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CHAPTER 4.0

Concentrations of air pollutants in the U.K.

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Introduction

4.1 In 1992 the Department of the Environment (DoE) established the Quality of Urban Air Review Group (QUARG) under the Chairmanship of Professor Roy Harrison. The Group published a report in January 1993, entitled 'Urban Air Quality in the United Kingdom' (available from Air Quality Division, Department of the Environment, Romney House, 34 Marsham Street, London SW1P 3PY, UK) which provides a detailed account of current monitoring and levels of a wide range of air pollutants. The following account draws heavily upon the QUARG report on a pollutant by pollutant basis. Only the major air pollutants: nitrogen dioxide, ozone, sulphur dioxide and particulate material are included. Data on levels of air pollutants and information on monitoring sites are reproduced by courtesy of the Warren Spring Laboratory.

4.2. The U.K. air pollution monitoring network run by the Department of the Environment has a number of components which are detailed in the QUARG report and summarized in Figure 4.1. These are mainly in urban areas. The EC directive networks were set up to monitor levels of NO₂, SO₂, smoke and lead. The Enhanced Urban Network (EUN) consists of an initial phase of 12 fixed sites in cities throughout the U.K. with sophisticated real-time monitoring of SO₂, NO₂, O₃ and PM₁₀ and CO. Despite recent investment by the DoE in air monitoring equipment the coverage of both rural and urban areas is still patchy and incomplete.

Nitrogen compounds

Trends in levels of nitrogen compounds

4.3. Despite clear growth in general vehicle usage in the U.K. it has not been possible to demonstrate a general trend in annual average concentrations of nitrogen dioxide in urban areas. This may be due to the siting of monitoring stations in heavily trafficked areas or close to major industrial sources: in both types of location little increase in emissions

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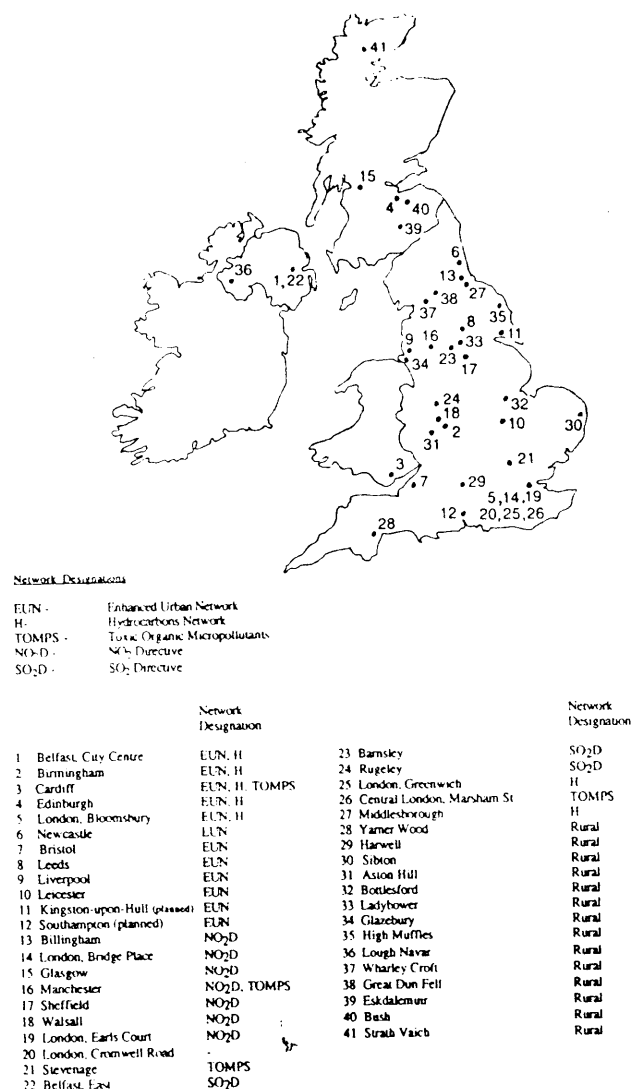


Figure 4.1. Map of the U.K. showing air pollution monitoring sites and their designation. EUN sites measure O₃, NO₂, SO₂, PM₁₀, CO and in some cases hydrocarbons. Rural sites measure O₃. (Adapted from Figure 2.6, QUARG First report, 1993 [30].)

is likely to have occurred in recent years. Levels of NO_x at Stevenage, ten miles north of London, however, have shown a steady upward trend, probably reflecting increased traffic density upon the nearby A1 (M) road. Data from a central

Table 4.1. Annual statistics for NO₂ for the calendar year January–December 1992. (Ref: Warren Spring Laboratory Annual Report January–December 1992)

Site	Annual mean (ppb)	Max hour (ppb)	Max 8 hour (ppb)	No. hrs>100 (ppb)	No. days when hrly >100 ppb
Stevenage	22	97	44	0	0
Cromwell Road	41	134	120	74	19
West London	32	142	89	20	9
Glasgow	25	94	62	0	0
Manchester	31	369	161	93	13
Walsall	27	269	165	24	5
Billingham	18	143	56	1	1
Sheffield	31	179	101	34	15
Bridge Place	39	175	111	95	26
Lullington Heath	7.6	90	37	0	0
Strath Vaich	0.7	13	9	0	0
Ladybower	9	57	39	0	0
London Bloomsbury	35	141	83	8	6
Edinburgh Centre	28	71	54	0	0
Cardiff Centre	25	79	52	0	0
Belfast Centre	23	130	67	4	4
Birmingham Centre	24	127	77	1	1
Newcastle Centre	27	285	68	8	8

Table 4.2. Extent to which NO₂ levels have exceeded WHO guidelines in 1992 in the U.K.

	DoE Bands		EC Directive		WHO	
	1 hr mean 100–299 ppb POOR	1 hour mean > 300 ppb V POOR	>105 ppb (98th%ile) (limit)	>71 ppb (98th%ile) (guide)	1 hr mean >210 ppb	Daily mean >80 ppb
Stevenage				*		
Cromwell Road	*			*		*
West London	*					
Glasgow						
Manchester	*	*		*	*	*
Walsall	*				*	*
Billingham	*					
Sheffield	*			*		
Bridge Place	*			*		*
Lullington Heath						
Strath Vaich						
Ladybower						
London Bloomsbury	*			*		
Edinburgh Centre						
Cardiff Centre						
Belfast Centre	*					
Birmingham Centre	*					
Newcastle Centre	*					

*Exceedences.

London monitoring site (rooftop of County Hall building) showed an increase from 25 ppb (annual average concentration) in 1978 to close to 40 ppb in 1989. A diffusion tube survey of levels of NO_2 at 240, mainly urban, sites reported in 1992 that the long-term average concentration of NO_2 had risen on average by 35% between surveys of 1986 and 1991. The interpretation of this result is not easy and year to year variations may explain a large part of the increase.

4.4. Annual statistics for the year January–December 1992 are shown in Table 4.1. These show a range of annual mean concentrations of NO_2 across the U.K. of between 0.7 and 41 ppb with maximal hourly concentrations ranging between 12.9 in Strath Vaich and 369 ppb in Manchester where there were 93 hours spread over 13 days in which concentrations exceeded 100 ppb and in Bridge Place where there were 95 hours over 26 days. Thus NO_2 levels were frequently high in several British cities.

4.5. To put these data in context it is useful to compare them with standards defined by the European Commission (EC) and by the World Health Organization (WHO). For the EC a limit value is specified of 105 ppb expressed as the 98th percentile of hourly averages over a period of one year and is set so as to protect human health. The EC also set a guide level, to aim at for the future, of 71 ppb as a 98th percentile of hourly averages over one year. The WHO guidelines have

been set with reference to the lowest observed effect concentration in asthmatics and are 210 ppb maximum one hour and 80 ppb maximum 24 hours. DOE bands for air quality designation are for hourly average <50 ppb very good, 50–99 ppb good, 100–299 ppb poor, >300 ppb very poor. Exceedences of these standards are shown on a site by site basis in Table 4.2.

Episodes of raised concentrations of nitrogen dioxide

4.6. From a health standpoint long-term average concentrations of nitrogen dioxide are difficult to interpret as the effects of chronic exposure to low concentrations of nitrogen dioxide are not clearly understood. Some studies of the effects of long-term exposure of children to oxides of nitrogen generated by gas cookers have suggested that such exposure may increase the incidence of respiratory infections in young children though others have failed to confirm this. (DH Advisory Group on the Medical Aspects of Air Pollution Episodes. Third Report: Oxides of Nitrogen. London HMSO 1993.)

4.7. Episodes of elevated concentrations of nitrogen dioxide are liable to occur in both summer and winter. In summer increased photochemical oxidation of NO to NO_2 occurs, in winter trapping of pollutants in cold, still air leads to a build up of ground-level concentrations. The major source of NO_2 accumulated during episodes in both summer and winter is motor vehicle exhaust.

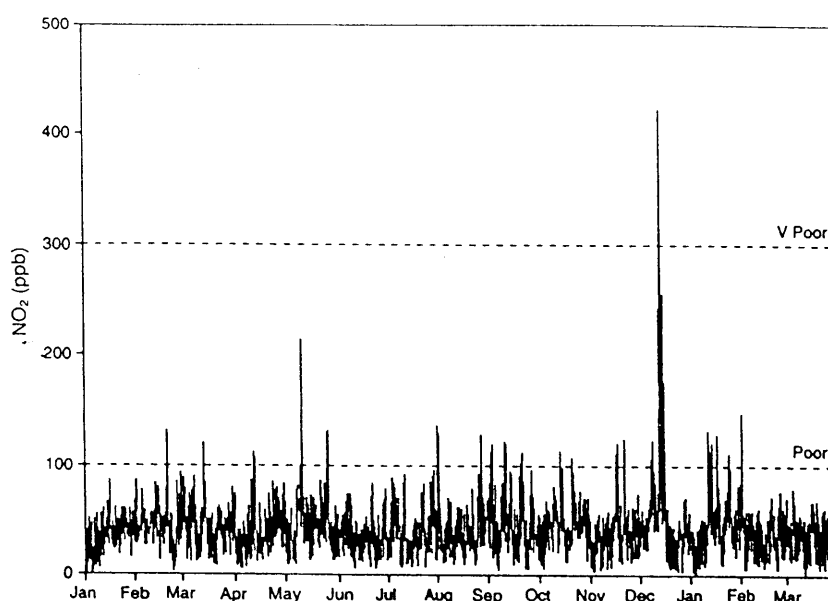


Figure 4.2. Concentrations of NO_2 during 1991/1992 at the Bridge Place monitoring site (not a kerbside site) showing the very high concentrations observed during December 1991. (Adapted from Figure 3.21. QUARG First report, 1993 [30].)

4.8. A marked episode of pollution by nitrogen dioxide occurred in London in December 1991. Concentrations rose, across London, close to or in excess of 400 ppb. A peak hourly average concentration of 423 ppb was recorded at the Bridge Place, Victoria monitoring site and is the highest ever recorded at a non-kerbside site in the U.K. Figure 4.2 shows a plot of hourly average concentrations of NO_2 at the Bridge Place monitoring site. Interestingly, the highest levels of NO_2 recorded during the episode occurred during the early hours of 13 December and not at a time of peak traffic density. The exact reasons for this remain unclear.

Ozone (O_3)

Trends in U.K. ozone concentrations

4.9. Motor vehicles are the main source of pollutants which give rise to ozone. In areas where vehicle density is high ozone levels are often low as ozone reacts with nitric oxide emitted in vehicle exhaust to form NO_2 . During hot summer weather ozone formation occurs in polluted air as it

moves away from cities and towns. Hydrocarbon oxidation is important in generating OH radicals and peroxy groups which aid in ozone formation. During photochemical episodes net ozone production may occur in large conurbations such as the London area, but is most evident within the downwind plume.

4.10. Ozone levels at background sites in Europe have risen during the 20th century though it is difficult to be sure whether levels are continuing to rise. Data from London (London, Victoria site) suggests that over the period 1972–1990 ozone levels have fallen in city centres possibly as a result of scavenging by NO. The introduction of catalytic converters resulting in decreased NO emissions may result in increased O_3 in city centres due to decreased scavenging of O_3 by NO, although this effect is not expected to be large.

Concentrations of ozone at U.K. monitoring sites

4.11. Until recently, O_3 was monitored, in the main, in rural areas the assumption being that ozone levels would be higher in rural compared to urban areas. This may not be univer-

Table 4.3. Ozone concentrations in the U.K. April 1992–March 1993

	Annual mean (ppb)	Max. hour (ppb)	Max. 8 hr (ppb)	No. hrs >100 ppb	No. days when hrly >100 ppb
Stevenage	15	89	70	0	0
Sibton	25	116	85	6	2
Bridge Place	10	76	52	0	0
Aston Hill	29	95	79	0	0
Lullington Heath	28	98	80	0	0
Strath Vaich	33	74	64	0	0
High Muffles	29	94	84	0	0
Lough Navar	25	81	62	0	0
Yarner Wood	28	108	84	4	2
Ladybower	23	107	79	1	1
Harwell	26	116	95	10	4
Bottesford	15	95	63	0	0
Bush	26	80	65	0	0
Eskdalemuir	25	75	63	0	0
Great Dun Fell	32	132	79	9	3
Wharley Croft	27	100	82	2	1
Glazebury	16	106	76	6	2
London Bloomsbury	9	73	58	0	0
Edinburgh Centre	11	41	27	0	0
Cardiff Centre	13	98	83	0	0
Belfast Centre	18	69	46	0	0
Birmingham Centre	15	86	58	0	0
Newcastle Centre	15	53	39	0	0
Leeds Centre	11	37	31	0	0
Bristol Centre	15	47	36	0	0

Table 4.4. Sites at which European and WHO guidelines were exceeded for ozone in 1992–1993

	DoE Bands		EC Directive		WHO	
	1 hour mean 90–179 ppb	1 hour mean ≥180 ppb	8 hour mean >55 ppb	1 hour mean ≥90 ppb	1 hour mean ≥76 ppb	8 hour mean ≥50 ppb
Stevenage			*		*	*
Sibton	*		*	*	*	*
Bridge Place			*		*	*
Aston Hill	*		*		*	*
Lullington Heath	*		*		*	*
Strath Vaich			*			*
High Muffles	*		*		*	*
Lough Navar			*		*	
Yarner Wood	*		*	*	*	*
Ladybower	*		*	*	*	*
Harwell	*		*	*	*	*
Bottesford	*		*		*	*
Bush			*		*	*
Eskdalemuir			*			*
Great Dun Fell	*		*	*	*	*
Wharley Croft	*		*	*	*	*
Glazebury	*		*	*	*	*
London Bloomsbury			*			*
Edinburgh Centre						
Cardiff Centre	*		*		*	*
Belfast Centre						
Birmingham Centre			*		*	*

sally true and though ozone levels close to traffic are likely to be low, levels in parks and suburban areas could approach rural levels. During the summer of 1994 concentrations in many city centres were in excess of EC and WHO guidelines with, for example, a peak level of 91 ppb in Leicester City Centre in June 1994. Table 4.3 gives the data for April 1991–

March 1992 from the predominantly rural 'ozone network' of monitoring stations. Across 25 monitoring sites in the U.K. annual mean ozone levels ranged between 10 and 29 ppb with maximum hourly concentrations between 37–132 ppb. Hourly mean concentrations of greater than 100 ppb were exceeded up to 10 days a year.

Table 4.5. Summary of Ozone Data for 1993 from the EUN sites (ppb)

Site	Peak hr	Peak 8hr	Number of hours exceeding EC directive thresholds	
			90–179 ppb	>180 ppb
London, Bloomsbury	73	64	0	0
London, Bridge Place	76	52	0	0
Newcastle	68	51	0	0
Belfast	71	55	0	0
Birmingham	81	69	0	0
Cardiff	99	93	11	0
Edinburgh	22	18	0	0

4.12. Though annual mean concentrations at rural sites tend to be rather similar, peak hourly average concentrations are highest at the monitoring sites on the south coast. Warmer weather, with more hours of sunshine, some drift of pollution from London and across the English Channel from Europe could explain this.

4.13. U.K. ozone levels are compared with international standards and guidelines in Table 4.4. For the DOE bands very good air quality is less than 50 ppb and good air quality between 50 and 89 ppb. It will be seen that exceedences of levels indicated in the recent EC Directive on Ozone and WHO Air Quality Guidelines (range 76–100 ppb) are common.

4.14. Systematic monitoring of ozone in urban areas began in 1992 with the Enhanced Urban Network of monitoring stations. EUN sites for ozone have not been in operation for sufficiently long for any conclusions regarding trends in ozone concentrations to be drawn. O_3 concentrations in EUN sites in 1993 are detailed in Table 4.5.

4.15. Episodes of raised ozone concentrations occur during warm summer weather. Data showing O_3 levels at Lullington Heath throughout 1992 are shown in Figure 4.3.

Sulphur dioxide (SO_2)

Trends in levels of SO_2 in the U.K.

4.16. SO_2 levels in urban areas have fallen dramatically since the 1950s–60s and in urban areas concentrations are now often little different from those in rural areas. Background levels of SO_2 tend to be more constant across large parts of the U.K. than in earlier times although local fumigations, produced by grounding of plumes from industrial sources, still occur. Generation of electricity by non-nuclear power stations along the Thames estuary leads to occasional local episodes of elevated levels of SO_2 in London while domestic coal burning is still a significant factor in some areas.

Concentrations of SO_2 at U.K. monitoring sites

4.17. Sulphur dioxide is monitored at more than 200 sites providing daily mean concentrations using ' SO_2 bubblers' and at 16 automatic, continuous reading sites. Most sites are in urban or industrial areas. Annual mean concentrations range between 0.3 and 23 ppb. However, hourly maxima range between 78 to 544 ppb with, in Barnsley and Belfast, the

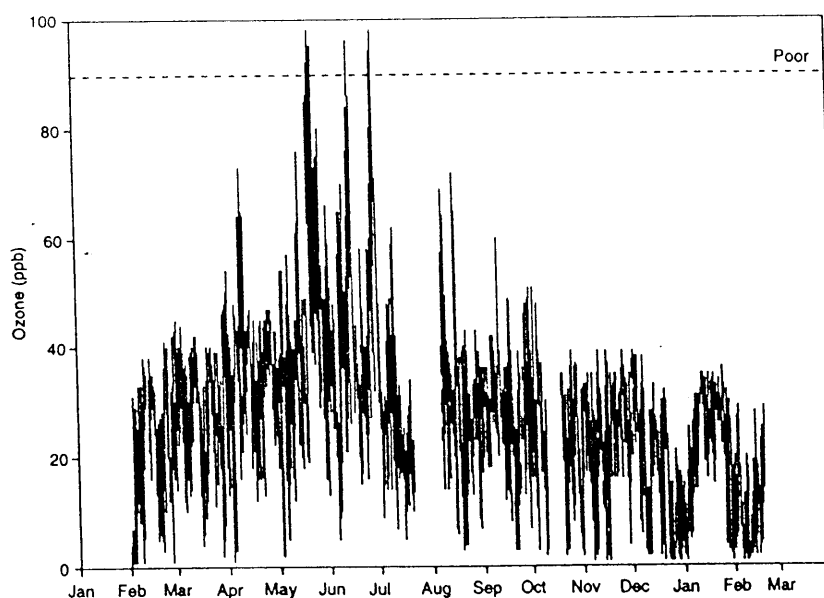


Figure 4.3. Concentrations of O_3 at Lullington Heath rural monitoring station from February 1992 to March 1993.

Table 4.6. Concentrations of SO₂ in the U.K. April 1992–March 1993

Site	Annual mean (ppb)	Max hour (ppb)	Max 8 hr (ppb)	No. hrs ≥122 ppb	No. days when hourly ≥122 ppb
Stevenage	6	124	36	0	0
Cromwell Road	14	190	78	5	3
Bridge Place	8	202	84	5	4
Lullington Heath	2.3	80	21.6	0	0
Strath Vaich	0.3	14.5	6.5	0	0
Ladybower	7.5	191.6	86.5	3	2
Belfast	23	544	194	165	36
Rugeley	13	435	284	31	9
Barnsley	23	343	201	217	59
Sunderland	9	274	161	5	1
London Bloomsbury	11	283	80	14	8
Edinburgh Centre	10	85	37	0	0
Cardiff Centre	7	144	64	3	2
Belfast Centre	16	385	139	58	16
Birmingham Centre	11	139	104	1	1
Newcastle Centre	7	226	109	5	3
Leeds Centre	12	175	75	1	1
Bristol Centre	7	78	36	0	0

number of hours exceeding 122 ppb being 217 and 165, respectively. Although average concentrations generally appear low there are clearly SO₂ blackspots in the U.K. where

concentrations can quite frequently be in a range likely to have adverse health effects. Data from the Sulphur Dioxide Network are detailed in Table 4.6. The fact that SO₂ concen-

Table 4.7. SO₂ exceedences from European and WHO guidelines in the U.K. in 1992–1993

	DoE Bands		EC Directive		WHO
	1 hr mean 125–399 ppb	1 hr mean > 400 ppb	Annual mean >15 ppb	Daily mean >37.5 ppb	1 hour mean >122 ppb
Stevenage	*		*		*
Cromwell Rd	*		*		*
Bridge Place	*				*
Lullington Heath					
Strath Vaich					
Ladybower	*		*		*
Belfast	*	*	*	*	*
Rugeley	*	*		*	*
Barnsley	*	*	*		*
Sunderland	*		*		*
London Bloomsbury	*		*		*
Edinburgh Centre					
Cardiff Centre	*		*		*
Belfast Centre	*	*	*		*
Birmingham Centre	*		*		*
Newcastle Centre	*				*
Leeds Centre					*
Bristol Centre					

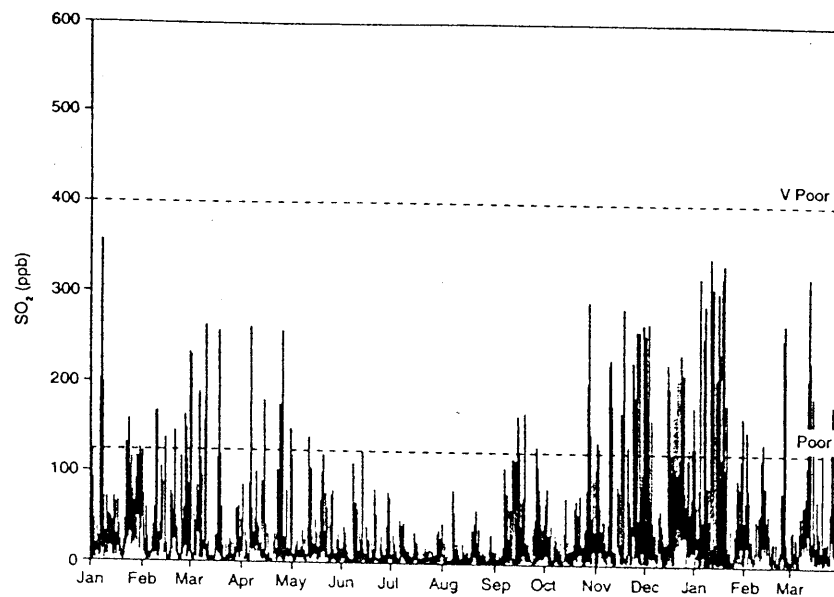


Figure 4.4. Concentrations of SO_2 in Barnsley during 1992/1993.

trations are still far from ideal in the U.K. is reflected in the number of exceedences of air quality guidelines detailed in Table 4.7.

Episodes of elevated concentrations of SO_2

4.18. Episodes of elevated concentrations of SO_2 are common in Belfast during the winter months. Belfast is not sup-

plied with piped gas and a large amount of coal and smokeless fuel continues to be used for domestic heating. Peak concentrations well in excess of the WHO 1-hour Air Quality Guideline of 122 ppb and the 10-minute guideline of 175 ppb occur frequently during winter.

4.19. Though peak levels of SO_2 tend to be greater in Belfast than other U.K. cities high levels may also be recorded

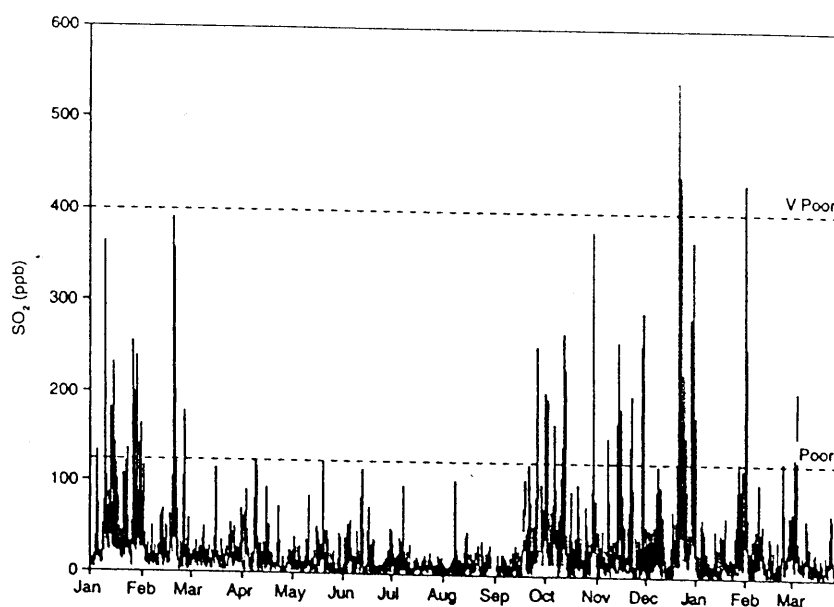


Figure 4.5. Concentrations of SO_2 in Belfast during 1992/1993.

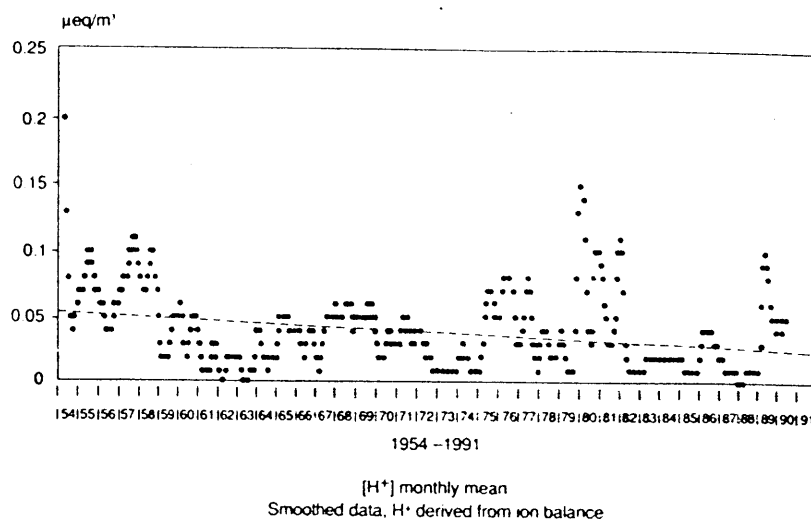


Figure 4.6. Concentrations of particulates measured in Chilton, Oxfordshire, from 1954–1991. (Figure 3.13 Second report AGMAAPE [19].)

elsewhere. Figures 4.4 and 4.5 shows data from Barnsley and Belfast for the period January 1991–March 1992.

Acid sulphates

Trends in levels of sulphates

4.20. SO_2 is oxidized in ambient air to sulphuric acid. Sulphuric acid reacts with ammonia to form the bisulphate (NH_4HSO_4) and the sulphate ($(\text{NH}_4)_2\text{SO}_4$). One would expect levels of sulphates to have fallen in urban areas as a

result of the decrease in levels of SO_2 . Monitoring of levels of acidic sulphates is technically difficult and few data are available in the U.K. Studies undertaken at the MRC Air Pollution Unit at St Bartholomew's Hospital in London in the 1960s demonstrated that in 1962 peak hourly levels of acidic particles reached $678 \mu\text{g}/\text{m}^3$ (Peak daily value = $347 \mu\text{g}/\text{m}^3$). In the period 1963 to 1972 the peak daily value recorded was $134 \mu\text{g}/\text{m}^3$. Studies conducted in London in 1990 showed that daily mean levels of sulphate did not exceed $20 \mu\text{g}/\text{m}^3$.

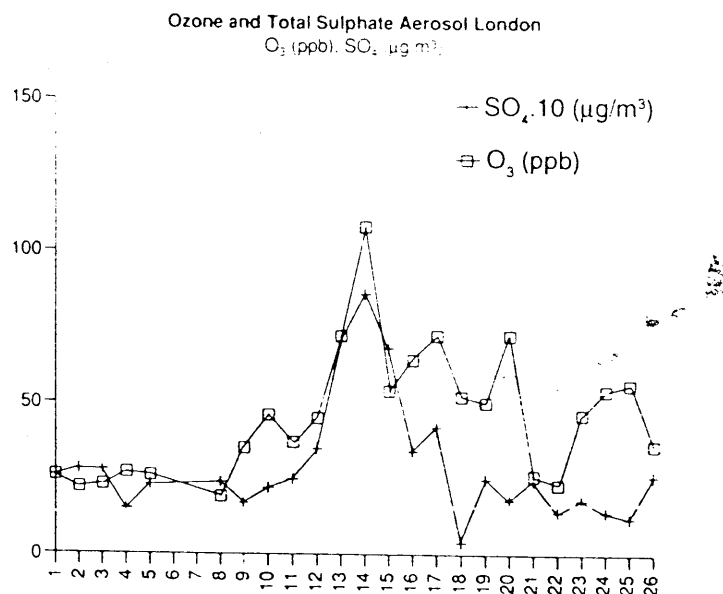


Figure 4.7. Relationship between concentrations of ozone and total sulphate aerosol in London during June 1989. (Figure 3.12 Second report AGMAAPE [19].)

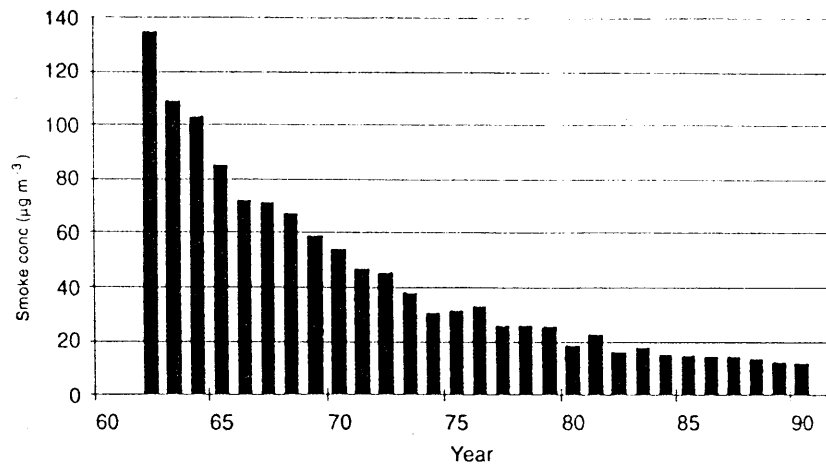


Figure 4.8. Mean urban concentrations of Black Smoke over the last three decades showing a steady reduction in levels over the time period. (Figure 4.8. QUARG [30].)

Concentrations of acid aerosols in the U.K.

4.21. No large-scale monitoring of acid aerosols is currently undertaken in the U.K. The best available data is from a long series of measurements made at AEA Technology, Harwell (Figure 4.6). These indicate that annual average concentrations of acid ($H^+ = (SO_4^{2-} + NO_3^-) - NH_4^+$ in equivalents) are of the order of 3–5 $\mu\text{g}/\text{m}^3$ H_2SO_4 .

Episodes of elevated concentrations of acid sulphates

4.22. When levels of SO_2 were raised in urban areas in foggy winter weather then levels of acid sulphates would also have been expected to be high. Peak daily levels of sulphate in

urban areas are now likely to be similar throughout the year, though monthly mean concentrations may be lower in summer. Increased oxidation of SO_2 to sulphate might be expected on days with raised O_3 concentrations: this may explain the findings in Figure 4.7 showing an association between total sulphate aerosol and O_3 during a photochemical episode.

Particulate air pollutants

Trends in urban particle levels in the U.K.

4.23. In the 1950s, before the Clean Air Act of 1956, very high levels of particles, generated by domestic coal fires, were found in urban air in the U.K. In December 1952 levels of

Table 4.8. Thoracic particulates PM_{10} network summary (from Annual Statistics, April 1992–March 1993)

Site	Annual mean ($\mu\text{g}/\text{m}^3$)	Max hour ($\mu\text{g}/\text{m}^3$)	Max day ($\mu\text{g}/\text{m}^3$)	No. days $\geq 70 \mu\text{g}/\text{m}^3$
London Bloomsbury	31	173	4	6
Edinburgh Centre	22	127	72	1
Cardiff Centre	28	296	85	1
Belfast Centre	30	872	248	14
Birmingham Centre	26	231	131	6
Newcastle Centre	28	274	72	3

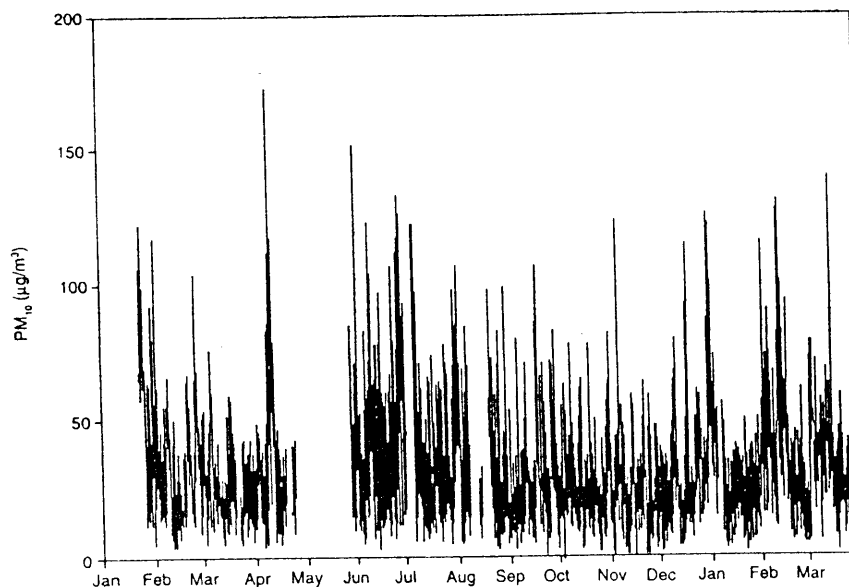


Figure 4.9. Time series plot of concentration of PM_{10} in London during 1992/1993.

particles in excess of 4 mg/m^3 were recorded in London by the Black Smoke, Reflectance, Method. Recently, continuous monitoring of airborne particles has begun in U.K. cities as part of the Enhanced Urban Network of monitoring sites. At these sites airborne particles are sampled using a selective inlet with a 50% efficiency cut-off of $10 \text{ }\mu\text{m}$ aerodynamic diameter (PM_{10}).

Concentrations of particulates in the U.K.

4.24. Mean urban levels of black smoke in the U.K. from 1960–90 are shown in Figure 4.8. These show a marked decline since the mid-1960s to the 1990s from an average of nearly $140 \text{ }\mu\text{g/m}^3$ to less than $20 \text{ }\mu\text{g/m}^3$.

4.25. Limited data is available as yet from the EUN. Statistics based upon hourly data collected from EUN sites over the period April 1992–March 1993 show an annual mean of between 22 and $31 \text{ }\mu\text{g/m}^3$ with maximal hourly concentrations of up to $873 \text{ }\mu\text{g/m}^3$ in Belfast and $296 \text{ }\mu\text{g/m}^3$. There were between 1 and 14 days in which concentrations of particulates exceeded $70 \text{ }\mu\text{g/m}^3$. Therefore, in a similar manner to SO_2 concentrations, although there has been an overall improvement, the annual mean figures conceals a picture of many days when air quality is poor. These data are detailed in Table 4.8.

In urban areas short-term peaks in PM_{10} concentration occur. Preliminary data from EUN sites suggested that peaks may exceed long-term averages by a factor of 5 (Figure 4.9).

(The views expressed above are those of the author (RLM) and should not be taken as those of the Department of Health.)