UK Smoke and Sulphur Dioxide Network

Summary Report for April 1997 - March 1998

Prepared by the National Environmental Technology Centre as part of the Department of the Environment, Transport and the Regions Air Quality Research Programme

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Executive Summary

This report presents the results from the UK Smoke and Sulphur Dioxide Network for the year April 1997 to March 1998, providing a summary of data from the 204 sites comprising the Network this year. These data are compared with the standards and objectives specified in the UK National Air Quality Strategy, and with the standards and guidelines specified in the existing and draft EC Directives on sulphur dioxide and suspended particles. Concentration trends and spatial distributions throughout the UK are also discussed. A computer disk, which contains the full year's dataset for all Network sites, accompanies this report (see inside back cover).

The year beginning April 1998 was the fifth consecutive year in which no site exceeded any of the limit values of the original EC Directive (80/779/EEC) on Sulphur Dioxide and Suspended Particulate Matter. There was still, however, widespread exceedence of the 24 hour guide values of the Directive, and some exceedence of the annual average sulphur dioxide lower guide value.

The original EC Directive is to be superceded in 2001 by the Framework Directive on ambient air quality assessment and management, and Daughter Directive on SO_2, NO_2, PM_{10} and lead. Seven sites exceeded the proposed Daughter Directive 24 hour limit for SO_2 during 1997; four in Belfast, two in South Yorkshire and one in Newcastle.

Daily average measurements from this Network cannot be used for direct comparison with the standards and objectives set for 15 minute average SO_2 concentrations in the UK National Air Quality Strategy. However, applying surrogate relationships to the Network data indicates that exceedence of the UK Strategy Objective for SO_2 is currently widespread. The Objective is to be met by 2005.

There is also a UK standard for particulate, but this specifically applies to PM_{10}, not black smoke, and the UK National Air Quality Strategy acknowledges that these two techniques are not the same. However, PM_{10} concentration is usually higher than black smoke except at very high "episode" concentrations, and hence, if smoke exceeds the PM_{10} limit, it is likely that PM_{10} has also done so. This was the case at many sites during 1997 - 98.

UK average concentrations in 1997 - 98 were 9.4 $\mu g\ m^{-3}$ for smoke and 20.6 $\mu g\ m^{-3}$ *(7.7ppb)* for SO_2. These averages are both slightly lower than last years' UK averages of 9.9 $\mu g\ m^{-3}$ and 22.4 $\mu g\ m^{-3}$ *(8.4 ppb)* for smoke and SO_2 respectively, as measured by this Network.

The spatial distributions for black smoke and SO_2 in 1997 - 98 were similar to those observed in previous years. Concentrations of black smoke were typically highest in areas where the use of coal for domestic heating is still relatively widespread, such as parts of Yorkshire and Northern Ireland, and also at some sites in large cities. Highest concentrations of SO_2 were also found in areas with widespread domestic coal burning, in particular, Northern Ireland, where natural gas currently has limited availability.

Contents

Appendices

1 Introduction

This annual report of the Smoke and Sulphur Dioxide Network presents a general description of the network, and a summary and review of the data for the period April 1997 to March 1998. The results for 1997 - 98 are compared with applicable air quality standards and guide values. Trends, spatial distribution of smoke and sulphur dioxide concentrations throughout the UK, data reporting commitments and data usage are discussed.

A detailed data summary is provided on the computer disk which accompanies this report. The main report is followed by Appendices, which contain details of the derivation and calculation of the results and statistics presented in the report, together with details of the data files on the disk.

2 Network Objectives

The UK Smoke and Sulphur Dioxide (SO_2) Network (Figure 1) serves two purposes. Firstly, to monitor compliance with the relevant EC Directives on sulphur dioxide and suspended particulate matter. The original Directive, 80/779/EEC[1], has been in force since 1980 but is to be superceded in future years; the European Commission have issued a Directive on the Assessment and Management of Ambient Air Quality [2] - the so-called "Framework Directive". "Daughter Directives" for pollutants including SO_2 and suspended particulate matter are being developed under the "Framework Directive", and reached Common Position stage in summer 1998[3]. However, the standards for suspended particulate relate to PM_{10}, not black smoke. The existing standards for monitoring of black smoke will remain in force until 2005.

Secondly, the Network is intended to provide a long-term database of smoke and SO_2 measurements to assess trends in concentration and spatial distribution. For this purpose, a "core" subset of sites is used to provide a representative sample of monitoring locations in major population centres throughout the UK, with a wide spatial coverage of the whole country, as recommended recently by an independent review[4]. A total of 204 Network sites (see Figure 1) were in operation during part or all of the period April 1997 to March 1998. Of these sites, 141 comprised the "core" subset used to provide national statistics. These figures include those sites operating for only part of the year, eg. those which started or ceased operation during this period. It should be emphasised that, in formally assessing smoke and sulphur dioxide concentrations by comparison with the limit and guide values of the EC Directive, analysis of all sites in the UK is undertaken.

page for Figure 1.

3 Data Reporting and Use

The UK Smoke and SO_2 Monitoring Network and its predecessor the National Survey provide one of the longest running database of air quality measurements in the UK. The results have shown clearly the dramatic decrease in the concentrations of these pollutants in the UK over the last 36 years. With the exception of the UK Nitrogen Dioxide Diffusion Tube Survey, the Smoke and SO_2 Monitoring Network still constitutes the most widespread air quality monitoring programme in the UK.

3.1 STATUTORY REPORTING: EC DIRECTIVE

The UK Smoke and Sulphur Dioxide Network fulfils the statutory monitoring requirements of the EC Directive on Sulphur Dioxide and Suspended Particulates[1]. In June and July each year, the previous pollution year's data are analysed with respect to the requirements of the Directives. The results are supplied to the Department of the Environment, Transport and the Regions for formal submission to the European Commission. The results of this analysis for 1997 - 98 are discussed in Section 5.

3.2 EC EXCHANGE OF INFORMATION

Under the terms of the EC Exchange of Information Decision[5], the Department of Environment, Transport and the Regions has agreed to supply to the Commission, full daily data for all sites in the Network, from 1997 onwards. The data are supplied to the European Topic Centre on Air Quality, for inclusion in their “AIRBASE” database, at **http://www.etcaq.rivm.nl/airbase/index.html**.

3.3 PUBLIC DISSEMINATION

This report provides the main route for public dissemination of data from the network. However, data are also summarised in the Digest of Environmental Statistics, published annually by the Department of the Environment, Transport and the Regions[6]. Also, a large number of ad hoc requests for data are serviced by retrievals from the database held at AEA Technology’s National Environmental Technology Centre (NETCEN). These are normally provided free of charge.

A comprehensive archive of air quality measurements, including smoke and SO_2 data, has been prepared on behalf of the Department of the Environment, Transport and the Regions. This is available via the World Wide Web, at web site :
http://www.environment.detr.gov.uk/airq/aqinfo.htm
Site information and summary data from 1963 onwards for the Smoke and SO_2 Network are available on the web site, with full daily data from 1990 onwards. These daily data are updated every three months; the annual statistics are updated yearly.

4 Results and Discussion

4.1 UNITS

Both smoke and sulphur dioxide concentrations are expressed in microgrammes per cubic metre (μg m^{-3}) in this report and on the disk.
(i) Smoke: in the UK, smoke concentrations are usually calculated according to the British Standard Smokestain (BS) Calibration. This report primarily uses the BS calibration, and all black smoke concentrations are in this form except where specified. However, elsewhere in Europe, the Organisation for Economic Co-operation and Development (OECD) Smoke Calibration Curve (OECD Publication no. 17913: 1964) is used. Concentrations given according to the BS calibration can be converted to OECD by dividing by 0.85. In any communication with the European Commission, it is normal to use the OECD calibration. OECD smoke concentrations have been included in this report where applicable, and are indicated as OECD and shown in *italics*.
(ii) SO_2 : In this report, SO_2 concentrations are given primarily in μg m^{-3}. However, concentrations of gaseous pollutants are sometimes expressed as parts per billion by volume (abbreviated to "ppb"). For SO_2, the conversion factor used by the EC is as follows: **1 ppb = 2.66 μg m^{-3}, at a temperature of 20^{o}C and 1013 mb pressure.** This **only** applies to SO_2; conversion factors are different for other gaseous pollutants. SO_2 concentrations in ppb are included where applicable, are indicated as such and shown in *italics*.

4.2 SUMMARY OF RESULTS

Summary statistics for the year 1997 - 98 for each Network site is provided in Table 1. The sites are listed by region (Scotland, North, North West, Yorkshire and Humberside, East Midlands, West Midlands, Wales, East Anglia, London, South East, South West, and Northern Ireland). Within each region they are grouped by the Local or Unitary Authority in whose area they are situated. In most cases, this Authority will be responsible for the operation of the site, although a small number are operated by other organisations such as universities.

For sites in England, Wales and Scotland, Table 1 gives the location as an Ordnance Survey grid reference, to the nearest 100m. For sites in Northern Ireland, the Irish Grid is used. Again, the co-ordinates are given to the nearest 100m, but both the easting and northing are prefixed by a 9, to indicate that the Irish Grid has been used.

The following abbreviations are used in Table 1:
1. "Valid Days" denotes the number of valid days' data obtained for the year.
2. " Max. Gap" is the maximum number of consecutive days for which no valid value was obtained. (Excludes periods when site was not in operation eg. those starting or ceasing part way through year.)
3. "Arith. Mean" is the arithmetic mean of all daily values, calculated by the usual method, as described in Appendix 1.
4. "Median" is the median of all daily values. Calculated by the usual method, see Appendix 1.
5. "98th %ile" is the 98th percentile for all daily values, see Appendix 1.
6. "Max. Day" is the maximum daily value measured during the year.

8 pages for Table 1.

4.3 DATA CAPTURE

Table 1 shows summary data for all sites irrespective of the data capture. It is, therefore, important to check on the actual data capture for any site, as provided in the column "Valid Days", to assess the significance and reliability of the summary statistics presented. Pollution Year 1997 - 98 contained 364 days (see Appendix 1 for details of the Pollution Calendar), so this value appearing in the "Valid Days" column indicates 100% data capture. The minimum data capture requirement of the EC Directive is 75% - equivalent to 273 days.

The data capture statistics for the Network for 1997 - 98 (excluding sites which started or ceased operation part way through the year) were as follows: 20% of sites achieved 100% data capture, 47% of sites had over 95% data capture, and 64% of sites had over 90% data. 15% of sites had less than 75% data capture. The percentages of sites with 100%, 95%, and 90% data capture are the same as for last year; however, the percentage with less than 75% data capture has been reduced. Hopefully, the downward trend in data capture observed in the past few years (thought to be due to equipment failure and resource shortages) is beginning to reverse. Advice for site operators on dealing with equipment faults and maximising data capture are given in the Instruction Manual, which was fully updated and re-issued to all site operators in 1997. Additional copies of the Manual are available from AEA Technology if required.

4.4 NATIONAL AVERAGE SMOKE AND SO_2 CONCENTRATIONS

Mean UK concentrations in 1997 - 98, based on the core sites subset only, were as follows:

- Smoke: 9.4 μg m^{-3} BS *(11.1 μg m^{-3} OECD).*
- SO_2 : 20.6 μg m^{-3} *(7.7 ppb).*

These values are slightly lower than the 1996-97 means of 9.9 μg m^{-3} *(11.6 μg m^{-3} OECD)* and 22.4 μg m^{-3} *(8.4 ppb)* for smoke and SO_2 respectively.

4.5 IDENTIFICATION OF SITES WITH HIGH CONCENTRATIONS

Table 2 lists the sites identified as having the highest annual average smoke concentrations. All those with annual average smoke concentrations of 14 μg m^{-3} or above have been included; these total 17 (only sites with at least 75% data capture, ie. 273 days' data, for the year are shown). The sites with the highest smoke concentrations were predominantly in areas where the use of coal for domestic heating is still prevalent (eg. South and West Yorkshire, Northern Ireland), with some others in large towns and cities (eg. Bradford, Manchester, London).

The highest annual average was 21 μg m^{-3} BS *(25 μg m^{-3} OECD)*, recorded at the LONDONDERRY 11 site. This site was near the top of the same table last year, and has exhibited a small increase. In recent years, HALIFAX 16 has occupied the top of this table. It is missing this year, as just less than 273 day's data were available. However, an annual average of 20 μg m^{-3} BS was recorded at HALIFAX 16, making it joint 2nd highest with BRADFORD 6. HALIFAX 16 has exhibited the highest annual average smoke concentration for six consecutive years, probably due to its location in the town centre, near a bus station, major roads, and several car parks. Eight of the sites in Table 2 are in the Yorkshire and Humberside region; specifically, in south and west Yorkshire.

Table 3 lists the sites identified as having the highest SO_2 concentrations. All those with annual mean SO_2 of 36 μg m^{-3} *(14 ppb)* or above have been included (again, excluding any with less than 273 days' data). The highest annual average was 53 μg m^{-3} *(20 ppb)* recorded at BELFAST 42 and LONDONDERRY 11. Eight sites in Northern Ireland appear in this list. DUNMURRY 2 occupied the top of this table in several previous years, but has now moved down. High SO_2 concentrations have frequently been observed in Northern Ireland (where natural gas is not available for domestic heating and use of coal is therefore higher), and the South Yorkshire and East Midlands areas historically associated with the coal industry, where again domestic use of coal is prevalent.

CARDIFF 12 appears in Table 3 this year, having exhibited a substantial increase in its measured concentrations of both pollutants, particularly SO_2 . Reasons for this are being investigated; the Cardiff Centre AUN site has not recorded a similar increase in SO_2 concentration, so a local source is suspected.

Three sites appear in both Table 2 and Table 3, showing relatively high concentrations of both smoke and SO_2. These are LONDONDERRY 11, (Northern Ireland), BRAMPTON 1, and MALTBY 2 (both near Rotherham). All of these sites are in areas where there is relatively high consumption of coal for domestic heating.

Table 2 Sites with Highest Annual Mean Smoke Concentrations, 1997 - 98

Site Name	**Region**	**Annual Mean Smoke concentration,** μ**g m**$^{-3}$ **BS**	*μg m^{-3} OECD*
LONDONDERRY 11	N. Ireland	21	*25*
BRADFORD 6	Yorks. & H'side	20	*24*
MANCHESTER 11	North-west	18	*21*
BRAMPTON 1	Yorks. & H'side	16	*19*
SOUTH KIRKBY 1	Yorks. & H'side	16	*19*
LISBURN 3	N. Ireland	16	*19*
LUNDWOOD (BARNSLEY) 1	Yorks. & H'side	15	*18*
WOMBWELL 2	Yorks. & H'side	15	*18*
ALFRETON 4	East Mids	15	*18*
SHOREDITCH 2	London	15	*18*
MAGHERAFELT 1	N. Ireland	15	*18*
FARNWORTH 8	North-west	14	*16*
BARNSLEY 9	Yorks. & H'side	14	*16*
GRIMETHORPE 2	Yorks. & H'side	14	*16*
MALTBY 2	Yorks. & H'side	14	*16*
SEDGLEY 5	West Mids	14	*16*
MAIDSTONE 8	South-east	14	*16*

Table 3 Sites with Highest Annual Mean SO_2 Concentrations, 1997 - 8

Site Name	Region	Annual Mean SO_2 concentration, $\mu g\ m^{-3}$	*ppb*
BELFAST 42	N. Ireland	53	*20*
LONDONDERRY 11	N. Ireland	53	*20*
BELFAST 13	N. Ireland	50	*19*
CHESTERFIELD 18	East Mids	49	*18*
BRAMPTON 1	Yorks. & H'side	47	*18*
DUNMURRY 2	N. Ireland	46	*17*
ARMADALE 2	Scotland	45	*17*
BARNSLEY 8	Yorks. & H'side	44	*17*
BELFAST 44	N. Ireland	44	*17*
MANSFIELD WOODHOUSE 2	East Mids	43	*16*
STEPNEY 5	London	42	*16*
MALTBY 2	Yorks. & H'side	41	*15*
CARDIFF 12	Wales	40	*15*
BELFAST 45	N. Ireland	40	*15*
CUDWORTH 2	Yorks. & H'side	37	*14*
BELFAST 12	N. Ireland	37	*14*
LONDONDERRY 14	N. Ireland	37	*14*
TRAFFORD 1	North-west	36	*14*

4.6 TRENDS

The timeseries of the annual mean smoke and sulphur dioxide concentrations for the UK as a whole is provided in Figure 2. The values shown in Figure 2 are averages from all sites in the network up to 1980, and thereafter from all sites in the core subset only. As explained in Section 2, this subset is intended to provide a representative selection of monitoring sites in urban areas throughout the UK. The resulting graph shows the rapid decrease in concentrations in the 1960s and 1970s and the more gradual decrease through the 1980s and 1990s.

4.7 SPATIAL DISTRIBUTION OF SMOKE AND SO_2

Figures 3 and 4 show annual means of smoke and SO_2 respectively, for the entire Network. Only sites with less than 75% data capture have been excluded.

The data for 1997 - 98 shows a similar pattern to that observed in previous years. Highest values for black smoke and sulphur dioxide occurred not only in large conurbations, but also some smaller towns; most notably those in areas with a history of coal mining, where domestic use of coal is still relatively prevalent. In addition, relatively high concentrations of SO_2 were measured in Northern Ireland, particularly Belfast; natural gas is has very limited availability for domestic heating in this region, so greater use is made of coal and oil.

Page for Figure 2

Page for colour Figure 3

Page for colour Figure 4

Page for Figure 5

4.8 SEASONAL PATTERNS

It has long been known that smoke and SO_2 exhibit a seasonal variation. Concentrations of both pollutants, but particularly black smoke, are typically higher in the winter months (October to March). This is partly because a major source of both pollutants is the combustion of coal and oil; this increases during winter, mainly because of domestic and industrial heating requirements. In addition, cold, still weather conditions may prevent dispersion.

Figure 5 shows UK monthly mean concentrations of smoke and SO_2 , for the period April 1997 - March 1998. These are based on all sites in the Network. The seasonal variation for smoke is clearly visible, with monthly mean concentrations typically 5 to 8 $\mu g\ m^{-3}$ during the summer months, but rising to 8-16 $\mu g\ m^{-3}$ during the winter. For SO_2, the pattern is much less pronounced, with monthly means between 21 and 24 $\mu g\ m^{-3}$ *(8-9 ppb)* throughout the year, only rising slightly in winter.

5 Comparison with EC Directive Limits and Guide Values

In previous years, data from the UK Smoke and SO_2 Network have been compared with the European Council Directive[2] 80/779/EEC on sulphur dioxide and suspended particulates. However, this Directive is undergoing review, and in 1998 the European Commission published their proposal for the Daughter Directive[3] on SO_2, oxides of nitrogen, particulate matter and lead.

The original Directive is still in force, and will remain so until the formal adoption of the Daughter Directive, expected in 2001. In addition, the limits relating to black smoke remain in force until 2005. The current report therefore compares results from the Smoke and SO_2 Network with the relevant sections of both the original and “new” Directives.

5.1 DIRECTIVE EEC/80/779 (THE SO_2 AND SMOKE DIRECTIVE)

The limit values are presented in Table 4 below, along with the non-mandatory guide values. It should be noted that the EC Directive cites smoke concentrations calculated using the OECD Smoke Calibration Curve (OECD Publication no. 17913: 1964).

Results from all sites operational in 1997 - 98 were examined for compliance with the EC Directive limit and guide values. Limit values are mandatory, whereas guide values are advisory only, and are intended to serve as long term precautions for health and the environment.
It should be noted that the EC require that percentile calculations (eg. median, 98th percentile) are calculated by their specified method. For checking formal compliance with the EC

Directive, the specified Directive method has always been used. Hence, percentiles calculated by the EC Directive method are discussed in this section.

Table 4. EC Directive Limit Values For Smoke And Sulphur Dioxide In Micrograms Per Cubic Metre

Reference Period	**Smoke** **$\mu g\ m^{-3}$ BS**	**Limit Values for Sulphur Dioxide**
YEAR (median of daily values)	68	if smoke ≤ 34:120 if smoke > 34: 80
WINTER (median of daily values October-March)	111	if smoke ≤ 51: 180 if smoke > 51: 130
YEAR (Peak) (98 Percentile of daily values)	213	if smoke ≤ 128: 350 if smoke > 128: 250
EC Directive Guide Values For Smoke And Sulphur Dioxide In Micrograms Per Cubic Metre		
Reference Period	**Smoke** **$\mu g\ m^{-3}$ BS**	**Guide Values for Sulphur Dioxide**
YEAR (arithmetic mean of daily values)	34 to 51	40 to 60
24 HOURS (daily mean value)	85 to 128	100 to 150

NOTE: The Limit and Guide Values given above for smoke according to the BS calibration are calculated from the original OECD calibration figures given in the EC Directive using the relationship: BS concentration = OECD concentration multiplied by 0.85

5.1.1 Exceedences of the EC Directive Limits

Analysis of the data for 1997 - 98 shows that for the fifth year running, no site exceeded any of the limit values of the EC Directive. The steadily decreasing number of sites at which exceedences have been recorded in previous years is shown in Table 5.

Table 5. Exceedences * of the EC Directive, year beginning Apr 1983 onwards

Year Beginning April	No. of sites exceeding any limit	Site names
1983	12	GOLDTHORPE 1, GRIMETHORPE 2, WOMBWELL 2, WHITEHAVEN 2, ASKERN 6, DONCASTER 27, DONCASTER 32, MOORENDS 1, MANSFIELD WOODHOUSE 2, SUNDERLAND 8, CASTLEFORD 9, ASHINGTON 4
1984	6	BELFAST 12, BELFAST 17, BELFAST 33, LONDONDERRY 8, NEWRY 3, NEWRY 4
1985	9	GRIMETHORPE 2, BARNSLEY 9, DONCASTER 29, DONCASTER 32, MOORENDS 1, ASKERN 8, SUNDERLAND 8, BELFAST 12, NEWRY 3
1986	5	LANGOLD 1, **SEAHAM 2,** HETTON-LE-HOLE 3, BELFAST 13, NEWRY 4
1987	9	CREWE 17, MEXBOROUGH 19, **SEAHAM 2,** SUNDERLAND 8, HETTON-LE-HOLE 3 HOUGHTON-LE-SPRING 2, FEATHERSTONE 1 ASHINGTON 4, BELFAST 39
1988	3	NEW OLLERTON 2, HETTON-LE-HOLE 3, BELFAST 39
1989	3	HETTON-LE-HOLE 3, BELFAST 42, NEWRY 3
1990	3	BELFAST 11, BELFAST 12, BELFAST 42
1991	2	**DURHAM SHERBURN 1,** BELFAST 42
1992	1	GRIMETHORPE 3
1993	0	-
1994	0	-
1995	0	-
1996	0	-
1997	0	-

* It should be noted that all these sites (with the exception of those shown in **bold)** are in areas which had derogation from the EC Directive until 1993 . Therefore, only those shown in bold constitute statutory exceedences under the Directive.

5.1.2 Sites "At Risk" of Exceeding EC Directive Limits

"At Risk" of exceeding a limit has been defined as being within 75% of the limit values. No sites were identified as being "At Risk" of exceeding the 98th percentile limit, the annual median limit, or the winter median limit.

The peroxide titration method of analysis used in the UK monitoring network is not the reference method of the Directive, but has been accepted as an equivalence method, under the terms of Article 10 of the Directive. However, under the terms of this acceptance as an equivalence method, it was agreed with the Commission in 1989, that a factor of 1.25 would be applied to the sulphur dioxide results to compensate for a possible underestimation of peak values. In practice, this is done by dividing the appropriate SO_2 limits by 1.25, and comparing measured data with this adjusted limit. No sites exceeded the adjusted limit values; also, 1997-98 was the first year in which no sites were “At Risk” of breaching any of the adjusted annual limits.

5.1.3 Comparison with EC Guide values

Numbers of sites exceeding the EC Directive guide values are given below:

Smoke: Annual Arithmetic Means of Daily Values
Sites with annual arithmetic mean smoke > 34 μg m^{-3} BS: **no sites**
Sites with annual arithmetic mean smoke > 51 μg m^{-3} BS: **no sites**
It has been rare for sites to exceed the lower smoke guideline in recent years.

SO_2: Annual Arithmetic Means of Daily Values
Sites with annual arithmetic mean > 40 μg m^{-3} : **12 sites**
This is a decrease on last year’s total of 19 sites.
Sites with annual arithmetic mean > 60 μg m^{-3} : **No sites**
Last year, one site exceeded this guideline. This is the first year in which no sites have done so.

Smoke: 24 hour means
Sites with one or more 24 hour mean > 85 μg m^{-3} BS: **39 sites**
This is a substantial reduction on last year’s total of 52 sites, and continues the downward trend.
Sites with one or more 24 hour mean > 128 μg m^{-3} BS: **8 sites**
This is a small increase on last year’s total of 6 sites.

SO_2: 24 hour means
Sites with one or more 24 hour mean > 100 μg m^{-3}: **41 sites**
Last year’s total was 54 sites.
Sites with one or more 24 hour mean > 150 μg m^{-3}: **11 sites**
This is a reduction on last year’s total of 18 sites.

5.2 THE DAUGHTER DIRECTIVE

The proposed Daughter Directive on SO_2, NO_2, PM_{10} and lead[3] reached Common Position in the summer of 1998. This Directive will contain limit values for these pollutants, aimed at protection of human health and, in some cases, of ecosystems.

Only the parts of the Daughter Directive relating to SO_2 and particulate will be discussed here; the limits are given in Table 6 and 7 below. *These limits are still at the proposal stage, and there may be some change before they come into force.*

Table 6. EC Proposed Daughter Directive Limits for SO_2

	Averaging period	**Limit value**	**Date by which limit is to be met**
1. Hourly limit value for protection of human health	1 hour	350 μg m^{-3} not to be exceeded more than 24 times per calendar year	1 January 2005
2. Daily limit value for protection of human health	24 hours	125 μg m^{-3} not to be exceeded more than 3 times per calendar year	1 Jan 2005
3. Limit value for the protection of ecosystems	calendar year and winter (1 Oct - 31 Mar)	20 μg m^{-3}	2 yrs from entry into force of Directive

There is also an "alert threshold" for SO_2 of 500 μg m^{-3} *(188 ppb)*, measured over three consecutive hours at representative sites over at least 100 km^2 or an entire zone or agglomeration, whichever is smaller. Public warnings and advice are to be issued if this threshold is exceeded.

The proposed Directive limits are accompanied by "upper and lower assessment thresholds", which specify what type of monitoring is required.

- The upper assessment threshold is the level below which a combination of measurements and modelling techniques may be used to assess air quality;
- the lower assessment threshold is the level below which modelling alone, or with objective estimation techniques, is considered sufficient for assessment of air quality.

This ensures that monitoring resources are targeted where they are most needed. Exceedence of these assessment thresholds is to be determined on the basis of data from the previous five years where available.

It is clearly not possible to compare data from the Smoke and SO_2 Network with the proposed hourly limit. Nor is it relevant to compare data from this urban network with the annual and winter limits for protection of ecosystems, which are intended for protection of rural areas. However, it is possible to compare the daily data from the Network with the proposed 24 hour limit, for protection of human health.

In the calendar year January - December 1997, there were 7 sites with more than three days over the proposed 24 hour limit of 125 μg m^{-3} for SO_2: these were as follows:

BARNSLEY 8
BELFAST 13
BELFAST 42
BELFAST 44
BELFAST 45
BRAMPTON 1
NEWCASTLE UPON TYNE 24

Table 7. Proposed EC Daughter Directive Limits for PM_{10}

	Averaging period	**Limit value**	**Date by which limit is to be met**
Stage 1			
1. 24 h limit value for protection of human health	24 hour	50 μg m^{-3} not to be exceeded more than 35 times per year	1 January 2005
2. Annual limit value for protection of human health	cal. year	40 μg m^{-3}	1 January 2005
Stage 2 *			
1. 24 h limit value for protection of human health	24 hour	50 μg m^{-3} not to be exceeded more than 7 times per year	1 January 2010
2. Annual limit value for protection of human health	cal. year	20 μg m^{-3}	1 January 2010

* To be reviewed in the light of further information and experience.

The proposed particulate limits relate to PM_{10}, not black smoke, and therefore Network data cannot be directly compared with these. However, PM_{10} is usually higher than black smoke except at very high “episode” concentrations (typically winter episodes of primary particulate), so if there are more than 35 days in the year on which mean black smoke concentration exceeded 50 μg m^{-3}, it is likely that this is also the case for PM_{10}, and the daily PM_{10} limit would be exceeded. Likewise, if the annual mean black smoke concentration for the 12 month period April 1997 to March 1998 exceeds 40 μg m^{-3}, it is likely that the annual mean PM_{10} concentration has also done so.

During the period April 1997 - March 1998, no sites had more than 35 daily mean black smoke concentrations greater than 50 μg m^{-3}. While this does not highlight any particular sites as being likely to exceed the 24 hour PM_{10} limit, it does not mean that no exceedences will occur.

Indeed, some exceedences are predicted, particularly at city centre and roadside locations, on the basis of data from automatic PM_{10} monitoring sites.

In addition, no sites had annual mean black smoke concentrations higher than 40 $\mu g\ m^{-3}$ BS; the highest was 21$\mu g\ m^{-3}$ (see Table 3.) Therefore, black smoke data do not indicate any specific sites where exceedence of the annual limit is likely. Again, however, exceedence of PM_{10} limits cannot be ruled out.

The black smoke limits of the Smoke and SO_2 Directive will remain in force until 1 January 2005.

6 Comparison with National Air Quality Standards

6.1 NATIONAL AIR QUALITY STANDARD FOR SO_2

The UK National Air Quality Strategy[7] was published in March 1997. It includes a standard for SO_2, of 266 $\mu g\ m^{-3}$ *(100ppb)* as a 15 minute average concentration, and an objective that the 99.9th percentile of 15 minute means is within this value by 2005. The UK National Air Quality Strategy standard applies only to 15 minute means, and does not provide any equivalents relating to daily data. It is therefore not possible to compare Network data with this standard, although the Network data are useful in identifying areas of high SO_2 concentration which can then be targeted for automatic monitoring.

However, a recent study[8] has found strong relationships between the 99.9th percentile of 15 minute means for SO_2, and both the annual mean and the maximum daily mean. This study was based on data from automatic monitoring sites, largely urban background and urban centre sites. This study of surrogate statistics found that it was likely that the 99.9th percentile of 15 minute mean will exceed *100 ppb* (267 $\mu g\ m^{-3}$) if -

- the annual mean exceeds *7ppb* (19 $\mu g\ m^{-3}$),
- the maximum 24 hour mean exceeds *48 ppb* (128 $\mu g\ m^{-3}$).

As the peroxide bubbler method of measurement used in this Network is known to underestimate peak SO_2 concentrations, a factor of 1.25 should be applied to data when using this relationship.

When applied to the Network data, these two surrogates predict very different numbers of exceedences. The surrogate for the annual mean, 19 $\mu g\ m^{-3}$, is less than the Network 1997-98 annual mean of 20.6 $\mu g\ m^{-3}$, and exceedence is very widespread; 117 sites had annual means greater than 19 $\mu g\ m^{-3}$ in 1997-98.

The surrogate for the maximum day, 128 μg m^{-3}, was exceeded by only 23 sites in 1997-98. Dividing the surrogate maximum day limit by 1.25 to account for under-reading by the method used gives 102 μg m^{-3} for the maximum day; 39 sites had maximum daily means greater than this value in 1997-98.

Of the two surrogate relationships, the latter showed the stronger correlation[8], and less uncertainty. In addition, both parameters relate to peak, rather than average, values. Therefore it would be expected that the latter relationship is the more reliable.

6.2 NATIONAL AIR QUALITY STANDARD FOR PM_{10}

There is also an objective for particulate; 50 μg m^{-3} measured as the 99th percentile of running 24 hour means (this in effect means that no more than four days in a full year's monitoring should exceed this concentration). The particulate objective specifically applies to PM_{10}, not black smoke, and the UK National Air Quality Strategy acknowledges that these two techniques are not the same. However, as explained above, PM_{10} is usually higher than black smoke except at very high "episode" concentrations, so if daily mean smoke exceeds 50 μg m^{-3}, it is likely that PM_{10} has also done so. Table 1 shows the 98th percentile of daily black smoke values exceeded 50 μg m^{-3} at many sites during 1997 - 98; in such cases it is likely that exceedence of the PM_{10} standard may also have occurred.

7 Local Air Quality Reviews and Assessments

7.1 STAGES OF THE REVIEW AND ASSESSMENT PROCESS

Data from the Smoke and SO_2 Network have always been widely used at a local level to help to define air quality, and are increasingly published in local authority and county environmental reports. One important potential use at the present time is in Local Authorities' air quality reviews and assessments, as required by Part IV of the Environment Act, 1995. Local Authorities are required to undertake a review and assessment of local air quality, with reference to the standards and objectives of the National Air Quality Strategy. There are three stages to the reviews, which must be carried out for all the pollutants covered by the Strategy (except ozone):

1. **First stage review and assessment.** This involves collating information on current and potential future sources of the pollutant, with a view to assessing whether the Strategy objectives are likely to be met by 2005. Pollutant Specific Guidance[9] lists processes and activities for each pollutant, which, singly or together, may emit significant quantities of the pollutant of concern. If there are none within the Local Authority's area, they need not proceed to the second stage.

2. **Second stage.** The aim of the second stage review and assessment is to provide a further screening of pollutant concentration. The emphasis should be on locations where the first stage predicted highest pollutant levels. This involves an estimation of background concentrations; maps are available from the DETR's Air Quality Archive on the World Wide Web. Contributions from specific sources can then be added to these. Measurements from existing monitoring programmes can be used; it is at this stage that data from non-automatic networks can make an important contribution.

3. **Third Stage.** Authorities will need to conduct a third stage review and assessment if the first and second stages have indicated that there is a significant risk of air quality objectives not being achieved by the end of 2005.

Local Authorities are currently engaged in this review and assessment, following Pollutant Specific Guidance issued by the DETR[9] . In the case of SO_2, many Authorities will have to proceed to the second or third stage, while for particulate matter, measured as PM_{10}, it is likely that almost all Authorities will have to proceed to at least a second stage review.

7.2 USE OF NON-AUTOMATIC SO_2 DATA IN REVIEW AND ASSESSMENT

For local authorities which have to proceed to the second stage for SO_2, data from Network or other sites can be of use. Daily data cannot of course be directly compared with the SO_2 objective for the annual 99.9th percentile of 15 minute means; however, the study on surrogate statistics[8] discussed in section 6.1 has found that the air quality objective is unlikely to be exceeded if the maximum daily mean is less than *48 ppb*. The relationship, which is only valid for SO_2, was determined on the basis of data from automatic monitors. If data from the Smoke and SO_2 Network is used, the maximum daily mean should be multiplied by a factor of 1.25, to take account of the tendency for the peroxide bubbler technique used in this Network to under-read at peak concentrations. A further point to note is that Network sites analyse their SO_2 data by acid titration, which measures total acidity rather than specifically SO_2. While not ideal, total acidity data from this network will still have a role to play in the second stage review and assessment for SO_2.

7.3 USE OF BLACK SMOKE DATA IN REVIEW AND ASSESSMENT

For several years, there has been considerable interest in the possibility of using black smoke data to model or predict concentrations of PM_{10}. However, there are considerable differences between these two methods of particulate measurement. While PM_{10} is specifically defined as the mass fraction of particles collected by a sampler with a 50% cut-off at aerodynamic diameter 10 μm, the size fraction sampled by the black smoke method is not well defined but has a 50% cut-off between 3 and 5 μm [10]. Black smoke is, therefore, likely to approximately represent "dark PM_4", and may be considered a subset of PM_{10}.

Work by Stedman [11,12], discussed in last year's report and elsewhere, includes development of a method to assign contributions to PM_{10} concentration to three sources;

- Primary particulate material, mostly form local combustion sources. Black smoke provides a good indicator of this component.
- Secondary material, mostly light coloured sulphate and nitrate particles. Measured sulphate concentrations, at the UK's network of eight rural sites, provides a good indicator of this component. It is important to note that nitrates may make a significant contribution to this material. However, sulphates do provide a good indicator, and are measured more widely than nitrates.
- Coarse material, such as pollen, sea salt and wind blown dust. This varies from day to day and site to site; typical annual means are in the range 7 to 11 $\mu g\ m^{-3}$.

From this work, AEA Technology have developed a regression model, relating daily PM_{10} to measured daily black smoke and sulphate concentrations. The relationship is of the form

$$\text{total } PM_{10} = A \times \text{smoke} + B \times \text{sulphate} + C$$

This was derived for six monitoring sites, for 1996, in cities where there was an automatic PM_{10} monitor, and at least one black smoke site. The sulphate concentration was taken from the nearest rural monitoring site, or the average of the two nearest (there were eight operating during 1996): concentration of sulphate and other secondary particulate is expected to be relatively uniform, due to its long atmospheric lifetime. The sulphate coefficient, B, represents the factor required to convert sulphate to total secondary particulate, taking into account counter ions such as ammonium, and also other components such as nitrate. The smoke concentration was the average of all the sites in the city, and the smoke coefficient A is typically between 0.6 and 1.0 depending on the site, and may reflect the types of local primary particulate sources. The constant C, representing the concentration of coarser particulate within the PM_{10} fraction, from wind-blown dust etc. is typically between 7 and 11 $\mu g\ m^{-3}$. These values are shown in Table 8, taken from the Airborne Particles Expert Group (APEG) Interim report on source apportionment[13].

Table 8. Regression coefficients for 1996 particulate data.

Site	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 Picadilly	0.60	2.46	9.77	0.74
Newcastle Centre	0.66	3.13	7.73	0.84
Belfast Centre (1996)	0.71	2.30	9.21	0.79
Belfast Centre (1995)	0.77	2.82	8.27	0.70

The technique has been extended to provide forecasts of PM_{10} concentrations in the years 2005 and 2010. Both primary combustion related particulate and secondary particulate are predicted to decrease in future years, while coarse particulate levels are predicted to remain unchanged.

Using the predicted changes in the various components, estimates can be made predicting future concentrations of total PM_{10}.

The APEG report[13] does not specifically concentrate on the requirements of Local Authority Air Quality Review and Assessments. However, during 1997 there were 37 automatic PM_{10} sites, whereas there were over 200 smoke and SO_2 Network sites. A useful application for this work is the potential for using daily measured black smoke data, together with daily measured sulphate data from the rural network, to predict PM_{10} in towns with no automatic PM_{10} monitoring, given sufficient additional information. The smoke coefficient for any given Local Authority area can be estimated by comparison with measurements from sites with automatic PM_{10} monitoring, together with UK Emission Inventory data. The sulphate coefficient, B, can be estimated on a regional basis from interpolation of measurements at the network of rural sites. This work forms the basis of a model which can estimate PM_{10} concentrations from black smoke data[13].

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