	13	12	13	7	5	10	7	9	17	11
2005 estimate based on 1995	-	2	6	6	5	0	1	10	11	-	-	-
2010 estimate based on 1996	7	9	9	7	10	5	5	8	6	11	13	10
2010 estimate based on 1995	-	2	4	2	3	0	1	9	8	-	-	-

Table 3.3 PM_{10} concentrations 1996 and 1995 (μgm^{-3}) for comparison with EU 'Daughter' Directive limit values

	Rochester	Cardiff Centre	Leeds Centre	Birmingham East	Hull Centre	Leicester Centre	Southampton Centre	London Bexley	Swansea	Middlesbrough	Sheffield Centre	Wolverhampton Centre
Annual mean												
1996	30	34	35	30	33	29	30	33	31	27	36	34
1995	-	33	33	29	31	26	29	31	35	-	-	-
EU 90th percentile												
1996	51	52	58	50	54	46	50	57	48	50	63	63
1995	-	51	55	47	49	42	48	52	58	-	-	-
EU 98th percentile												
1996	77	83	93	83	90	75	71	88	70	84	101	99
1995	-	70	82	75	70	60	66	83	79	-	-	-
Fixed daily means above 50μgm^{-3}												
1996	36	35	65	32	42	24	36	46	30	37	61	45
1995	-	33	48	24	34	18	17	40	48	-	-	-

Table 3.4 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, nitrogen oxides and sulphate data, "business as usual" primary and secondary emissions reduction scenario (μgm^{-3}) for comparison with EU 'Daughter' Directive limit values

	Rochester	Cardiff Centre	Leeds Centre	Birmingham East	Hull Centre	Leicester Centre	Southampton Centre	London Bexley	Swansea	Middlesbrough	Sheffield Centre	Wolverhampton Centre
Annual mean												
2005 estimate based on 1996	25	29	27	23	26	23	25	26	27	25	27	26
2005 estimate based on 1995	-	26	25	23	25	21	22	26	31	-	-	-
2010 estimate based on 1996	22	26	23	22	25	21	22	23	26	22	25	23
2010 estimate based on 1995	-	23	22	21	23	20	20	25	29	-	-	-
EU 90th percentile												
2005 estimate based on 1996	42	43	48	41	44	37	41	48	44	44	50	47
2005 estimate based on 1995	-	43	42	38	40	34	35	44	52	-	-	-
2010 estimate based on 1996	37	41	44	36	39	34	36	43	41	40	46	41
2010 estimate based on 1995	-	39	38	34	46	31	31	41	48	-	-	-
EU 98th percentile												
2005 estimate based on 1996	64	72	76	70	76	62	59	72	65	71	82	77
2005 estimate based on 1995	-	60	63	55	58	48	53	73	71	-	-	-
2010 estimate based on 1996	59	66	69	65	71	57	54	66	64	66	74	71
2010 estimate based on 1995	-	55	57	50	53	44	47	69	67	-	-	-
Fixed daily means above $50\mu gm^{-3}$												
2005 estimate based on 1996	24	24	31	17	25	13	16	28	22	23	36	19
2005 estimate based on 1995	-	15	22	17	25	13	8	28	38	-	-	-
2010 estimate based on 1996	14	19	20	15	20	10	10	19	18	18	27	16
2010 estimate	-	9	16	15	20	10	4	22	30	-	-	-

based on 1995

4 PM_{10} Projections for alternative emissions scenarios

The PM_{10} projections presented in the APEG report represent our current best estimates of the likely impact of current national and international policy measures on PM_{10} concentrations in the UK. PM_{10} projections for a range of alternative scenarios are presented in this section and the receptor modelling results are clearly relatively insensitive, even to extreme reductions in either primary or secondary particle concentrations. At least to some extent, this is due to high concentrations of ‘other’ particles within the receptor modelling (section 2.4). Projections for comparison with the NAQS objective are listed in Tables 4.1 to 4.8. The scenarios that we have examined include emissions reductions additional to those assumed in the business as usual scenario. The reductions listed below are all relative to business as usual. The non-traffic primary combustion PM_{10} contribution and the ‘other’ particle contribution are held at 1996/1995 levels in all scenarios:

Table	Primary	Secondary
Table 4.1	50% less traffic emissions	business as usual
Table 4.2	100% less traffic emission	business as usual
Table 4.3	business as usual	50% less secondary
Table 4.4	50% less traffic emissions	50% less secondary
Table 4.5	100% less traffic emission	50% less secondary
Table 4.6	business as usual	100% less secondary
Table 4.7	50% less traffic emissions	100% less secondary
Table 4.8	100% less traffic emission	100% less secondary

It should be noted that no specific policy measures have been identified which could achieve the reductions implied by these alternative scenarios.

Table 4.1 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, 50% reduction of traffic emissions, "business as usual" secondary particle concentrations (mgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	23	19	20	20	18	20	16	19
2005 estimate based on 1995	22	18	18	-	16	20	17	21
2010 estimate based on 1996	22	18	19	19	17	19	15	18
2010 estimate based on 1995	20	16	17	-	15	19	16	20
				NAQS 99th percentile				
2005 estimate based on 1996	78	67	66	68	79	74	52	65
2005 estimate based on 1995	67	58	53	-	54	77	56	62
2010 estimate based on 1996	72	64	64	63	70	69	51	60
2010 estimate based on 1995	63	53	50	-	50	76	55	60
				Fixed daily means above 50µgm^{-3}				
2005 estimate based on 1996	11	8	6	7	10	7	3	7
2005 estimate based on 1995	9	3	13	-	2	8	3	6
2010 estimate based on 1996	8	6	5	4	6	6	1	5
2010 estimate based on 1995	8	2	0	-	2	8	2	6

Table 4.2 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, 100% reduction of traffic emissions, "business as usual" secondary particle concentrations (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	22	18	19	19	17	16	15	18
2005 estimate based on 1995	20	16	17	-	15	17	16	20
2010 estimate based on 1996	20	17	18	18	16	16	15	17
2010 estimate based on 1995	19	15	16	-	14	16	16	19
				NAQS 99th percentile				
2005 estimate based on 1996	71	61	65	65	77	55	50	60
2005 estimate based on 1995	65	53	51	-	51	62	55	61
2010 estimate based on 1996	69	58	61	61	68	55	48	57
2010 estimate based on 1995	63	52	50	-	48	62	54	59
				Fixed daily means above $50\mu gm^{-3}$				
2005 estimate based on 1996	9	7	6	4	8	3	3	6
2005 estimate based on 1995	9	2	0	-	2	6	3	4
2010 estimate based on 1996	6	3	4	4	6	3	1	4
2010 estimate based on 1995	7	2	0	-	1	5	1	4

Table 4.3 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, “business as usual” primary emissions reduction scenario, 50% reduction of secondary particle concentrations (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	21	16	19	18	15	18	15	18
2005 estimate based on 1995	20	16	15	-	14	19	16	20
2010 estimate based on 1996	19	15	17	17	14	17	14	16
2010 estimate based on 1995	18	14	14	-	13	18	15	19
				NAQS 99th percentile				
2005 estimate based on 1996	64	56	57	58	52	61	45	56
2005 estimate based on 1995	60	56	50	-	45	80	52	58
2010 estimate based on 1996	59	51	53	53	49	58	42	50
2010 estimate based on 1995	57	51	49	-	43	77	50	57
				Fixed daily means above $50\mu gm^{-3}$				
2005 estimate based on 1996	6	3	2	4	3	4	0	3
2005 estimate based on 1995	5	2	0	-	0	7	2	3
2010 estimate based on 1996	4	3	2	2	1	4	0	2
2010 estimate based on 1995	3	2	0	-	0	7	1	2

Table 4.4 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, 50% reduction in traffic emissions, 50% reduction of secondary particle concentrations (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	19	15	17	17	14	17	14	16
2005 estimate based on 1995	18	14	14	-	13	18	15	18
2010 estimate based on 1996	18	14	16	16	13	17	13	15
2010 estimate based on 1995	17	14	13	-	12	17	14	18
				NAQS 99th percentile				
2005 estimate based on 1996	60	53	53	55	50	59	43	52
2005 estimate based on 1995	57	51	47	-	42	75	51	57
2010 estimate based on 1996	56	49	50	50	48	57	41	47
2010 estimate based on 1995	56	50	46	-	40	74	50	56
				Fixed daily means above $50\mu gm^{-3}$				
2005 estimate based on 1996	5	2	2	2	3	4	0	3
2005 estimate based on 1995	3	2	0	-	0	7	1	3
2010 estimate based on 1996	3	2	2	1	1	3	0	2
2010 estimate based on 1995	2	2	0	-	0	6	1	1

Table 4.5 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, 100% reduction in traffic emissions, 50% reduction of secondary particle concentrations (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	17	14	16	15	13	14	13	15
2005 estimate based on 1995	17	13	13	-	12	15	14	17
2010 estimate based on 1996	17	13	15	15	13	14	13	14
2010 estimate based on 1995	16	13	12	-	11	14	14	17
				NAQS 99th percentile				
2005 estimate based on 1996	55	50	49	51	48	47	41	48
2005 estimate based on 1995	55	48	44	-	40	60	50	55
2010 estimate based on 1996	53	47	47	48	46	44	39	44
2010 estimate based on 1995	54	47	43	-	38	60	49	55
				Fixed daily means above $50\mu gm^{-3}$				
2005 estimate based on 1996	2	1	2	1	1	0	0	2
2005 estimate based on 1995	1	2	0	-	0	4	1	0
2010 estimate based on 1996	2	1	2	1	1	0	0	2
2010 estimate based on 1995	1	1	0	-	0	4	1	0

Table 4.6 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, "business as usual" primary emissions reduction scenario, 100% reduction of secondary particle concentrations (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	16	13	15	15	11	16	12	15
2005 estimate based on 1995	16	12	10	-	11	17	14	17
2010 estimate based on 1996	16	12	15	14	11	15	12	14
2010 estimate based on 1995	15	12	10	-	10	16	13	16
				NAQS 99th percentile				
2005 estimate based on 1996	46	48	47	41	34	55	37	45
2005 estimate based on 1995	52	50	48	-	38	78	47	53
2010 estimate based on 1996	44	45	44	39	32	53	36	43
2010 estimate based on 1995	50	49	47	-	36	75	46	52
				Fixed daily means above $50\mu gm^{-3}$				
2005 estimate based on 1996	1	2	1	2	0	3	0	2
2005 estimate based on 1995	1	0	0	-	0	7	0	2
2010 estimate based on 1996	1	2	1	2	0	3	0	2
2010 estimate based on 1995	0	0	0	-	0	6	0	1

Table 4.7 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, 50% reduction in traffic emissions, 100% reduction in secondary particle concentrations (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	15	11	14	14	10	15	12	13
2005 estimate based on 1995	14	11	9	-	10	16	13	16
2010 estimate based on 1996	14	11	14	13	10	14	11	13
2010 estimate based on 1995	14	11	9	-	9	15	13	15
				NAQS 99th percentile				
2005 estimate based on 1996	41	43	41	38	31	50	35	42
2005 estimate based on 1995	49	48	44	-	36	73	46	52
2010 estimate based on 1996	40	41	39	37	30	48	35	41
2010 estimate based on 1995	49	48	42	-	35	72	45	51
				Fixed daily means above $50\mu gm^{-3}$				
2005 estimate based on 1996	1	2	1	1	0	3	0	2
2005 estimate based on 1995	0	0	0	-	0	6	0	0
2010 estimate based on 1996	1	1	1	1	0	3	0	2
2010 estimate based on 1995	0	0	0	-	0	6	0	0

Table 4.8 Predicted PM_{10} concentrations for 2005 and 2010 based on 1996 and 1995 analysis. Individual site analysis of PM_{10}, black smoke and sulphate data, 100% reduction in traffic emissions, 100% reduction of secondary particle concentrations (μgm^{-3})

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Newcastle Centre	Belfast Centre	Edinburgh Centre	Liverpool Centre
				Annual mean				
2005 estimate based on 1996	13	10	13	12	9	11	11	12
2005 estimate based on 1995	13	10	8	-	9	12	12	14
2010 estimate based on 1996	13	10	13	12	9	11	11	12
2010 estimate based on 1995	13	10	8	-	9	12	12	14
				NAQS 99th percentile				
2005 estimate based on 1996	38	38	37	34	27	39	34	38
2005 estimate based on 1995	47	44	41	-	32	55	44	50
2010 estimate based on 1996	38	38	37	34	27	39	34	38
2010 estimate based on 1995	47	44	41	-	32	55	44	50
				Fixed daily means above 50μgm^{-3}				
2005 estimate based on 1996	1	1	1	1	0	0	0	1
2005 estimate based on 1995	0	0	0	-	0	3	0	0
2010 estimate based on 1996	1	1	1	1	0	0	0	1
2010 estimate based on 1995	0	0	0	-	0	3	0	0

5 PM_{10} Projections based on 1997 monitoring data

5.1 INTRODUCTION

There was a substantial increase in the number of automatic PM_{10} monitoring sites within the DETR national monitoring networks during 1996 and 1997. This has enabled us to calculate projections from a 1997 base year for many more sites than was possible for 1996 and 1995. Projections for urban background and rural sites are discussed in this section and the results are compared with those for the 1996 and 1995 base years. The extension of the receptor modelling methods to roadside and industrial sites is discussed in sections 6 and 7.

5.2 PROJECTIONS FOR URBAN BACKGROUND SITES

Projections of PM_{10} concentrations have been calculated for comparison with both the NAQS objective and the EU Daughter Directive limit values. These projections are based on an analysis of 1997 monitoring data for a total of 30 sites classified as either urban background, urban centre, suburban or rural. We have used daily measurements of PM_{10} and NO_x at each site along with rural sulphate values. A regression analysis then enables us to divide the measured roadside PM_{10} concentrations into the following components

- primary (based on the site NO_x)
- secondary (based on rural sulphate)
- other (largely background coarse, calculated by difference)

The regression coefficients obtained for these 30 sites are listed in Table 5.1. The data for most urban sites fit the model reasonably well, with coefficients close to those calculated using 1995 and 1996 data.

Table 5.1 Regression coefficients for NO_x and Sulphate receptor modelling of 1997 PM_{10} data (NO_x concentration expressed in ppb)

	NO_x	SO_4	Intercept	r^2
Belfast Centre	0.322	2.25	7.66	0.65
London Bexley	0.133	2.50	7.36	0.71
Birmingham East	0.147	1.96	8.28	0.66
Birmingham Centre	0.171	1.78	8.48	0.61
London Bloomsbury	0.121	2.27	8.55	0.62
Bolton	0.163	2.24	6.96	0.64
London Brent	0.110	2.75	7.22	0.73
Bristol Centre	0.138	1.43	10.42	0.76
Cardiff Centre	0.169	1.94	12.89	0.45
Derry	0.423	1.77	11.21	0.49
Edinburgh Centre	0.095	2.94	7.38	0.61
Glasgow Centre	0.126	2.82	8.61	0.60
London Hillingdon	0.099	2.50	5.37	0.75
Hull Centre	0.162	2.18	10.38	0.27
London N. Kensington	0.131	2.30	8.95	0.78
Leamington Spa	0.173	1.81	8.65	0.57
Leeds Centre	0.201	2.75	7.08	0.44
Leicester Centre	0.142	2.33	7.35	0.65
Liverpool Centre	0.190	1.76	9.12	0.62
London Eltham	0.117	2.31	8.02	0.71
Manchester Piccadilly	0.187	1.89	8.56	0.63
Narberth	0.781	1.14	7.43	0.44
Newcastle Centre	0.144	2.08	8.35	0.61
Nottingham Centre	0.171	2.34	6.97	0.70
Rochester	0.194	1.97	9.08	0.54
Sheffield Centre	0.173	2.46	7.26	0.72
Southampton Centre	0.142	2.08	9.20	0.72
Stockport	0.146	1.96	7.95	0.67
Thurrock	0.146	2.59	7.44	0.64
Wolverhampton Centre	0.233	2.22	5.48	0.71

PM_{10} concentration forecasts were calculated using these coefficients and the business as usual scenario. These projections are listed in Table 5.3 and the results have been compared with NAQS objective and EU limit values:

NAQS -	2005: 99 th percentile not to exceed 50 μgm^{-3}.
EU Stage 1 -	2004: 90 th percentile not to exceed 50 μgm^{-3}; with the maximum annual mean of 40 μgm^{-3}.
EU Stage 2 -	2009: 98 th percentile not to exceed 50 μgm^{-3}; with the maximum annual mean of 20μgm^{-3}.

The results listed in Table 5.2 suggest that most sites would exceed the NAQS 2005 99th percentile objective for the business as usual scenario. All sites should achieve the EU stage 1 and 2 objectives for annual mean. Leeds is the only site predicted to exceed the EU stage 1 2004 90th percentile target. However, many sites - Belfast Centre, London Bexley, Bloomsbury, Derry, London Hillingdon, Hull Centre, London N. Kensington, Leeds Centre, Sheffield Centre, Southampton Centre, Thurrock and Wolverhampton Centre would exceed the EU 2009 98th percentile.

NAQS 99th percentile and EU Stage 1 90th percentile projections for base years 1995, 1996 and 1997 for background sites are summarised in Table 5.3. The projections based on 1996 data are generally the highest. The 1997 based values are generally similar to the 1995 based values, with the 1997 value often being a bit lower. At a few sites the NAQS objective is achieved for projections based in 1997 data.

Table 5.2. PM_{10} projections for background sites based on 1997 monitoring data (μgm^{-3}).

NAQS	Belfast Centre	London Bexley	Birmingham East	Birmingham Centre	London Bloomsbury	Bolton	London Brent	Bristol Centre	Cardiff Centre	Derry	London Eltham	Edinburgh Centre	Glasgow Centre	London Hillingdon	London N. N. Kensington
1997 annual mean	25	23	20	21	27	20	21	23	26	24	20	18	21	25	24
1997 99th percentile	75	79	62	52	73	58	68	74	70	79	56	53	61	84	82
1997 Days>=50	18	14	5	2	17	3	9	9	9	4	3	1	7	15	17
Est. An. Mean 2004	22	20	20	18	23	17	18	20	23	22	18	16	18	21	21
Est. An. Mean 2005	21	19	17	18	22	17	18	20	23	21	17	16	18	20	21
Est. An. Mean 2009	20	18	16	17	20	16	17	18	21	20	16	15	17	18	19
99th perc. 2005	66	66	52	47	65	54	59	58	62	67	51	45	52	64	63
99th perc. 2009	44	65	50	44	59	53	55	53	59	63	49	41	50	57	58
2005 Days>=50	9	5	3	1	7	2	4	4	4	2	0	0	3	6	10
2009 Days>=50	9	4	1	0	5	0	3	3	4	1	0	0	1	4	5
EU															
1997 annual mean	33	30	26	27	35	26	27	30	34	31	26	23	27	33	31
1997 90th percentile	53	50	43	44	52	43	43	49	51	50	43	37	43	54	49
1997 98th percentile	77	74	62	55	78	61	69	77	72	67	58	53	64	77	84
1997 Days>=50	41	33	21	19	43	17	18	18	39	10	21	7	18	50	34
Est. An. Mean 2004	29	26	26	23	30	22	23	26	30	29	23	21	23	27	27
Est. An. Mean 2009	26	23	21	22	26	21	22	23	27	26	21	20	22	23	25
2004 90th percentile	47	43	38	38	45	37	37	41	47	47	38	32	37	44	45
2009 90th percentile	44	39	35	35	41	34	34	37	45	45	35	30	34	40	39
2004 98th percentile	71	64	52	48	67	52	57	62	60	63	50	47	53	64	70
2009 98th percentile	66	59	47	44	60	46	53	53	56	61	47	43	49	57	64
2004 Days>=50	26	18	12	5	25	7	10	10	21	7	8	4	9	22	26
2009 Days>=50	22	12	7	3	24	6	10	10	17	7	5	4	6	13	20

Table 5.2 (continued) PM_{10} projections for background sites based on 1997 monitoring data (µgm^{-3}).

NAQS	Leamington Spa	Leeds Centre	Leicester Centre	Liverpool Centre	Manchester Piccadilly	Newcastle Centre	Nottingham Centre	Narberth	Rochester	Sheffield Centre	Southampton Centre	Stockport	Thurrock	Wolverhptn. Centre
1997 annual mean	20	28	20	24	24	21	22	14	20	26	24	21	22	22
1997 99th percentile	54	113	56	77	71	55	65	37	55	74	69	60	79	71
1997 Days>=50	0	30	3	8	8	2	3	9	3	12	11	5	9	8
Est. An. Mean 2004	18	23	17	21	20	18	19	12	18	21	21	18	19	18
Est. An. Mean 2005	18	23	17	20	20	18	18	12	18	21	20	18	19	18
Est. An. Mean 2009	16	21	16	19	18	16	17	12	17	19	19	17	18	16
99th perc. 2005	47	102	51	65	53	49	53	31	50	61	61	47	63	56
99th perc. 2009	45	94	47	60	47	46	47	30	49	56	55	43	57	49
2005 Days>=50	0	14	0	4	2	0	2	4	2	5	4	1	5	4
2009 Days>=50	0	11	0	4	1	0	1	4	1	3	2	1	3	2
EU														
1997 annual mean	26	36	26	31	31	27	29	18	26	34	31	27	29	29
1997 90th percentile	44	63	43	50	49	44	40	29	41	52	48	44	47	49
1997 98th percentile	58	114	58	65	68	56	58	36	58	71	75	64	73	66
1997 Days>50	13	60	21	35	31	19	11	39	18	39	25	15	26	30
Est. An. Mean 2004	23	30	22	27	26	23	25	16	23	27	27	23	25	23
Est. An. Mean 2009	21	27	21	25	23	21	22	16	22	25	25	22	23	21
2004 90th percentile	39	54	37	42	43	39	36	25	38	44	41	38	42	10
2009 90th percentile	36	48	34	37	39	35	33	24	35	40	38	35	38	37
2004 98th percentile	52	96	49	59	55	49	49	33	53	59	59	51	65	56
2009 98th percentile	48	85	45	54	50	45	45	31	50	55	53	44	59	54
2004 Days>=50	8	42	7	14	17	7	4	21	9	18	17	8	16	11
2009 Days>=50	3	29	5	9	7	5	3	17	8	11	9	3	13	8

Table 5.3 Comparison of NAQS and EU Stage 1 PM_{10} projections for 1995, 1996 and 1997 base years ($\mu g\,m^{-3}$)

	London Bloomsbury	Birmingham Centre	Bristol Centre	Manchester Piccadilly	Belfast Centre	Newcastle Centre	Edinburgh Centre	Liverpool Centre	Rochester	Cardiff Centre	Leeds Centre
NAQS 99%ile 2005 1995	69	65	57	-	82	57	57	63	-	57	65
NAQS 99%ile 2005 1996	82	76	70	71	76	82	55	70	74	71	72
NAQS 99%ile 2005 1997	65	47	58	53	66	49	45	65	50	62	102
EU 90%ile 2005 1995	49	40	43	-	44	37	36	51	-	43	42
EU 90%ile 2005 1996	54	42	45	46	47	42	35	45	42	43	48
EU 90%ile 2004 1997	45	38	41	43	47	39	32	42	38	47	54

	Birmingham East	Hull Centre	Leicester Centre	Southampton Centre	London Bexley	Sheffield Centre	Wolverhampton Centre	London Brent	North Kensington	London Eltham
NAQS 99%ile 2005 1995	62	63	49	49	73	-	-	-	-	-
NAQS 99%ile 2005 1996	72	76	69	67	78	86	81	-	-	-
NAQS 99%ile 2005 1997	52	74	51	61	66	61	56	59	63	51
EU 90%ile 2005 1995	38	40	34	34	44	-	-	-	-	-
EU 90%ile 2005 1996	41	44	37	37	48	50	47	-	-	-
EU 90%ile 2004 1997	38	45	37	41	43	44	40	37	45	38

	Glasgow Centre	Leamington Spa	Nottingham Centre	Thurrock	Stockport	Bolton
NAQS 99%ile 2005 1995	-	-	-	-	-	-
NAQS 99%ile 2005 1996	-	-	-	-	-	-
NAQS 99%ile 2005 1997	52	47	53	63	47	54
EU 90%ile 2005 1995	-	-	-	-	-	-
EU 90%ile 2005 1996	-	-	-	-	-	-
EU 90%ile 2004 1997	37	39	36	42	38	37

6 PM_{10} Projections for roadside monitoring sites

The receptor modelling methods have been extended to calculate projections for 1997 of roadside PM_{10} concentrations for comparison with the NAQS objective and EU limit values. We have used daily measurements of PM_{10} at the roadside along with rural sulphate values and measurements of NO_x at the roadside and at a nearby urban background monitoring site. A regression analysis has been carried out to find the coefficients *A, B* and *R:*

$$PM_{10} = A.\text{Background } NOx + B.\text{Sulphate} + R.\text{Roadside enhancement of } NO_x + C$$

Where the *Roadside enhancement of* NO_x is defined as the measured daily mean NO_x concentration at the roadside site with a background daily mean NO_x concentration from a nearby background site subtracted:

roadside enhancement concentration = roadside concentration - background concentration

The regression coefficients and correlation coefficients obtained from this analysis are listed in Table 6.1.

Table 6.1 Coefficients of regression analysis of roadside sites (NO_x expressed as ppb)

	Sulphate	Background NOx	Roadside NOx	Intercept	r^2
London A3	2.74	0.177	0.0423	6.43	0.74
Bury Roadside	2.64	0.138	0.0662	6.90	0.71
Camden Roadside	2.33	0.120	0.0696	11.2	0.77
Haringey Roadside	2.53	0.125	0.0776	7.90	0.80
Glasgow Kerbside	3.11	0.0689	0.1234	6.92	0.79
London Hillingdon	2.42	0.135	0.0748	5.60	0.78
Marylebone Road	3.26	0.122	0.0901	6.12	0.79
Sutton Roadside	2.40	0.110	0.0961	7.04	0.74

We have then calculated projections for 2004 and 2005 and 2009 using the business as usual scenario. We have assumed that the roadside enhancement of PM_{10} consists of half and half fine exhaust emissions and coarse resuspended dust. This is consistent with a comparison of the roadside enhancements of PM_{10}, $PM_{2.5}$ and NO_x at Marylebone Road carried out by APEG (APEG 1998). Figure 6.1 shows that the slope of the regression line between the roadside enhancement of particle concentration and the roadside enhancement of NO_x for PM_{10} is twice the slope for $PM_{2.5}$. The exhaust emissions are projected to reduce in line with urban traffic emissions and the coarse resuspended dust is projected to remain at 1997 levels.

The resulting projections are shown in Table 6.2. All sites are projected to exceed the NAQS objective in 2005 and the EU Stage 2 2009 98th percentile. Four of the sites are projected to exceed the EU 24-hour limit value in 2004, with three other sites having concentrations close to 50 μgm^{-3}. At Marylebone Road the projected annual mean is higher than the annual limit value of 40 μgm^{-3}.

Table 6.2. PM_{10} projections for Roadside sites based on 1997 monitoring data (μgm^{-3}).

NAQS	London A3	Bury Roadside	Camden Roadside	Haringey Roadside	Glasgow Kerbside	London Hillingdon	Marylebone Road	Sutton Roadside
1997 annual mean	28	30	32	26	31	25	39	24
1997 99th percentile	68	79	91	87	81	85	99	78
1997 Days>=50	7	14	32	19	19	15	26	16
Est. An. Mean 2004	24	25	28	23	26	22	32	21
Est. An. Mean 2005	23	25	28	22	26	21	32	21
Est. An. Mean 2009	21	23	26	21	24	19	29	19
99th perc. 2005	58	66	73	70	71	70	76	60
99th perc. 2009	53	61	68	64	68	65	68	58
2005 Days>=50	1	6	17	9	10	7	14	7
2009 Days>=50	0	5	13	7	3	6	10	3
EU								
1997 annual mean	36	39	42	34	40	33	51	31
1997 90th percentile	57	61	62	55	61	54	76	49
1997 98th percentile	70	80	96	81	81	77	103	74
1997 Days>=50	25	47	83	51	74	50	66	34
Est. An. Mean 2004	31	33	36	30	34	29	42	27
Est. An. Mean 2009	27	30	34	27	31	25	38	25
2004 90th percentile	48	51	54	47	52	45	65	43
2009 90th percentile	43	46	50	43	48	41	59	38
2004 98th percentile	60	69	80	66	69	65	81	65
2009 98th percentile	55	62	73	62	64	61	72	58
2004 Days>=50	12	27	46	25	36	20	37	22
2009 Days>=50	1	18	36	22	20	14	20	15

7 PM_{10} Projections for monitoring sites in industrial areas

Several of the PM_{10} monitoring sites within the national monitoring network are known to be in industrial areas, where industrial emissions may have a significant impact on ambient air quality. Regression analysis of measured PM_{10}, NO_x and sulphate concentrations using the same method as successfully applied to urban background monitoring sites in section 5 yielded very poor correlation coefficients and large intercepts for the four sites listed in Table 7.1. This was because no attempt had been made to account for the local industrial source contribution to measured PM_{10} at these sites. The local industrial source contribution to PM_{10} at these sites will not have the same temporal variation as the contribution from local traffic sources.

The receptor modelling methods have been extended further in order to separate the measured daily mean PM_{10} concentrations at these sites into the following sources:

- Primary combustion - calculated from the measured daily mean NO_x concentrations at the industrial site by multiplying by a typical coefficient (*A*) derived at sites where traffic is the dominant source of both NO_x and primary combustion PM_{10} ($A = 0.15$).
- Secondary - calculated from the measured daily mean sulphate concentrations at the nearest rural monitoring site by a typical coefficient (*B*) derived at other sites ($B = 2.22$).
- Other - taken from the receptor modelling results for other sites (Bristol Centre for the South Wales sites and Newcastle Centre for the Teesside sites) and calculated by difference (*'other' PM10 = Urban Centre site* PM_{10} *- primary combustion - secondary*). This approximately corresponds with the urban background concentration of coarse particles.
- Industrial - calculated by difference (*Industrial site* PM_{10} *- primary combustion - secondary - other*).

Table 7.1 shows the contributions that each of these sources is estimated to contribute to the 1997 annual mean. Both Port Talbot and Redcar look to have significant industrial contributions, while the contributions at Swansea and Middlesbrough are small.

Table 7.1. Estimated contributions to annual mean PM_{10} concentrations at industrial sites in 1997 (μgm^{-3})

site	total	primary	secondary	other	industrial
Port Talbot	25.7	3.8	4.9	10.5	6.5
Swansea	23.6	7.3	4.9	10.6	0.9
Middlesbrough	19.3	4.1	5.6	8.3	1.4
Redcar	22.4	2.9	5.2	8.1	6.1

The split between 'industrial' and 'other' sources is the least certain. In our projections of business as usual PM_{10} concentrations for future years listed in Table 7.2 we have, however, assumed that both of these contributions will remain at 1997 values. The primary combustion and secondary particle concentrations have been projected using the same business as usual scenario as for has been used for the background and roadside projections. The NAQS 99th percentile is expected to be at least 70 μgm^{-3} at Port Talbot and Middlesbrough and about 50 μgm^{-3} at Swansea and Redcar. Possibly of more concern are the EU stage 1 90th percentiles, which are projected to be 52 μgm^{-3} at Port Talbot and 47 μgm^{-3} at Redcar.

Table 7.2. Projected PM10 concentrations at industrially influenced monitoring sites ($\mu g m^{-3}$)

NAQS	Port Talbot	Swansea	Middlesbrough	Redcar
1997 annual mean	26	24	19	22
1997 99th percentile	85	61	72	58
1997 Days>=50	13	4	11	3
Est. An. Mean 2004	24	21	17	21
Est. An. Mean 2005	24	20	17	21
Est. An. Mean 2009	23	19	16	20
99th perc. 2005	76	51	70	52
99th perc. 2009	72	47	69	50
2005 Days>=50	9	1	7	1
2009 Days>=50	8	0	7	1
EU				
1997 annual mean	34	31	25	29
1997 90th percentile	55	47	42	50
1997 98th percentile	70	59	60	58
1997 Days>=50	38	18	21	18
Est. An. Mean 2004	31	27	22	27
Est. An. Mean 2009	94	61	21	26
2004 90th percentile	52	41	39	47
2009 90th percentile	52	38	36	45
2004 98th percentile	66	54	57	56
2009 98th percentile	64	52	55	54
2004 Days>=50	35	9	16	11
2009 Days>=50	30	7	13	9

We have also examined the wind directions corresponding to the top 10 days with the highest industrial contributions and these are listed in Table 7.3. This analysis clearly indicates the impact the steel works at Port Talbot, which is about 750 m to the SW of the monitoring site. This same steel works is about 10 km to the east of the Swansea site and the industrial contributions are correspondingly lower. The Teesside steel works is about 2 km to the NW of the Redcar site.

This analysis does not provide a definite indication of a significant industrial source contribution on a particular days because this component has been derived by difference. A good example of this is provided by the Middlesbrough monitoring site, which experienced extremely high concentrations of PM_{10} on the 5th November 1997, due to an enthusiastic bonfire celebration taking place immediately adjacent to the site.

Table 7.3. Top ten industrial source days at each site (daily mean total PM_{10} and estimated industrial source PM_{10} concentrations are shown, $\mu g m^{-3}$)

date	total	industrial	wind direction
Port Talbot			
08/07/97	88	63	SW
25/12/97	74	54	SW
04/09/97	59	44	WSW
11/02/97	51	37	SSW
06/12/97	52	37	SW
16/09/97	50	34	SW
10/12/97	58	32	WSW
11/12/97	48	31	WSW
24/12/97	49	31	S
09/12/97	43	30	WSW
Swansea			
29/10/97	34	17	SE
16/01/97	45	17	ENE
17/02/97	29	16	SW
28/10/97	23	16	E
27/10/97	33	14	E
19/07/97	34	12	SE
25/11/97	39	12	E
19/12/97	36	12	SE
25/10/97	34	12	ESE
16/02/97	28	12	WSW
Middlesbrough			
05/11/97	149	118	BONFIRE!
19/07/97	63	43	NE
11/03/97	95	40	SE
12/08/97	80	30	SE
21/07/97	52	30	SE
20/07/97	47	28	CALM
04/06/97	58	26	SSE
07/08/97	55	25	SE
06/08/97	44	24	ENE
03/05/97	53	23	CALM
Redcar			
13/10/97	37	31	WNW
24/10/97	43	27	WNW
17/08/97	50	27	no data
01/10/97	43	25	W
31/10/97	50	23	SSW
12/10/97	26	22	WNW
01/07/97	25	20	WSW
02/10/97	43	19	NW
27/11/97	43	17	CALM

8 Projections for sites expected to exceed the EU Stage 1 limit value

Additional PM_{10} projections have been calculated for the five monitoring sites for which the 1997 receptor modelling indicated that concentrations may exceed the EU stage 1 24-hour limit value in 2004 for the business as usual scenario. Four of these sites are roadside: Bury Roadside, Glasgow Roadside, Camden Roadside and Marylebone Road and one is industrial: Port Talbot.

The scenarios examined were:

- **Scenario a** Business as usual.
- **Scenario h** A 30% reduction in traffic emissions including buses, lorries etc. Business as usual for secondary particle emissions.
- **Scenario i** A 30% reduction in car emissions. Business as usual for secondary particle emissions.
- **Scenario j** Traffic emissions reduced by 50% and a reduction of 50% of the business as usual levels for secondary particles.

It should be noted that no specific policy measures have been identified which could achieve the reductions implied in scenario j.

Port Talbot forecasts were made as described for industrial sites. The other sites were treated as previously described for roadside sites. The projections for the different scenarios are listed in Table 8.1.

Bury Roadside achieves the EU Stage 1 objective under each of the new scenarios. Glasgow and Camden sites achieve the objective under scenarios h and j, whilst both London Marylebone Road and Port Talbot exceed the objective under even the most optimistic scenario.

Table 8.1 PM_{10} projections for different scenarios for sites likely to exceed the EU stage 1 24-hour limit value in 2004 for the business as usual scenario ($\mu g m^{-3}$) .

	Bury Roadside				Glasgow Kerbside				Camden Roadside			
NAQS	a	h	i	j	a	h	i	j	a	h	i	j
1997 annual mean	30	30	30	30	31	31	31	31	32	32	32	32
1997 99th percentile	79	79	79	79	81	81	81	81	91	91	91	91
1997 Days>=50	14	14	14	14	19	19	19	19	32	32	32	32
Est. An. Mean 2004	25	23	24	21	26	23	25	20	27	25	27	21
Est. An. Mean 2005	25	23	24	20	25	23	24	20	27	25	26	20
Est. An. Mean 2009	23	21	22	19	23	22	23	19	25	23	24	18
99th perc. 2005	66	62	65	54	72	62	71	53	70	65	69	52
99th perc. 2009	61	58	60	52	65	57	61	52	64	60	63	47
2005 Days>=50	6	5	6	1	10	7	8	2	17	12	15	2
2009 Days>=50	5	1	4	1	6	2	1	2	10	7	9	0
EU												
1997 annual mean	39	39	39	39	40	40	40	40	42	42	42	42
1997 90th percentile	61	61	61	61	61	61	61	61	62	62	62	62
1997 98th percentile	80	80	80	80	81	81	81	81	96	96	96	96
1997 Days>=50	47	47	47	47	74	74	74	74	83	83	83	83
Est. An. Mean 2004	33	30	31	27	34	30	33	26	35	33	35	27
Est. An. Mean 2009	30	27	29	25	30	29	30	25	33	30	31	23
2004 90th percentile	51	46	49	41	52	49	51	43	52	49	51	40
2009 90th percentile	45	42	44	38	48	45	47	41	47	45	46	35
2004 98th percentile	69	65	68	56	70	67	69	58	77	70	75	56
2009 98th percentile	63	60	62	52	65	61	65	55	68	65	67	48
2004 Days>=50	27	19	22	8	36	21	31	13	42	32	40	15
2009 Days>=50	17	10	16	7	20	15	17	9	29	22	26	4

Table 8.1(continued)PM$_{10}$ projections for different scenarios for sites likely to exceed the EU stage 1 24-hour limit value in 2004 for the business as usual scenario (mgm^{-3}) .

	London Marylebone Road				Port Talbot			
NAQS	a	h	i	j	a	h	i	j
1997 annual mean	39	39	39	39	26	26	26	26
1997 99th percentile	99	99	99	99	85	85	85	85
1997 Days>=50	26	26	26	26	13	13	13	13
Est. An. Mean 2004	33	30	32	26	24	23	24	21
Est. An. Mean 2005	32	30	32	25	24	23	24	21
Est. An. Mean 2009	30	28	29	24	23	23	23	20
99th perc. 2005	76	67	73	58	76	72	75	67
99th perc. 2009	69	64	66	57	72	69	71	66
2005 Days>=50	16	11	13	1	9	8	9	7
2009 Days>=50	10	9	10	1	8	7	7	7
EU								
1997 annual mean	51	51	51	51	34	34	34	34
1997 90th percentile	76	76	76	76	55	55	55	55
1997 98th percentile	104	104	104	104	70	70	70	70
1997 Days>=50	65	65	65	65	38	38	38	38
Est. An. Mean 2004	43	39	42	34	31	30	31	27
Est. An. Mean 2009	39	36	38	31	94	90	92	86
2004 90th percentile	66	63	65	52	52	52	52	51
2009 90th percentile	62	58	60	49	52	65	66	50
2004 98th percentile	83	76	79	65	66	52	52	63
2009 98th percentile	73	70	72	61	64	64	64	63
2004 Days>=50	37	26	35	16	35	32	34	29
2009 Days>=50	23	19	21	14	30	30	30	28

9 Projections for sites measuring PM_{10} and $PM_{2.5}$

9.1 INTRODUCTION

Co-located monitoring of PM_{10} and $PM_{2.5}$ commenced at four sites within the national monitoring network during the summer of 1997 and these four sites are listed in Table 9.1. We have undertaken receptor modelling and projections of concentrations to future years for $PM_{2.5}$ at these sites. Projections have been based on the monitoring data from the start of $PM_{2.5}$ monitoring until June 1998, which provides about one year of data for all of the sites except Harwell, where measurements started in September 1997. PM_{10} projections have also been calculated from data for this period so that a direct comparison can be made between the $PM_{2.5}$ and PM_{10} projections. The PM_{10} projections are however, generally very similar to those presented in Tables 5.2 and 6.2 which were derived from 1997 data.

Projections have been calculated for both NO_x and black smoke based receptor models, and the differences in the projected concentrations are generally small. The results are discussed in section 9.4,

9.2 PROJECTIONS USING A NO_X BASED RECEPTOR MODEL

The regression coefficients and correlation coefficients obtained for PM_{10} and $PM_{2.5}$ are listed in Table 9.1. Projections are listed in Tables 9.2 and 9.3.

Table 9.1 Coefficients of regression analyses of PM_{10} and $PM_{2.5}$ using NO_x and sulphate data.

PM_{10}	NO_x coeff.	SO_4 coeff.	Intercept	r^2
Marylebone Road	0.0877	2.97	12.0	0.63
London Bloomsbury	0.131	2.66	9.21	0.61
Rochester	0.206	2.73	9.25	0.58
Harwell	0.230	1.20	8.98	0.50
$PM_{2.5}$	NO_x coeff.	SO_4 coeff.	Intercept	r^2
Marylebone Road	0.0572	2.46	6.04	0.63
London Bloomsbury	0.106	2.04	4.52	0.63
Rochester	0.187	1.65	4.05	0.13

Harwell	0.110	2.69	3.14	0.55

Table 9.2 Projected PM_{10} concentrations based on NO_x and sulphate measurements 1997/98 (μgm^{-3}).

PM_{10}	Marylebone Road	London Bloomsbury	Rochester	Harwell
1997 annual mean	36	26	20	16
1997 99th percentile	80	70	54	42
1997 Days>=50	28	10	2	0
Est. An. Mean 2004	30	22	18	15
Est. An. Mean 2005	30	22	17	14
Est. An. Mean 2009	27	20	16	14
99th perc. 2005	69	65	48	37
99th perc. 2009	64	62	46	36
2005 Days>=50	16	6	1	0
2009 Days>=50	10	5	0	0
EU				
1997 annual mean	47	34	26	21
1997 90th percentile	68	53	42	35
1997 98th percentile	88	74	57	46
1997 Days>=50	85	33	38	1
Est. An. Mean 2004	39	29	22	18
Est. An. Mean 2009	35	26	21	18
2004 90th percentile	55	46	38	30
2009 90th percentile	51	43	36	30
2004 98th percentile	77	66	51	41
2009 98th percentile	70	62	47	40
2004 Days>=50	47	17	7	1
2009 Days>=50	25	11	3	1

Table 9.3 Projected $PM_{2.5}$ concentrations based on NO_x and sulphate measurements 1997/98 (μgm^{-3}).

$PM_{2.5}$	Marylebone Road	London Bloomsbury	Rochester	Harwell
1997 annual mean	23	18	13	12
1997 99th percentile	54	52	42	34
1997 Days>=50	2	2	1	0
Est. An. Mean 2004	19	17	12	11
Est. An. Mean 2005	18	17	12	11
Est. An. Mean 2009	17	16	11	10
99th perc. 2005	46	50	88	32
99th perc. 2009	43	49	87	31
2005 Days>=50	0	2	0	0
2009 Days>=50	0	2	0	0
EU				
1997 annual mean	30	23	17	16
1997 90th percentile	46	38	29	27
1997 98th percentile	61	53	42	38
1997 Days>=50	19	10	2	0
Est. An. Mean 2004	23	22	16	14
Est. An. Mean 2009	22	21	14	13
2004 90th percentile	38	36	24	24
2009 90th percentile	35	35	22	23
2004 98th percentile	52	52	36	32
2009 98th percentile	47	51	31	31
2004 Days>=50	9	7	1	0
2009 Days>=50	2	6	1	0

9.3 PROJECTIONS USING A BLACK SMOKE BASED RECEPTOR MODEL

The regression coefficients and correlation coefficients obtained for PM_{10} and $PM_{2.5}$ are listed in Table 9.4. Projections are listed in Tables 9.5 and 9.6.

Table 9.4 Coefficients of regression analyses of PM_{10} and $PM_{2.5}$ using black smoke and sulphate data.

PM_{10}	Smoke coeff.	SO_4 coeff.	Intercept	r^2
Marylebone Road	0.958	2.16	18.2	0.59
London Bloomsbury	0.712	2.78	9.16	0.63
Rochester	0.348	2.70	7.31	0.53
Harwell	0.462	2.33	6.79	0.44
$PM_{2.5}$	Smoke coeff.	SO_4 coeff.	Intercept	r^2
Marylebone Road	0.858	1.82	9.64	0.64
London Bloomsbury	0.651	1.93	5.94	0.69
Rochester	0.412	2.18	1.60	0.74
Harwell	0.568	1.86	2.99	0.57

Table 9.5 Projected PM_{10} concentrations based on black smoke and sulphate measurements 1997/98 ($\mu g m^{-3}$).

PM_{10}	Marylebone Road	London Bloomsbury	Rochester	Harwell
1997 annual mean	36	26	19	17
1997 99th percentile	93	71	56	42
1997 Days>=50	36	12	3	1
Est. An. Mean 2004	32	22	16	15
Est. An. Mean 2005	31	22	16	14
Est. An. Mean 2009	30	20	14	13
99th perc. 2005	75	66	49	38
99th perc. 2009	70	65	47	37
2005 Days>=50	24	7	1	0
2009 Days>=50	16	4	0	0
EU				
1997 annual mean	47	34	25	22
1997 90th percentile	68	52	41	35
1997 98th percentile	89	74	57	46
1997 Days>=50	67	44	12	2
Est. An. Mean 2004	42	29	21	20
Est. An. Mean 2009	39	26	18	17
2004 90th percentile	59	45	34	31
2009 90th percentile	55	42	30	29
2004 98th percentile	80	66	49	41
2009 98th percentile	74	61	44	39
2004 Days>=50	67	21	4	2
2009 Days>=50	52	14	4	2

Table 9.6 Projected $PM_{2.5}$ concentrations based on black smoke and sulphate measurements 1997/98 ($\mu g m^{-3}$).

$PM_{2.5}$	Marylebone Road	London Bloomsbury	Rochester	Harwell
1997 annual mean	23	26	14	13
1997 99th percentile	54	70	43	40
1997 Days>=50	2	12	1	0
Est. An. Mean 2004	20	23	12	11
Est. An. Mean 2005	19	23	11	10
Est. An. Mean 2009	18	21	10	10
99th perc. 2005	45	65	39	35
99th perc. 2009	42	63	38	32
2005 Days>=50	0	9	0	0
2009 Days>=50	0	6	0	0
EU				
1997 annual mean	30	34	18	17
1997 90th percentile	46	52	33	28
1997 98th percentile	61	73	46	39
1997 Days>=50	19	44	3	1
Est. An. Mean 2004	26	30	16	14
Est. An. Mean 2009	23	27	13	13
2004 90th percentile	38	46	29	24
2009 90th percentile	34	43	26	22
2004 98th percentile	51	66	40	36
2009 98th percentile	47	61	36	33
2004 Days>=50	11	23	1	1
2009 Days>=50	1	17	1	1

9.4 DISCUSSION

The NO_x based receptor model provides the most reliable estimates for the Marylebone Road monitoring site because measurements of black smoke from background monitoring sites do not provide a good surrogate for roadside PM_{10} (the receptor model for roadside sites has not been applied to this data, the simpler APEG model has been used). Black smoke measurements do, however, seem to provide a better surrogate than NO_x for primary combustion PM_{10} at the two rural sites at Rochester and Harwell. The NO_x based model is particularly poor for $PM_{2.5}$ at Rochester.

The results from the NO_x and black smoke based models are very similar. Both London Marylebone Road and London Bloomsbury sites are predicted to exceed the NAQS 2005 99th percentile target for PM_{10}, with Rochester close to exceedance. Marylebone Road is the only site that doesn't attain the EU stage 1 90th percentile limit value and the two London sites are forecast to exceed the EU stage 2 98th percentile.

Both Marylebone Road and London Bloomsbury are very close to exceeding the NAQS and EU stage 2 98th percentile levels for $PM_{2.5}$ alone. Rochester's $PM_{2.5}$ forecast in table 9.3 is unreliable due to the poor regression analysis results.

10 Daily mapping of PM_{10} concentrations

10.1 INTRODUCTION

Maps of estimated annual mean background PM_{10} concentrations have been calculated for 1996 (Stedman 1998). Projections of the annual mean concentrations that current policies are likely to deliver in 2005 can also be calculated by making certain assumptions about the likely changes in primary and secondary particle concentrations.

Background PM_{10} concentrations are made up from contributions from primary, secondary and coarse particles, and the relative proportions vary from day to day. This is why the relationships between numbers of days above threholds, high percentiles and annual means are not very reliable, particularly if it is applied to future years, such as 2005, when the relative contributions from primary, secondary and coarse particles to PM_{10} are likely to have changed.

Maps of both current and projected PM_{10} concentrations are however required for the quantification of health impacts similar to those presented by COMEAP (1998). Whilst maps of annual mean concentrations are required for the health quantification work, the calculation of these maps from a series of daily maps enables maps of other statistics of interest to be calculated, without having to make assumptions about the relationship between means and numbers of days above thresholds. This report provides the first maps of annual means and numbers of exceedence days for comparison with the PM_{10} objective and limit values. The use of these mapping methods does, however, increase the uncertainty of the projections compared with the projections presented in this report for individual sites.

10.2 METHOD

The following data has been used:

- daily mean particulate sulphate concentrations at eight rural sites;
- daily PM_{10}, black smoke and rural particulate sulphate concentrations for eight different cities have been analysed in order to provide estimates of primary, secondary and 'other' particle concentrations for each day for the following sites:
    - London Bloomsbury
    - Edinburgh Centre
    - Belfast Centre
    - Birmingham Centre
    - Newcastle Centre

- Liverpool Centre
- Bristol Centre
- Manchester Piccadilly;

- a 1 km x 1 km grid square map of combustion related emissions of PM_{10} from the National Atmospheric Emissions Inventory.

The daily PM_{10} map for each day is calculated as follows:

PM_{10} map = primary map + secondary map + 'other' map

where

secondary map is calculated by multiplying a map of particulate sulphate by 2.46, which is both a reasonable theoretical factor and consistent with the daily individual site analysis. The map of particulate sulphate concentrations is interpolated from the daily sulphate measurement data at eight rural sites.

'other' map is interpolated from the daily estimates of 'other' particle (largely coarse particle) concentrations derived from the daily analysis of concentrations at urban sites. This is likely to overestimate coarse particle concentrations in rural areas but probably not to a large extent.

primary map consists of two components:

- long range transported primary particle concentration
- local primary particle concentration

The long range transported component is expected to be relatively small and show a similar spatial variation to secondary particle concentrations. Daily concentrations have been estimated by multiplying the daily secondary concentration by 0.08333.

The local primary particle concentration has been calculated by multiplying the map of annual combustion related emissions by a factor *k*. This factor represents the efficiency of the dispersion of these local emissions within a 5 km x 5 km box and is allowed to vary both spatially and from day to day. A map of the *k* factor is interpolated for each day and is allowed to vary by dividing the estimates of the daily primary contribution to PM_{10} from the analysis of daily concentrations at individual urban sites by the estimated contribution that primary particles make to annual mean PM_{10} concentration.

$k = k_a [p]/[p]_a$

where
k is the coefficient used to derive daily mean local primary PM_{10} concentration from annual emissions estimates;
k_a is the coefficient between annual emissions and annual mean primary particle concentration;
[p] is the daily mean primary particle concentration derived from the daily analysis of PM_{10}, black smoke and sulphate measurements;

$[p]_a$ is the annual mean of primary particle concentration aggregated from the daily analysis of PM_{10}, black smoke and sulphate measurement.

10.3 RESULTS FOR 1995 AND 1996

The general pattern of annual mean concentrations shown in Figures 10.1 are similar to that derived from an analysis of annual concentrations (Stedman 1998). Rural concentrations are highest in the south and east due to the varying magnitude of the secondary particle contribution. Urban concentrations are higher due to the local primary emissions. Rural concentrations are estimated to be rather higher in 1996 than in 1995, while urban centre concentrations were not much higher in 1996 than in 1995. A comparison of the mapped estimates with measured annual mean concentrations has shown reasonably good agreement. Concentrations in central London are, however, overestimated. The high concentrations in North Wales in 1995 are probably caused by the mapping method and are unlikely to be representative.

In common with the individual site receptor modelling results, we have not scaled the maps of number of days with concentrations >= 50 μgm^{-3} to enable direct comparison with the NAQS objective because of the uncertainties associated with the large scaling factor that would be required. The maps presented in Figure 10.2 represent the number of days with fixed 24-hour mean PM_{10} concentrations >= 50 μgm^{-3}. There is a striking difference between the two years, with the secondary PM_{10} episodes during the early part of 1996 leading to much many more days above 50 μgm^{-3} in both rural and urban areas.

10.4 PROJECTIONS FOR 2005

Projections for 2005 have been calculated from the 1995 and 1996 maps using the same business as usual scenario as for the individual site receptor modelling. Annual mean maps for 2005 are shown in Figure 10.1. The projected annual mean PM_{10} concentrations for 2005 are significantly lower than those for 1995 and 1996 and the values calculated from the 1996 are not very different from those calculated from the 1995 map.

Maps of the estimated number of days with PM_{10} concentrations >= 50 μgm^{-3} for 2005 based on either 1995 or 1996 meteorology are also shown in Figure 10.2. Large areas of the country have more than four days with projected concentrations greater than 50 μgm^{-3} , even for projections based on 1995 monitoring data. This is also likely to be a significant underestimate of the number of days with running 24-hour mean concentrations greater than 50 μgm^{-3}, as discussed above.

10.5 PROJECTIONS FOR COMPARISON WITH EU LIMIT VALUES

Figure 10.3 shows maps of the number of days with estimated PM_{10} concentrations >= 50 μgm^{-3} for comparison with the EU 24-hour limit values. The Stage 1 limit value is that 50 μgm^{-3} should not to be exceeded more than 35 times in 2004. This mapping analysis indicates that central London may be at risk of exceeding this limit value in years such as 1995 and the whole of the London area may be at risk in a year such as 1996. It is likely, however, that concentrations in the London area have been overestimated by the mapping method because the individual site analysis indicated exceedance for 1996 only, and this was confined to central London.

The indicative Stage 2 24-hour limit value of 50μgm^{-3}, not to be exceeded more than 7 times in 2009 is likely to be exceeded over most of England and Wales for the business as usual scenario.

11 Conclusions

Projections of PM_{10} concentrations for future years have been calculated using the receptor modelling methods developed by the Airborne Particles Expert Group. Projections have been calculated for a business as usual scenario and indicate that significant exceedences of the National Air Quality Strategy objective for PM_{10} are likely in 2005. Projected 99th percentiles are well in excess of 50 μgm^{-3} for urban background monitoring site locations in major cities and concentrations are likely to be in excess of the objective in many smaller urban areas, particularly for years with elevated secondary particle concentrations such as 1996.

The picture is similar for the EU 'Daughter Directive' indicative Stage 2 limit values for 2009 with exceedences in many areas likely with current national and international policy measures. Projected concentrations in 2004 are expected to be lower than the EU 'Daughter Directive' Stage 1 limit values at most urban background locations, with the possible exception of central London.

Concentrations at the roadside are expected to be higher than at nearby background locations. Concentrations higher than the EU Stage 1 limit value are therefore expected at the roadside of heavily trafficked roads in urban areas in 2004. Concentrations at sites with significant industrial source contributions to measured ambient PM_{10} concentrations are also expected to be at risk of exceeding this limit value.

The receptor modelling results indicate that the projected PM_{10} concentrations in 2005 are relatively insensitive to changes in primary combustion particle emissions due to the important contributions of secondary and 'other' particle sources to ambient concentrations. It is likely that the receptor modelling may overestimate the contribution from 'other' particle sources on some days because this concentration has been derived from the residual of the regression analysis. An examination of co-located PM_{10} and $PM_{2.5}$ measurements does, however, indicate that the 99th percentile of daily mean coarse particle concentration (PM_{10} - $PM_{2.5}$) are typically in the range 20 - 30 μgm^{-3}.

12 Acknowledgement

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