European Topic Centre on Air Quality

AIR QUALITY IN EUROPE, 1993
A PILOT REPORT

By

Steinar Larssen and Leif Otto Hagen

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European Environment Agency
Kongens Nytorv 6
DK - 1050 Copenhagen K
Denmark
Tel: +45 33 36 71 00
Fax: +45 33 36 71 99
E-mail: eea@eea.dk
Homepage: http://www.eea.dk

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Summary

An overview of air quality in Europe for 1993 is presented. The overview covers air pollution levels on the urban/local and regional scales.

The intention of such reports from the European Topic Centre for Air Pollution is to present comprehensive, annual summaries of European air pollution, covering all components of interest, all scales and trends. The precondition for presenting such summaries is that data from representative stations throughout Europe is made available and collected in a data base. Presently, APIS (Air Pollution Information System) is the only international (EU) data base covering pollution on the urban/local scale. Only a few EU countries report data to APIS on a regular basis. Regarding the regional scale, the EMEP data base is regularly updated with data from 92 stations in 26 countries.

The Topic Centre on Air quality is working to develop further the data bases on the European scale, and to define a "European Air Quality Network" which should cover the regions and scales of European air pollution in a representative way. For this 1993 report, the Topic Centre had to resort to the fairly limited amount of data which were available in the APIS/EoI base after a special update which took place in the fall of 1995, as part of the Topic Centre activities.

The following 7 compounds are included in this report: Sulphur dioxide, nitrogen dioxide, black smoke, suspended particles, ozone, lead and CO. The ozone data are from 1994, not from 1993. The 1994 data had previously been collected by the Topic Centre on Air quality in preparation of their report to the Commission on the occurrence of exceedances of ozone threshold values for 1994.

This draft pilot report is based upon the data available for 1993 (including winter 1993-94) in APIS and on EoI data files, and upon data contained in national reports which were available to the ETC-AQ. Data were available for a total of 21 countries, of which the APIS provided data from 6 countries, EoI for 4 additional countries, and national reports from 11 additional countries. Even for many of these countries, the information available cannot be said to be complete. The data and information on regional concentrations, and their evaluation, is based upon the EMEP report for 1993.

The extent of data available on local and urban pollution is not large enough to fully characterise European air quality on this scale. At this stage, the presentations and summarising in the report should be considered as a first cut on how European air quality can be presented and summarised.

The available data show that for all compounds on the local/urban scale, concentrations are highest in Central and South Europe. East Europe is represented only by data from the Czech Republic and Slovakia, and local concentration from those countries are on the high side. The available data show that EU Limit values for SO_2 and black smoke are still exceeded in some European cities. The EU and WHO Guide values are extensively

exceeded for SO_2, NO_2, black smoke and suspended particles, and WHO Guidelines for CO are also exceeded.

The spatial distribution of the regional concentrations and deposition of sulphur and nitrogen compounds in Europe is well known from the EMEP work, based on measurements and modelling. The highest long-term SO_2 levels occur in Central Europe (Czech Republic and neighbouring areas), while maximum of sulphate in aerosol and sulphate deposition occurs further to the east. Long-term regional NO_2 concentrations peak over the Iberian peninsula, while nitrate deposition has maximum in Central Europe.

The EU threshold values for ozone for protection of human health and vegetation were exceeded substantially in 1994 in all EU Member States which provided data. The threshold values for information and warning of the population were exceeded during a limited number of days. The warning level was reported exceeded at three monitoring stations.

1. Introduction

The Project MA 2 of the 1994-95 Work Programme of the European Environmental Agency (EEA 1994 a, b) entitled **"Establishment and Maintenance of the European air quality monitoring network and data bases"**, has the following 6 sub projects:

MA 2-1 : Review current database systems (APIS/GIRAFE) for air quality data and monitoring stations.

MA 2-2 : Evaluate experience on EU exchange of information and other international air quality data collection.

MA 2-3 : Report on maintenance and development of air quality data bases.

MA 2-4 : Annually collect agreed air quality data and prepare report on data collected and overview of air quality state and trends in Europe.

MA 2-5 : Following recommendations from MA 1, evaluate representativeness and quality of monitoring networks.

MA 2-6 : Define in detail requirements for air quality monitoring at the European level.

MA 2-1, 2-2 and 2-3 concerns databases, the evaluation of current ones and current collection and exchange of data, and the recommended development of improved air quality data bases and data collection and exchange.

MA 2-5 and 2-6 concerns representativity of monitoring sites and networks and recommended requirements to European-wide air quality monitoring networks and systems.

In between these activities of the MA 2 project, in MA 2-4 available data are actually to be collected and summarised, to report an annual overview of the state and trends of air quality in Europe. From the MA 2-4 experiences, recommendations can be made, based on the extent, quality and overview of the data, regarding the improvement of the European-wide air quality monitoring systems and the data collection and exchange process.

2. Aim and scope of this report

The **aim** of the MA 2-4 project is to:

- report on the data collected in accordance with the draft EoI Decision and the Framework Directive,

- prepare a pilot report on European air quality and deposition and trends, and identify deficiencies and gaps.

The aim of this report is to present the requested overview of air quality in Europe for the year 1993, including the winter 1993-94.

The **scope** of the work, as indicated in the project plan, includes:

- to collect data available from the Commission (DG XI), collected under the EoI Decision, and available in the APIS and EoI data bases,

- to survey other bases of European air quality data, such as the EMEP data base,

- to summarise the data, and present overview in the form of tables and graphs, forming a suitable background for evaluating the state and trend of European air quality,

- to evaluate the European air quality, using effects relevant indicators, comparing the state and trend of air quality with relevant guidelines and critical loads.

- to establish the requirements for EEA's annual air quality reporting, as needed for EEA's reporting tasks with the EU, and to the public.

3. EU exchange of data requirements

The 1982 decision of the Commission on Exchange of Information (EoI) from air pollution monitoring (82/459/"EØF") requires reporting of measurements as described below:

- Compounds: SO_2 (or acidity), suspended particles (or black smoke), NO_2 (and NO_x or NO), CO, O_3.

- Stations: Selection of sites, preferably sites with more than one compound measured, and such that they represent different types of urban areas and the variations in air pollution levels occurring in each state.

- Reporting should be sent to the Commission within 6 months in the new year.

- Additionally, the Member States shall inform the Commission of studies of comparison of methods.

- The Commission publish annual reports.

The activity under this EoI decision has dwindled over the years, and thus a new Draft EoI Decision has been formulated (94/C281/07). Relative to the 1982 decision, the new one requires some additions:

- *Compounds*: Those covered by Directives (as above), and in addition 31 compounds to the extent Member States measure them, incl. e.g. 7 heavy metals, VOC and benzene, formaldehyde, PAN and 7 specific organic compounds, PAH and BaP, and S and N deposition. The averaging time is 1 h for some compounds (e.g. O_3, NO_x, CO, PAN), 24 h for most of them, and 1 month for deposition.

- *Stations*: A selection of sites operated under the compound-specific Directives, sites operated under the 1982 EoI Decision, and additional sites established for the additional compounds. The selected sites should be distributed over the national territory, to represent different pollution categories and levels.

  The sites should be described very detailed regarding local environment and influences from sources according to a predescribed set of parameters and format.

- *The data statistics* to be reported should be:
  - Conc. in air: average, median, P98, Maximum (on an annual basis).
  - For ozone: in addition, 8-hour statistics.
  - Deposition: monthly averages.

- Reporting should be sent to the Commission within 1 October in the new year.

4. Air Quality Limit Values

Guidelines and limit values for air quality have been set by EU in various Council Directives, by the World Health Organization (WHO) and also by many of the national states.

The table below lists the Limit and Guide values of EU, and the Guideline values of WHO, for the following components:

- SO_2 (with associated values for black smoke/suspended particles)
- Black smoke (BS)
- Suspended Particles
- Lead
- NO_2
- O_3
- CO

More details around the values are given in the section on each component in chapter 6.

Table 4.1: Overview of EU Limit and Guide Values and WHO Guideline Values (WHO, 1987) for the listed compounds (µg/m³). Reference to EU Directives are given in chapter 6.

Compound	Median value		98 percentile	Maximum value		
Type of value	Year	Winter	value	24h	8h	1h
SO_2						
EU Limit Values	80-120[1]	130-180[1]	250-350[1,3]			
EU Guide Values	40-60 (mean value)			100-150		
WHO Guidelines	50[2] (mean value)			125[2]		350
Black smoke						
EU Limit Values	80	130	250[3]			
EU Guide Values	40-60 (mean value)			100-150		
WHO	50[2] (mean value)			125[2]		
Suspended particles						
EU Limit Values	150 (mean value)		300 (95 percentile)			
WHO				120 (TSP)[2,4] 70 (TP)[4]		
Nitrogen Dioxide						
EU Limit Values			200[5]			
EU Guide Lines	50		135[5]			
WHO				150		400
Carbon Monoxide						
WHO					10 000	30 000
Lead						
EU Limit Values	2					
WHO	0,5-1					
Ozone						
EU Threshold Values						
- Health protection					110[6]	
- Vegetation “				65		200
- Population info.						180
- Population warning						360
WHO					100-120	150-200

1) Dependent upon the associated black smoke/suspended particle concentrations.
2) Assuming approx. equal concentrations of SO_2 and black smoke/suspended part.
3) Not to be exceeded for more than 3 consecutive days.
4) Values of total suspended particles (TSP) and thoracic particles (TP ~PM_{10}), to be considered tentative.
5) Based upon 1 h averages. (All other 98-percentile values are based upon 24 h averages)
6) This value is a mean value over 8 hours and is a non-overlapping moving average; it is calculated four times a day from eight hourly values between 0 and 9.00, 8.00 and 17.00, 16.00 and 1.00, 12.00 and 21.00.

5. Data sources

The list of sources of data from each country utilised in this report is given in Table 5.1. Appendix A references the various national reports utilised. The various data sources are summarily described in the following.

5.1 APIS and EoI data bases

The basic source of data for the present report was to be the data files transmitted to the DG XI under the EoI Decision, and the APIS data base into which the EoI data files are fed for statistics calculations and presentations.

Following the decision that the first annual AQ report was to present 1993-94 data, the EoI files and APIS had to be updated. This updating process was carried out by deviance Consulting, SA, Brussels, under a separate contract with the Topic Centre on Air Quality. The updating process was finalised in the end of October 1995. Updated EoI files and APIS was made available to the Topic Centre, complete as far as data were available from the states, by that same date.

Table 5.1 shows which countries provided EoI/APIS data for the 1993-94 update. The data from the new EU countries have not yet been entered into APIS.

For the reported stations, the EoI data base contains the necessary air pollution data asked for by the EU Council Directives. For some cities and stations it was rather difficult to find the city and station names.

For the reported stations, the APIS data base seems complete concerning the air pollution data asked for by the EU Council Directives. Information on geographical co-ordinates and description of the local environment are not complete for all stations. For many stations there is no information available as to the traffic conditions in the environments.

Trend figures for SPM do not show the 95 percentile of daily values which is asked for in the EU Council Directive, but instead the 98 percentile is shown.

The 1993-94 data in the APIS/EoI data base was rather limited. Only 9 EU Member States have reported data. APIS does not contain data from non EU Member States.

5.2 Other sources of country-specific data

After the updating process of APIS, it was apparent that the extent of data for 1993-94 contained in APIS and in EoI files was rather limited, and much too limited to provide a basis for evaluation of European air quality for that year. Data was missing completely from many countries. Also, APIS and EoI base contains data only for EU Member States.

In order to be able to present a somewhat more complete picture of local air quality in Europe in the first pilot report, it was then decided to resort to other sources of data on the national level. National air quality reports were collected to the extent they were easily available, or could easily be acquired through contact persons. No request was sent out to all countries.

National reports were thus available from the following countries: Czech Republic, Denmark, Germany, the Netherlands, Norway, Liechtenstein, Slovakia, Sweden, Switzerland, United Kingdom (only for the automatic network). References are listed in Appendix A. Data listings were available from France, Italy and Portugal.

The national reports are naturally quite different regarding layout, data statistics parameters calculated, and presentations of the data. As a general rule, the national reports do not give all of the statistics parameters that are requested in the EU Directives or EoI Decisions. Thus, the national reports do extend the picture of European air quality, but summaries of similar data from each country tend to be rather restricted, because the actual data values are not available.

5.3 Other sources of data

- The EMEP report for 1993 was used to give a summary on regional air quality in Europe.

- The ozone report prepared by ETC-AQ (de Leeuw et al., 1995) was used to give a summary of urban and regional tropospheric ozone in Europe, although this report contains data only from 1994.

5.4 Total extent of data used in this report

Table 5.1 gives an overview the main sources of information on local air pollution from each country. It is seen that EoI data has been available from 5 countries, APIS data from 6 countries (also in EoI), and data from national reports from 13 countries. Totally, data from 21 countries were available on local air pollution. Table 5.1 also gives the number of cities and stations for each of the countries.

All the data available from these cities and sites are given in the country-wise tables in Appendix B.

A selection was made for the purpose of presenting a preliminary overview of local air quality in Europe in the present pilot report. For each country, 1-5 cities with fairly high air pollution levels were selected. In each city, the most polluted site with a fairly complete list of compounds monitored, was chosen. Later, the selection can be made more complete. The selected cities are shown on the European map in Figure 5.1. The names of the selected cities in each country is given in Table 5.2.

The EMEP data base contains regional pollution data from 26 countries, for a total of 92 stations. The ozone data base (1994 data) collected by the ETC-AQ contains data from 13 EU Member States, and a total of 378 stations (annual statistics data).

Table 5.1: Overview of extent of data from the various data sources on local air pollution.

Country	APIS		EoI		National Reports	
	Number		Number		Number	
	Cities	Stations	Cities	Stations	Cities	Stations
Albania						
Austria					7	41
Belarus						
Belgium	7	18	4	17	-	-
Bulgaria						
Croatia						
Cyprus						
Czech Republic	-	-	-	-	2	16
Denmark	2	2	-	-	2	3
Estonia						
Finland	-	-	4	5	-	-
France					5	36
Germany	-	-	-	-	39	141
Greece	1	3	-	-	-	-
Hungary						
Iceland	-	-	1	1	-	-
Ireland	-	-	3	6	-	-
Italy					21[1)]	186
Latvia						
Liechtenstein	-	-	-	-	1	1
Lithuania						
Luxembourg	-	-	1	1	-	-
Malta						
Moldova						
the Netherlands	13	26	-	-	-	-
Norway	-	-	-	-	7	7
Poland						
Portugal					14[2)]	69
Romania						
Russia						
Slovakia	-	-	-	-	2	11
Slovenia						
Spain	4	14	-	-	-	-
Sweden	-	-	-	-	10	13
Switzerland	-	-	-	-	5	18
Turkey						
Ukraine						
United Kingdom	13	15	-	-	9	10

1) Including province of Milano.
2) Including 7 industrial areas.

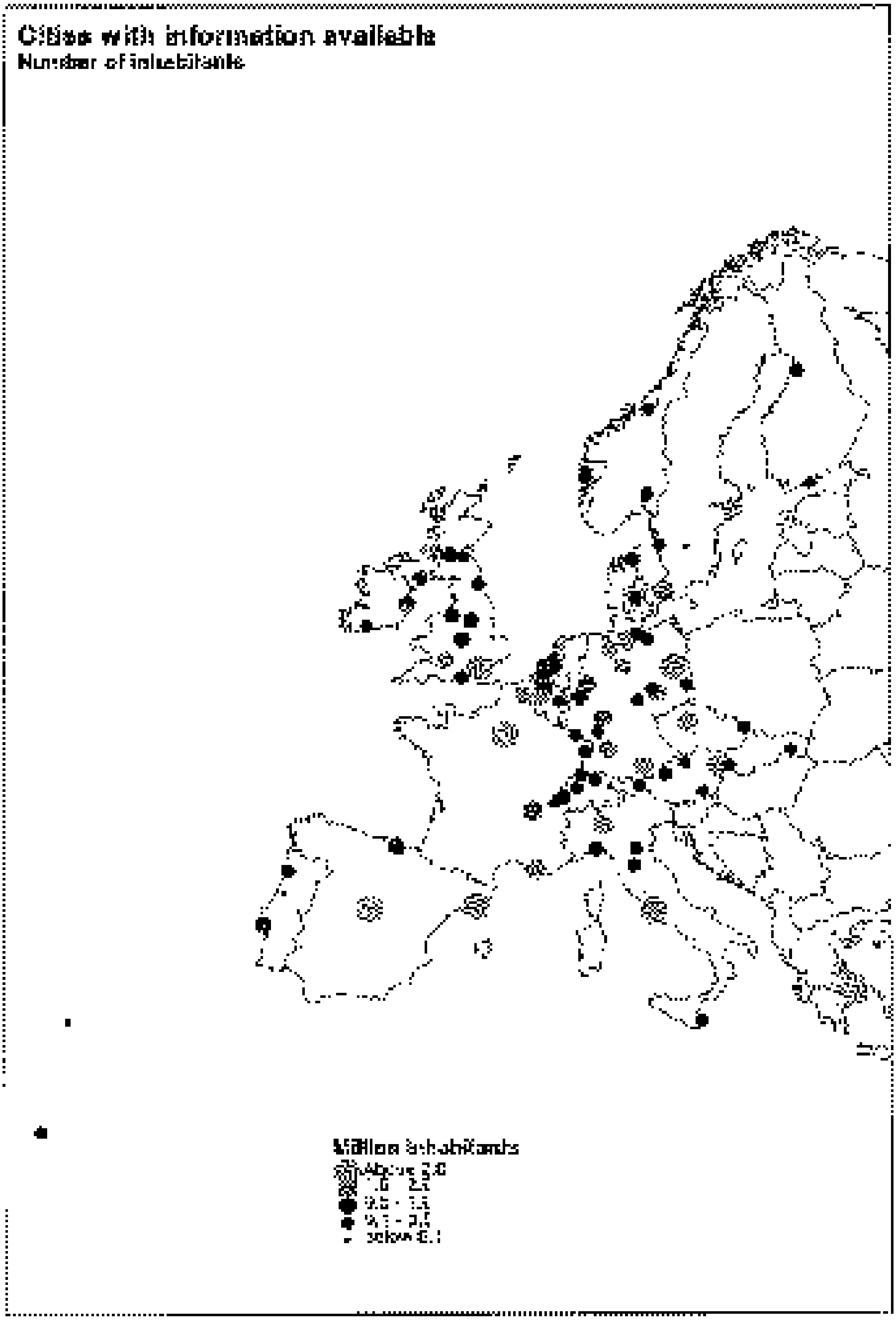


Figure 5.1: *Selected cities in 20 countries for presenting a preliminary overview of local air quality in Europe.*

Table 5.2: Selected cities in 20 countries for presenting a preliminary overview of local air quality in Europe.

Country	City
Austria	Graz Innsbruck Klagenfurt Linz Salzburg Villach Wien
Belgium	Antwerp Bruxelles Liege
Czech Republic	Ostrava Prague
Denmark	Aalborg Copenhagen Odense
France	Lille Lyon Marseilles Paris Strasbourg
Finland	Helsinki Oulu
Germany	Berlin Bremen Cottbus Dortmund Erfurt Frankfurt Halle Hamburg Hannover Köln Leipzig Lübeck Ludwigshafen-Frankental München Saarbrücken Schwerin Stuttgart
Greece	Athens
Ireland	Cork Dublin

Country	City
Italy	Bologna Firenze Genova Milano Roma Siracusa-Augusta
Liechtenstein	Vaduz
Luxembourg	Steinfort
The Netherlands	Amsterdam Den Haag Rotterdam Utrecht
Norway	Bergen Oslo Trondheim
Portugal	Coimbra Funchal Lisboa Porto
Slovakia	Bratislava Košice
Spain	Barcelona Bilbao Madrid Tenerife
Sweden	Göteborg Jönköping Luleå Stockholm
Switzerland	Basel Bern Genève Lausanne Zürich
United Kingdom	Belfast Birmingham Bristol Edinburgh Glasgow Liverpool London Newcastle Sheffield Southampton

6. Air Quality and Deposition Summaries, Local and Regional Air Pollution

In the following, air quality summaries are presented compound-wise: sulphur compounds, nitrogen compounds, black smoke, suspended particulate matter, ozone, lead, carbon monoxide. Only for sulphur and nitrogen compounds, regional data summaries are presented. For the other compounds, regional data of sufficient extent have not been available in preparing this report.

6.1 Sulphur compounds

6.1.1 Behaviour, effects, emissions

Sulphur dioxide (SO_2) and particles emitted from the combustion of sulphur containing fuels are major air pollutants in urban areas, and SO_2 is the principal pollutant associated with the acid deposition problem. Sulphur oxides and particulate matter are parts of a complex pollutant mixture, and are often considered together, since their effects cannot be distinguished from each other. In guidelines, the following categories are considered:

a) sulphur dioxide
b) acid aerosols from oxidation of sulphur dioxide
c) sulphur dioxide plus particles.

In urban air dominated by local emissions, SO_2 is the most abundant sulphur compound. Urban SO_2 occurs in short term concentrations typically up towards several hundred µg/m^3, and in extreme cases up to several thousands µg/m^3. It is oxidised through several steps, via HSO_3 to various forms of sulphates (sulphuric acid, ammonium sulphate and others). These reactions are fairly slow (in the range a few % per hour, dependent upon the composition of the ambient air). In highly polluted atmospheres, SO_2 may enter into photochemical reactions, which are also rather slow. Removed from the vicinity of sources (as in regional air pollution), SO_2 and sulphates often occur in concentrations of about equal magnitudes, in Europe up towards 30 µg/m^3 as long term averages.

In periods with regionally poor dispersion and increased emissions, short term regional SO_2 and particle concentrations may occasionally reach several hundred µg/m^3.

SO_2 and sulphates are removed from the atmosphere through wet and dry deposition, causing acidification of water and soil. Wet deposition of particulate sulphur dominates the total deposition.

Health effects of sulphur in air is caused by the absorption of SO_2 on the mucous membrane of the nose and upper respiratory tract, and the deposition of sulphate aerosol in the respiratory tract. SO_2 causes acute severe effects in the bronchii at very high concentrations (>10,000 µg/m^3). Asthmatics experience effects at much lower concentration. Epidemiological studies indicate possible small reversible declines in children's lung function at 250-450 µg/m^3, and increased mortality at 500-1,000 µg/m^3. Sulphuric acid cause human health effects, with a lowest demonstrated effects level of 100 µg/m^3 on exercising adolescent asthmatics. High concentrations (>1,000 µg/m^3)

together with elevated particulate matter concentrations are believed to have been responsible for high mortality during smog episodes such as in London in 1952.

Acid deposition can affect terrestrial and aquatic ecosystems, if the deposition exceeds the critical load of the area. Effects include needle loss of conifers, and fish death. SO_2 have a direct effect on vegetation at high concentrations (>some thousand µg/m3). SO_2 plays an important role in the deterioration of stonework and metal corrosion.

Major SO_2 sources in Europe are fossil fuel combustion for public power production and heating (54%) and small-scale heating (11%), industrial combustion (25%), and industrial processes (3%). (Percentage figures refer to the CORINAIR inventory, 1990).

The trend in SO_2 emissions in Europe, as calculated for the EMEP area by the EMEP Meteorological Synthesizing Centre - West (Berge et al., 1995) is shown in Figure 6.1.

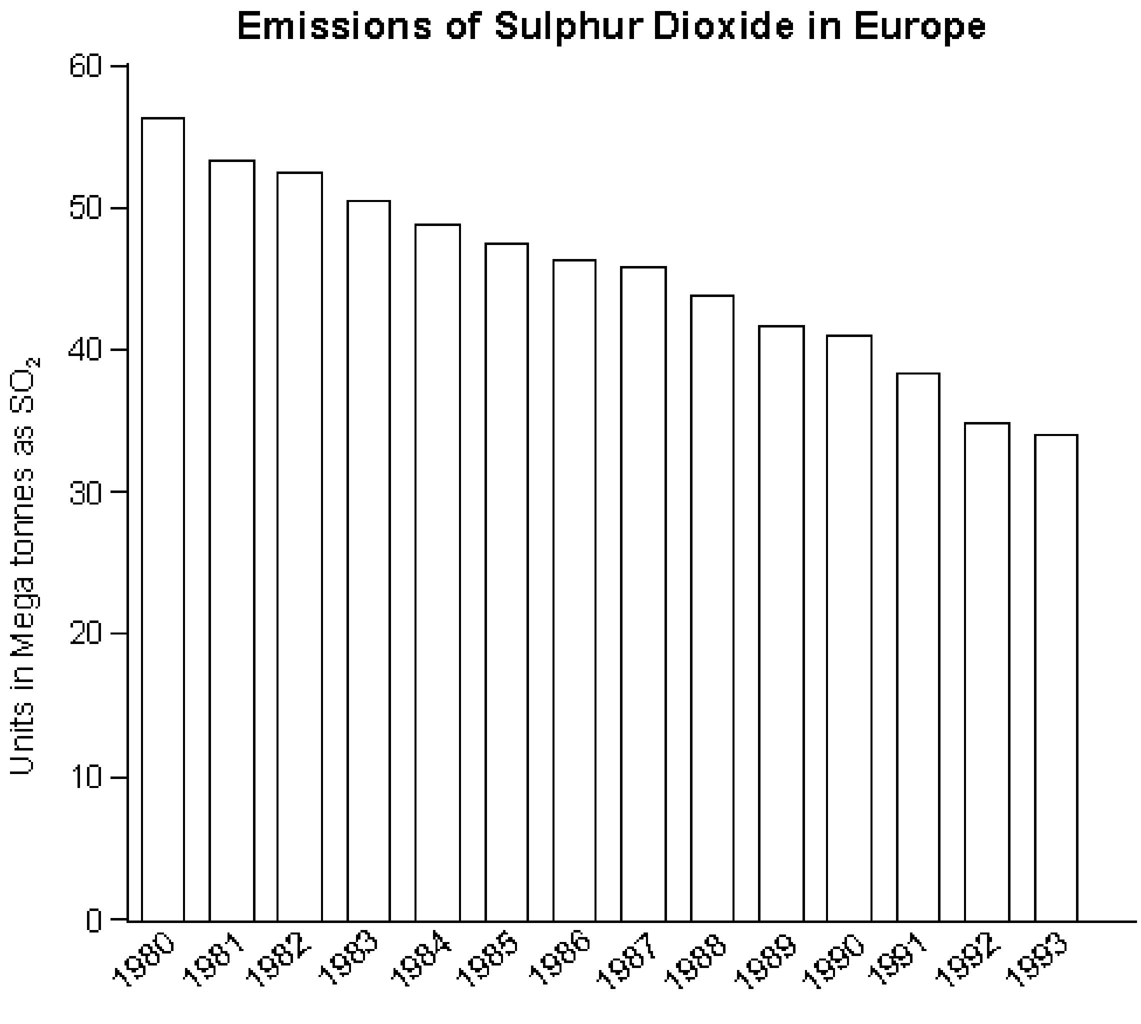


Figure 6.1: Emissions of sulphur dioxide in Europe, 1980-1993. (Ref.: Berge et al., 1995).

The calculated emissions were 40% lower in 1993 than in 1980, and the downward trend has been fairly steady over the entire period.

For 1990, there was good agreement between the EMEP and CORINAIR emissions data for each of 23 European countries (Berge et al., 1995).

6.1.2 Air Quality Limit and Guide Values

The complete EU Limit and Guide values for SO_2 with associated values for black smoke and suspended particulates are given in Table 6.1 together with Guideline values for Europe given by WHO.

Table 6.1: EU Limit and Guide Values for SO_2 and associated values for BS (black smoke) and suspended particles (gravimetric) (µg/m³)
EU Council Directives 80/779/EEC and 89/427/EEC.
WHO Guideline values for SO_2 (µg/m³).

	SO_2		Associated values for BS		Associated values for suspended particles	
Limit Values	Median of 24 h values	98 percentile of 24h values	Median of 24h values	98 percentile of 24h values	Median of 24h values	98 percentile of 24h values
Year	80		>40		>150	
Year	120		≤40		≤150	
Winter	130		>60		>200	
(1.10.-31.3.)	180		≤60		≤200	
Year		250[1]		>150		>350
Year		350[1]		≤150		≤350
Guide Values	Mean of 24h values	Maximum 24h average				
Year	40-60	100-150				
WHO Guideline Values	Max. 10 min average	Max. 1 h average				
Reference period not specified	500	350				

1 EU Member States must take all appropriate steps to ensure that this value is not exceeded for more than three consecutive days. More over, EU Member States must endeavour to prevent and to reduce any such instances in which this value has been exceeded.

WHO Guideline values for Europe for combined exposure to SO_2 and particulate matter (BS, TSP or TP) (EHO, 1987).

Substance	Mean values for averaging time	
	24 h	1 year
SO_2	125	50
BS1)	125	50
TSP2)	120 3)	
TP4)	70 3)	

1) Black smoke
2) Total suspended particulates measured by high volume sampler without any size selection.
3) Value to be regarded as tentative at this stage.
4) Thoracic particles measured by a sampler having a 50% cut-off at 10 µm.

The WHO Guideline values are maximum values. They are not to be exceeded.

6.1.3 Urban and Local SO_2 concentrations

Concentrations

SO_2 data with associated values for black smoke and/or suspended particles from cities all over Europe are given in detailed tables in Appendix B. The data are from the APIS and EoI data bases and from national reports.

In Appendix B SO_2 data from 17 countries are given. The stations are ranged according to the 98 percentile daily values. The stations with the highest values are given in Table 6.2. Also the maximum and median values are given, if available.

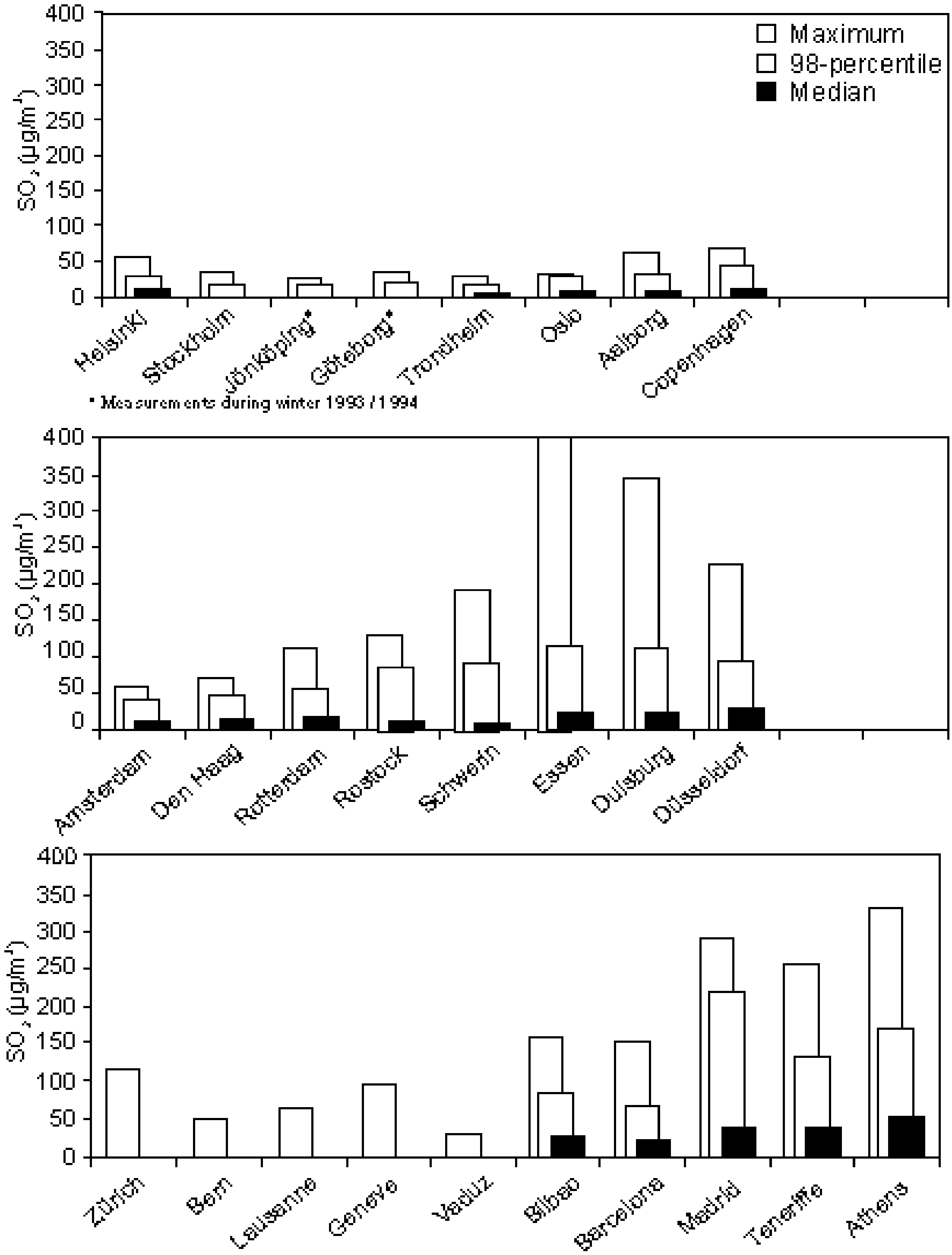


Figure 6.2 clearly shows the rather low concentrations in the Nordic countries. The highest 98 percentile and median values are observed in Germany (eastern part), the Czech Republic and in the Mediterranean countries.

Data from the selected cities in Figure 5.1/Table 5.2 are shown in Figure 6.3-Figure 6.6. These figures give the median, mean, 98 percentile and maximum values based on 24h values. These data indicate the highest SO_2 levels in Germany and the eastern part of Europe.

Table 6.2: Maximum, 98 percentile and median SO_2 values for 1993 for European cities ranged according to the 98 percentile values ($\mu g/m^3$). (For complete table, see Appendix B).

Country	Name	City Class	Station	SO_2 24 hour values Maximum		98 percentile		Median	
Germany	Chemnitz		Zwickau-Zentrum			570	5		
Germany	Chemnitz		Chemnitz-Mitte 1			470	5		
Germany	Leipzig		Leipzig-Mitte 2			460	5		
Germany	Leipzig		Delitzch			410	5		
Germany	Chemnitz		Chemnitz-Mitte 2			393	5		
Germany	Dresden		Pirna			342	5		
Germany	Greiz		Greiz			321	*	54	10
Germany	Chemnitz		Plauen 2			317	5		
Germany	Dresden		Dresden-Ost			281	5		
Germany	Altenburg		Altenburg			270	*	42	*
Czech Republic	Prague		Námesti Republiky	460		266	9		
Portugal	Porto		Fac. Engenharia	266		257		25	
Germany	Weimar		Weimar, Goeth.			254	*	37	10*
Germany	Dresden		Dresden-Mitte			254	5		
Germany	Dresden		Zittau-Ost			253	5		
Germany	Leipzig		Leipzig-Mitte 1			250	5		
Germany	Gera		Gera, Frieder.			247	*	45	*
Czech Republic	Prague		Riegrovy sady	457		228	9		
Italy	Porto Torres		Rio Mannu			223		6	
Germany	Erfurt		Erfurt, Krämpf.			222	*	28	*
Germany	Dresden		Zinnwald			220	5		
Spain	Madrid	1	Cuatro Caminos	288	b	216		41	6
United Kingdom	Belfast	4	Belfast centre	354		213	6	29	5
Germany	Cottbus	6	Cottbus-Süd	345		198	5	32	
Czech Republic	Prague		Pocernicka	442		194	9		5
Germany	Cottbus	4	Cottbus-City	375		192	5	23	1-6
Italy	Genova		Enel 1 (Ponte Etiopia)			192		47	
United Kingdom	Liverpool	4	Liverpool centre	200	1	189	1-6	24	5
Germany	Brandenburg	5	Brandenburg-Zentrum	235		184	5	21	
Germany	Dresden		Radebeul-Wahnsdorf			183	5		
Czech Republic	Prague		Vysocany	524		178	9		
Czech Republic	Prague		Výstavište	495		178	9		
Czech Republic	Prague		Mlynárka			175	9		
Germany	Braunschweig	4	Schlosspark	316		174			
Czech Republic	Ostrava		Ostrava-Slez.Ostrava	433		171	9		
Czech Republic	Prague		Veleslavin	513		170	9		
Greece	Athens	1	Patission 147	327	a	170		52	
Germany	Braunschweig	4	Am Sackring	329		167			
Portugal	Carregado		Faiel	210		165		9	
Italy	Siracusa-Augusta		Farodromo			164		20	
Portugal	Tapada Outeiro		Medas	502		163			
Germany	Cottbus	5	Cottbus-LUA	292		162	5	17	
Germany	Eisenach		Eisenach			158	*	13	*
Italy	Venezia (ind. zone)		Stab. Sirma			153		26	
Germany	Berlin		Charlottenburg	179		152	5	29	5
Germany	Hannover	3	Welfenplatz	248	4	151			
Czech Republic	Prague		Kobylisy	498		150	9		

Re. footnotes: See the full table in Appendix.

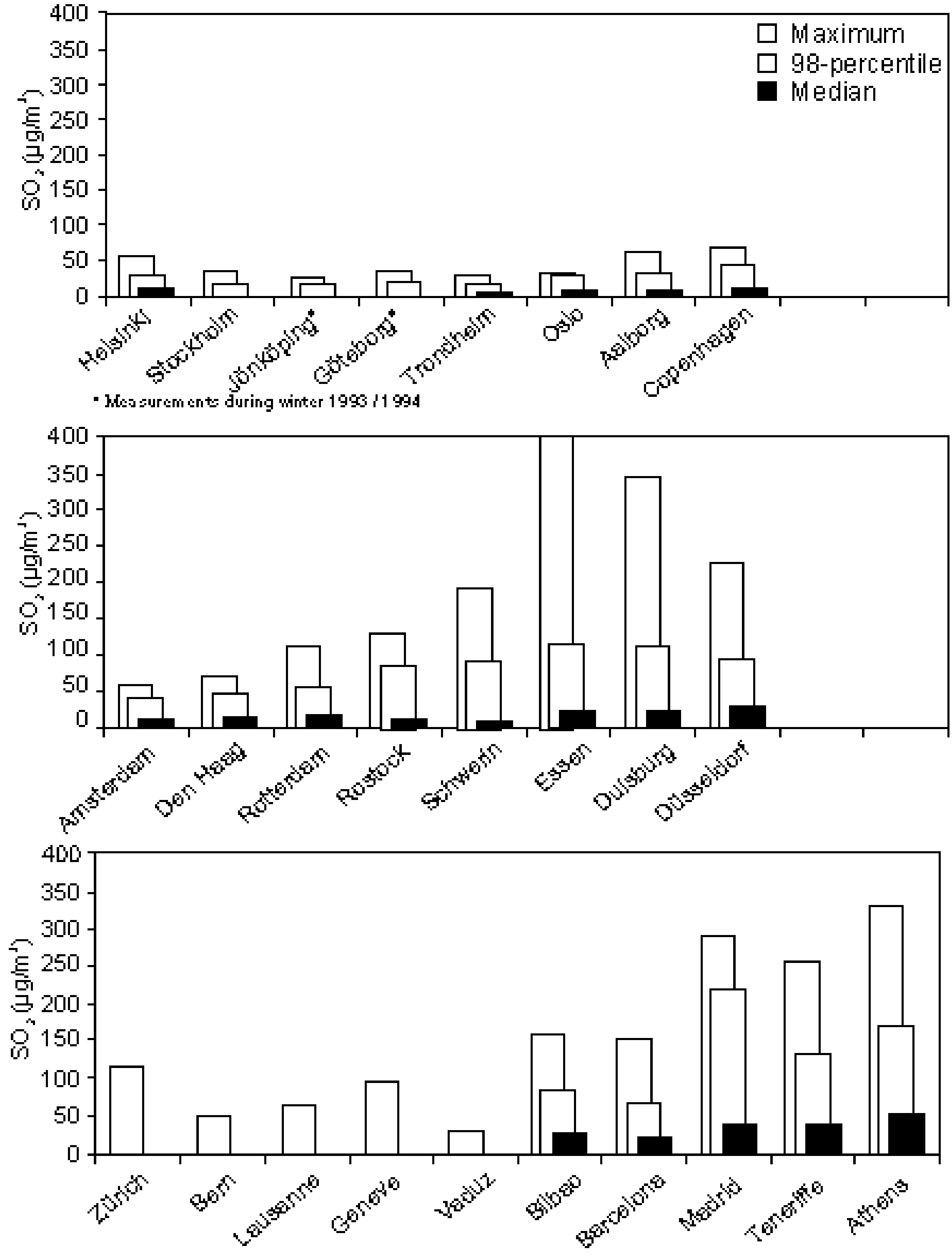


Figure 6.2: *24h maximum, 98 percentile and median SO_2 values for 1993 for selected stations and cities (µg/m3).*

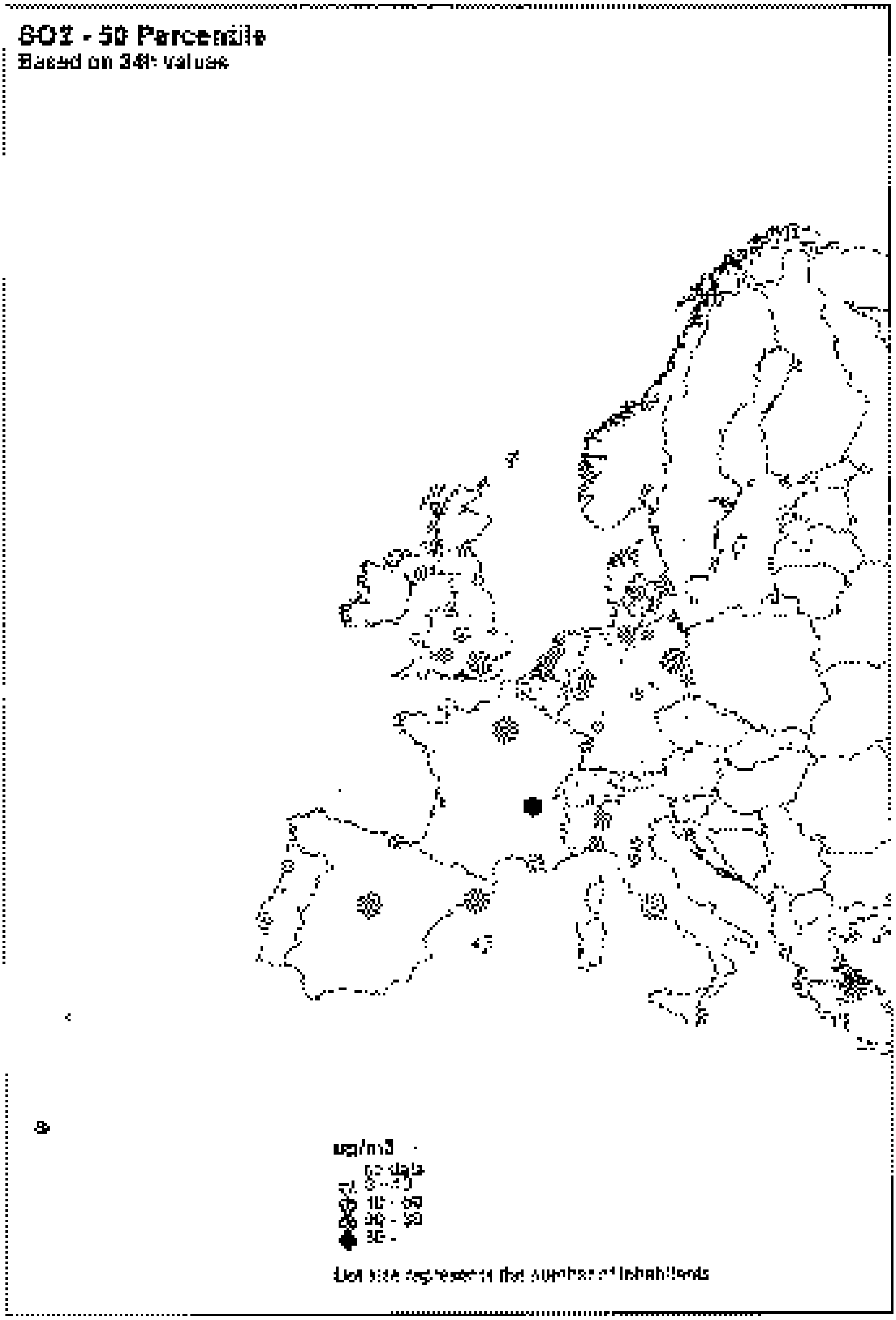


Figure 6.3: *SO_2 median 24h values in selected cities (µg/m³).*

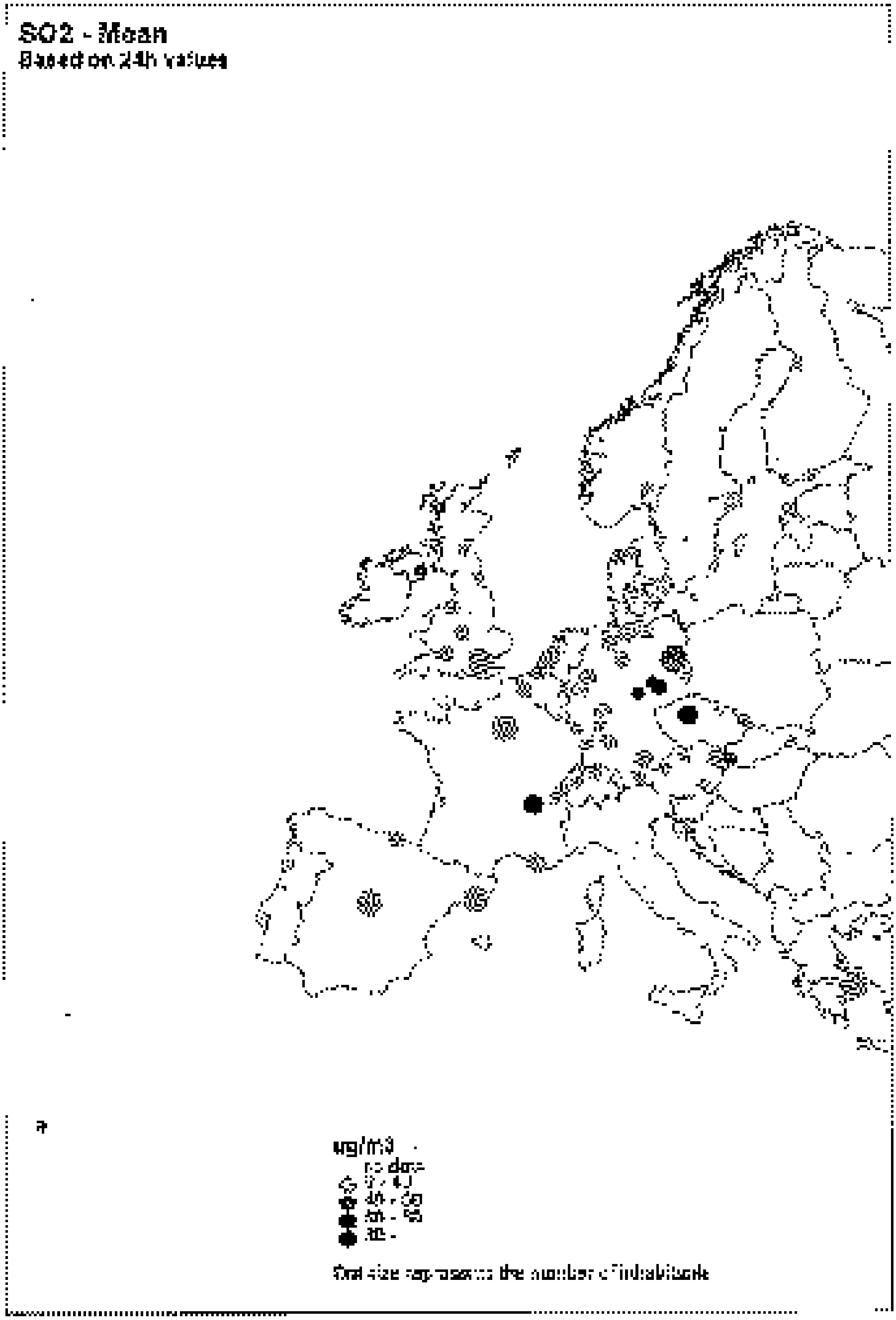


Figure 6.4: *SO_2 mean values in selected cities (µg/m3).*

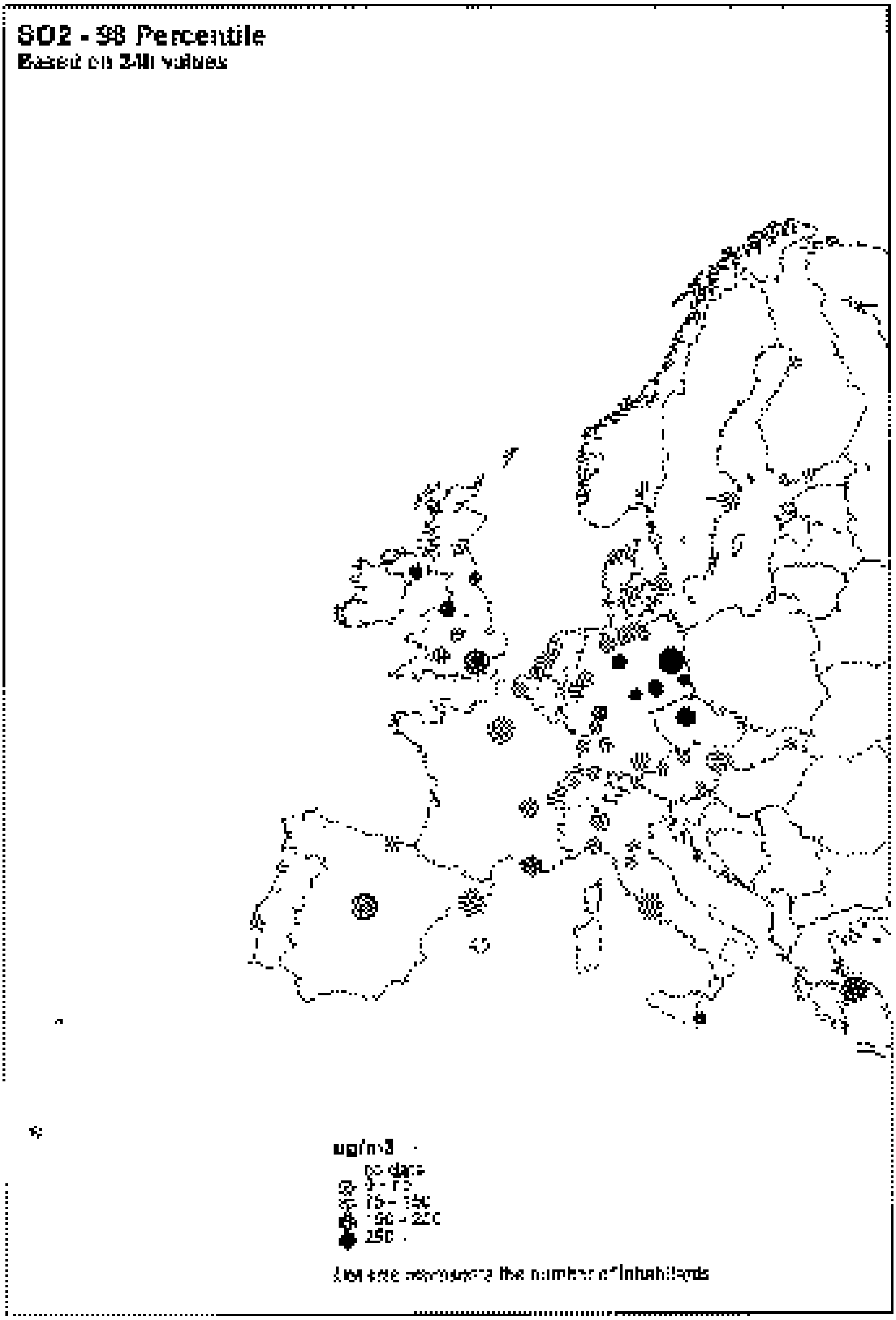


Figure 6.5: *SO_2 98 percentile values based on 24h values in selected cities (µg/m3).*

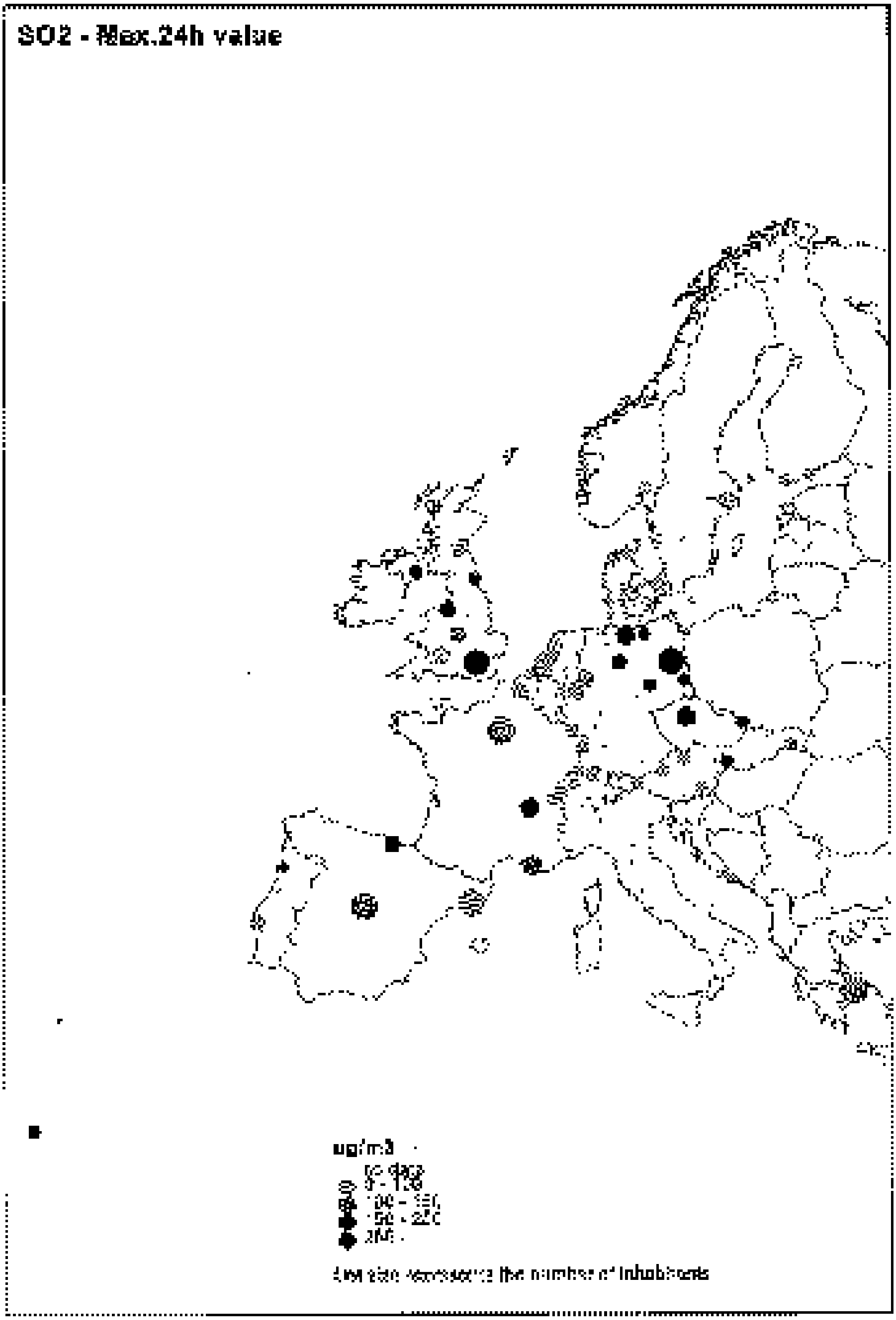


Figure 6.6: *SO_2 maximum 24h values in selected cities (µg/m³).*

Exceedances

Table 6.3 shows stations with exceedances of EU Limit Values for SO_2 for combined exposure to sulphur dioxide and black smoke/particulate matter. Some other stations in eastern Germany, which have only reported 98 percentile 1/2h values, may also have 98 percentile 24h values above 250 µg/m^3 . A few stations in Prague reporting 95 percentile 24h values probably have 98 percentile 24h values above the EU Limit Value. The available data statistics from national reports do not usually give (enough) information about exceedances of EU Limit Values.

Table 6.4 shows stations with exceedances of EU Guide values and WHO Guideline values for SO_2 for combined exposure to sulphur dioxide and black smoke/particulate matter. Stations marked with * show exceedance of WHO Guideline values. Stations in bold show exceedance of the upper EU Guide value.

The table shows that a great number of European cities in many countries have mean values and especially maximum 24h SO_2 concentrations well above EU Guide values and WHO Guideline values. Especially Czech values, but also some Germany values are very high.

Table 6.3: Exceedances of EU Limit Values for SO_2.

Country	City	Station name	24h values		
			1 year	1 year	Winter
			Median >80	P98 >250	Median >130
France	Lyon	Lyon Berthelot	80		
Germany-Thüringen	Altenburg	Altenburg		270*	
	Greiz	Greiz		321*	
	Weimar	Weimar, Goeth.		254*	
Portugal	Porto	Fac. Engenharia		257	

* April 1993-February 1994.

Table 6.4: Exceedances of EU and WHO Guide Values for SO_2.

Country	City	Station	Mean > 40-60	Max. 24 h > 100-150
Czech Republic	Ostrava	Ostrava-Slez.Ostrava	56*	**433***
	Prague	Branik	54*	
		Kobylisy	54*	**498***
		Mlynárka	**61***	
		Námesti Republiky	**103***	**460***
		Pocernicka	**66***	**442***
		Riegrovy sady	**73***	**457***
		Santinka	52*	**416***
		Veleslavin	57*	**513***
		Vršovice	**61***	**441***
		Vysocany	**70***	**524***
		Výstavište	58*	**495**
France	Lille	Tourcoing		116
	Lyon	Croix rousse		**225***
		Lyon Berthelot	**84***	**225***
		Lyon Garibaldi		**168***
		Lyon Puits Gaillot	55*	
		Saint Just		**268***
	Marseille	Paradis		133*
		Rabatau		137*
	Paris	Neuilly/Seine (92)		**154***
		Paris 13ème et.		111
		Paris Ch. de Mars		125*
		Paris Tour St-Jacques		144*
	Strasbourg	Hoerdt		101
		Reichstett		**196***
		Rue du 22 novembre		105
Germany	Altenburg	Altenburg	**88***	
	Berlin	Charlottenburg	42	**179***
		Frankfurter Tor		**174***
		Neukölen		**164***
		Schöneberg		**158***
		Wedding		**180***
	Brandenburg	Brandenburg-Nord		**231***
		Brandenburg-Zentrum		**235***
	Braunschweig	Am Fernmeldeturm		**343***
		Am Sackring		**329***
		Schlosspark		**316***
	Cottbus	Cottbus-City		**375***
		Cottbus-LUA		**292***
		Cottbus-Süd		**345***
	Dortmund	Dortmund-Asseln		149*
		Dortmund-Hörde		**164***
		Dortmund-Mitte		**203***
	Duisburg	Duisburg-Buchholz		**405***
		Duisburg-Kaldenhausen		**275***
		Duisburg-Meidenrich		**342***
		Duisburg-Walsum		**287***

Table 6.4 (contd.)

Country	City	Station	Mean > 40-60	Max. 24 h > 100-150
Germany (contd.)	Düsseldorf	Düsseldorf-Einbrungen		**191***
		Düsseldorf-Genresheim		**190***
		Düsseldorf-Lörick		**246***
		Düsseldorf-Mörsenbroich		**222***
		Düsseldorf-Reisholz		**218***
	Erfurt	Erfurt, Krämpf.	**68***	
	Essen	Essen-Altendorf		**234***
		Essen-Bredeney		**164***
		Essen-Leithe		**178***
		Essen-Ost		**420***
		Essen-Vogelheim		**398***
	Gera	Gera, Frieder.	**80***	
	Greiz	Greiz	**117***	
	Halle	Halle	**83***	**509***
	Hamburg	06, LO Lokstedt		**192***
		09 RA, Rahlstedt		**179***
		11 HO, Hochkamp		**199***
		12 BA, Bahrenfeld		**223***
		13 ST, Sternschanze		**190***
		14 LS, Lübecker Strasse		**190***
		15 HR, Horner Rennbahn		**177***
		18 WA Waltershof		**210***
		19 SW, Steinwerder		**193***
		20 VE, Veddel		**209***
		21 BI, Billbrook		**180***
		26 KI, Kirchdorf		**166***
		27 Ta, Tatenberg		**190***
		30 GT, Göhlbochtal		**184***
	Hannover	Fischeteichweg		**225***
		Göttinger Strasse		**214***
		Welfenplatz		**248***
	Köln	Köln-Chorweiler		**166***
		Köln-Riehl		**178***
		Köln-Rodenkirchen		**246***
		Köln-Vogelsang		**230***
	Magdeburg	Magdeburg	40	**293***
	Rostock	Rostock-Holbein Platz		126*
	Saarbrücken	Saarbrücken-Eschberg		**182***
		Saarbrücken-Stadtmitte		**183***
	Schwerin	Schwerin (Burmeister-Bade-Platz)		**190***
		Schwerin-UBA		**246***
	Weimar	Weimar, Goeth.	58*	
Greece	Athens	Patission 147	**62***	**327***
		Pireas Platia Dinotikou	52*	**170***
		Smyrni Cementry		141*

Table 6.4 (contd.)

Country	City	Station	Mean > 40-60	Max. 24 h > 100-150
The Netherlands	Ligging voor	Zaaidijk-Axel		127*
	Rotterdam	Schiedamsevest		110
	Sas van Gent	Westkade		**221***
	Vlaardingen	Floreslaan		108
		Lyceumlaan		135*
Portugal (contd.)	Area Sines	Santiago		148*
	Barrero/Seixal	Av. da Praia		141*
		Camara Municipal		100
	Carregado	Cast. Ribatejo		**282***
		Faiel		**210***
		TAK		102
		Vinha		**193***
	Estarreça	Teixugueira		**158***
	Lisboa	Beato		126*
		Jerònimos		133*
		R. Sèculo		**161***
	Porto	Fac. Engenharia	50*	**266***
	Setúbal	Setenave		**151***
	Tapada Outeiro	Aldeia Nova		105
		Lever		**162***
		Lixa		**439***
		Medas		**502***
		Vila Cova		**171***
Slovakia	Bratislava	Karmenné námestic		**198***
		Marmateyova		**284***
		Trnavské mýto		**301***
		Turbinová	51*	**301***
	Košice	Podhvadová		120
		Strojárenská		137*
		Štúrova		136*
Spain	Barcelona	Molina Pl.		**151***
		Prat del Llobregat	52*	123
	Bilbao	Gecho		114
		Lab. Sanidad		**158***
	Madrid	Arturo Soria		100
		Carlos V		**192***
		Cuatro Caminos	**61***	**288***
		Plaza Castilla		108
		Plaza España		**167***
Tenerife		Santa Cruz	52*	**256***
Switzerland	Zürich	Schimmelstrasse		114
United Kingdom	Belfast	Belfast centre	48	**354***
	Birmingham	Birmingham centre		144*
	Cardiff	Cardiff centre		101
	Edinburgh	Edinburgh centre		133*
	Leeds	Leeds centre		**160***
	Liverpool	Liverpool centre	40	**200***
	London	London Bloomsbury		**203***
	Newcastle	Newcastle centre		**168***

Mean: *) > 50 WHO Guidelines Max: *) >125 WHO Guidelines.

Trends

Figure 6.7-Figure 6.10 show, as examples, trends in the SO_2 data on an annual basis for some selected stations in different countries. The figures show the maximum, 98 percentile and median of 24 h values from Norway, Denmark, the Netherlands, Spain and Greece. German data (from Bremen) show 98 percentile and mean values based on ½ h values, while Swiss data show 95 percentile and mean values based on ½ h data. Each of the trend figures covers a part of the period 1976-1994.

Most stations show a downward trend in SO_2-concentrations. The downward trend is very clear in Norway, Denmark, the Netherlands and Switzerland. In Germany (Bremen) and Spain the downward trend is less pronounced. In Greece (Athens) top values have increased and median and mean values have been rather stable at a relatively high level compared to other countries.

For East Europe there are no trend data available to us.

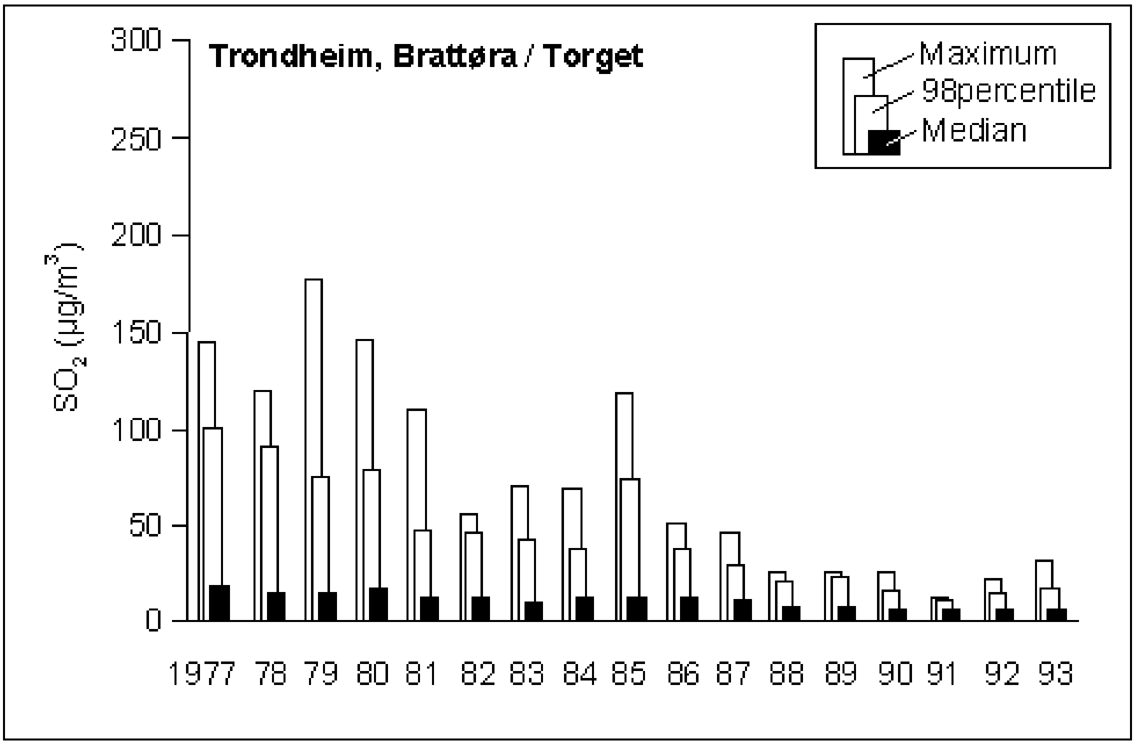
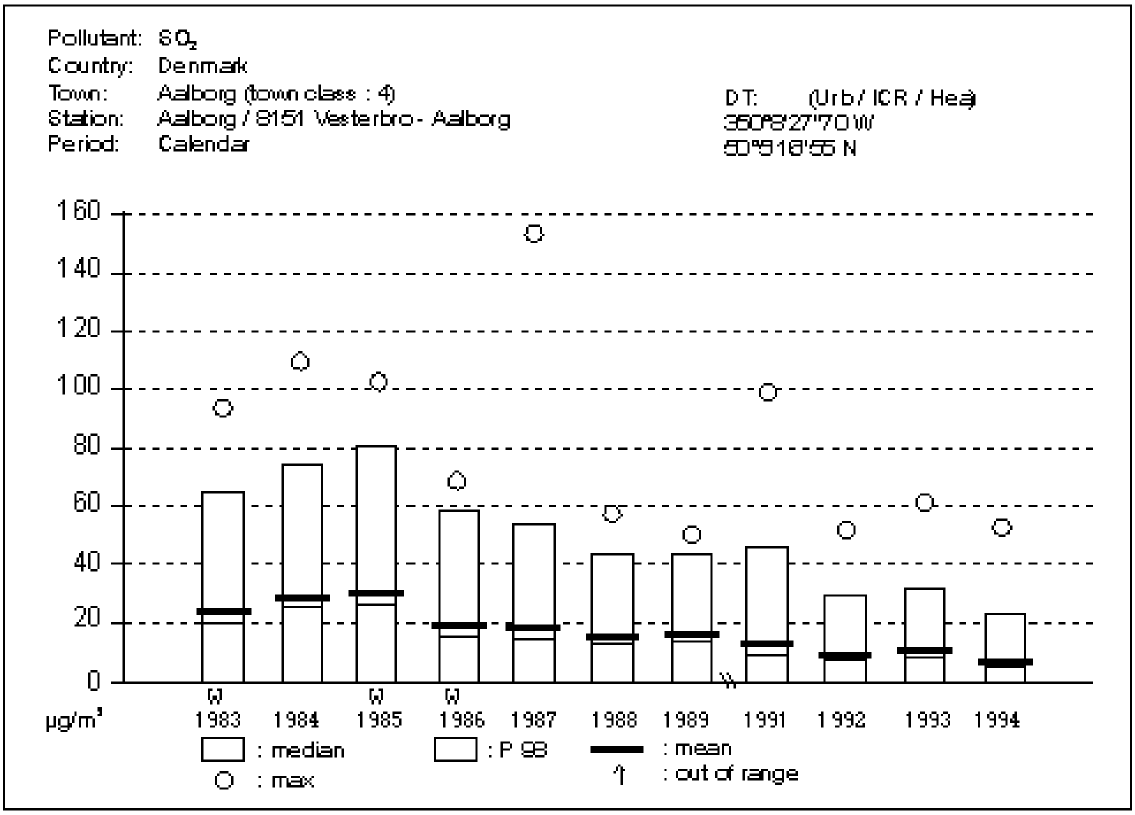


Figure 6.7: *SO_2 trend in Norway 1977-1993 (µg/m^3).*
Data from national reports.



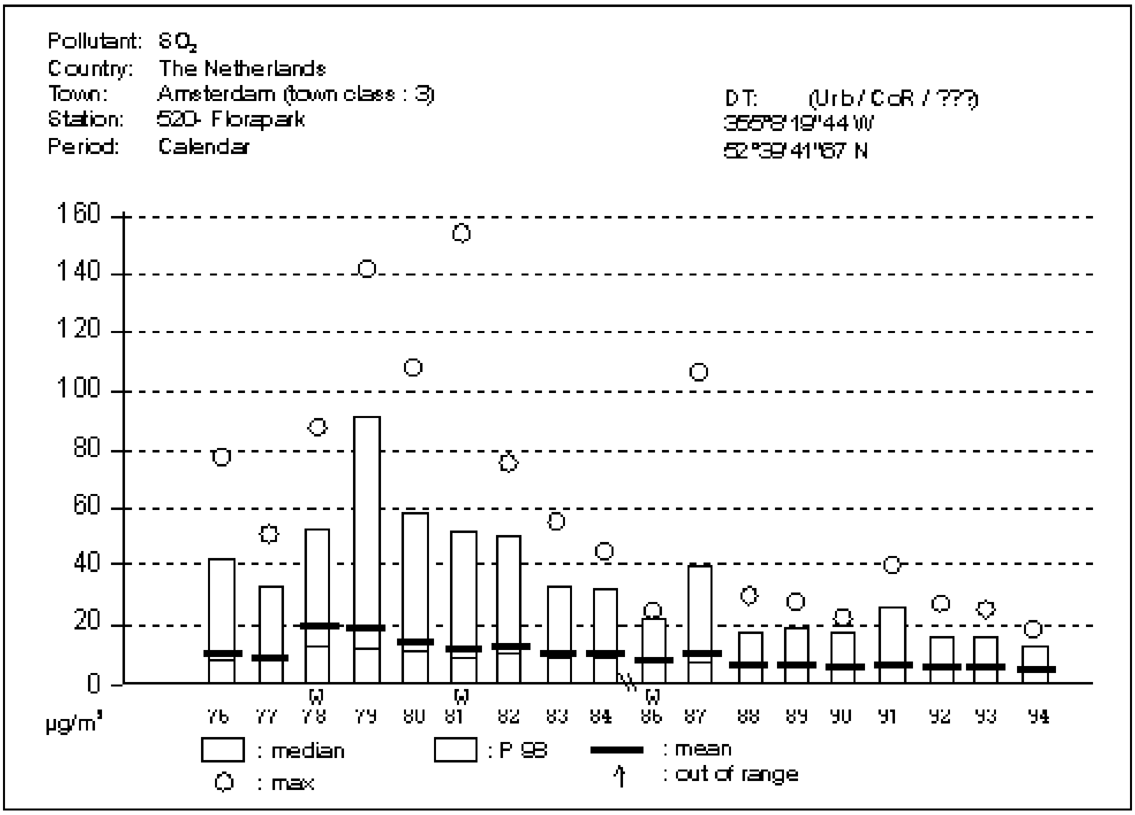
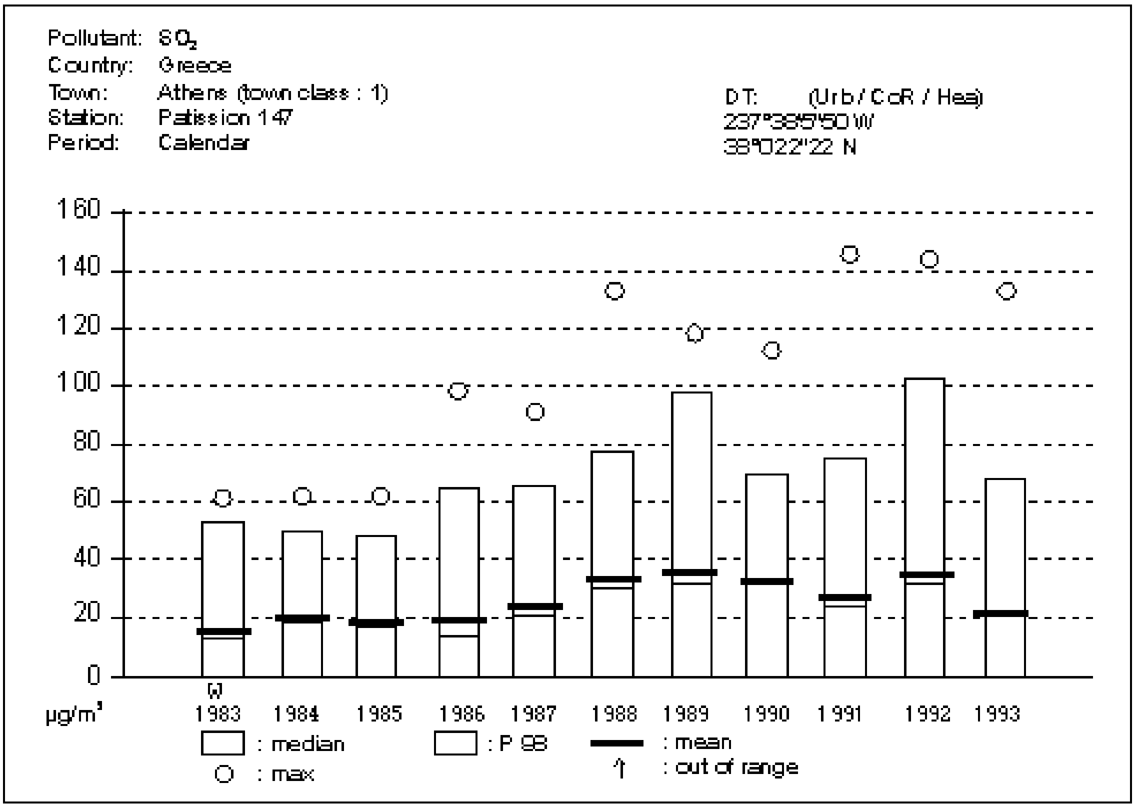


Figure 6.8: *SO_2 trend in Aalborg, Denmark 1983-1994 and Amsterdam, the Netherlands, 1976-1994 (µg/m3), APIS data.*



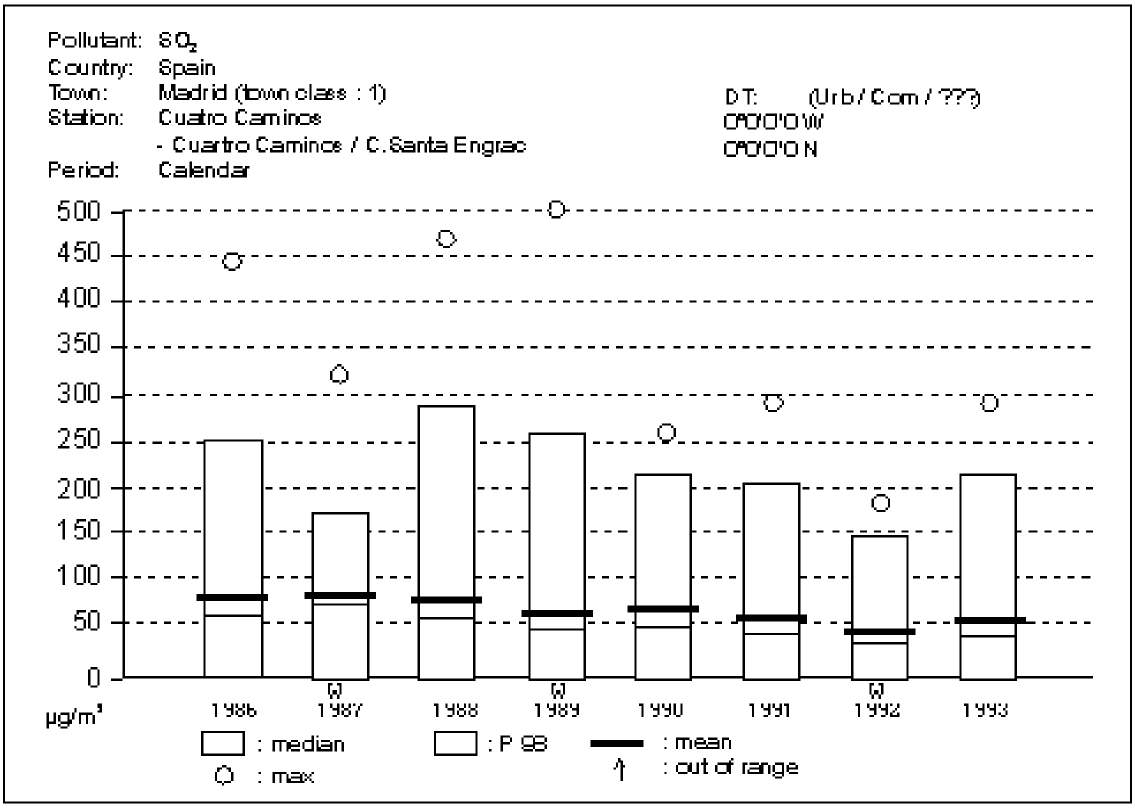


Figure 6.9: *SO_2 trend in Athens, Greece 1983-1993 and Madrid, Spain, 1986-1993 (µg/m3), APIS data.*

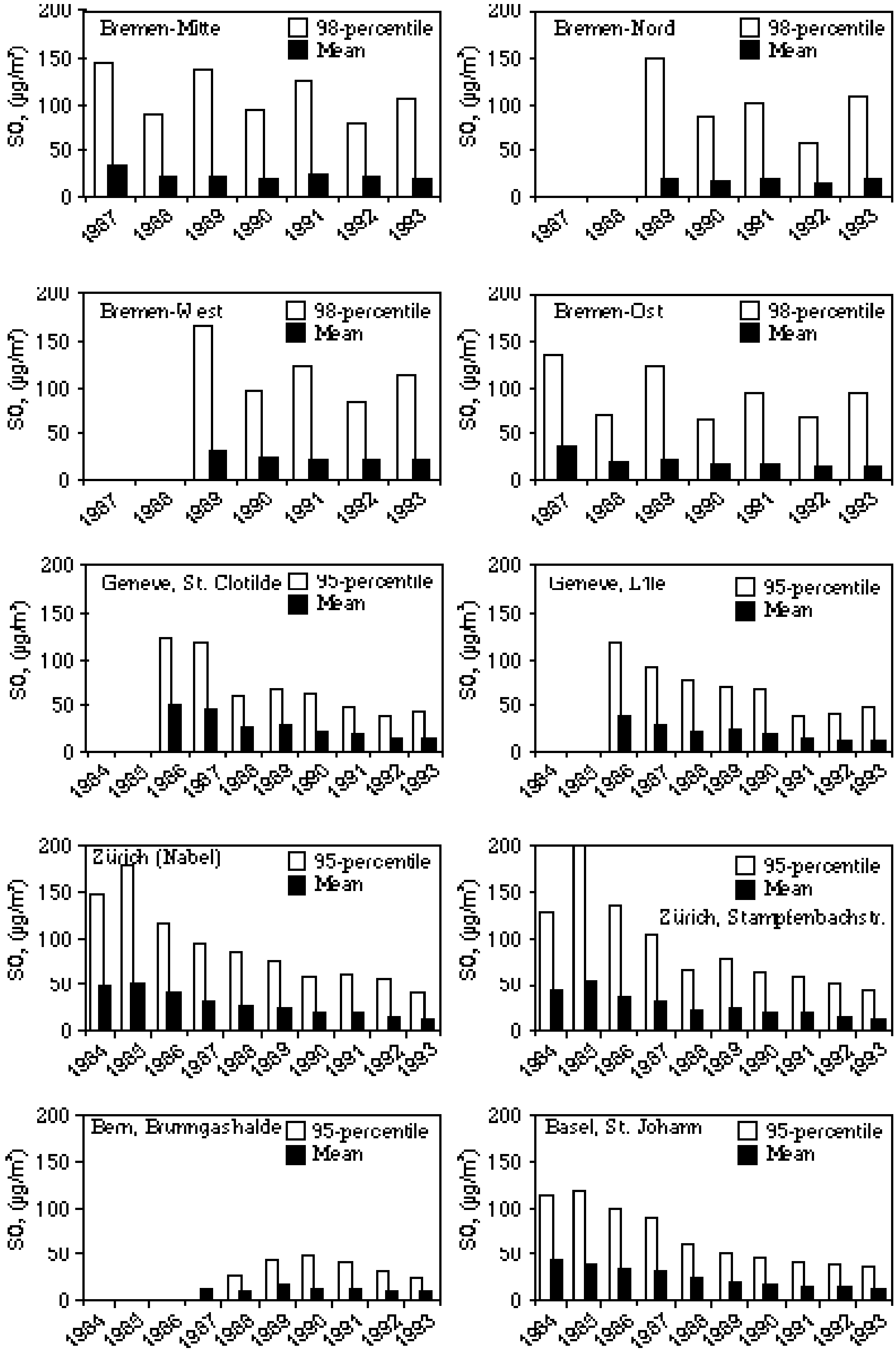


Figure 6.10: *SO_2 trend in Bremen, Germany, 1987-1993 and from Switzerland, 1984-1993 (µg/m3). Data from Bremen State and Swiss reports. The figures are based on ½ h values.*

6.1.4 Regional sulphur oxides concentrations and deposition

The EMEP measurement programme started in 1978. There were 99 monitoring stations in operation in 1993 in 26 countries. 77 stations reported precipitation data and 92 stations reported air concentration data during 1993.

A short description of the EMEP programme, including station list, is given in Appendix C.

The following presentation is based directly upon the 1993 EMEP data report (EMEP, 1995).

Data presentation

Annual averages of the 1993 air and precipitation data are presented in maps. The yearly precipitation mean concentrations are calculated from the daily values as precipitation-weighted averages. Average air concentrations are arithmetic averages of the daily means.

Kriging procedure

The concentration fields have been calculated using kriging methods. The EMEP grid is divided in 9 subareas. During the kriging process each area consists of 11x11 grid elements. In addition, 3 grid elements were added on each side of the sub-area in order to get an overlap and thus obtain a smooth concentration field for the whole area. After calculation on each of the sub-areas, consisting of 17x17 grid-elements, the results for each of the original 11x11 elements were concatenated to one 33x33 element concentration field. One grid element is 150 km x 150 km. In the kriging process, the averages are expressed through random functions. Separate calculations on nine subgrids rather than one calculation over a large grid area reduces the effects of the systematic concentration differences present in Europe.

Concentrations

Sulphur dioxide

The EMEP sites have been located away from local sources and are as far as possible representative for a larger region. One consequence of this is that the sulphur dioxide concentrations in Europe is higher in industrialised regions than the concentrations shown in Figure 6.11.

The lowest concentrations of SO_2 during 1993 are found on the Atlantic coast in Ireland and in northern Scandinavia, where the averages are lower than 0.5 µg S/m^3. From the United Kingdom eastward the concentrations increase from mainly 1–2 µg S/m^3 to the highest SO_2 concentrations measured in the network, in the area of eastern Germany, southern Poland, the Czech Republic, Slovakia and the north eastern part of Austria. In this region the annual average of SO_2 in rural areas is above 5 µg S/m^3, and peaks around 10 µg S/m^3 are seen at one German and one Czech station. In Germany and Poland the concentrations decrease towards the north.

The concentrations of SO_2 over the western part of Russia, the Baltic and southern Scandinavia are in the range 1 to 2.5 µg S/m^3. Romania and Bulgaria do not take part in the measurements, and there is only one site in Greece. For this reason the kriged concentrations in this area are very uncertain and are thus removed from Figure 6.11. The situation is similar in the southern half of Italy. Relatively low concentrations are seen over France and central Spain.

The regional concentrations in central Europe (>10 µg SO_2/m^3, annual average) are higher than in most cities of Scandinavia and parts of North-western Europe.

Sulphate in aerosol

Figure 6.12 presents the annual averages of sulphate in aerosols in 1993. Large parts of Ireland and Scandinavia have averages lower than 0.5 µg S/m^3. Towards south and east the concentrations increase to 1–1.5 in southern England to Denmark, southern Sweden and the Baltic. Most parts of western Europe experience concentrations in the range 1–2 µg S/m^3. The highest concentrations are observed over south-eastern Europe, more than 8 µg S/m^3 at one station in Greece and around 4 µg S/m^3 at one station in Hungary. However, the sites in this area are relatively few and the inaccuracies are thus large. In Portugal and Spain the averages increases from 1–1.5 µg S/m^3 in the north to 1.5–2 µg S/m^3 in the south.

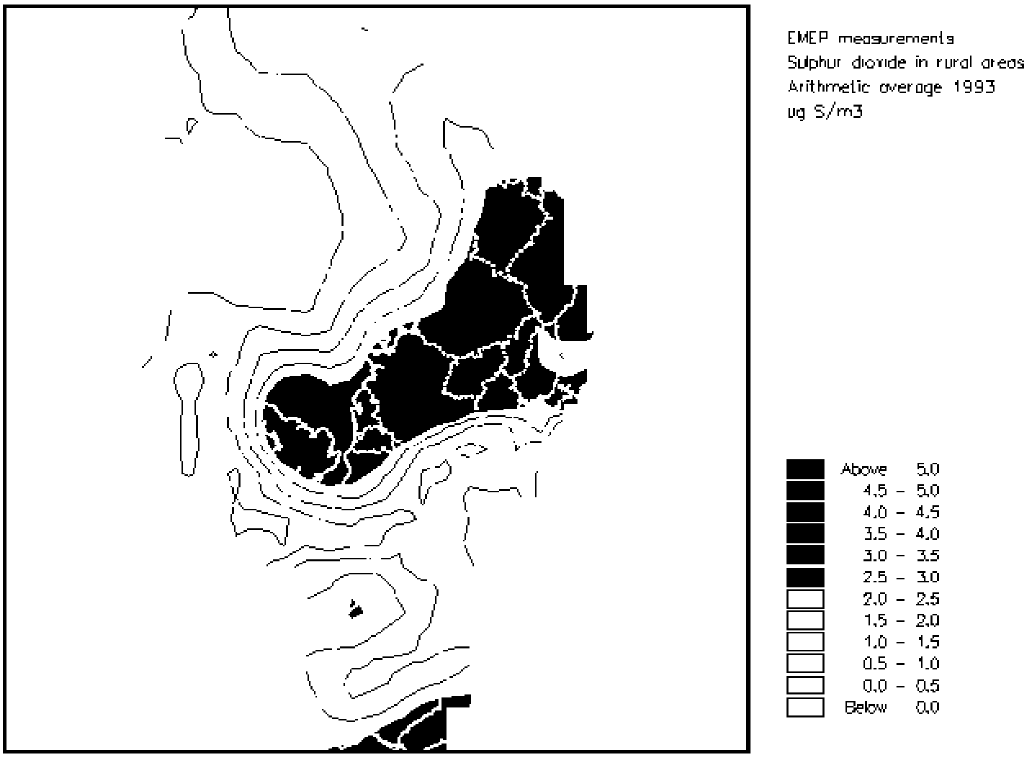


Figure 6.11: Sulphur dioxide in rural areas 1993, annual average (µg S/m^3).

Factor $\frac{SO_2}{S} = 2.0.$

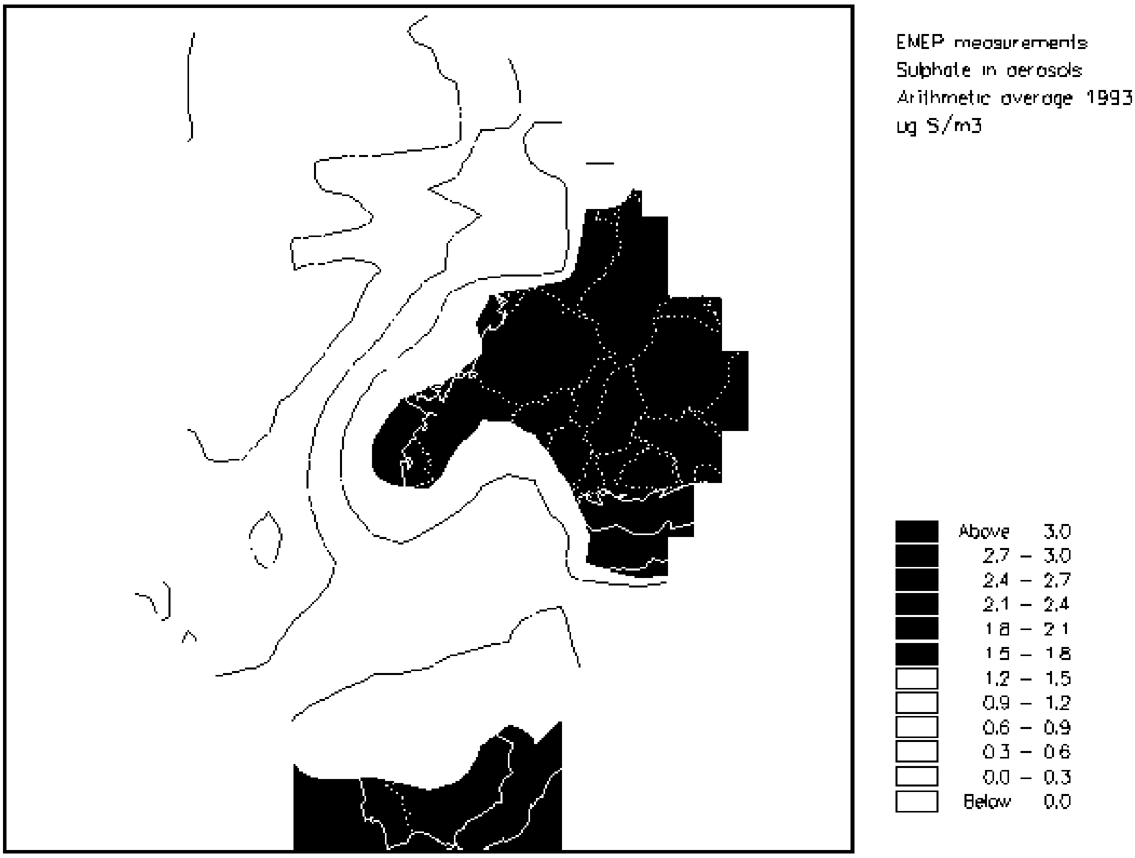


Figure 6.12: Sulphate in aerosols 1993, annual average (µg S/m3).
Factor $\frac{SO_4}{S} = 3.0.$

Wet deposition

Sulphate in precipitation

Sulphate in precipitation, corrected for sea-salt contributions are presented in Figure 6.13. As for most other pollutants of anthropogenic origin, the lowest concentrations are seen at the Atlantic coasts of Portugal and Ireland and in northern Scandinavia. Most of the Continent is exposed to annual averages less than 1 mg S/l. As for sulphate in aerosol phase, the region with higher concentrations stretch over the eastern parts of Europe, around 1.5 mg S/l or higher at stations in Croatia, Hungary, Poland and Yugoslavia. There is also a station in Ireland with concentrations at the same level. In Portugal and Spain there is a west to east increasing gradient, with a concentration of about 1 mg/l in the eastern parts.

pH in precipitation

The annual averages of pH in precipitation are presented in Figure 6.14. Over most parts of Europe the pH is lower than 5. The lowest pH values are seen in Poland and in middle Sweden; below 4.4, equivalent to an acid concentration of 40 µeql. Towards southern Europe there is in general an increase of pH.

Calcium in precipitation

Both industrial emissions of fly ash and other mineral particles, and soil dust are sources for calcium in precipitation, Figure 6.15. The high concentrations in southern Europe are mainly derived from soil dust, from wind erosion in the Sahara desert, and from local sources. The calcium content in both soil and rocks is high in many places in southern Europe. In eastern Europe industrial emissions, e.g. from cement plants, steelworks and power plants, give rise to concentrations of 10-20 µg/l of Ca in precipitation, while the concentrations of calcium in precipitation is low in the northern part of Great Britain and in most of Scandinavia and Finland. Calcium and other base cations increase the pH of precipitation.

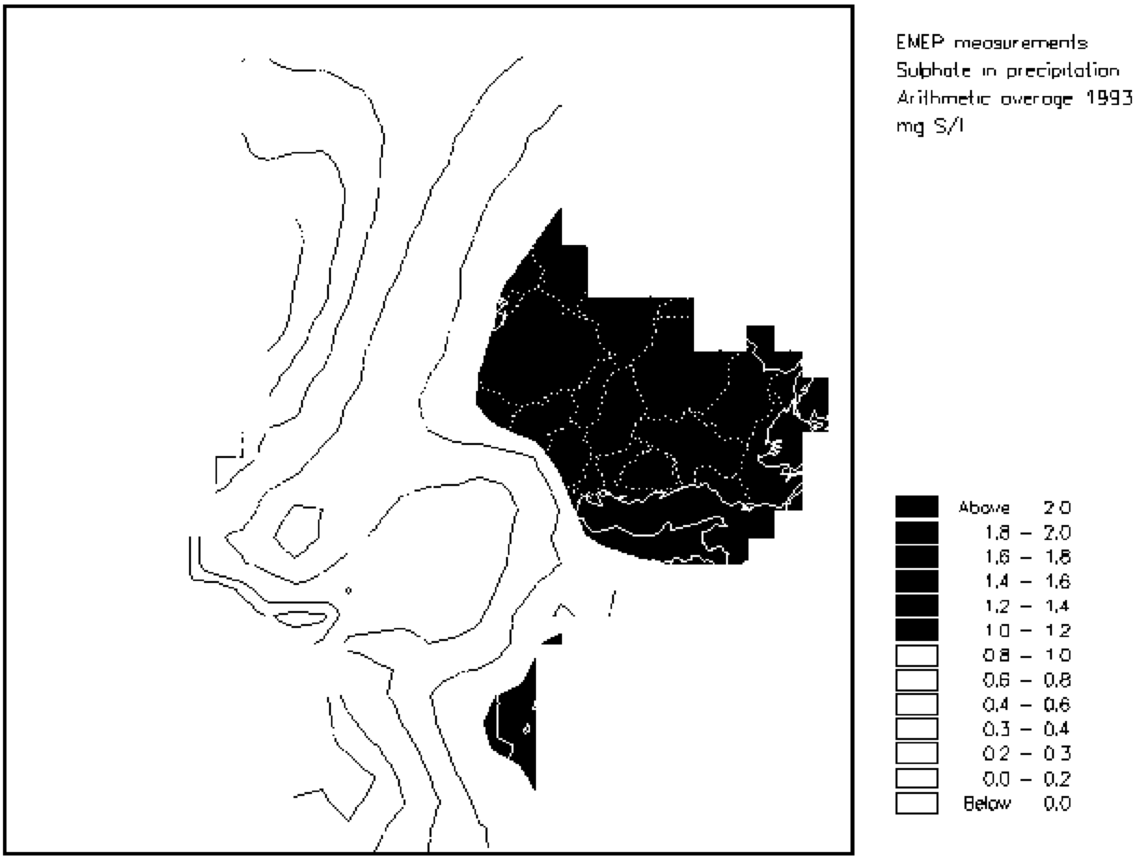


Figure 6.13: Sulphate in precipitation 1993 (mg S/l).

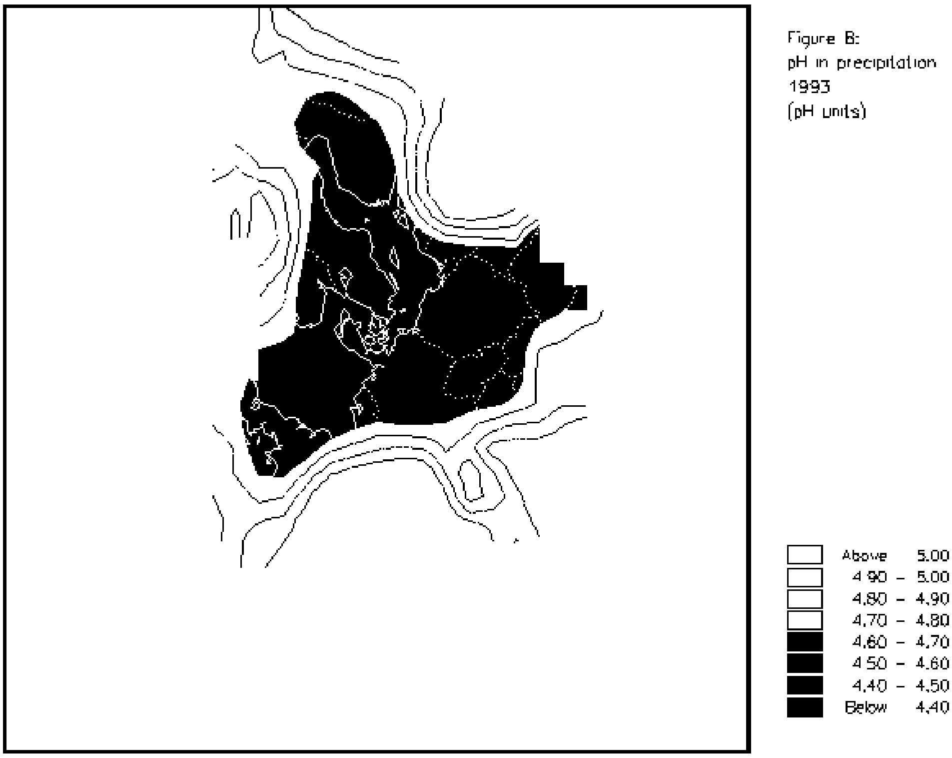


Figure 6.14: pH in precipitation 1993 (pH units).

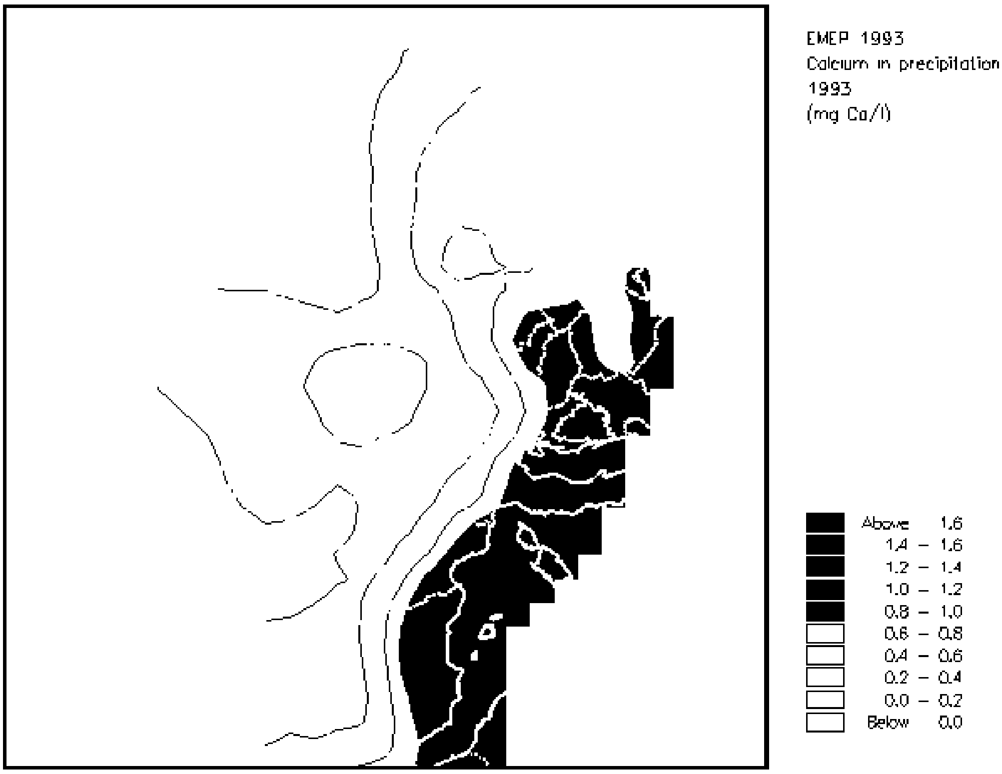


Figure 6.15: Calcium in precipitation 1993 (µg Ca/l).

Trends for the years 1985-1993

The EMEP Meteorological Synthesizing Centre-West (The Norwegian Meteorological Institute) has calculated sulphur reduction trends with distance from major emission sources for the period 1985-1993.

The EMEP-monitoring network have been classified into three broad groups. Stations have been grouped geographically according to the average straight-line distances of transport of deposition. **"Long distance"** sites are those lying approximately 1000 km or more on average from deposition quantity weighted sources, **"medium distance"** sites are those at between 500 km and 1000 km, and **"short distance"** stations are those under 500 km on average from sources. For sulphur dioxide, airborne sulphate, and sulphate in precipitation average monitored and modelled concentrations are plotted. The selection criteria for sites is as standard, i.e. that model and monitored results must be available on 25% of common days for precipitation results, and that air quality results must be reported for 75% of days. The further constraint is that stations must satisfy the criteria during each of the years. The time period considered is from 1985 to the end of 1993 for SO_2 and $SO_4^=$ in air, with 1992 the final date for sulphate in precipitation due to a lower number of stations reporting results at time of analysis.

Figure 6.16-Figure 6.18 show observed and modelled levels and trends of SO_2 in air, sulphate in air and sulphate in precipitation.

The main conclusions from this trend analysis, are:

- There is a downward trend for all the sulphur parameters.

- Totally, there has been a close to 50% reduction from 1985 to 1993.

- Both measured and modelled results show that the reduction has been largest for SO_2 in air, about 60%.

- The reduction has been the smallest for SO_4 in deposition at sites far away from source areas, about 35% reduction.

The analysis show some discrepancies between the measured and modelled results.

It should also be noticed that the trend analysis has been done on a selected and rather limited set of sites (as shown in the figures), selected based on the criteria mentioned above. No analysis has been published on possible differences in trend between various parts of Europe.

The reduced SO_2 concentrations in regional air over Europe coincides well, on the macro scale, with the reduced SO_2 emissions described earlier in this chapter.

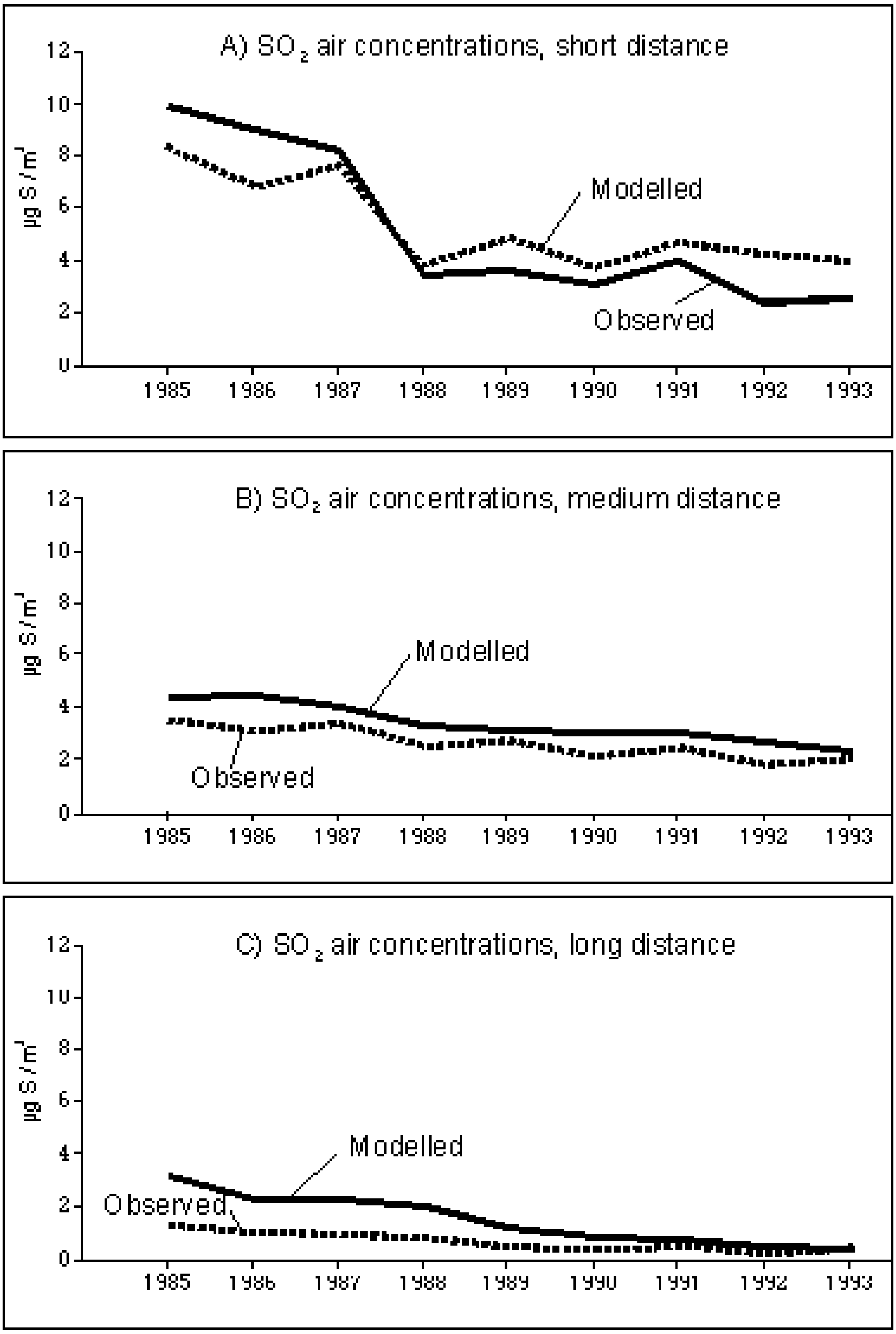


Figure 6.16: Time trend comparison for SO_2 in air across the EMEP network.
a) Short distances from sources (<~500 km).
b) Intermediate distance (~500-1000 km).
c) Longer distances from sources (>~1000 km).

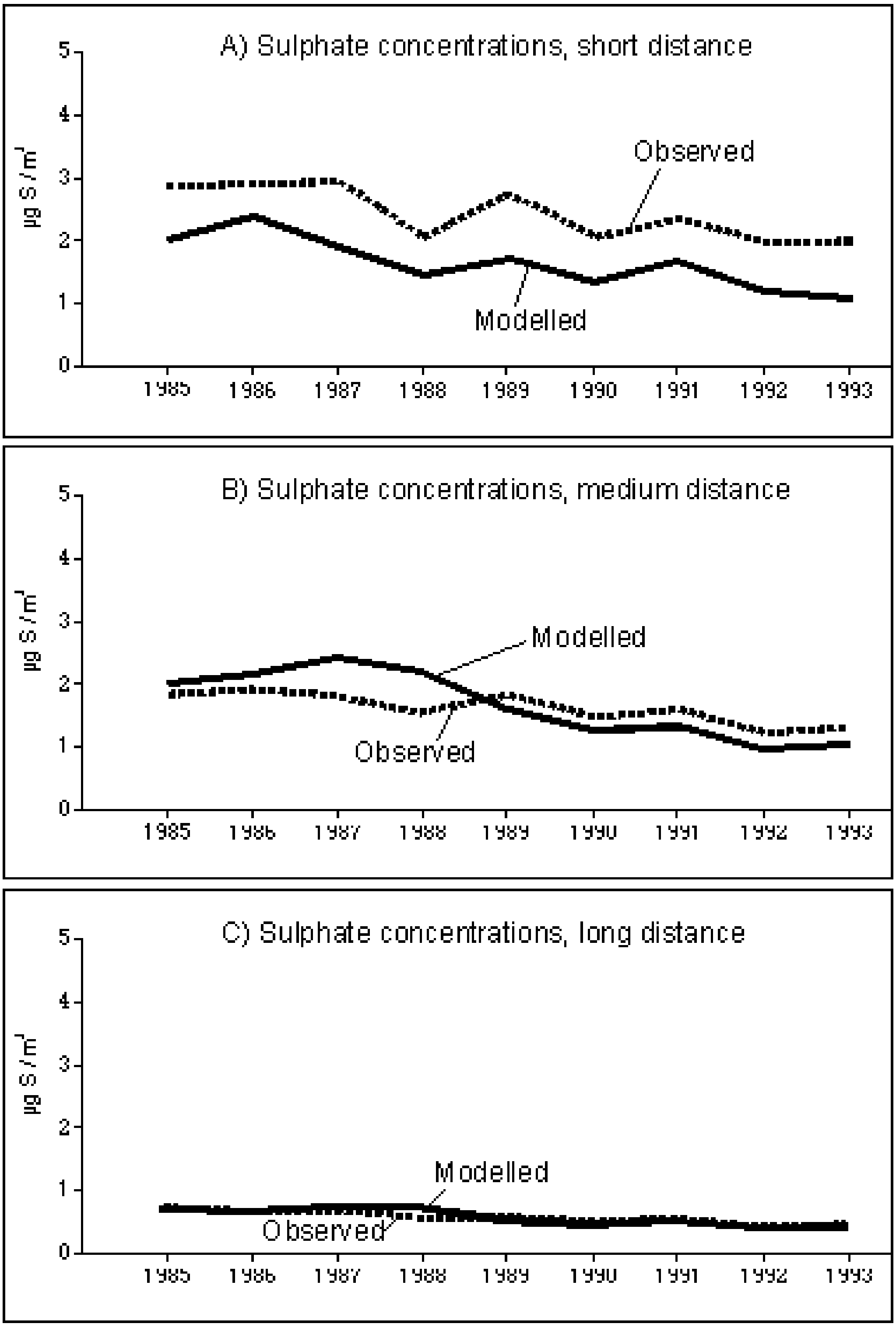


Figure 6.17: Time trend comparison for SO4= in air across the EMEP network.
a) Short distances from sources (<~500 km).
b) Intermediate distance (~500-1000 km).
c) Longer distances from sources (>~1000 km).

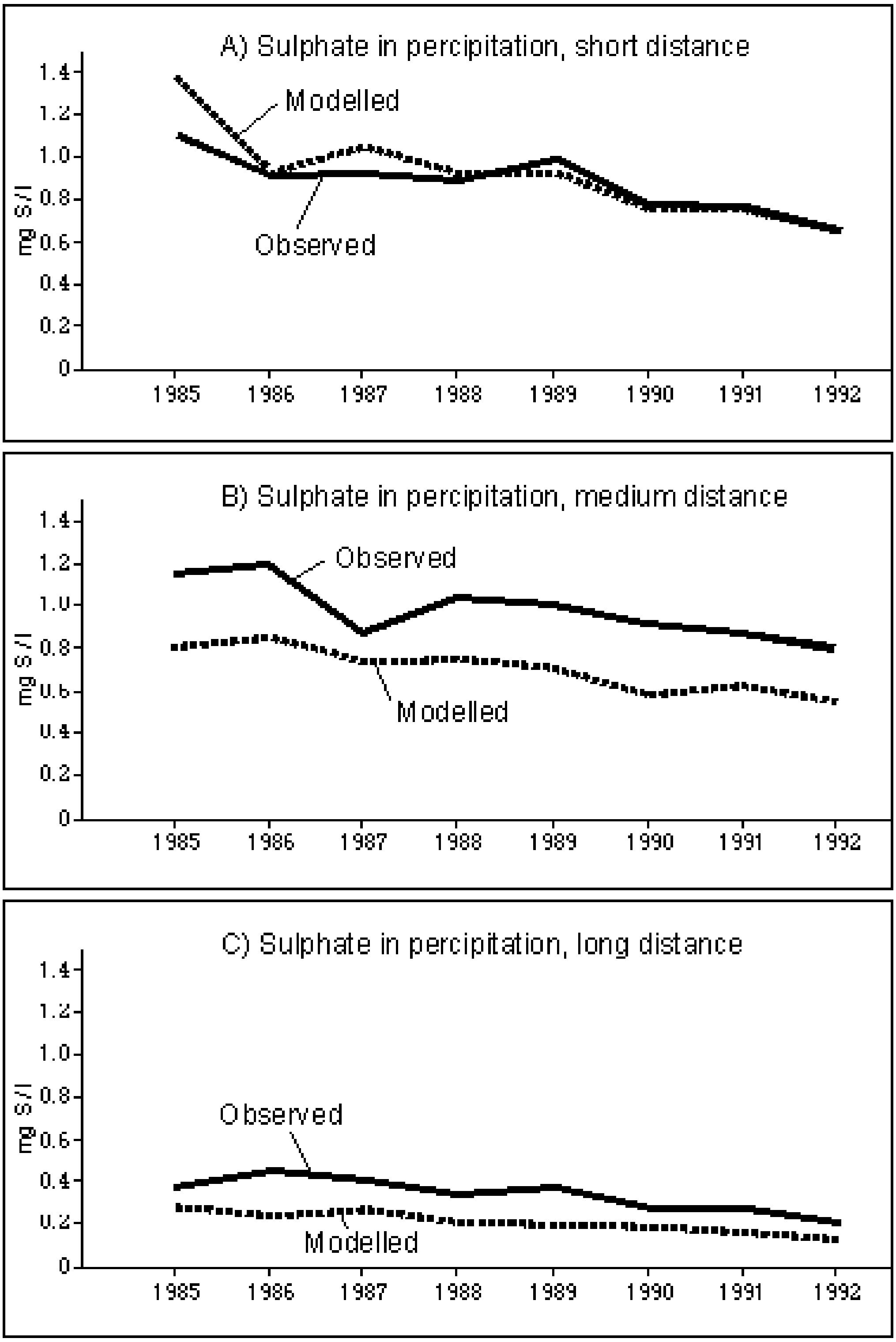


Figure 6.18: *Time trend comparison for $SO_4^{=}$ in precipitation across the EMEP network.*
a) Short distances from sources (<~500 km).
b) Intermediate distance (~500-1000 km).
c) Longer distances from sources (>~1000 km).

6.2 Nitrogen compounds

6.2.1 Behaviour, effects, emissions

Nitrogen oxides (NO_x) has natural and anthropogenic sources. The natural sources (bacterial and volcanic action, and lightening) cause a low-level background NO_2 concentration. The main anthropogenic source is combustion of fossil fuel, which causes elevated concentrations in near-source areas. NO_x is usually considered the sum of nitrogen monoxide (NO) and nitrogen dioxide (NO_2). In the anthropogenic emissions, NO dominates (typically 80-90%). In the atmosphere, NO reacts quickly with O_3 to form NO_2. Further reactions depend mainly upon the concentrations of VOC in the air, and the intensity of sunlight. There is a photochemical equilibrium condition between NO, NO_2 and O_3 with the equilibrium concentrations dependent upon the concentration of OH and other radicals resulting from photochemical reactions. NO_2 is eventually converted to HNO_3 by reaction with OH radicals. HNO_3 is then removed from the atmosphere by wet deposition, and to a lesser extent by dry depositions, adding to the acid deposition problem.

Major sources in most urban areas today are motor vehicle exhaust, which dominates, and combustion of fossil fuels in stationary installations. Large power plants with tall stacks are significant sources of NO_x which, however, seldom causes high exposures in nearby areas.

Urban annual average NO_2 concentrations are generally in the range 20-90 $\mu g/m^3$, and peak daily and hourly concentrations may reach several hundred and more than 500 $\mu g/m^3$ respectively in periods of poor dispersion.

NO_2 affects the respiratory system, and a range of effects have been reported from short-term or long-term exposures from controlled human exposure experiments and epidemiological studies: altered lung functions and symptomatic effects, increased prevalence of acute respiratory illness and symptoms, lung tissue damage (at high exposures), increased susceptibility to infections. Young children and individuals with respiratory system decease, such as asthmatics and other chronic respiratory illnesses are those most sensitive to NO_2 exposures.

NO_x and NO_2 contribute to the acid deposition problem, and cause visible injury to vegetation at concentration higher than those occurring in ambient air in Europe, but may occur near a few point sources.

The trend in NO_x emissions in Europe (see Figure 6.19) has been calculated and reported by EMEP (Berge et al., 1995). NO_x emissions in the EMEP area changed little prior to 1985. Later, emission data show a very rapid increase, culminating in 1989, and after that it has declined down to the pre-1985 emission level. It should be noted that the accuracy of emission numbers before 1985, or even before 1990, may be limited, especially for Eastern Europe. After 1990, the decline is mostly due to reported reduced emissions in East European countries, but also decreasing emissions in West European countries, partly due to the introduction of catalyst cars.

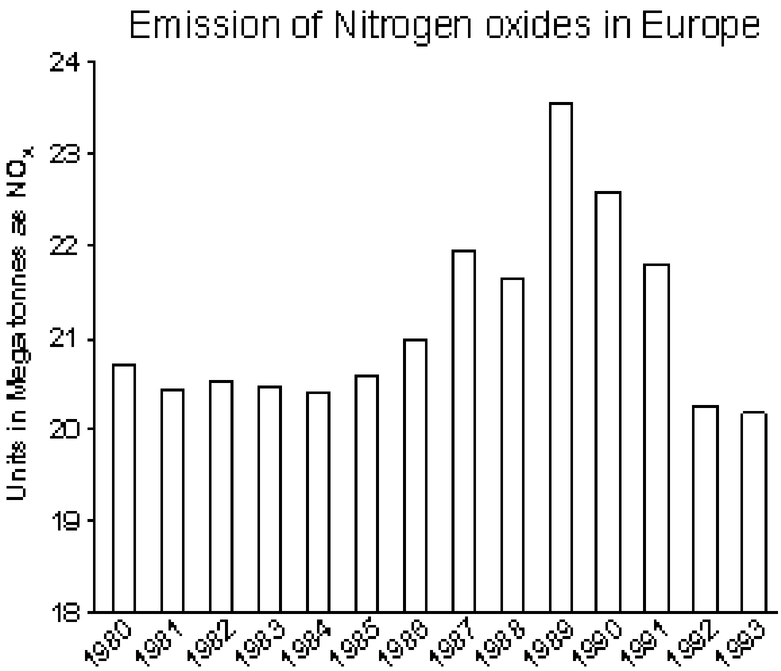


Figure 6.19: Trend in annual NO_x emissions in the EMEP area. (Berge et al., 1995).

6.2.2 Air Quality Limit and Guide Values

EU Limit and Guide values and WHO Guideline values for NO_2 are given in Table 6.5. The WHO Guideline values are maximum values and are not to be exceeded.

Table 6.5: EU Limit and Guide Values for NO_2 ($\mu g/m^3$)
EU Council Directive 85/203/EEC
WHO Guideline values for NO_2 ($\mu g/m^3$).

Limit values	Median of 1 h values	98 percentile of ≤1 h values
Year		200
Guide values		
Year	50	135
WHO Guideline values	Maximum 1 h average	Maximum 24 h average
	400	150

6.2.3 *Urban and local NO_2 concentrations*

In Appendix B NO_2 data from 17 countries are given. The stations are ranged according to the 98 percentile of hourly values. The stations with the highest values are given in Table 6.6. Also the maximum and median hourly values are given.

Figure 6.20 show maximum, 98 percentile and median hourly values for selected stations and cities. The figure does not show much lower concentrations in the Nordic countries as the SO_2 data do. 98 percentile and median values do not vary much over Europe, except for higher values in Spain and Greece. As shown in Table 6.6 and Appendix B, stations in Italy and Portugal also have high 98 percentile values.

NO_2 data from the selected cities in Figure 5.1/Table 5.2 are shown in Figure 6.21 and Figure 6.22. These figures give the median and 98 percentile of hourly values, respectively. These figures, together with Table 6.6 and Appendix B, show the highest NO_2 values in southern Europe, and some large cities like London and Paris.

Table 6.6: 1 h maximum, 98 percentile and median NO_2 values for 1993 for European cities ranged according to the 98 percentile hourly values (µg/m^3). (For complete table, see Appendix B).

Country	Name	City Class	Station	Maximum		98-percentile	Median
Italy	Bologna		Via Marconi			348	
Portugal	Lisboa		Entrecampos			311	69
Italy	Milano		Statuto			289	
Italy	Piacenza		Via Giordani			264	
Italy	Milano prov.		Monza			256	
Italy	Milano prov.		Sesto s. g. comune			252	
Greece	Athens	1	Patission 147	554	a	247	98
Italy	Milano		Senato			247	
Italy	Milano		Juvara			246	
Italy	Milano		Zavattari			233	
Italy	Milano prov.		Lainate			226	
Italy	Milano		Marche			222	
Italy	Milano		Liguria			218	
Italy	Bologna		Via Matteotti			214	
Italy	Bologna		Via Irnerio I			211	
Italy	Milano prov.		Legnano Tosi			202	
Italy	Roma		Fermi			198	
Italy	Torino		Via madama Cristina			198	
Italy	Torino		Via Consolata			197	
Italy	Genova		C. SO Europa			195	
Italy	Roma		Gondar			195	
Italy	Genova		Acquasola			193	
Italy	Milano prov.		Villasanta			192	
Italy	Milano prov.		Agrate			192	
Italy	Milano prov.		Limito			192	
Italy	Bologna		Via Emilia Ponente			190	
Italy	Roma		M. Grecia			190	
Italy	Venezia (ind. zone)		Stab. Montedipe 1			190	
Italy	Milano prov.		Settimo			188	
Italy	Torino		Corso Vercelli			188	
Italy	Torino		Via Guido Reni			188	
Spain	Madrid	1	Plaza España	470		187	57
Italy	Venezia (ind. zone)		Piazza s. Antonio (Marghera)			186	
Italy	Milano prov.		Inzago			186	
Italy	Milano prov.		Corsico			184	
Italy	Milano prov.		Melegnano			183	
Portugal	Carregado		Cast. Ribatejo			181	
Italy	Milano prov.		Cuggiono			181	
Italy	Roma		Preneste			179	
Italy	Genova		Villa Serra			178	
Italy	Piacenza		Via Taverna			178	
Spain	Madrid	1	Cuatro Caminos	448		177	72
Italy	Milano prov.		Rivolta			176	
Italy	Milano prov.		Robecchetto			176	
Italy	Firenze		Mosse			174	
Italy	Piacenza		Via Alberoni			174	
Italy	Milano prov.		Legnano com.			173	
France	Paris	1	R.N 13 Rue Malmaison	424		172	69
Italy	Bologna		Fiera			171	
Italy	Bologna		P. Za dei Martiri			170	

Re. footnotes: See the full table in Appendix.

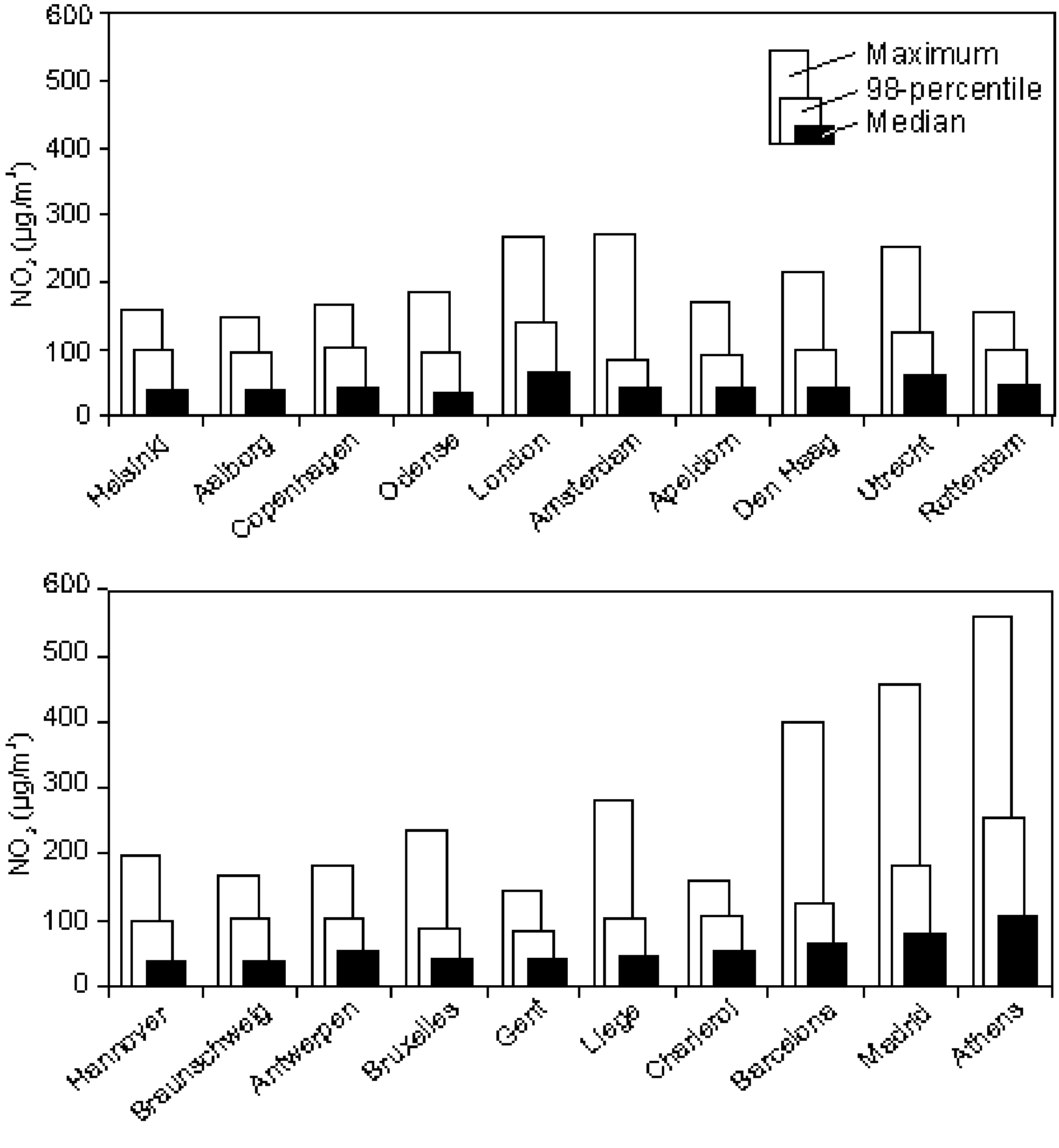


Figure 6.20: 1 h maximum, 98 percentile and median NO_2 values for 1993 for selected stations and cities ($\mu g/m^3$).

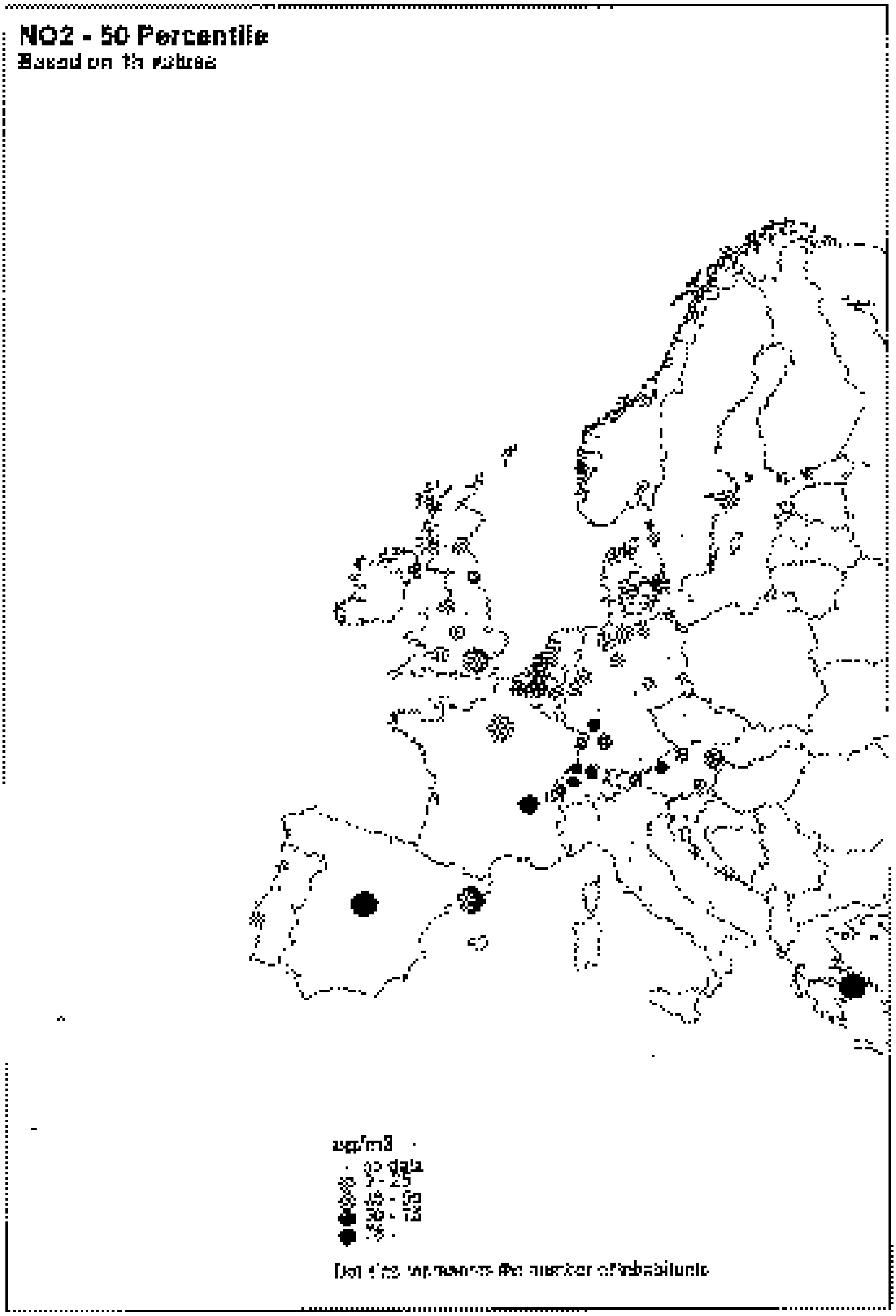


Figure 6.21: NO_2 median 1h values in selected cities (µg/m3).

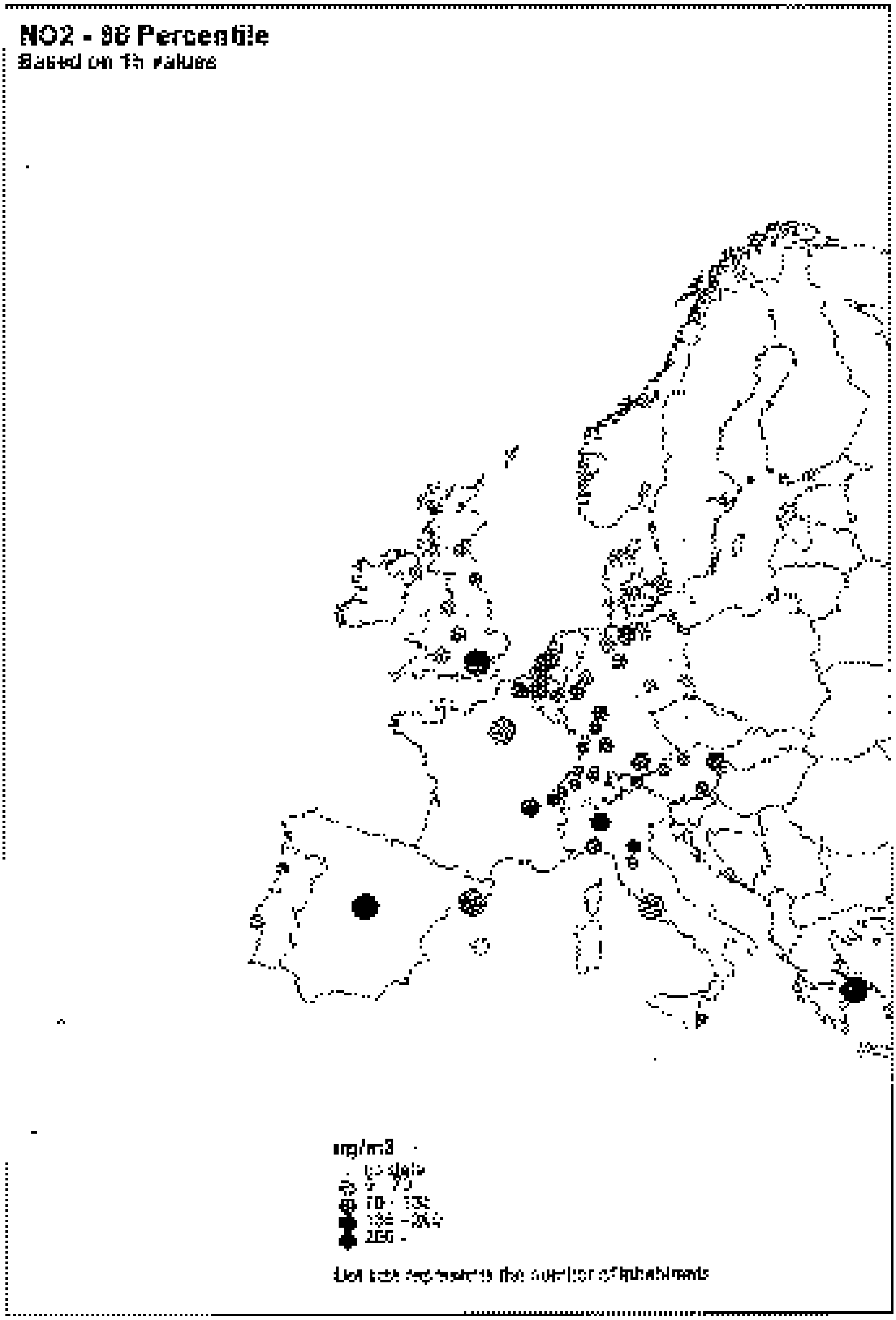


Figure 6.22: NO_2 98 percentile 1h values in selected cities (µg/m3).

Exceedances

Table 6.7 shows stations with exceedances of the EU Limit value for NO_2 (98 percentile of hourly values, 200 µg/m^3). This limit value is rather high. It is exceeded at one station in Greece and Portugal and at a number of stations in Italy. Some stations in Austria have rather high maximum 1/2h NO_2 values, but 98 percentile values are not given. Probably the EU Limit value is not exceeded in Austria. From Eastern Europe there are no available NO_2 data to be compared with the EU Limit value.

Table 6.8 shows exceedances of EU Guide values and WHO Guideline values for NO_2. WHO Guideline values are much higher than EU Guide values and are exceeded only in a few countries. EU Guide values seems to be exceeded commonly in Western Europe. Data from Eastern Europe are not available.

Table 6.7: Exceedances of EU Limit Values for NO_2.

Country	City	Station name	1h values 1 year
			P98 >200
Greece	Athens	Patission 147	247
Italy	Genova	Via Cantore	214**
		Piazza Masnata	201**
	Bologna	Via Marconi	348
		Via Matteotti	214
		Via Irnerio I	211
	Firenze	Roselli	220**
	Milano	Marche	222
		Invara	243
		Zavattari	233
		Liguria	218
		Verziere	252**
		Senato	247
		Cenisio	272**
		Aquileia	257**
		Statuto	289**
	Milano (province)	Sesto s. g. Comune	252
		Monza	256
		Cinisello	218**
		Pero	296**
		Arrese	231**
		Lainate	226
		Legnano Tosi	202
	Piacenza	Via Giordani	264
Portugal	Lisboa	Entrecampos	311

** Data availability <75%.

Table 6.8: Exceedances of EU and WHO Guide(line) values for NO_2.

Country	City	Station	EU Guide Values		WHO Guideline Values	
			Median 1h > 50	P98 1h >135	Max. 1h >400	Max. 24 h >150
Austria	Graz	Süd				151
(mean values)	Linz	24-er-Turm				172
		BH-Urfahr				155
		Kleinmünchen				162
		ORF-Zentrum				167
	Salzburg	Rudolfplatz	71			
	Wien	Hietzinger Kai	74			
France	Lyon	Lyon Berthelot	80	160	452	166
		Lyon Garibaldi	65	162	481	
		Lyon Puits Gaillot	67	164	403	
	Paris	Neuilly/Seine (92)	58		418	177
		Paris Ch. de Mars	52		435	166
		Paris Tour St-Jacques	63	150		167
		R.N 13 Rue Malmaison	69	172	424	197
		Rue Danzig (15ème)	61	145	437	159
		Tour Eiffel (1er et.)	50	154		172
	Strasbourg	rue du 22 novembre	50			
Germany	Berlin	Charlottenburg	56	155		
	Düsseldorf	Düsseldorf-Mörsenbroich	61			
	Erfurt	Erfurt, Krämpf.		137		
	Essen	Essen-Ost	53			
	Gera	Gera, Frieder.		141		
	Hamburg	Stresemannstrasse	58	142		
	Hannover	Göttinger strasse		136		
	Karlsruhe	Karlsruhe-Mitte	51			
	Koblenz	Friedrich-Ebert-Ring	57			
	Ludwigshafen-Frankental	Frankental	57			
		Mundenheim	51			
	Mainz-Mombach	Parcusstrasse	67	163		
	Wiesbaden	W-Ringkirche		136		
Greece	Athens	Patission 147	98	247		253
		Pireas Platia Dimotikou	67	136		
Italy	Bologna	Fiera		171		
		P. Za dei Martiri		170		
		Via Emilia Ponente		190		
		Via Irnerio I		211		
		Via Marconi		348		
		Via Matteotti		214		
	Firenze	Mosse		174		
		Via Bassi		145		
	Genova	Acquasola		193		
		C. SO Europa		195		
		Villa Serra		178		

Table 6.8 (contd.)

Country	City	Station	EU Guide Values		WHO Guideline Values	
			Median 1h > 50	P98 1h >135	Max 1h >400	Max 24 h >150
Italy (contd.)	Milano	Juvara		246		
		Liguria		218		
		Marche		222		
		Senato		247		
		Statuto		289		
		Zavattari		233		
	Milano prov.	Agrate		192		
		Cassano d'Adda		169		
		Corsico		184		
		Cuggiono		181		
		Galliate		166		
		Inzago		186		
		Lainate		226		
		Legnano com.		173		
		Legnano Tosi		202		
		Limito		192		
		Lodi		159		
		Melegnano		183		
		Monza		256		
		Rivolta		176		
		Robecchetto		176		
		Sesto s. g. comune		252		
		Settimo		188		
		Turbigo		143		
		Villasanta		192		
	Modena	Cavour		141		
		Via Giardini		167		
	Piacenza	Via Alberoni		174		
		Via Giordani		264		
		Via Taverna		178		
	Ravenna	S.A.P.I.R		136		
	Roma	Fermi		198		
		Francia		159		
		Gondar		195		
		M. Grecia		190		
		Preneste		179		
	Torino	Corso Vercelli		188		
		Parco Lingotto		160		
		Via Consolata		197		
		Via Guido Reni		188		
		Via madama Cristina		198		
	Trento	Trento		163		
		Trento Nord		144		
	Venezia	Piazza s. Antonio (Marghera)		186		
	(ind. zone)	Stab. Montedipe 1		190		
The Netherlands	Utrecht	Witte Vrouwenstraat	58			

Table 6.8 (contd.)

Country	City	Station	EU Guide Values		WHO Guidelines Values	
			Median 1h > 50	P98 1h >135	Max 1h >400	Max 24 h >150
Norway	Bergen	CMI	59	135		204
(based upon 24h	Drammen	Engene	74			
values)	Fredrikstad	Broch street	50			
	Oslo	St. Olavs square	50			
	Skien	Kings street	57			
	Stavanger	Handelens hus	63			
	Trondheim	Torget	57			
Portugal	Carregado	Cast. Ribatejo		181		
	Faro	Faro	80	141		
	Lisboa	Benéfica	69	151		
		Entrecampos	69	311		
		Rua da Prata	52	137		
	Setúbal	Setubal-Cicade		167		
Spain	Barcelona	Molina Pl.	55			
	Madrid	Arturo Soria	53	159		
		Carlos V	57	151		154
		Cuatro Caminos	72	177	448	184
		Plaza Castilla	58	141		
		Plaza España	57	187	470	189
		Villaverde	72	151		
Switzerland	Basel	Feldbergstrasse	57			
(mean values)	Bern	Bern	57			
	Genève	Ile	60			
	Lausanne	Lausanne	50			
		Rue César Roux 2	56			
	Zürich	Schimmelstrasse	57			
United Kingdom	Edinburgh	Edinburgh centre	50			
	Leeds	Leeds centre	50			
	Liverpool	Liverpool centre	50			
	London	Bridge Place	63	136		192
		London Bloomsbury	65			
	Newcastle	Newcastle centre	54			

Trends

Figure 6.23-Figure 6.28 show, as examples, trends in NO_2 data on an annual basis for some selected stations in different countries. The figures show the maximum, 98 percentile and median of 1 h data from Denmark, United Kingdom, the Netherlands, Belgium, Germany (only 98 percentile), Switzerland (mean instead of median), Spain and Greece, while Norwegian values are based on 24 h data.

Most stations show a relative stable NO_2 level for the last 10 years, even though some stations might show slightly decreasing median and mean values over the last few years, for instance Aalborg, Rotterdam, Bruxelles and several Swiss towns. Rather high values, especially maximum values, are measured in Athens.

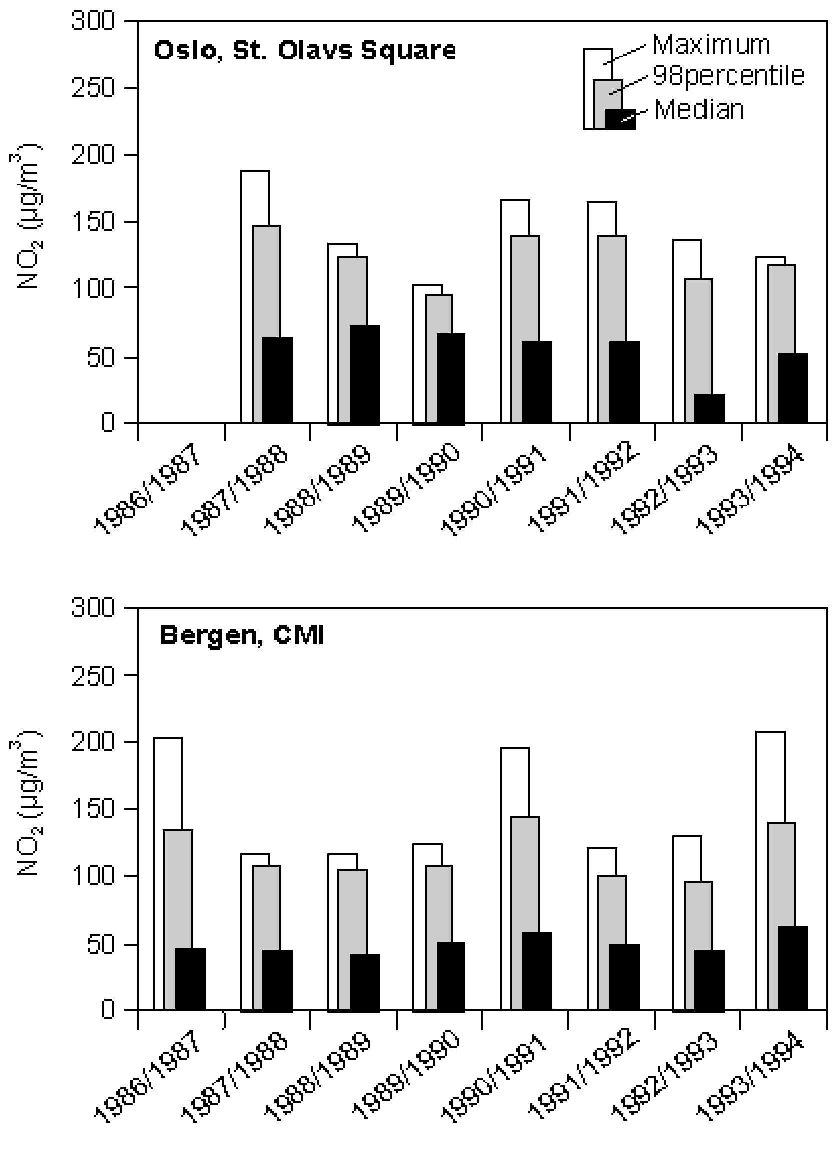
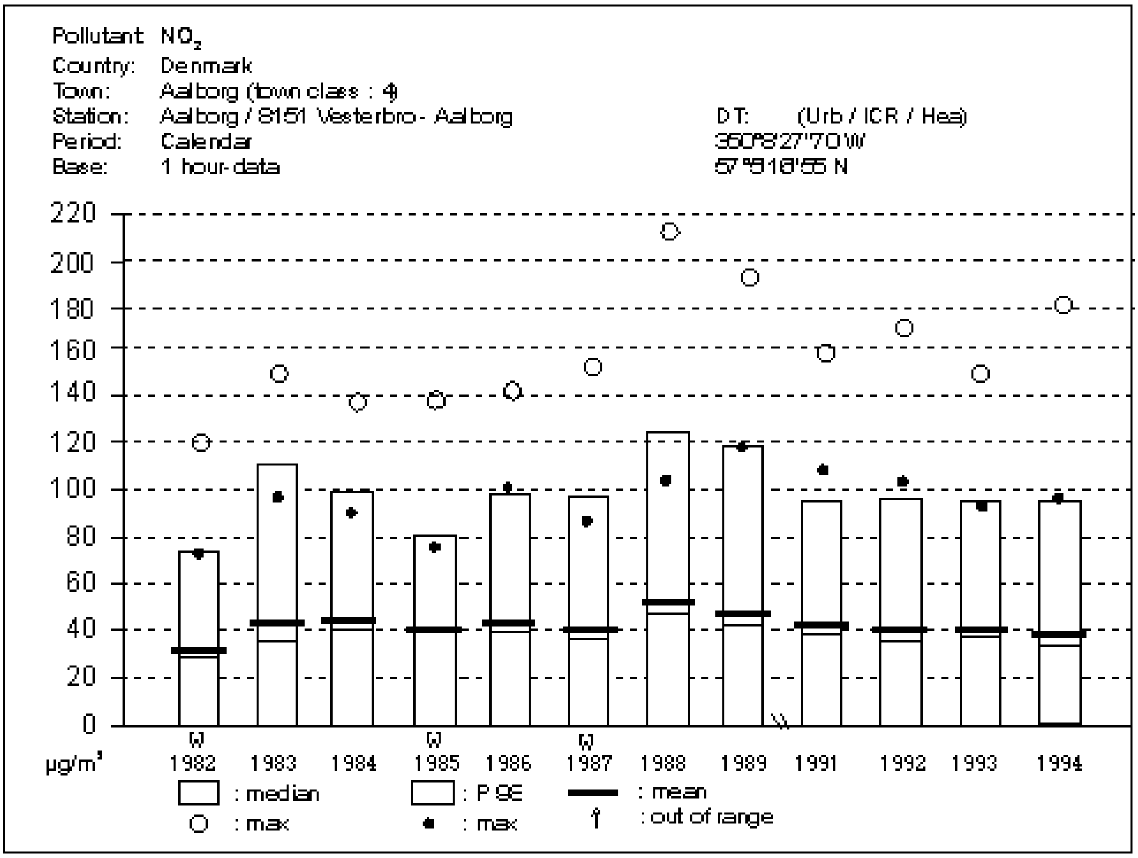


Figure 6.23: NO_2 trend in Norway 1986-1994 (only winter data and 24 h values) (µg/m³). Data from national reports.



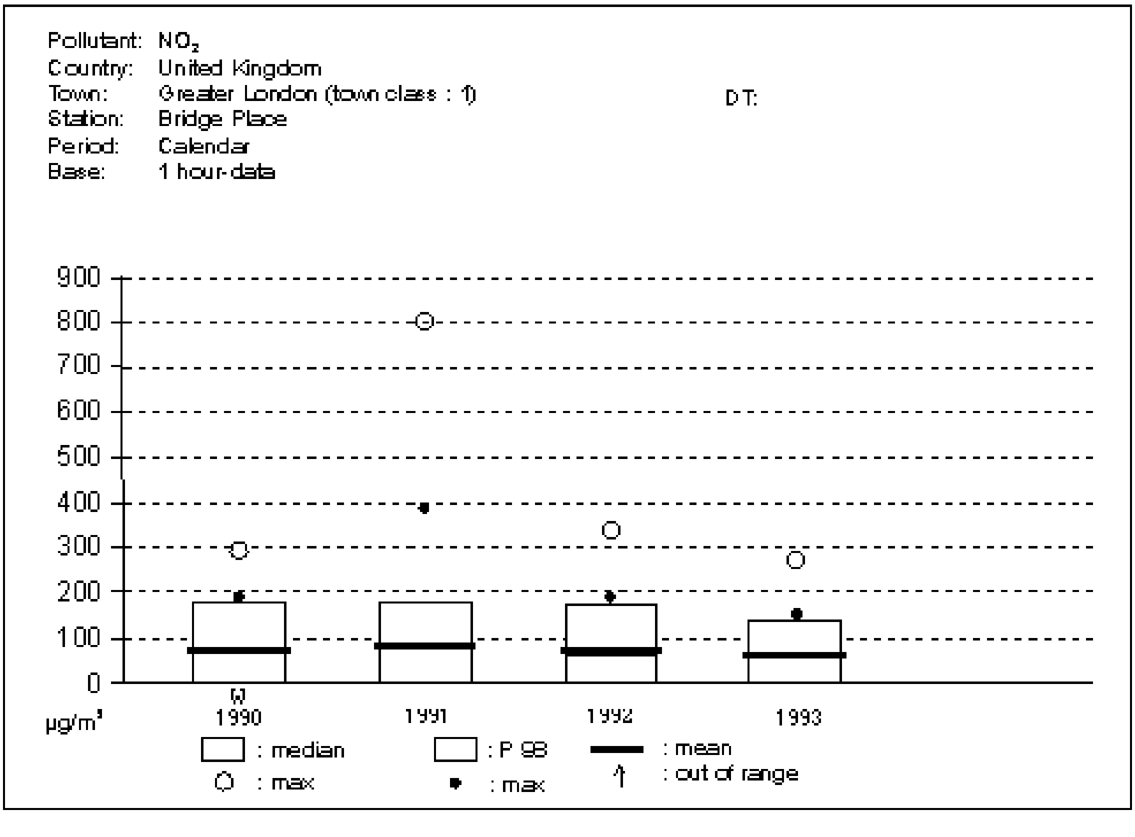


Figure 6.24: *NO_2 trend in Aalborg, Denmark 1982-1994 and Bridge Place (Greater London), UK 1990-93 (µg/m^3). APIS data.*

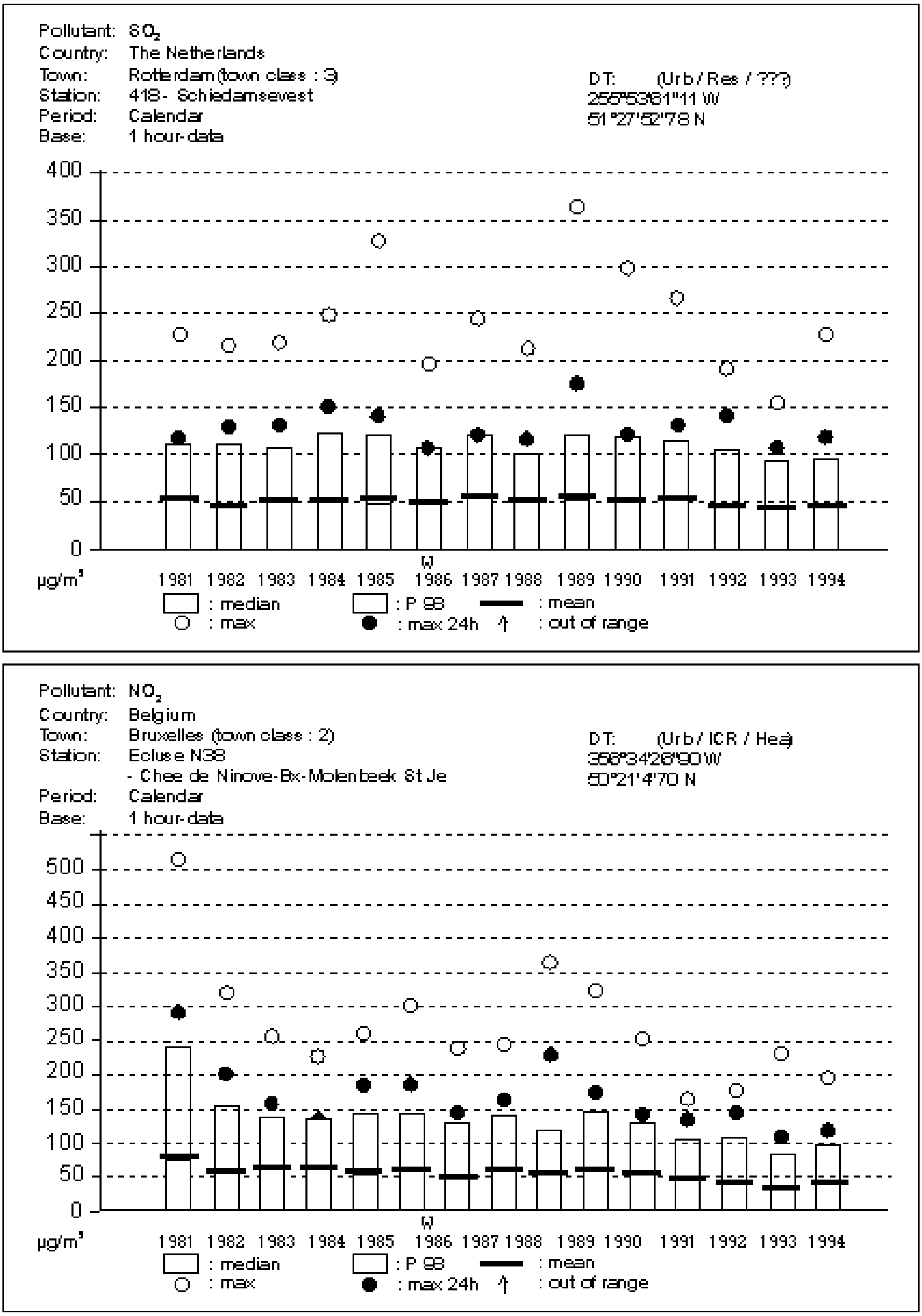


Figure 6.25: NO_2 trend in Rotterdam, the Netherlands 1981-1994 and Bruxelles, Belgium 1980-1994 (µg/m³). APIS data.

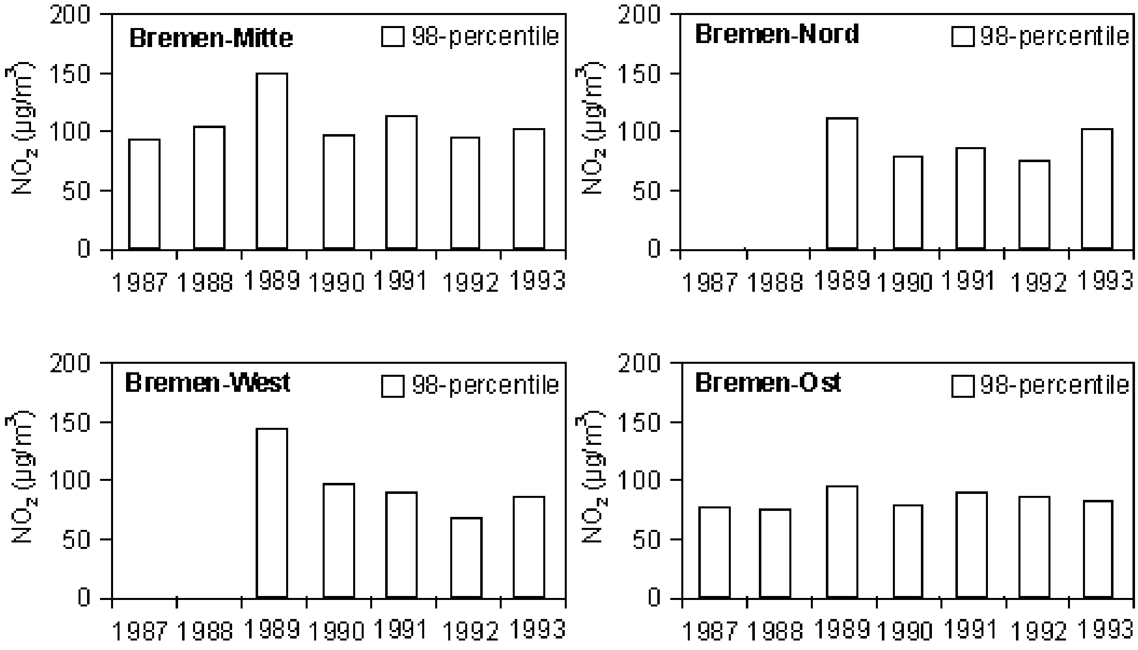


Figure 6.26: NO_2 trend in Bremen, Germany 1987-1993 (µg/m³). Data from Bremen State report.

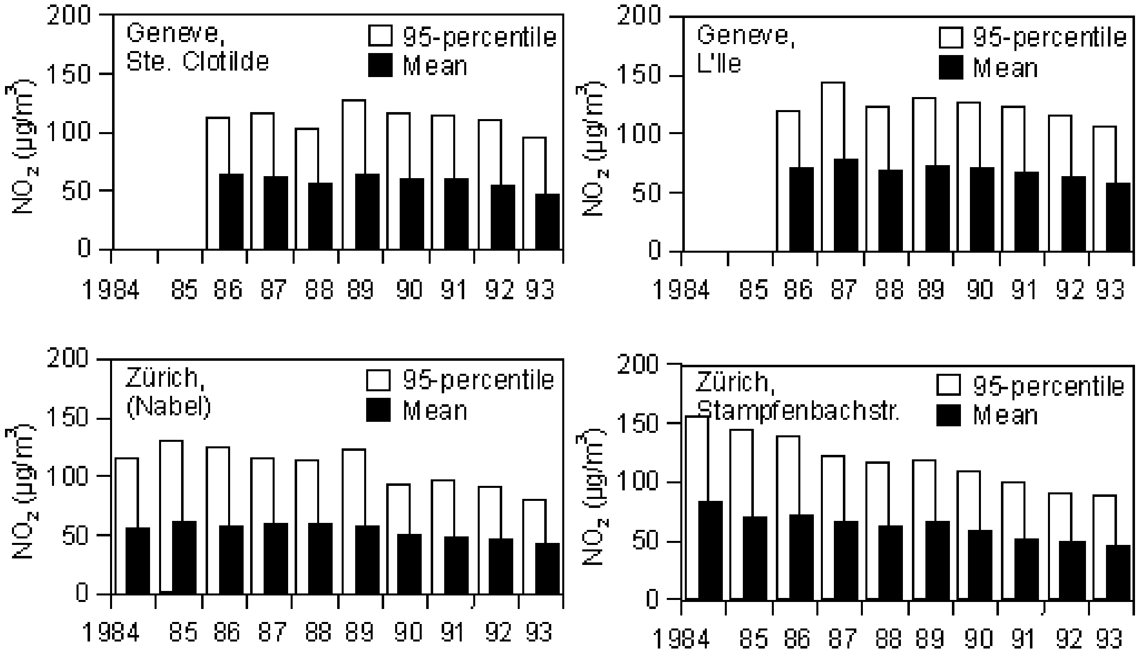


Figure 6.27: NO_2 trend in Switzerland 1984-1993 (µg/m³). The Swiss trend figures are based on ½ h values, and the numbers given are the 95 percentile and mean values. Data from national report.

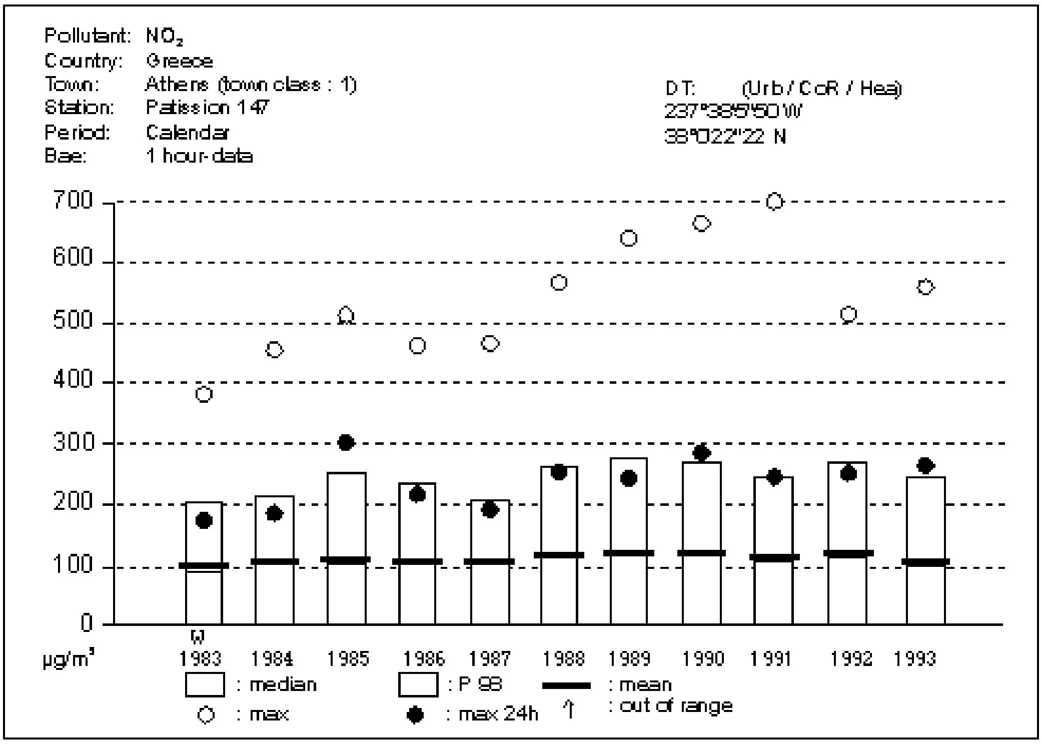


Figure 6.28: NO_2 trend in Greece 1983-1993 (µg/m³). APIS data.

6.2.4 Regional nitrogen compound concentrations and deposition

The following presentation is based directly upon the 1993 EMEP data report (EMEP, 1995).

Concentrations

Nitrogen dioxide

The number of sites reporting NO_2 data during 1993 were 30% less than the number of sites reporting SO_2. For this reason and due to the fact that there are larger local NO_2 concentrations, and larger inaccuracies in the measurements of NO_2, the uncertainties in the NO_2 concentrations in Figure 6.29 are generally much larger than for SO_2. The reservations made for SO_2 with respect to site location and presence of higher concentrations in industrialised, densely populated areas are also valid for NO_2. In addition, even higher concentrations will be found in areas with heavy traffic.

In northern Scandinavia, the annual values are below 1 µg N/m³. For United Kingdom, no NO_2 data are available for 1993. A decreasing gradient from England over the Netherlands to Germany is indicated by the Irish and the Continental results. The highest concentrations of NO_2, >6 µg N/m³, are reported from four stations in Spain, one in Italy and one in the Netherlands. In central Europe the NO_2 concentrations range from 2 to 6 µg N/m³.

Deposition

Nitrate in precipitation

Annual averages of nitrate in precipitation is presented in Figure 6.30. The pattern is somewhat similar to that of sulphate in precipitation. Most areas have annual concentrations lower than 0.6 mg N/l. In Portugal. western Ireland and northern Scandinavia, the annual averages are lower than 0.2 mg N/l. The areas with the highest levels are mainly located in eastern parts of Europe; Poland and towards south-east. High nitrate concentrations are also measured at stations in Germany, Italy and Spain. There is a sharp gradient over the Iberian peninsula, with low concentrations in the west and high concentrations in north-eastern Spain.

Ammonium in precipitation

The ammonium levels presented in Figure 6.31, are also relatively low. In contrast to the anthropogenic sources of NO_x giving nitrate in precipitation after a series of photochemical reaction, the sources for ammonia, which give ammonium are mainly related to agricultural activities, including domestic animal keeping and the conversion from gaseous ammonia to ammonium is relatively rapid. The pattern for ammonium is usually quite different from that of nitrate and sulphate. Two maximum areas are indicated, one in south-western France and one in southern Poland, Ukraine and Romania. Concentrations of ammonium in precipitation higher than 1 mg N/l are measured at stations in Lithuania and Poland. Concentrations around 1 mg N/l are measured at stations in France and Croatia. In most parts of Europe the concentrations are lower than 0.7 mg N/l and in the outskirts of Europe, in northern Scandinavia, even below 0.2 mg N/l.

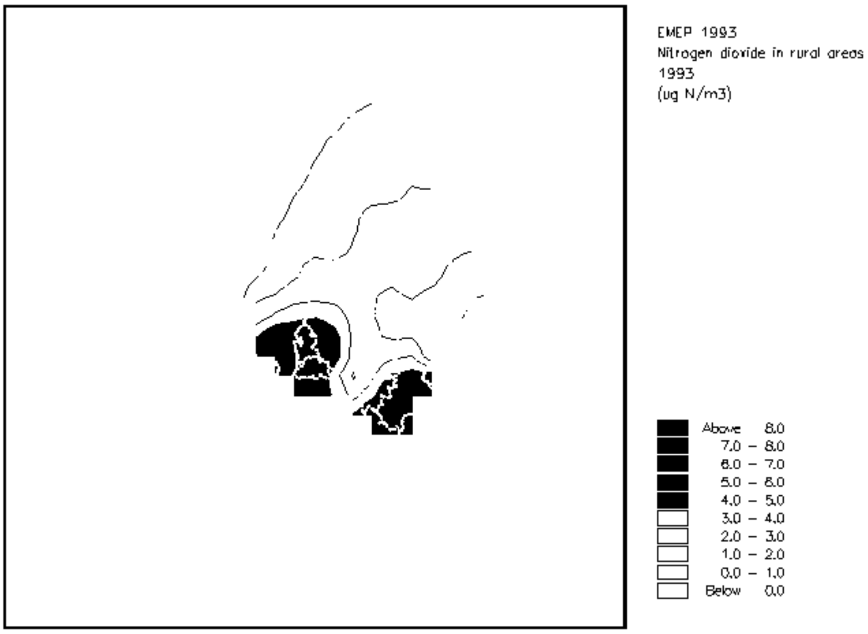


Figure 6.29: Nitrogen dioxide in rural areas 1993, annual average (µg N/m3).

Factor: $\frac{NO_2}{N} = 3.28.$

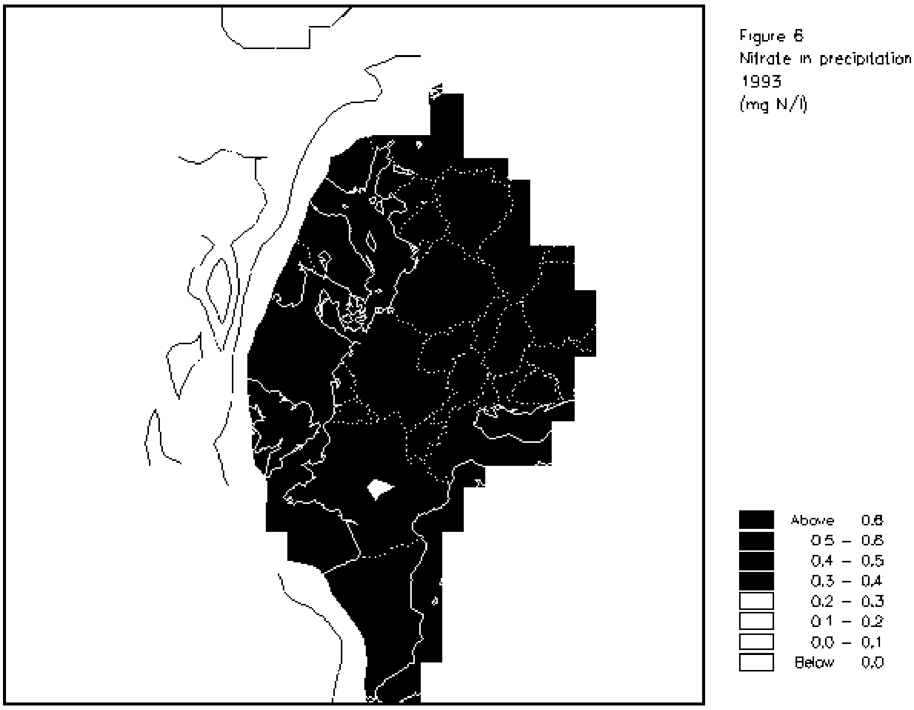


Figure 6.30: *Nitrate in precipitation 1993 (mg N/l).*

Factor: $\frac{NO_3}{N} = 4.43.$

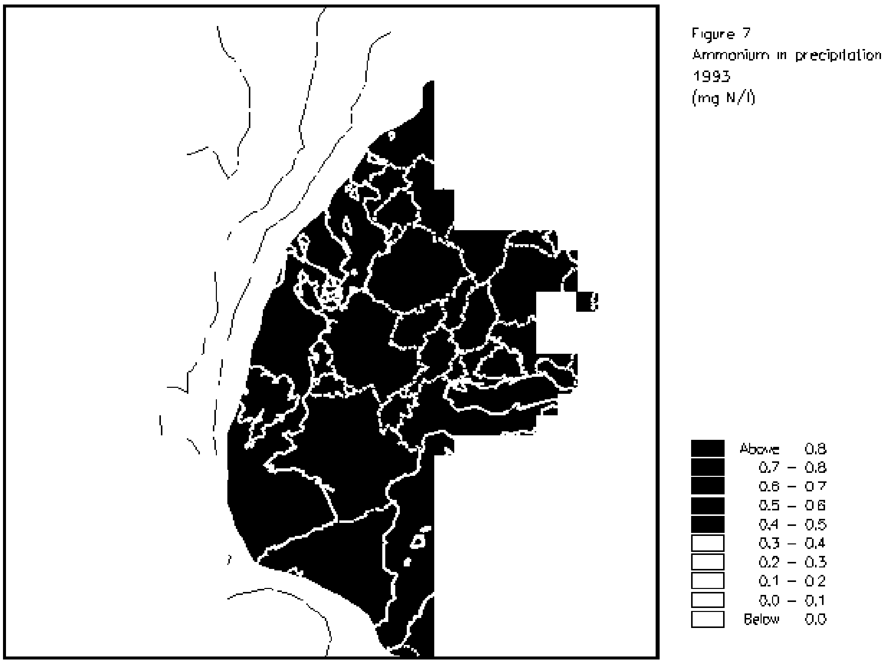


Figure 6.31: *Ammonium in precipitation 1993 (mg N/l).*

Factor: $\frac{NH_3}{N} = 1.21.$

6.3 Black smoke (BS)

6.3.1 Behaviour, effects, emissions

(See under Suspended Particles, chapter 6.4.1.)

6.3.2 Air Quality Limits and Guide Values

EU Limit and Guide values for black smoke and WHO Guideline values for combined exposure to SO_2 and particulate matter are given in Table 6.9 and Table 6.10.

Table 6.9: EU Limit and Guide Values for BS (black smoke) (µg/m³). EU Council Directive 80/779/EEC.

Limit Values	Median of 24h values	Mean of 24h values	98 percentile of 24h values	Maximum of 24h values
Year	80		250[1)]	
Winter (1.10-31.3)	130			
Guide Values				
Year		40-60		100-150

1) EU Member States must take all appropriate steps to ensure that this value is not exceeded for more than three consecutive days. Moreover, EU Member States must endeavour to prevent and to reduce any such instances in which this value has been exceeded.

Table 6.10: WHO Guideline values for Europe for combined exposure to SO_2 and particulate matter (BS, TSP or TP) (WHO, 1987).

Substance	Mean values for averaging time	
	24 h	1 year
SO_2	125	50
BS[1)]	125	50
TSP[2)]	120[3)]	
TP[4)]	70[3)]	

1) Black smoke
2) Total suspended particulates measured by high volume sampler without any size selection.
3) Value to be regarded as tentative at this stage.
4) Thoracic particles measured by a sampler having a 50% cut-off at 10 µm.

6.3.3 Urban and local black smoke concentrations

In Appendix B black smoke data from 10 countries are given. The stations are ranged according to the 98 percentile of 24h values. The stations with the highest values are given in Table 6.11. Also the maximum and median 24h values are given.

Figure 6.32 shows that black smoke concentrations in Sweden are lower than in other countries even though the measurements only cover the winter period which usually has the highest pollution level. Swedish stations are urban city centre stations, but they are located well away from traffic sources. They also are “above ceiling” stations. Black smoke levels in Norway, Denmark, Scotland and England are about the same. Maximum levels in Northern Ireland, Ireland, the Netherlands, Belgium and Greece are higher. Black smoke levels in Athens are much higher than in the other cities.

Data from the selected cities in Figure 5.1/Table 5.2 are shown in Figure 6.33-Figure 6.36. These figures give the median, mean, 98 percentile and maximum values based on 24h values. Black smoke data are rather limited throughout Europe. Black smoke levels seem to be highest in Southern Europe, but again Eastern Europe data are missing.

Table 6.11: 24 h maximum, 98 percentile and median black smoke values for 1993 for European cities ranged according to the 98 percentile values (µg/m³). Swedish data cover the winter 1993/94. (For complete table, see Appendix B).

Country	City			Black smoke 24 h values				
	Name	Class	Station	Maximum		98 percentile		Median
Greece	Athens	1	Patission 147	329	c	265		93
Spain	Tenerife	4	Santa Cruz	367	m	238	1	78
Belgium	Bruxelles	2	Maison Communale, Place du Conseil	149	3	149.0	3	26.5
Norway	Trondheim	4	Torget	149	2	138	2	15
Belgium	Bruxelles	2	30 rue Marche aux Chabon	179	3	134.4	3	22
United Kingdom	Belfast	4	Belfast 12 Royal Victoria Hospital	235	1	133		14
Greece	Athens	1	Pireas Platia Dimotikou	157	d	130		39
Belgium	Bruxelles	2	3 rue Cortenbach, Police div. 10	174	3	126.6	3	25
The Netherlands	Utrecht	4	Witte Vrouwenstraat	177	a	126		51
Belgium	Gent	4	Abeelstraat, Politie Bur	152	3	120.0	3	25
Belgium	Gent	4	Groothandelsmarkt	122	3	116.3	3	22
Belgium	Gent	4	Kastel Speltink	153	3	113.8	3	22
France	Marseille	3	Plombières	146		108		62
France	Marseille	3	Rabatau	136		108		42
Belgium	Gent	4	Sirt Kruisdorp	108	3	102.9	3	13
Ireland	Cork	4	Market, Princes St.	159		98		14.5
Belgium	Gent	4	Zwimbad, Purshaaf, Nimferstraat	102	3	97.9	3	22.5
Belgium	Charleroi	4	505, Burcau C.A.P.	108	3	93	3	19
France	Strasbourg	4	rue du 22 novembre			93		
France	Marseille	3	Saint Marcel	112		93		36
Ireland	Dublin	3	Rathmines	152		87.3		20
France	Marseille	3	Timone	112		87		38
Greece	Athens	1	Smyrni Cementry	118		86		19
Norway	Drammen	5	Engene	113		86		30
Belgium	Bruxelles	2	Maison Communale, Place Tomberg	89	3	85.9	3	14
Belgium	Bruxelles	2	175 Av. de la Couronne	90	3	84.3	3	13.5
United Kingdom	Belfast	4	Belfast 11 16 College st.	213		83		15
Belgium	Charleroi	4	509, Hôtel de ville	109	3	82	3	19
Norway	Oslo	3	St. Olavs square	134	1	77	1	15
Norway	Fredrikstad	5	Broch street	103	2	77	2	22
Spain	Bilbao	4	Lab. Sanidad	95		77		31
Belgium	Liege	4	202, Ecole St. Sépulcre	212		75		15
France	Paris	1	Paris Tour St-Jacques	125		75		22
United Kingdom	Glasgow	2	23 Montrose st.	108		75		22
France	Strasbourg	4	Aspa			74		
Belgium	Antwerpen	3	Antwerpen School, Quellingstraat	83	3	69.9	3	26.5
Belgium	Liege	4	218, Caserne Pompiers	139		68		21
The Netherlands	Utrecht	4	Kard. de Jongweg	177		68		20
Spain	Bilbao	4	Zorroza	103	2	68	2	20
Ireland	Dublin	3	Mountjoy Square	95		66.3		12
Belgium	Brugge	4	Ministerie Volksgezondheid	67	3	65.1	3	13
Spain	Bilbao	4	Gecho	150		63		18
Belgium	Antwerpen	3	Linkeroewer, Haleurinjnlaan 86	64	3	60.8	3	13
Ireland	Dublin	3	Finglas, Corp. Amsing Dept	80		60		12
United Kingdom	London	1	London City 16	109		59		21
United Kingdom	Sheffield	3	Town Chambers	85	1	56	1	12
Belgium	Liege	4	Université	87		53		10

Re. footnotes: See the full table in Appendix.

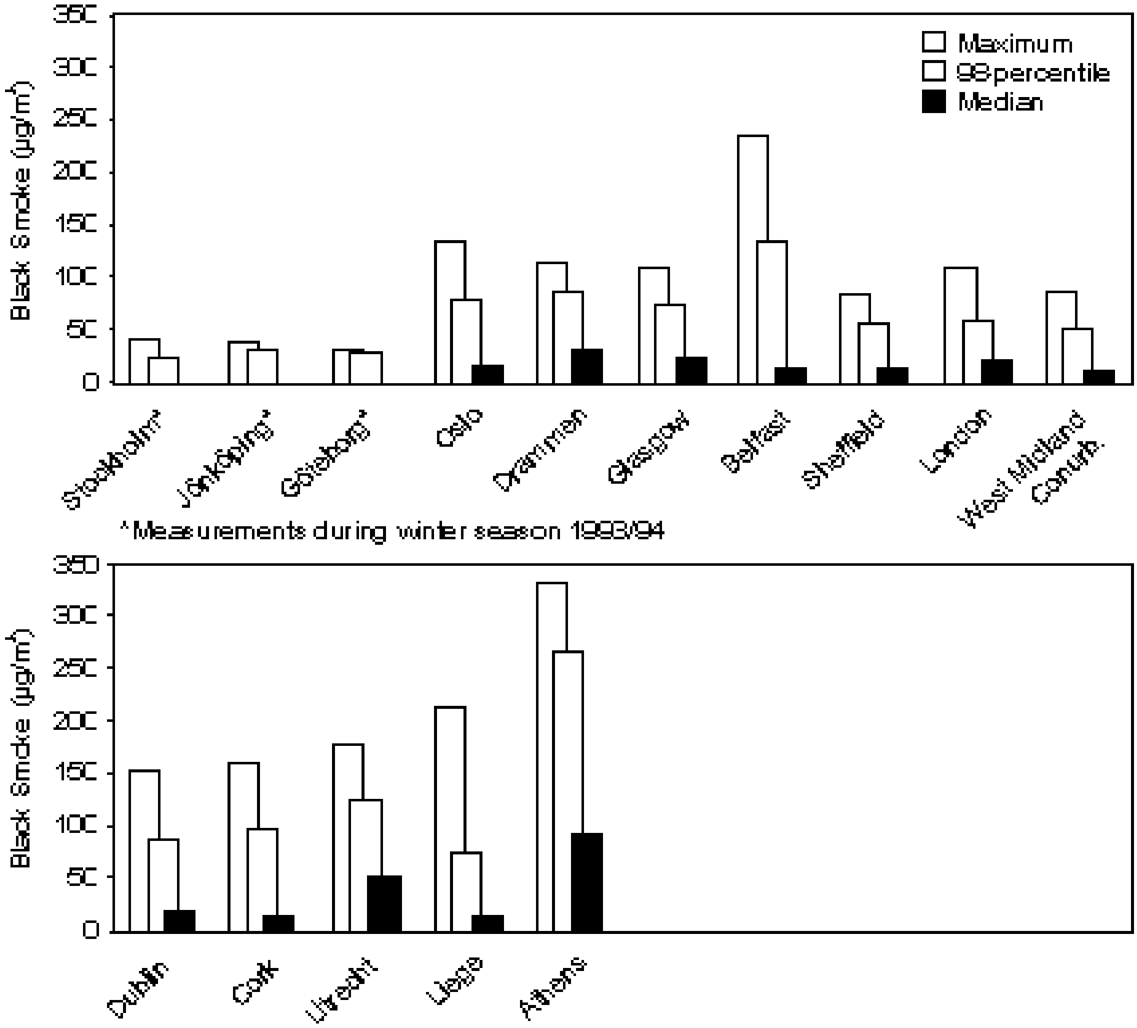


Figure 6.32: *24 h maximum, 98 percentile and median black smoke values for 1993 for selected stations and cities (µg/m3). Swedish data cover the winter 1993/94.*

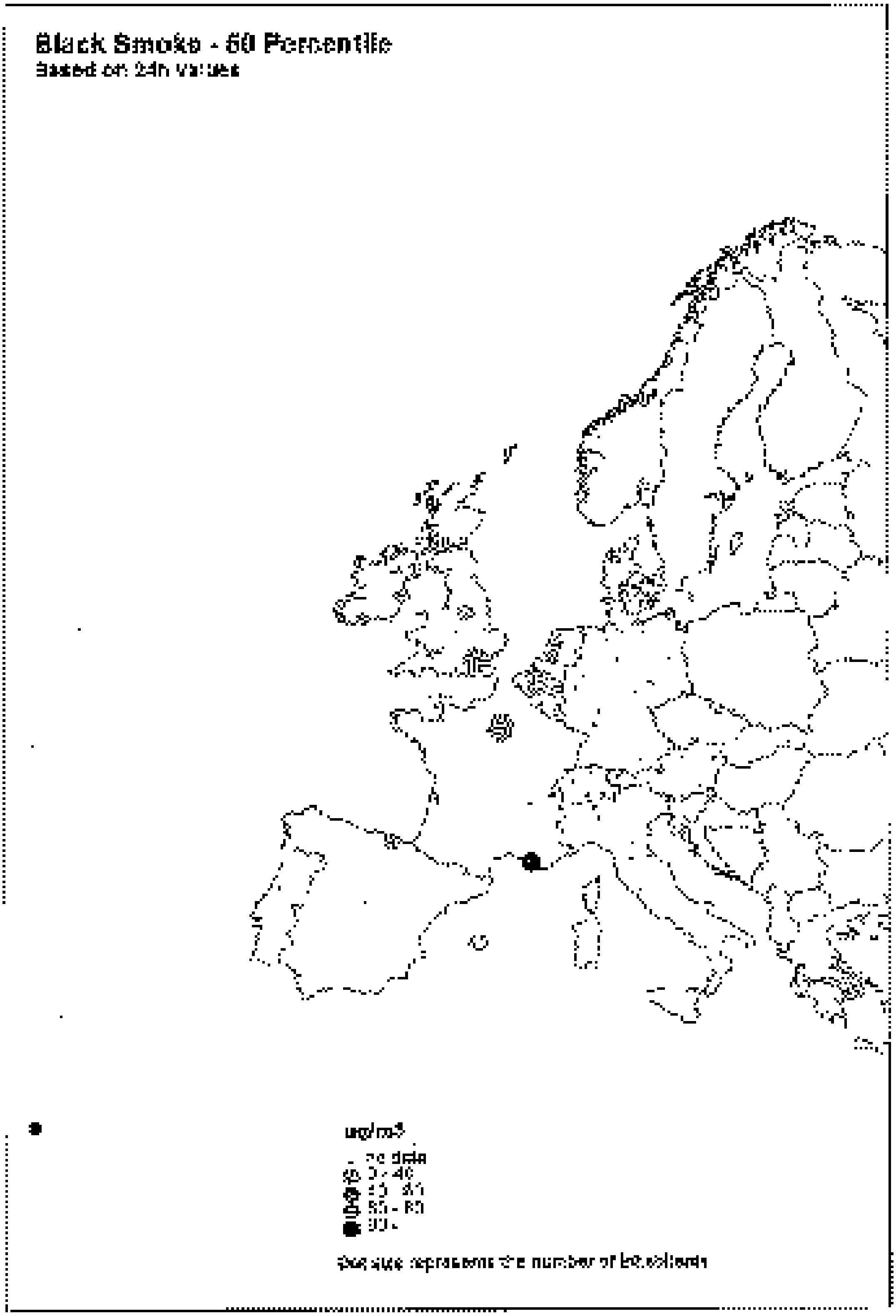


Figure 6.33:   Black smoke median 24h values in selected cities (µg/m3).

Figure 6.34: Black smoke mean values in selected cities (µg/m³).

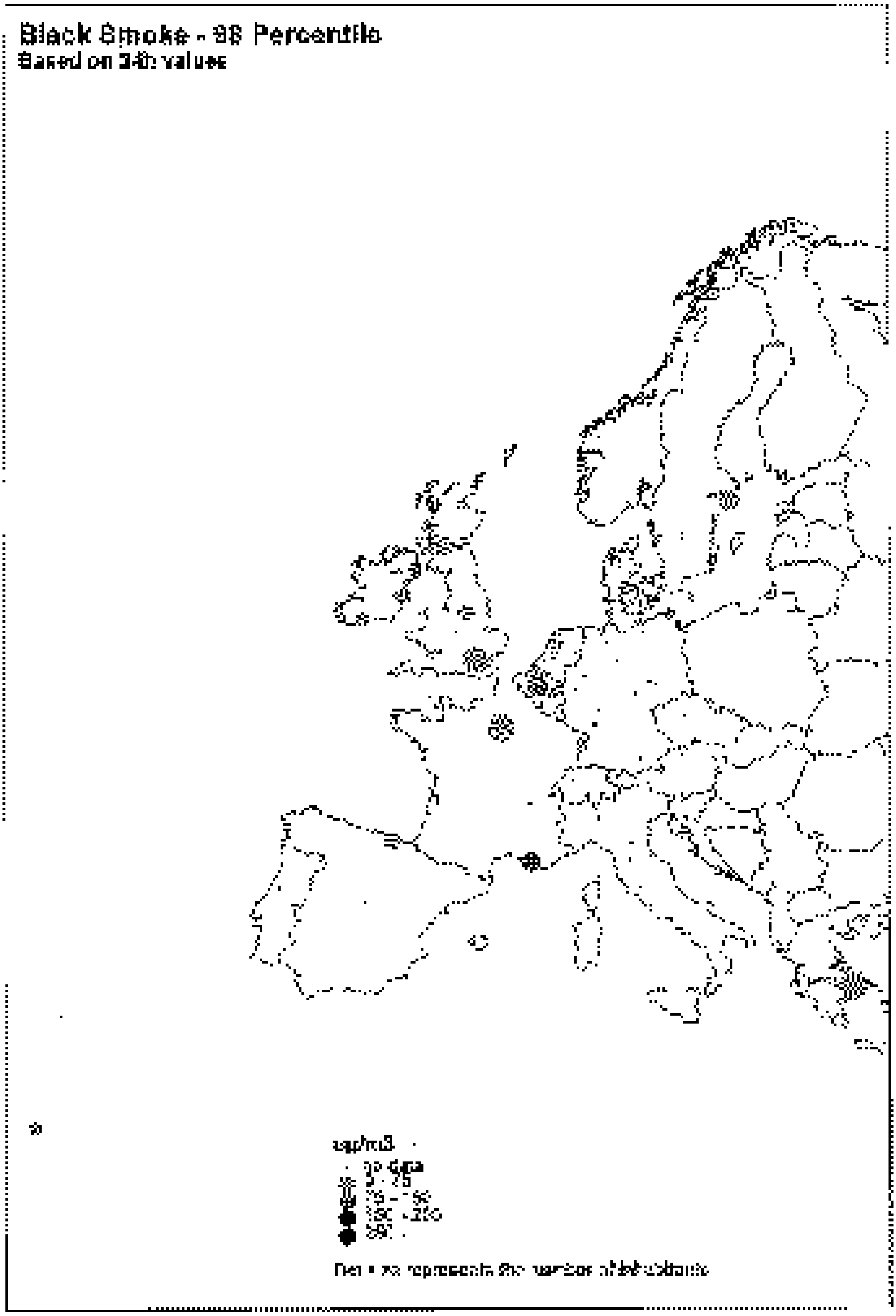


Figure 6.35: Black smoke 98 percentile values based on 24h values in selected cities ($\mu g/m^3$).

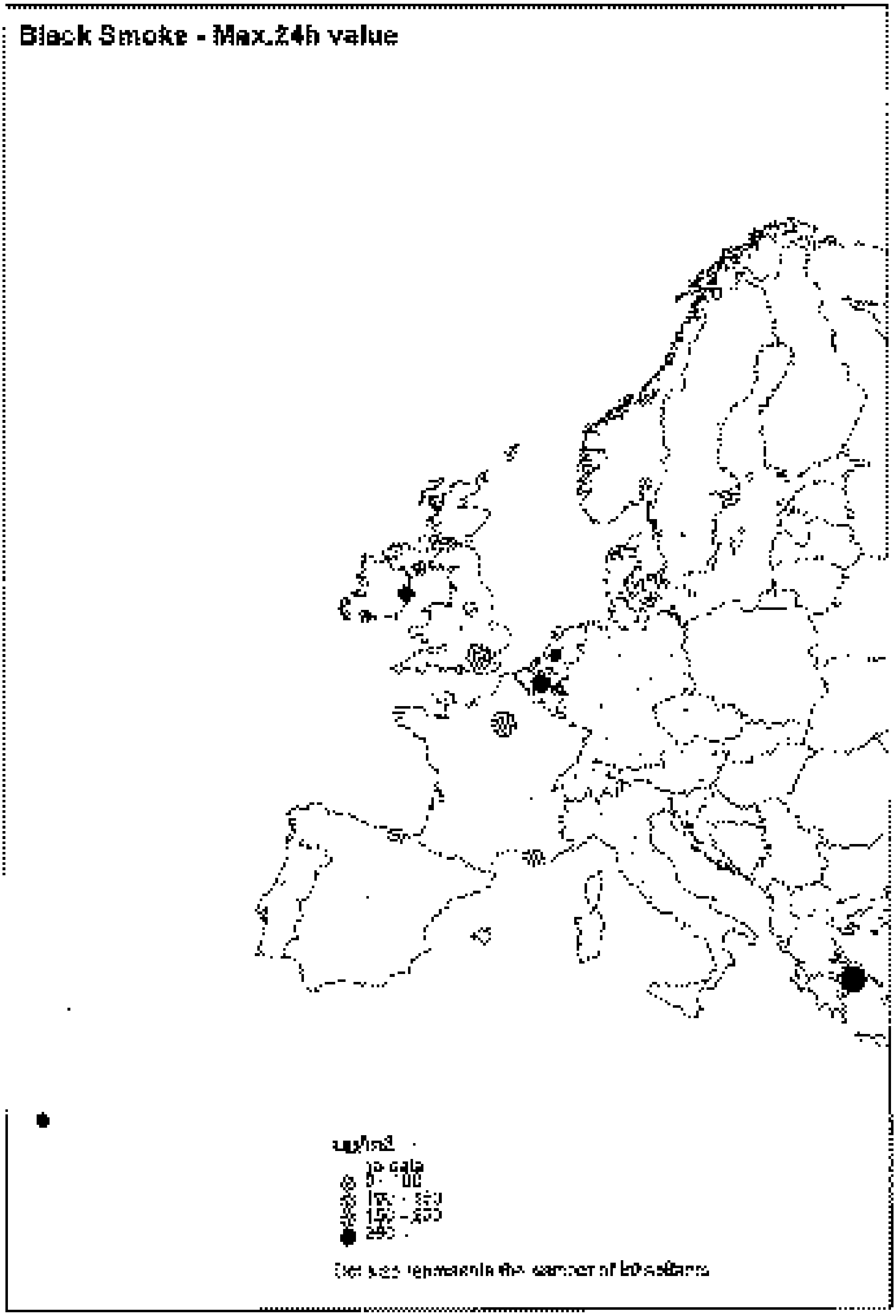


Figure 6.36: Black smoke maximum 24h values in selected cities (µg/m³).

Exceedances

Table 6.12 shows that one of the stations in Athens is the only one with exceedances of the EU Limit values for black smoke (median >80 µg/m^3 and 98 percentile >250 µg/m^3, 24h values).

Table 6.12: Exceedances of EU Limit Values for black smoke.

Country	City	Station name	1 year	1 year	Winter
			Median >80	P98 >250	Median >130
Greece	Athens	Patission 147	93	265	

Table 6.13 shows exceedances of EU Guide values and WHO Guideline values for combined exposure to SO_2 and black smoke/particulate matter. Stations marked with * show exceedance of WHO Guideline values. Stations in bold show exceedance of the upper EU Guide value.

The table indicates that exceedances of these guide values are quite common in Europe. Black smoke values in parts of Germany and Eastern Europe may be even higher.

Table 6.13: Exceedances of EU and WHO Guide Values for Black Smoke.

Country	City	Station	Mean > 40-60	Max. 24h > 100-150
Belgium	Bruxelles	30 rue Marche aux Charbon		**179***
		3 rue Cortenbach, Police div. 10		**174***
		Maison Communale, Place du Conseil		149*
	Liege	202 Ecole St. Sépulcre		**212***
		218 Caserne Pompiers		139*
	Charleroi	505, Burrau C.A.P.		108
		509, Hôtel de ville		109
	Gent	Kastel Speltink		**153***
		Groot handelsmarkt		122
		Abulstraat, Politie Bur.		**152***
		Zwiimbad, Purshaaf Nimenstraat		102
		Sirt Kruisdorp		108
France	Marseille	Timone	41	112
		Plombières	**62***	146*
		Rabateau	45	136*
		Saint Marcel	41	112
	Paris	Paris Tour St.-Jacques		125*
Greece	Athens	Patission 147	**108***	**329***
		Pireas Platia Dimotikou	46	**157***
		Smyrni Cementry		118
Ireland	Dublin	Rathmines		**152***
	Cork	Market, Princes St.		**159***
The Netherlands	Ligging voor Achtergrondmetingen	Pompstation-Braakman		103
	Utrecht	Witte Vrouwenstraat	53.6*	**177***
		Kard. de Jongweg		**177***
Norway	Oslo	St. Olav Square		134*
	Bergen	CMI		108
	Trondheim	Torget		149*
	Drammen	Engene		113
	Fredrikstad	Broch street		103
	Skien	Kings street		118
Spain	Bilbao	Gecho		**150***
	Tenerife	Santa Cruz	**103.7***	
United Kingdom	Belfast	Royal Victoria Hospital		**235***
		Belfast 11, 16 College St.		**213***
	London	London city 16		109
	Glasgow	23 Montrose St.		108

Mean: *) > 50 WHO Guidelines
Max: *) > 125 WHO Guidelines

Trends

Figure 6.37-Figure 6.40 show trends in black smoke data on an annual basis for selected stations in different countries. The figures show the maximum, 98 percentile and median of 24 h data from Norway, United Kingdom, the Netherlands, Belgium, Spain and Greece.

Median values seem to show a slightly decreasing trend at most stations. Maximum and 98 percentile values show more variability from year to year, especially in Belfast, Charleroi and Bilbao. Black smoke levels in Athens are much higher than in other cities.

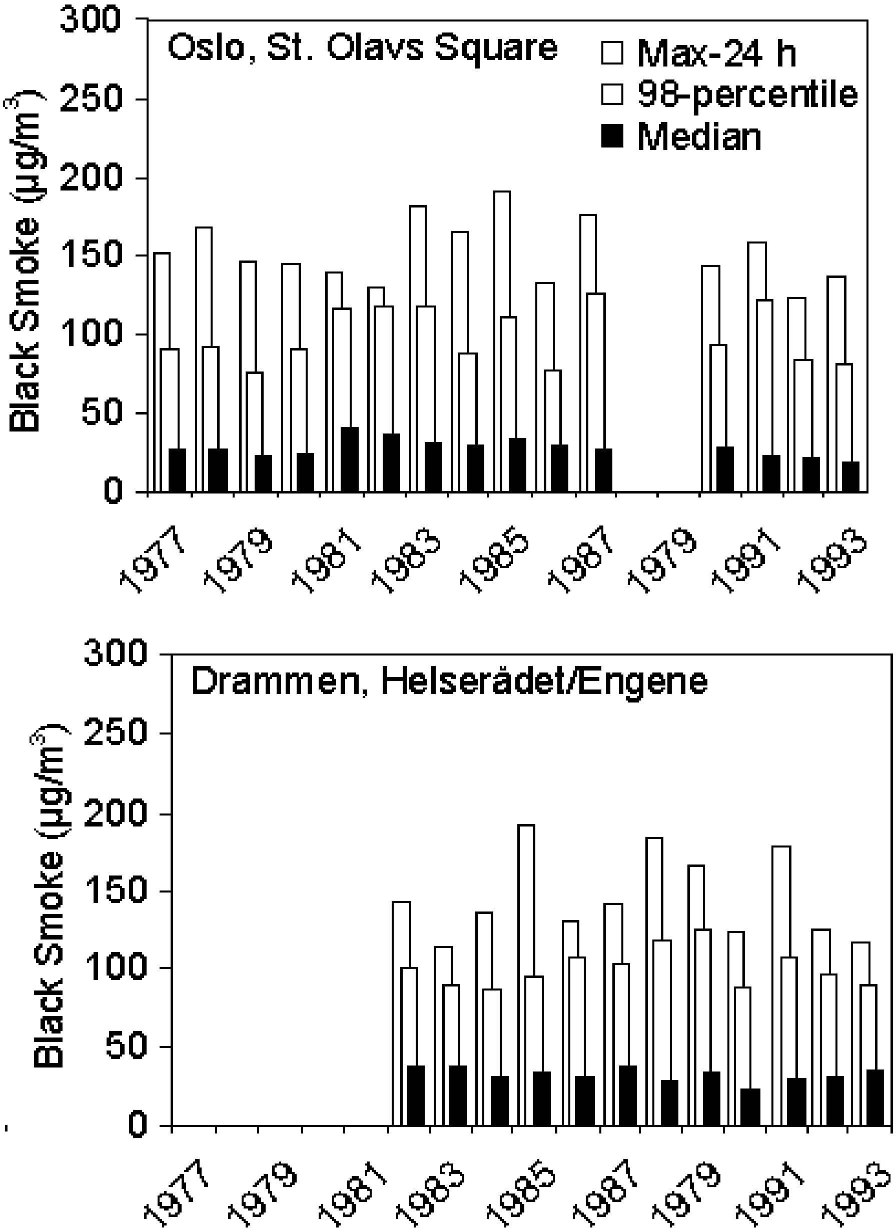
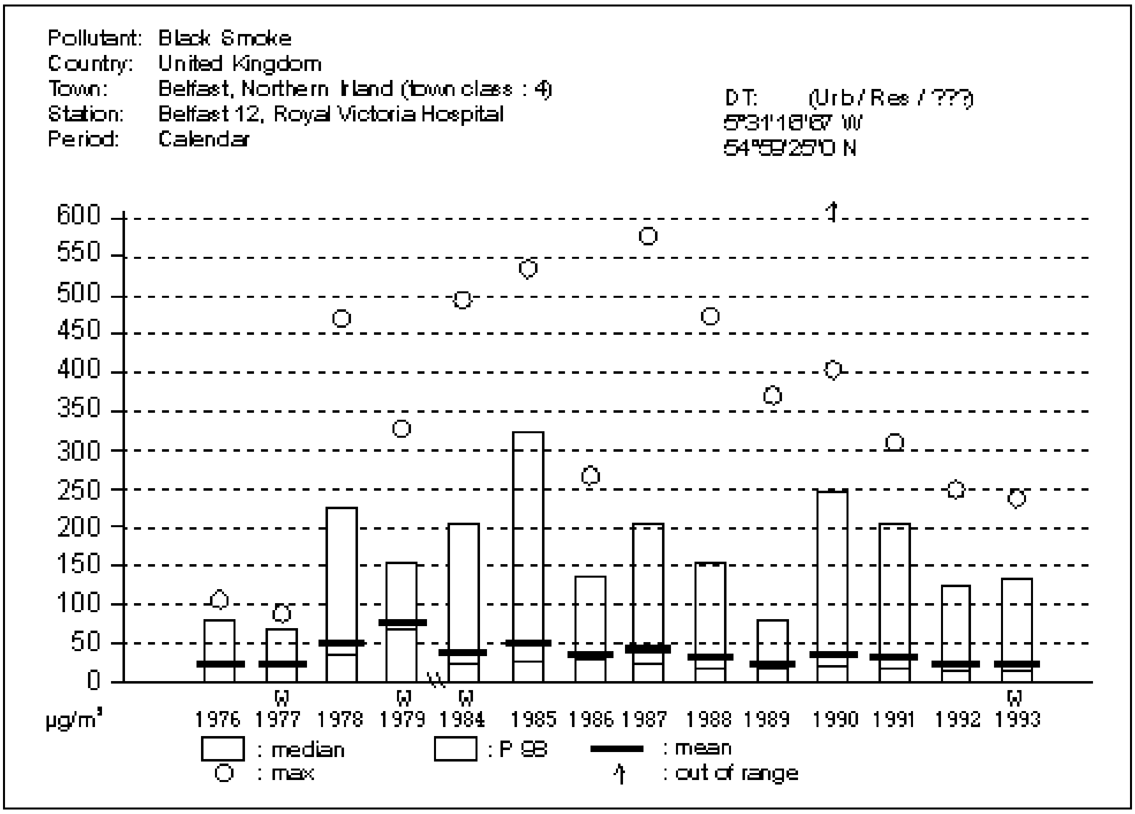


Figure 6.37: Black smoke trend in Norway 1977-1993 (µg/m3). Data from national reports.



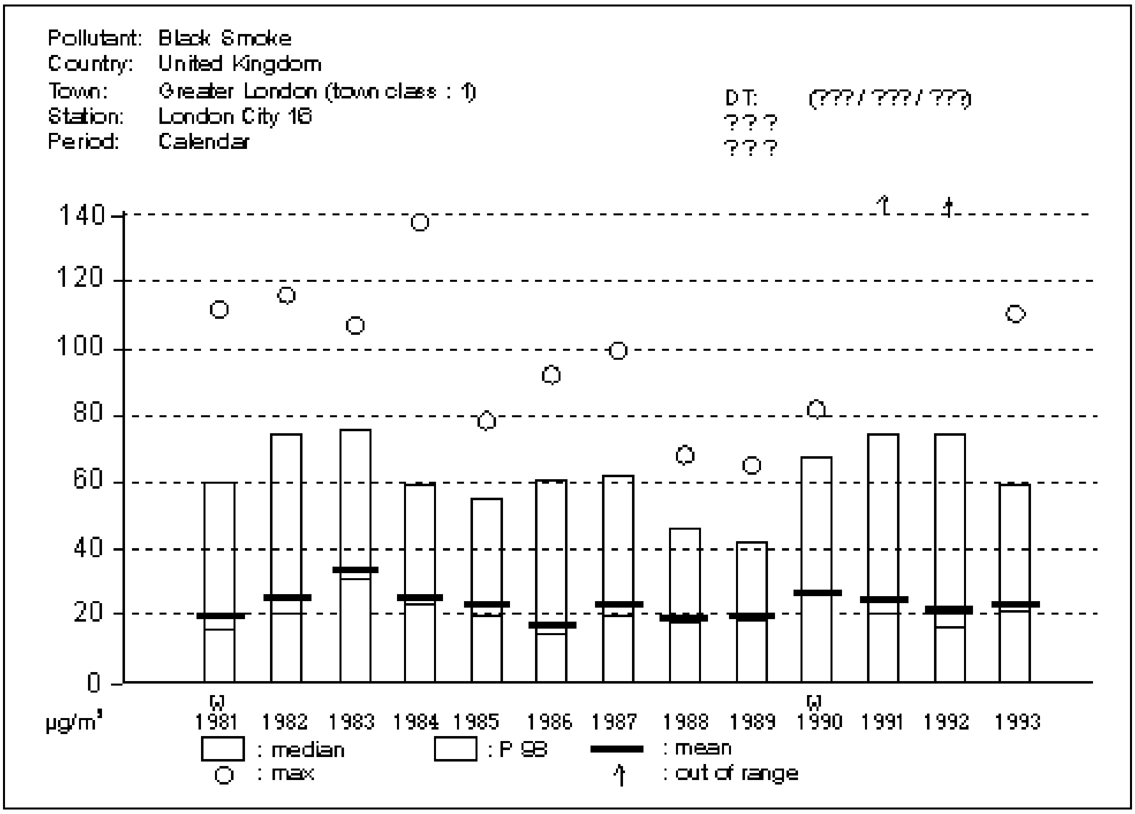


Figure 6.38: Black smoke trend in Belfast and London City, UK 1976-1993. APIS data.

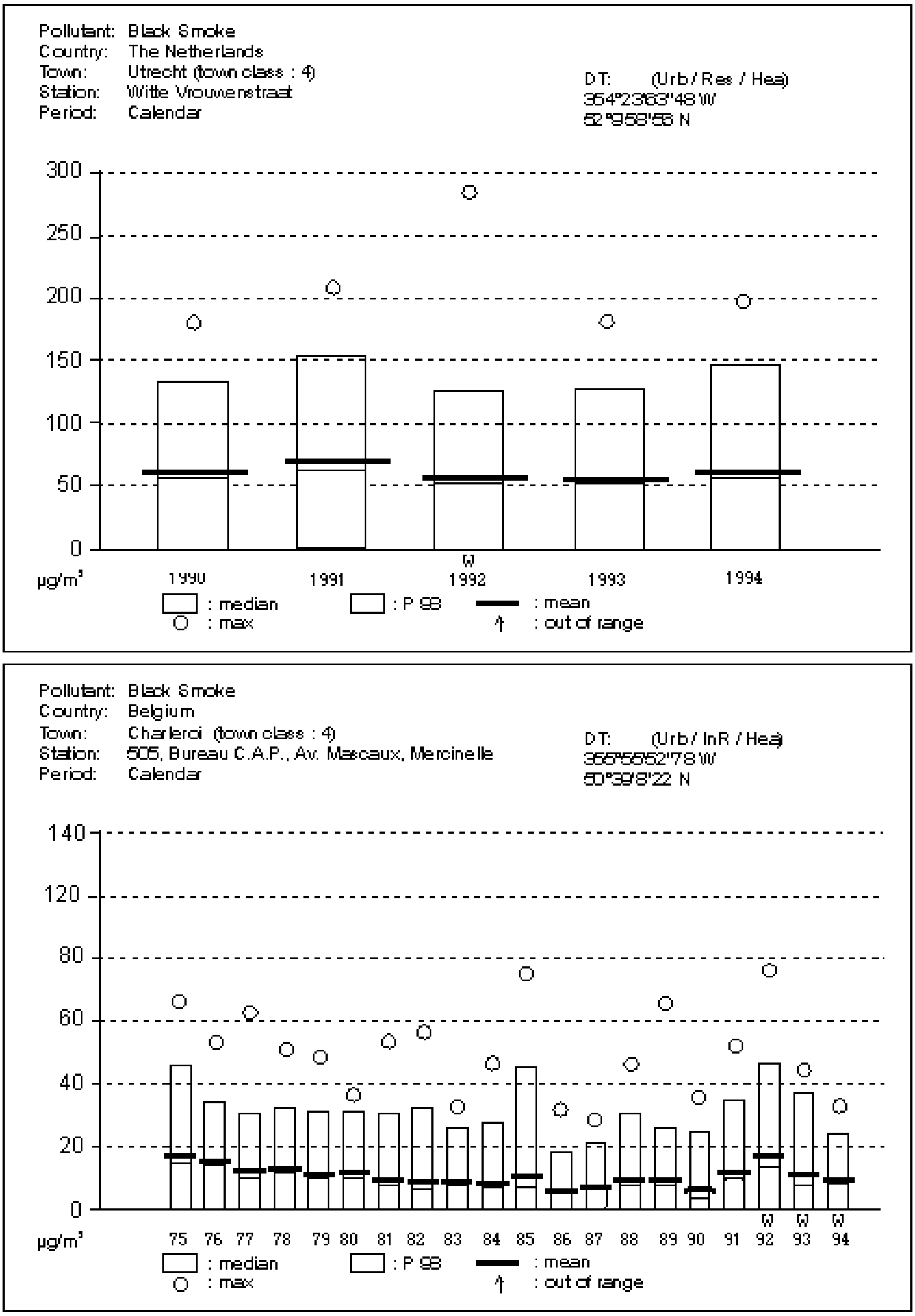


Figure 6.39: Black smoke trend in Utrecht, the Netherlands 1990-1994 and Charleroi, Belgium 1975-1994. APIS data.

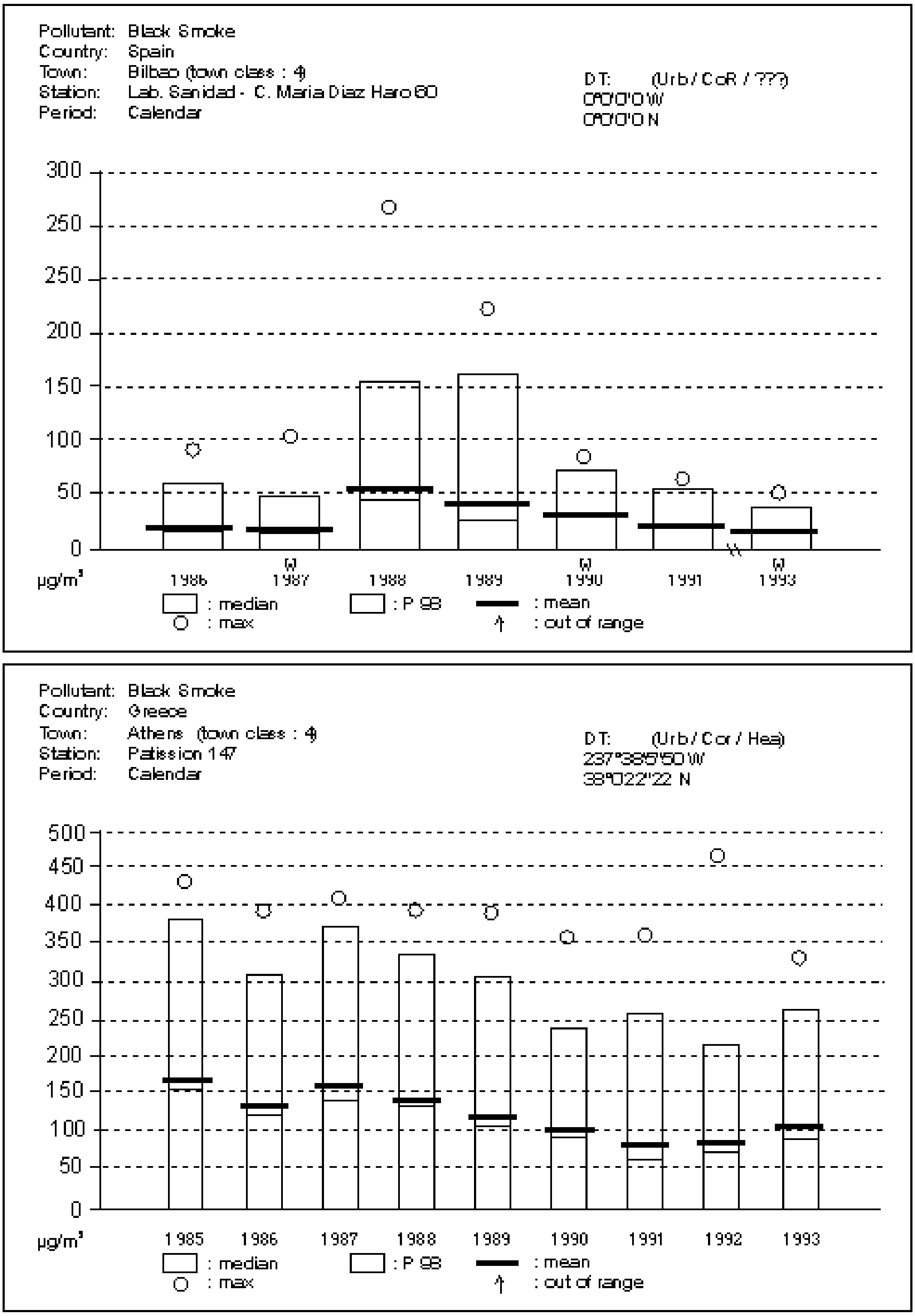


Figure 6.40: Black smoke trend in Bilbao, Spain 1986-1993 and Athens, Greece 1985-1993 (µg/m3). APIS data.

6.4 Suspended particulates (TSP/SPM)

6.4.1 Behaviour, effects, emissions

Particulate matter

Airborne particulate matter represents a complex mixture of organic and inorganic substances, covering a wide range of diameters, from <0.1 µm and up to some 100 µm. Mass and composition tend to divide into two principal groups: coarse particles larger than 2.5 µm in aerodynamic diameter, and fine particles smaller than 2.5 µm in aerodynamic diameter. The smaller particles contain the secondarily formed aerosols (gas to particle conversion), combustion particles and recondensed organic and metal vapours. The bulk of fine particulate mass comprise particles of diameter range 0.1-0.5 µm. The larger particles usually contain earth Crystal materials and fugitive dust from roads and industries. The acid component of particulate matter, and most of its mutagenic activity, is generally contained in the fine fraction, although in fog some coarse acid droplets are also present.

Important parts of the “secondary aerosol” are sulphate particles (important for acid deposition and visibility reduction on the regional scale), and organics-containing particles as a result of photochemical reactions (important in large urban areas with photochemical pollution).

“Suspended particulate matter” is measured and characterised in various ways:

- Total Suspended Particles is the fraction sampled with high-volume samplers, approximately particle diameters <50-100 µm.
- PM_{10}: Inhalable particles, diameter <10 µm. Penetrates through the nose, by nose breathing.
- Thoracic particles: approx. equal PM_{10}.
- $PM_{2.5}$: “Fine fraction”, diameter <2.5 µm. Penetrates to the lungs.
- Black smoke: a measure of the blackness of a particle sample, sampled on a white filter paper, transformed to a mass value (µg/m^3) for the particle sample by means of a standard curve. Gives a relative value for the soot content of the sample.

Major sources of primary particles are industrial processes, road traffic, power plants, domestic burning (coal, wood, etc.), incineration, and resuspension of road and construction dust. Particulate matter is removed from the atmosphere by wet and dry deposition.

Short term health effects of exposure to combined SO_2, black smoke and particulates include increased mortality, morbidity and deficits in pulmonary function. Some of the “lowest-observed effect” levels for short term exposure to particulate matter are: excess mortality ~500 µg/m^3 (smoke); increased acute respiratory morbidity (adults) ~250 µg/m^3 (smoke); decrements in lung function (children) ~180 µg/m^3 (total suspended particulates)/110 µg/m^3 (thoracic particles). Smoke levels of up to 1,500 µg/m^3 occurred in the 1952 London smog.

Other environmental effects include the soiling of exposed surfaces, impairment of visibility, potential modification of climate and contribution to acid deposition.

6.4.2 Air Quality Limit and Guide Values

EU Limit values for suspended particulates are given in Table 6.14.

Table 6.14: EU Limit values for suspended particulates (gravimetric method) (µg/m³). EU Council Directive 80/779/EEC.

Limit Values	Mean of 24h values	95 percentile of 24h values
Year	150	300

WHO Guideline values for combined exposure to SO_2 and particulate matter are given in Table 6.10 in section 6.3.2. These values are 24h maximum values of 120 µg/m³ TSP and 70 µg/m³ TP (Thoracic particles ≈ PM_{10}).

6.4.3 Urban and local TSP/SPM concentrations

Concentrations

In Appendix B TSP/SPM data from 14 countries are given. The stations are ranged according to the 95 percentile daily values. The stations with the highest values are given in Table 6.15. Also the maximum and mean values are given, if available.

Table 6.15 and Figure 6.41 show the highest TSP/SPM levels in Southern and Eastern Europe. In Western Europe concentrations are low and do not vary so much from country to country, except for higher values in some German cities.

Data from the selected cities in Figure 5.1/Table 5.2 are shown in Figure 6.42-Figure 6.44. These figures give the mean, 95 percentile and maximum values based on 24h values.

Table 6.15: 24 h maximum, 95 percentile and mean SPM values for 1993 for European cities ranged according to the 95 percentile values (µg/m3). (For complete table, see Appendix B).

	City			SPM 24h values		
Country	Name	Class	Station	Maximum	95 percentile	Mean
Portugal	Carregado		Faiel	495	416	163
Portugal	Barreiro/Seixal		Paio Pires	479	405	196
Portugal	Carregado		RDP	523	327	147
Italy	Torino		Strada Aeroporto		321	268
Portugal	Barreiro/Seixal		Escavadeira	360	319	112
Portugal	Alhandra		CN. Cimpor	600	300	116
Portugal	Setúbal		Subestacao	358	279	66
Italy	Torino		Via Consolata		266	134
Czech Republic	Ostrava		Ostrava-Fifejdy	683	261	109
Czech Republic	Prague		Námesti Republiky	455	244	127
Portugal	Carregado		Ironfer	360	242	125
Czech Republic	Ostrava		Ostrava-Domovduch	709	240	93
Portugal	Setúbal		Troia	248	239	56
Italy	Torino		Corso Vercelli		233	116
Portugal	Barreiro/Seixal		Camara Municipal	261	230	90
Italy	Bologna		Fiera		229	137
Czech Republic	Ostrava		Ostrava NH	522	226	94
Czech Republic	Prague		Výstavište	466	223	100
Italy	Torino		Parco Lingotto		209	104
Italy	Modena		Via Garibaldi		208	113
Italy	Milano		Marche		207	109
Portugal	Barreiro/Seixal		Seixal	330	207	86
Portugal	Barreiro/Seixal		Casal do Marco	272	205	90
Portugal	Carregado		TAK	536	204	87
Portugal	Alhandra		S. Martins	401	202	88
Portugal	Barreiro/Seixal		Siderurgia	460	201	77
Italy	Genova		XX Settembre (B/C)		197	117
Spain	Barcelona	1	Moncada	316 [f]	197	111.3
Czech Republic	Ostrava		Ostrava-Slez.Ostrava	506	189	94
Germany	Erfurt		Erfurt, Krämpf.		189	76
Italy	Modena		Via Giardini		184	106
Portugal	Setúbal		Setenave	301	181	53
Czech Republic	Prague		Pocernicka	478	180	89
Czech Republic	Prague		Branik		175	83
Czech Republic	Prague		Mlynárka	485	175	67
Italy	Milano province		Villasanta		173	88
Italy	Milano province		Rho Centro		171	95
Portugal	Alhandra		Marquesa	241	169	72
Germany	Altenburg		Altenburg		169 *	72
Italy	Genova		Villa Serra		165	94
Czech Republic	Prague		Riegrovy sady	455	165	81
Czech Republic	Prague		Veleslavin	588	165	78
Italy	Roma		C so Francia		164	74
Portugal	Alhandra		Escusa	284	161	61
Slovakia	Košice	4	Štúrova	257	156	80
Portugal	Barreiro/Seixal		Arrentela	201	154	63
Czech Republic	Prague		Kobylisy	605	153	79
Czech Republic	Prague		Vysocany	626	152	78

Re. footnotes: See the full table in Appendix.

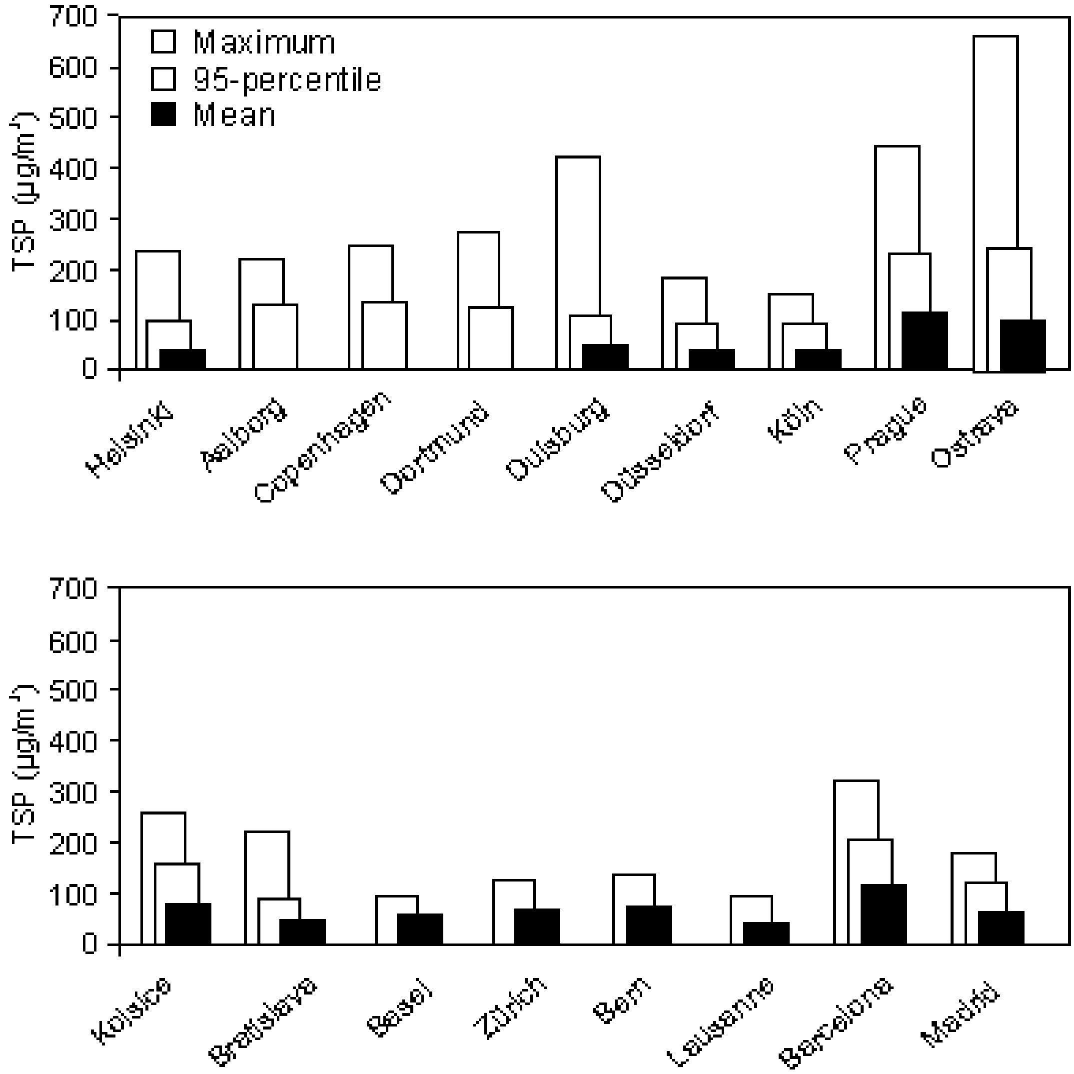


Figure 6.41: 24 h maximum, 95 percentile and mean TSP/SPM values for 1993 for selected stations and cities (µg/m³).

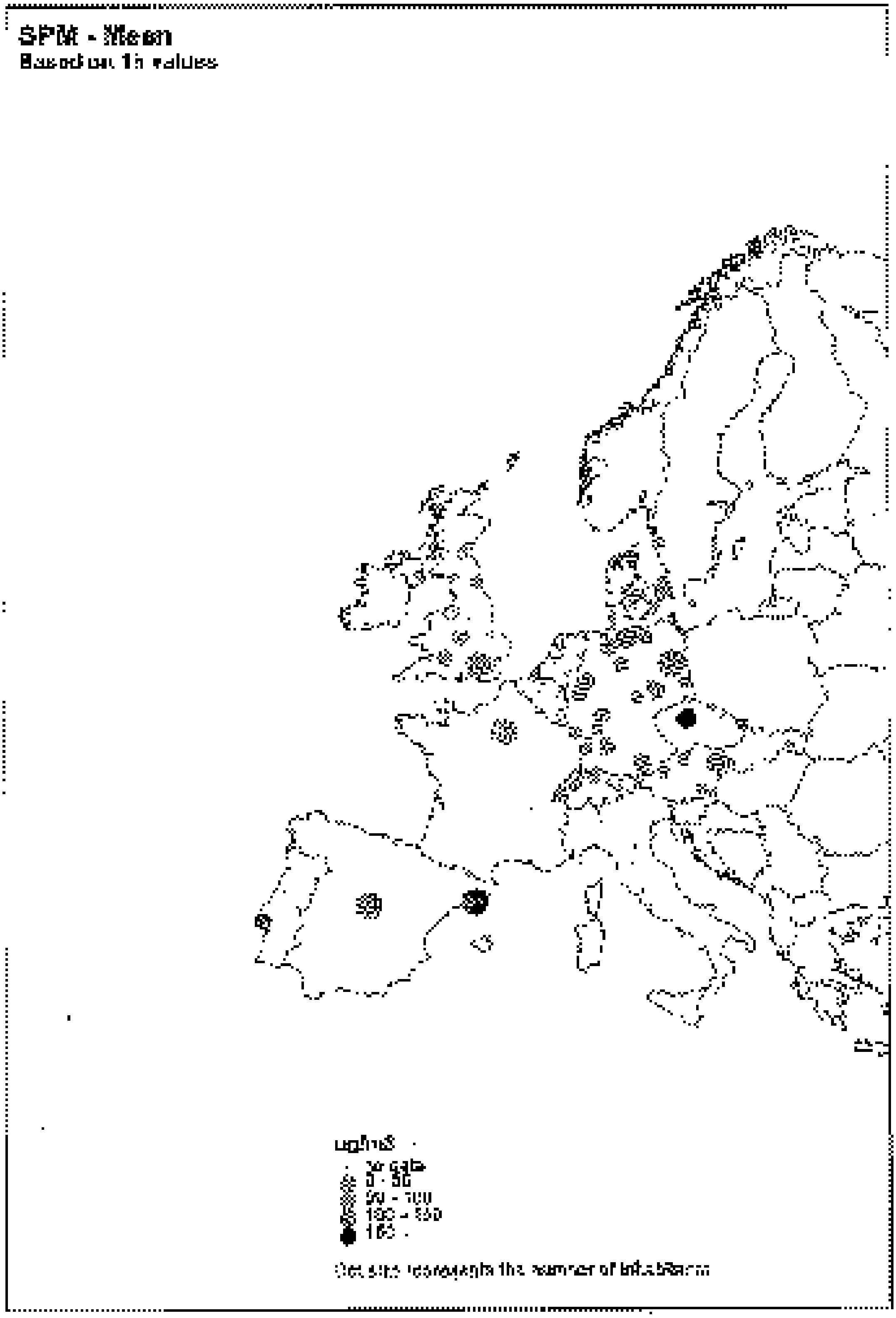


Figure 6.42: SPM mean values in selected cities (µg/m3).

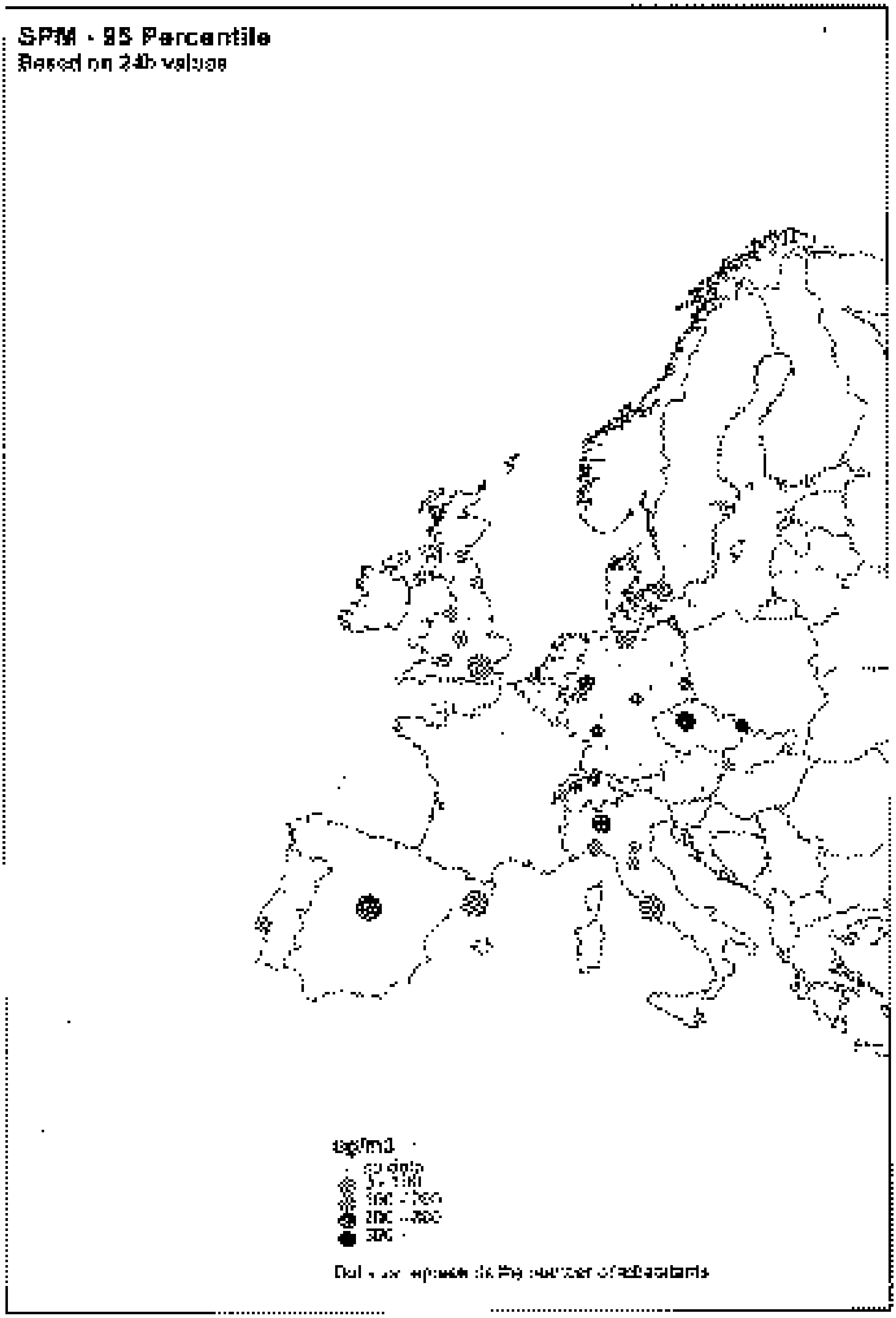


Figure 6.43: SPM 95 percentile values based on 24h values in selected cities (µg/m3).

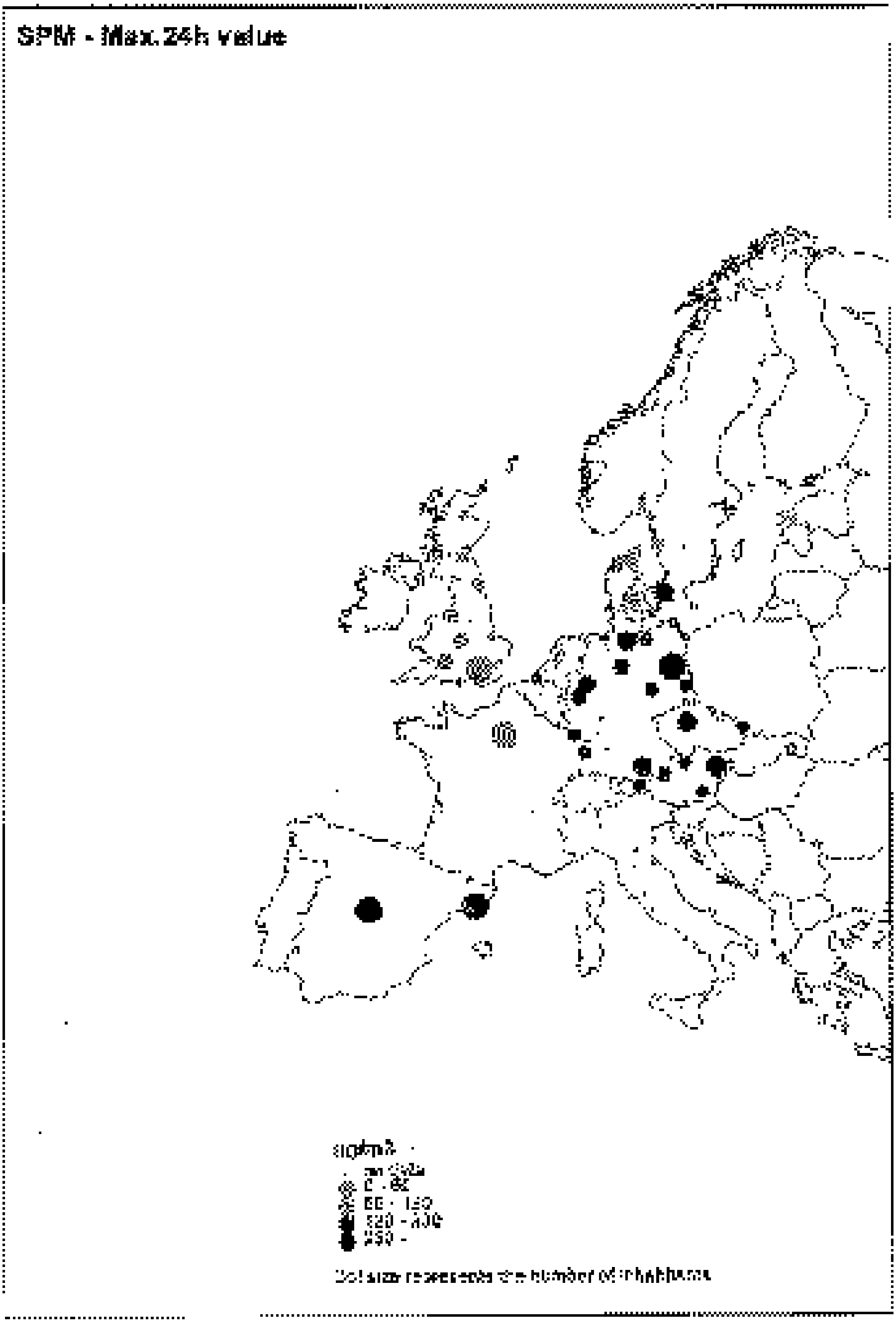


Figure 6.44: SPM maximum 24h values in selected cities (µg/m3).

Exceedances

Table 6.16 shows stations with exceedances of EU Limit values for TSP/SPM (mean 150 µg/m^3 , and 95 percentile 300 µg/m^3 , 24h values). These values are very high compared to the WHO Guideline values. EU Limit values are exceeded at stations in Italy and Portugal.

Table 6.17 show exceedances of WHO Guideline values for PM_{10} and SPM. The SPM maximum 24h value are exceeded in many countries. Especially high values are measured in the Czech Republic and Portugal.

UK has reported exceedances of the WHO PM_{10} Guideline value in major cities. PM_{10} is not commonly measured in Europe yet. The WHO Guideline value of 70 µg/m^3 for 24h will obviously be exceeded in many countries and cities all over Europe. The main mass fraction of particulate matter is in the <10 µm-fraction. These particles are most relevant to health effects.

Table 6.16: Exceedances of EU Limit Values for SPM.

Country	City	Station name	24 h values	
			1 year	1 year
			Mean >150	P95 >300
Italy	Genova	Rimessa Amt	170**	336**
	Torino	Strada Aeroporto	268	321
Portugal	Alhandra	CN. Cimpor		300
	Barreiro/Seixal	Escavadeira		319
		Paio Pires	196	405
	Carregado	RDP		327
		Faiel	163	416

** Data availability <75%.

Table 6.17: Exceedances of WHO Guideline Values for PM_{10}/SPM.

Country	City	Station	WHO Guideline Values PM_{10} Max. 24h >70	WHO Guideline Values SPM Max. 24h >120
Austria	Graz	Mitte		201
		Nord		187
		Ost		164
		Süd		211
		Süd West		252
		West		209
	Innsbruck	Olympisches Dorf		164
		Reichenau		174
	Klagenfurt	Koschatstrasse		136
	Linz	24-er-Turm		384
		Berufschulzentrum		233
		BH-Urfahr		301
		Hauserhof		237
		Kleinmünchen		191
		ORF-Zentrum		226
		Ursulinenhof		263
	Salzburg	Itzlingen		140
		Rudolfplatz		182
	Villach	Villach		159
	Wien	Belgradplatz		390
		Floridsdorf		240
		Hietzinger Kai		141
		Hohe Warte		250
		Kaiserebersdorf		210
		Kendlerstr.		240
		Laaer Berg		320
		Stadlau		231
		Stephansplatz		134
		Taborstr.		297
		Wäringer Gürtel		179
Czech Republic	Ostrava	Ostrava NH		522
		Ostrava-Domovduch		709
		Ostrava-Fifejdy		683
		Ostrava-Poruba		511
		Ostrava-Slez.Ostrava		506
	Prague	Kobylisy		605
		Mlynárka		485
		Námesti Republiky		455
		Pocernicka		478
		Riegrovy sady		455
		Santinka		603
		Veleslavin		588
		Vysocany		626
		Výstavište		466

Table 6.17 (contd.)

Country	City	Station	WHO Guideline Values	
			PM_{10}	SPM
			Max. 24h >70	Max. 24h >120
Denmark	Aalborg	Vesterbro		224
	Copenhagen	Jagtvej		252
	Odense	9154		248
		9155 Albanigade		212
Finland	Espoo	Luukki		147
	Helsinki	Vallila		240
Germany	Berlin	Charlottenburg		255
		Frankfurter Tor		305
		Neuköllen		228
		Schöneberg		192
		Wedding		283
	Brandenburg	Brandenburg-Zentrum		225
	Cottbus	Cottbus-City		199
		Cottbus-Süd		217
	Dortmund	Dortmund-Asseln		133
		Dortmund-Hörde		180
		Dortmund-Mitte		278
	Duisburg	Duisburg-Buchholz		183
		Duisburg-Kaldenhausen		231
		Duisburg-Meidenich		285
		Duisburg-Walsum		330
	Düsseldorf	Düsseldorf-Einbrungen		153
		Düsseldorf-Genresheim		181
		Düsseldorf-Lörick		184
		Düsseldorf-Mörsenbroich		158
		Düsseldorf-Reisholz		187
	Essen	Essen-Altendorf		298
		Essen-Bredeney		183
		Essen-Leithe		191
		Essen-Ost		239
		Essen-Vogelheim		423
	Halle	Halle		232
	Hamburg	06 LO, Lokstedt		155
		09 RA, Rahlstedt		161
		11 HO, Hochkamp		164
		12 BA, Bahrenfeld		165
		13 ST, Sternschanze		164
		14 LS, Lübecker Strasse		175
		15 HR, Horner Rennbahn		146
		18 WA, Waltershof		196
		19 SW, Steinwerder		177
		20 VE. Veddel		185
		21 BI, Billbrook		158
		26 KI, Kirchdorf		164
		27 TA, Tatenberg		137
		30 GT, Göhlbochtal		146

Table 6.17 (contd.)

Country	City	Station	WHO Guideline Values	
			PM_{10}	SPM
			Max 24h >70	Max 24h >120
Germany (contd.)	Köln	Köln-Chorweiler		157
		Köln-Riehl		142
		Köln-Rodenkirchen		131
		Köln-Vogelsang		140
	Magdeburg	Magdeburg		166
	München	Effnerplatz		148
		Johanneskirchen		171
		L.Kiesselbach-Platz		155
		Lothstrasse		185
		Pasing		153
		Stachus		162
	Nürnberg	Mögeldorf		122
		Olgastrasse		177
		Willy Brandt Platz		152
	Rostock	Rostock-Holbein Platz		151
	Saarbrücken	Saarbrücken-Stadtmitte		144
	Schwerin	Schwerin (Burmeister-Bade-Platz)		239
		Schwerin-UBA		146
Portugal	Alhandra	CN. Cimpor		600
		Escusa		284
		Marquesa		241
		Pisc. Cimpor		287
		S. Martins		401
	Area Sines	EDP/Sul		271
	Barreiro/Seixal	Arrentela		201
		Camara Municipal		261
		Casal do Marco		272
		Escavadeira		360
		Paio Pires		479
		Seixal		330
		Siderurgia		460
	Carregado	Cast. Ribatejo		136
		Faiel		495
		Ironfer		360
		RDP		523
		TAK		536
		Vinha		231
	Lisboa	Entrecampos		210
	Pego	Mouriscas		166
	Setúbal	Movauto		333
		S. Filipe		318
		Setenave		301
		Subestacao		358
		Tróia		248
Slovakia	Bratislava	Karmenné námestic		185
		Marmateyova		213
		Trnavské mýto		181
	Košice	Štúrova		257

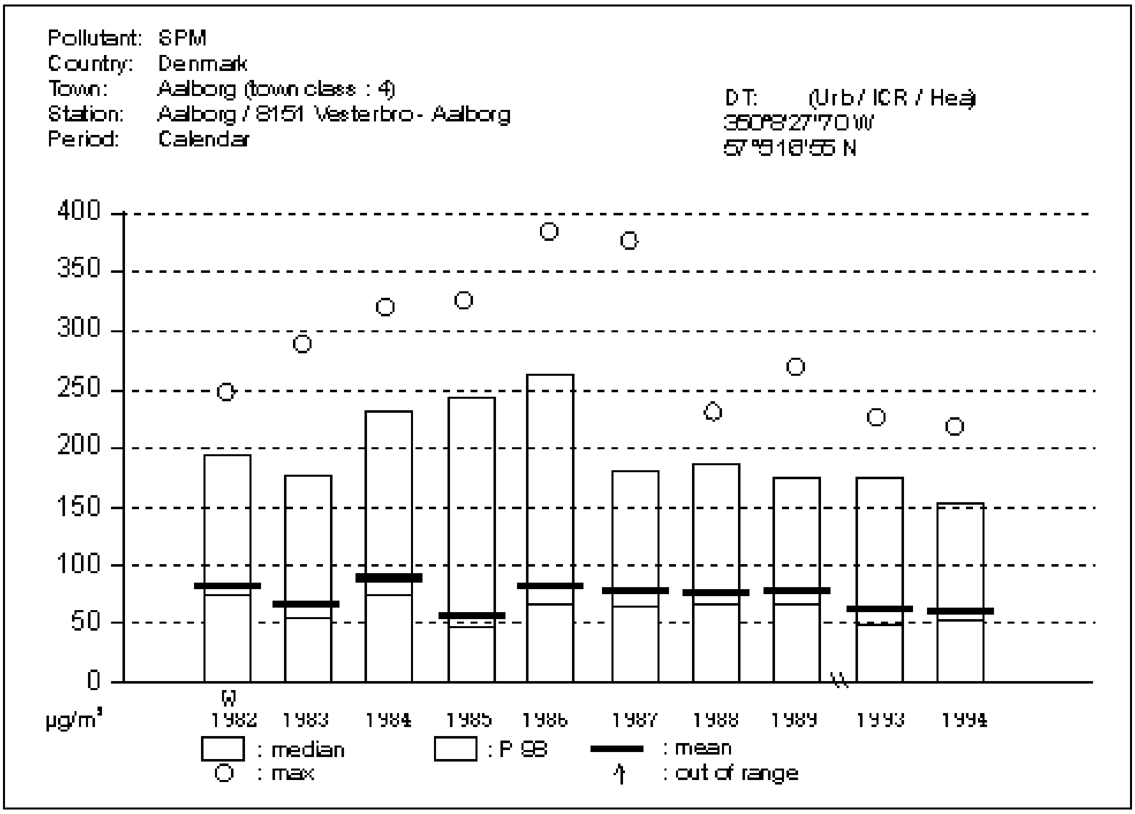
Table 6.17 (contd.)

Country	City	Station	WHO Guideline Values	
			PM_{10}	SPM
			Max 24h >70	Max 24h >120
Spain	Barcelona	Molina Pl.		174
		Moncada		316
		Poblé nov.		167
	Madrid	Carlos V		202
		Cuatro Caminos		174
		Plaza Castilla		166
		Plaza España		165
		Villaverde		151
United Kingdom	Belfast	Belfast centre	120	
	Birmingham	Birmingham centre	102	
	Bristol	Bristol centre	81	
	Cardiff	Cardiff centre	89	
	Leeds	Leeds centre	96	
	Liverpool	Liverpool centre	163	
	London	London Bloomsbury	100	
	Newcastle	Newcastle centre	79	

Trends

Figure 6.45-Figure 6.48 show trends in TSP/SPM data on an annual basis for selected stations in different countries. The figures are not quite comparable because different parameters are given. The figures from Aalborg and Madrid (from APIS) do not give the 95 percentile, which is requested by the EU Council Directive, but instead the 98 percentile. German and Swiss data are taken from national reports. Mean values from the Ruhr area, Düsseldorf and Köln/Bonn are mean values from several stations in several cities.

German and Swiss data show a slight decrease in TSP/SPM mean values over the last 10-20 years. In Aalborg, Denmark maximum and 98 percentile values are more reduced than mean values.



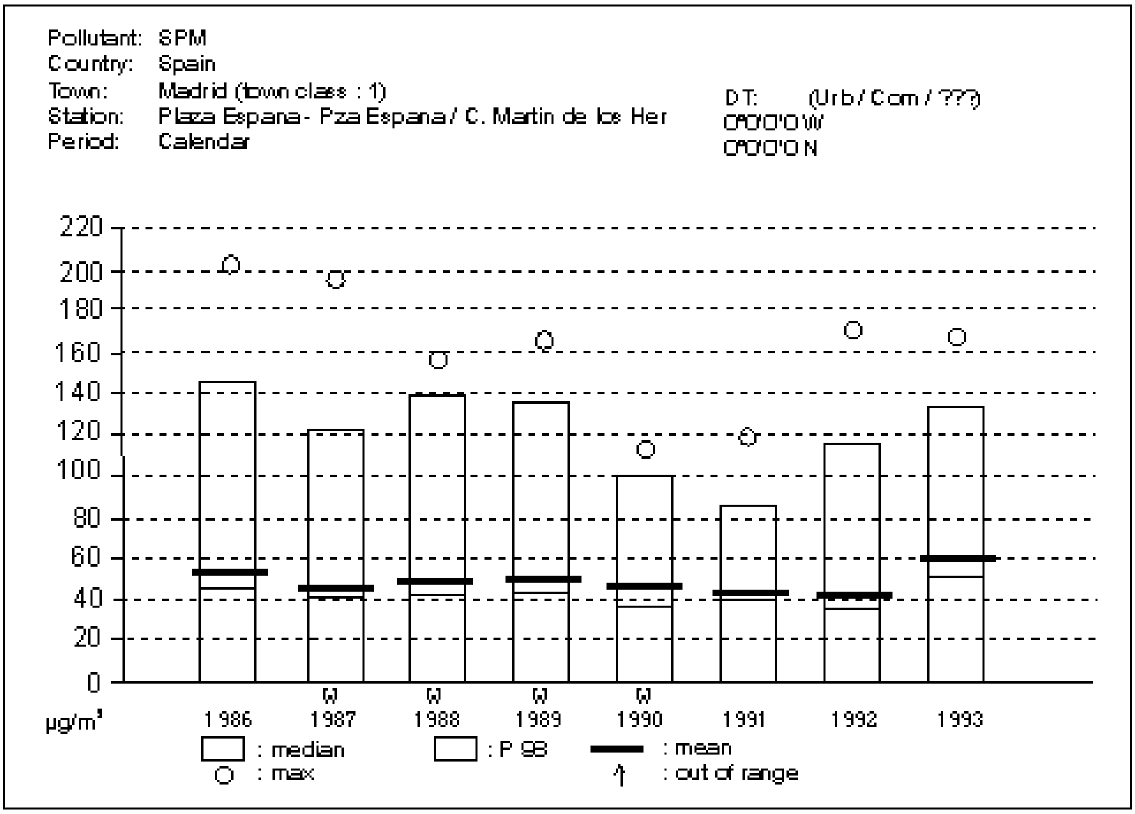


Figure 6.45: TSP/SPM trend in Aalborg, Denmark 1982-1994 and Madrid, Spain 1986-1993 (µg/m³). APIS data.

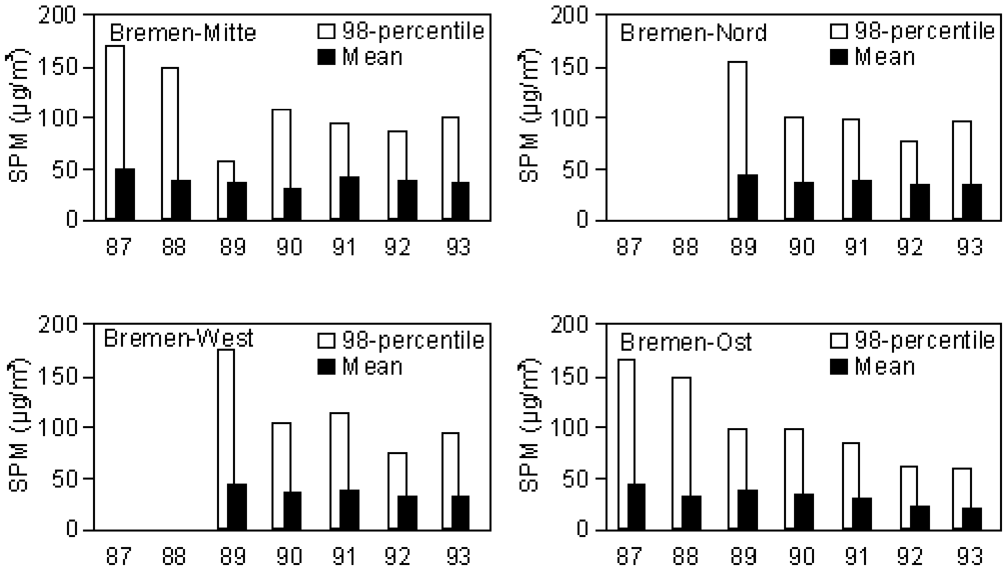


Figure 6.46: TSP/SPM in Bremen, Germany 1987-1993 (µg/m3). Data from Bremen State report.

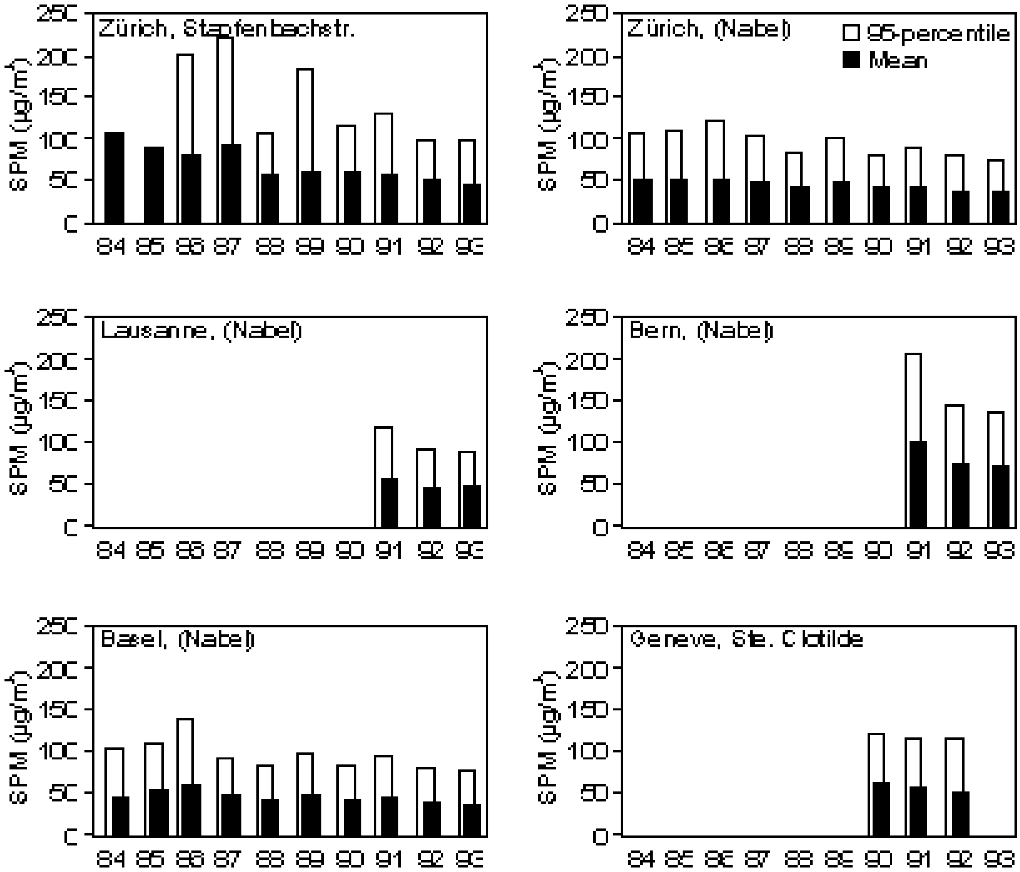


Figure 6.47: TSP/SPM trend in Switzerland 1984-1993 (µg/m3). Data from national report.

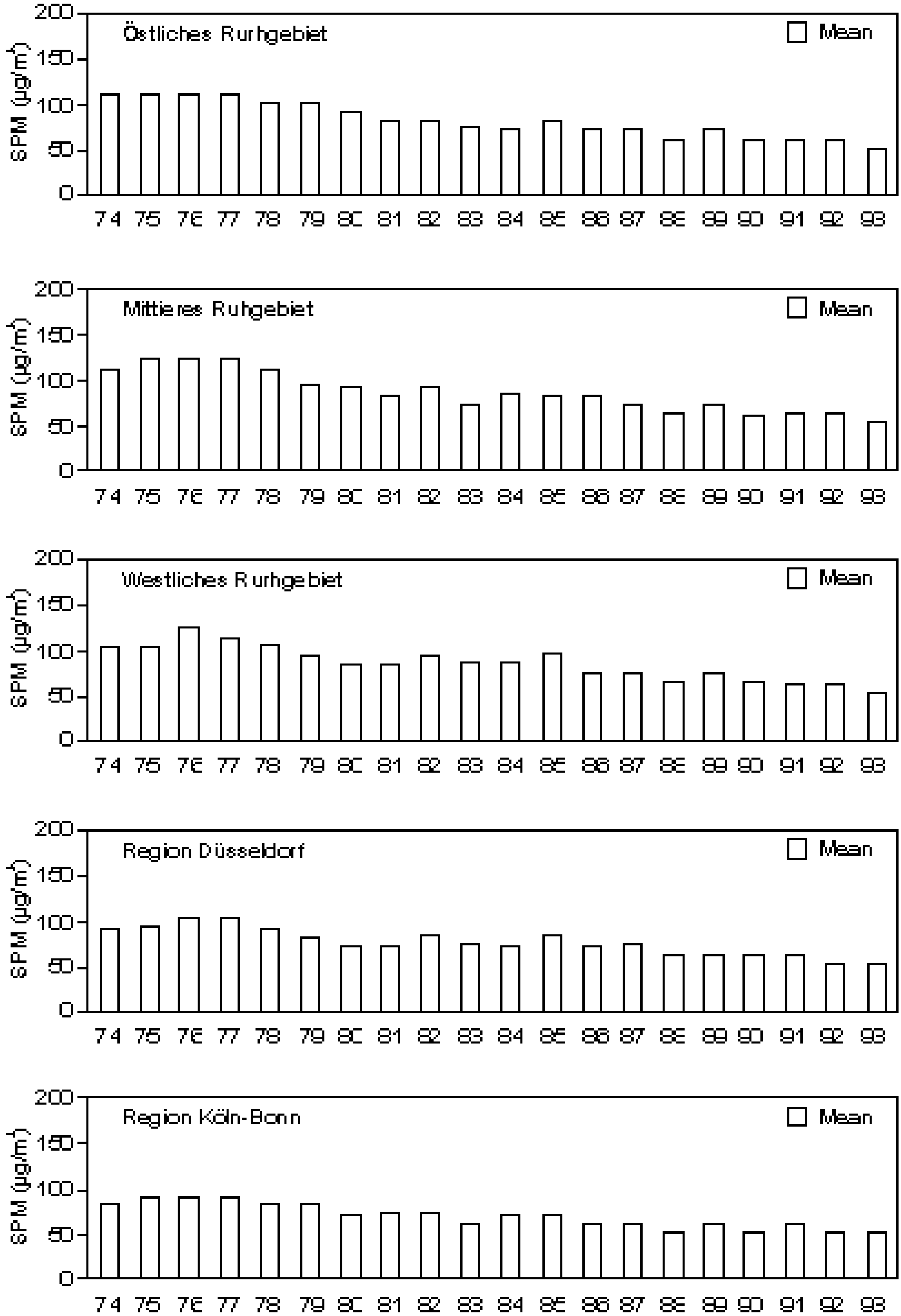


Figure 6.48: TSP/SPM trend in Nordrhein/Westfalen 1974-1993 (µg/m3). Mean values for several stations and cities from Nordrhein/Westfalen State report.

6.5 Ozone (O_3)

6.5.1 Behaviour, effects, emissions

Ozone, oxygen in the tri-atomic form, is one of the strongest oxidising agents, thus it is very reactive. There are only minute emissions of O_3 to the atmosphere. A part of tropospheric ozone (may be 10-15%) is transported from the stratosphere where it is formed by UV radiation on O_2. Most of the ozone in the troposphere is formed indirectly by the action of sunlight on nitrogen dioxide.

The precursor emissions concerning tropospheric photochemical production of ozone are NO_x and VOC emissions. In the steady state, there is a photochemical equilibrium between NO, NO_2 and O_3. The presence of hygroxyl radicals and volatile organic compounds from anthropogenic or national origin causes a shift in the equilibrium towards higher concentrations of ozone. The production of ozone, and thus the concentrations reached, depend upon the input NO, NO_2 and VOC concentrations, and also the ratios between them. There are favourable conditions for ozone production at VOC/NO_x ratio between 4:1 and 10:1. Production of ozone is a fairly slow process (hours or more). Photochemical ozone occurs during unfavourable dispersion conditions in summer time (strong UV intensity) in large urban areas particularly in Southern Europe, and regionally in large parts of Europe, including Southern Scandinavia, due to prolonged reaction time in air parcels receiving continuous input of VOC and NO_x through its transport.

O_3 and other oxidants cause a range of acute effects including eye, nose and throat irritation, chest discomfort, cough and headache. These have been associated with hourly oxidant levels of about 200 µg/m^3 . Pulmonary function decrements in children and young adults have been reported at hourly average O_3 concentrations in the range 160-300 µg/m^3. Increased incidence of asthmatic attacks and respiratory symptoms have been observed in asthmatics exposed to similar levels of O_3. The non-ozone components of the photochemical mixture cause eye irritation at O_3 levels of about 200 µg/m^3.

Other environmental effects include damage to materials (including as a result of prolonged exposure to low concentrations), and vegetation effects.

6.5.2 Air Quality Limit and Guide Values

EU Threshold values and WHO Guideline values for O_3 is given in Table 6.18. All values are maximum values.

Table 6.18: EU Threshold values for O_3 (µg/m³). EU Council Directive 92/72/EEC. WHO Guideline values (µg/m³).

EU Thresholds for	Average O_3 values[1)] over		
	1h	8h	24h
Health protection		110[2)]	
Vegetation protection	200		65
Population information	180		
Population warning	360		
WHO Guideline values for health protection	150-200	100-120	

1) Concentrations must be measured continuously.
2) The mean over 8 hours is a non-overlapping moving average; it is calculated 4 times a day from the 8 hourly values between 0 and 9.00, 8.00 and 17.00, 16.00 and 1.00, 12.00 and 21.00.
For the information to be provided pursuant to Article 6 (1), first indent, the mean over 8 hours is a simple moving average, calculated each hour h from the 8 hourly values between h and h-9.

According to the Ozone Directive the EU Member States have to provide the following information for the annual reference period:

- maximum, median and 98 percentile of 1 h and 8 h average concentrations;
- the number, date and duration of periods during which threshold values as presented in Table 6.18 are exceeded.

The following paragraphs on O_3 concentrations, exceedances and trends are based on 1994 data reported by RIVM and NILU in “Exceedance of Ozone Threshold Values in the European Community in 1994” which again is based on an internal report to the Commission by the European Environment Agency Topic Centre on Air Quality (de Leeuw et al., 1995).

6.5.3 Extent of data and monitoring stations

An overview of O_3 data available for 1994 is presented in Table 6.19. For 1994 complete or nearly complete information on ozone concentrations (annual statistics and/or exceedance information) has been received for 461 monitoring stations. For the preceding five years data transmission is less extensive. For nearly all stations information on measurement methods, instruments and on calibration procedures has been submitted. The location of the stations and a description of the immediate and local environments of the monitoring station is less completely available.

Table 6.19: Overview of data received by ETC-AQ. For each item and for each year the number of Member States and the total number of stations for which data has been submitted, is indicated.

	Information on annual statistics					
	1989	1990	1991	1992	1993	1994
Member states	3	3	3	5	6	13
Stations	63	62	57	83	181	378
	Information on exceedances					
	1989	1990	1991	1992	1993	1994
Member states	3	3	3	5	6	14
Stations	n.e.	n.e.	n.e.	n.e.	n.e.	423

n.e.: not evaluated in this report due to time limitations.

The location of monitoring stations reporting 1994 data is presented in **Error! Reference source not found.**. In total information for 461 stations and 14 Member States has been received. All Member States use the reference method (UV absorption) as prescribed in Annex V of the Ozone Directive.

Figure 6.49: Location of ozone monitoring stations as reported by Member States in the framework of the ozone Directive for the reference period 1994.

6.5.4 O_3 concentrations in Europe 1994

A summary of the maximum concentrations measured at any of the reporting stations in each country when exceedance of a threshold value is observed is presented in Table 6.20. When exceedances of a threshold has not been reported by a country this is indicated with a dash (-). In a few cases no conclusive answer whether exceedances have occurred could be given; in Table 6.20 this is indicated with a question mark. Exceedances are counted on a daily basis. A day on which at least one hourly or eight hourly values exceed the threshold values, is marked as exceedance.

Table 6.20: Maximum ozone concentrations measured in each country during a period of exceedance of threshold values (reference period 1 January-31

December 1994). A dash (-) indicates that no exceedances have been observed at any of the monitoring stations in the Member State. A question mark (?) indicates that no information on exceedances has been provided in computer readable form.

	180 1h	200 1h	360 1h	110 8h (a)	110 8h (b)	65 24h
Austria	294	294	-	197	205	172
Belgium	250	250	-	250	250	162
Denmark	197	-	-	172	189	129
Finland	-	-	-	149	138	139
France	318	318	-	?	?	?
Germany	293	293	-	248	248	199
Greece (c)	400	400	400	?	?	?
Ireland	-	-	-	111	113	94
Italy	490	490	490	251	256	214
Luxembourg	235	235	-	207	212	179
the Netherlands	303	303	-	205	241	144
Portugal	368	368	368	?	?	126
Spain	324	324	-	230	234	183
Sweden	201	201	-	187	182	150
United Kingdom	254	254	-	200	217	185

(a) Based on three non-overlapping eight hourly values between 0.00-8.00; 8.00-16.00; 16.00-24.00.

(b) Based on the eight hourly value between 12.00-20.00.

(c) Based on annual statistical information.

An overview of the reported 50 and 98 percentile values (based on hourly and moving eight hourly averaged concentrations) is presented in Table 6.21.

Table 6.21: Range in reported 50- and 98-percentile values (based on hourly and moving eight hourly averaged concentrations) observed at monitoring stations in Member States (in µg/m³), period 1 January-31 December 1994.

	50 P (1h)		98 P (1h)		50 P (8h)		98 P (8h)	
	min	max.	min	max.	min	max.	min	max.
Austria	9	93	102	161	14	93	93	159
Belgium	12	52	87	152	13	52	80	145
Denmark	50	63	108	124	49	63	103	121
Finland	29	73	80	107	30	73	73	104
France	?	?	?	?	?	?	?	?
Germany	11	88	75	193	16	88	66	185
Greece	21	60	106	170	24	60	95	153
Ireland	52	58	86	92	51	57	85	86
Italy	5	61	47	190	8	59	39	159
Luxembourg	18	62	89	166	19	63	79	163
the Netherlands	16	50	86	156	18	50	78	144
Portugal	6	86	61	124	19	86	60	120
Spain	7	74	41	161	10	74	37	146
Sweden	55	69	100	129	55	68	98	127
United Kingdom	14	74	70	130	14	74	70	130

The geographical distribution of 98-percentile values calculated on the basis of moving eight hourly averaged concentrations are presented in Figure 6.50 for background stations and in Figure 6.51 for urban stations and stations of unspecified type.

The 1994 data set does not allow a thorough assessment of geographical differences in Europe since spatial coverage is too fragmented and data are less useful because of the lack of knowledge on the representativeness of stations. From the available data no distinct regional differences are apparent in 50 percentile values (both hourly and 8 hourly) apart from the fact that coastal stations on the average report higher 50 percentile values then inland (urban) stations. Peak concentrations, as presented by the 98 percentile, in general show an increase from North-West to Central Europe; the elevated location of the monitoring stations may play a role her.

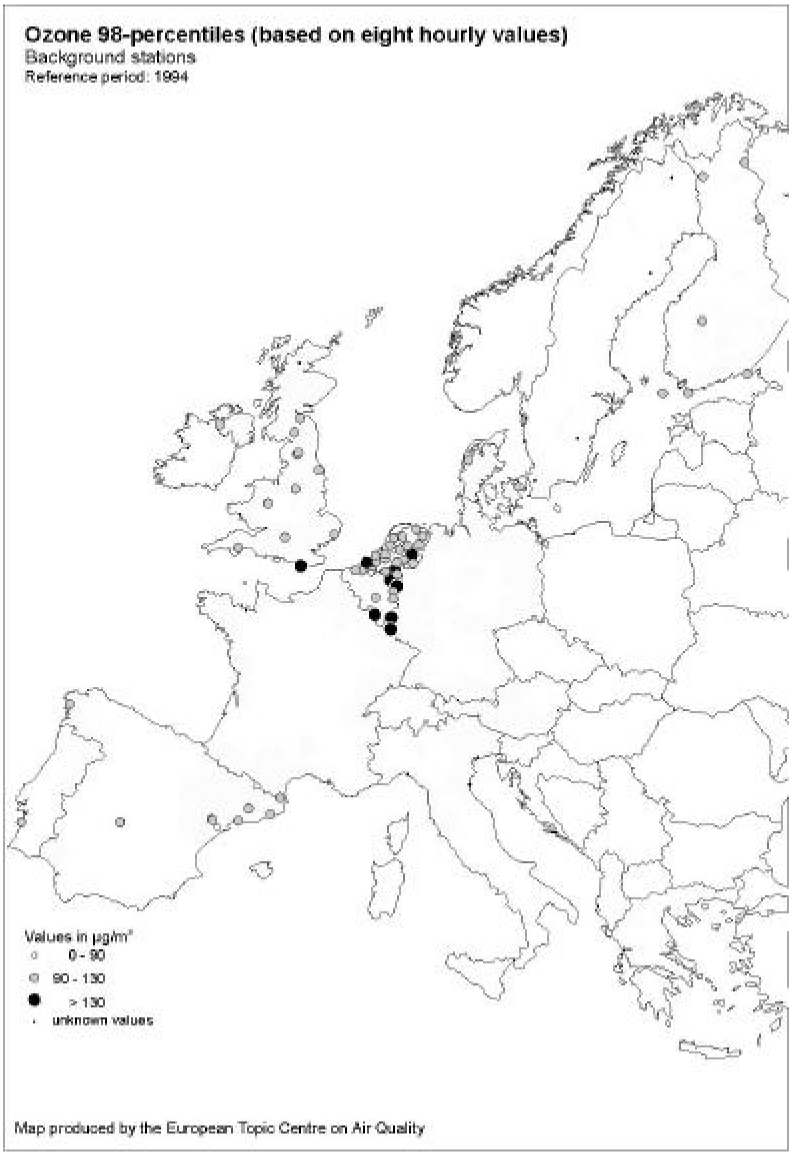


Figure 6.50 percentiles (based on moving eight hourly concentrations; µg/m3) measured at background stations, calendar year 1994.

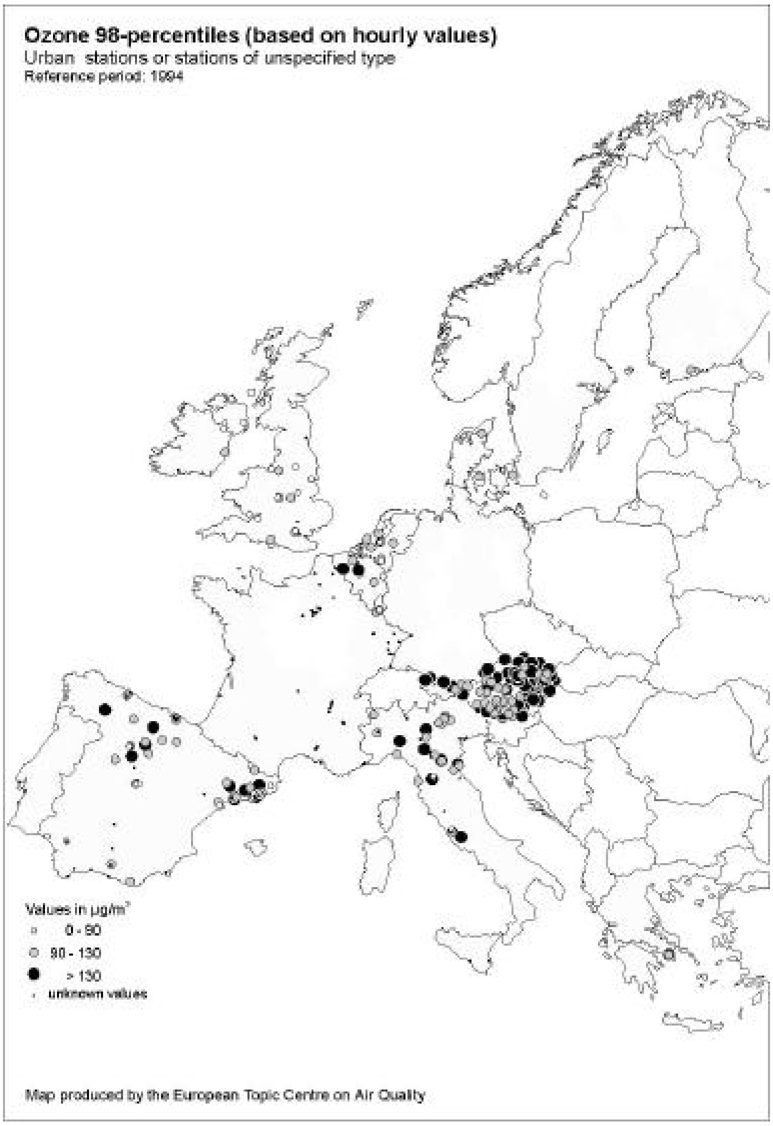


Figure 6.51 percentiles (based on moving eight hourly concentrations; µg/m³) measured at urban and unspecified stations, year 1994.

6.5.5 O_3 exceedances in Europe 1994

Exceedances of the threshold value of 360 µg/m³ for hourly values has been observed at three stations in three member states, see Table 6.22.

Table 6.22: Location, date and maximum concentration (hourly value, in µg/m³) of all reported exceedances of the threshold value of 360 µg/m³ for the calendar year 1994.

Country	Station	Date	Max. conc. (µg/m³)
Greece	Lykobrissi	25 May 1994	400
Italy	Melilli	24 May 1994	490
Portugal	Hospital Velho	7 January 1994	368

The averaged number of observed exceedances per station of the other threshold values is summarised in Table 6.23. As the number of monitoring stations differ widely from country to country, the absolute numbers of exceedances are less suitable for comparison. Full details on the number of exceedances at the individual stations is presented in Table I.1 of Appendix E.

Table 6.23: Number of exceedances averaged over all reporting stations (reference period 1 January-31 December 1994).

	180 1h	200 1h	110 8h (a)	110 8h (b)	65 24h
Austria	2.7	0.8	40.4	47.0	117.8
Belgium	5.8	2.2	21.2	25.9	44.2
Denmark	0.8	0.0	15.4	21.2	110.6
Finland	0.0	0.0	5.0	4.4	76.8
France	7.3	3.5	?	?	?
Germany	7.5	2.8	42.2	35.8	66.6
Greece	>0	>0	?	?	?
Ireland	0.0	0.0	0.3	0.7	61.0
Italy	8.2	4.3	16.9	24.0	44.1
Luxembourg	7.2	2.2	26.2	28.0	66.0
the Netherlands	7.3	3.6	15.8	23.5	48.9
Portugal	>0	>0	?	?	18.6
Spain	1.5	0.7	10.1	15.1	50.4
Sweden	0.5	0.2	?	?	?
United Kingdom	1.2	0.7	4.8	6.3	58.0

(a) Based on three non-overlapping eight hourly values between 0.00-8.00; 8.00-16.00; 16.00-24.00.

(b) Based on the eight hourly value between 12.00-20.00.

Exceedances of threshold values for protection of human health

The threshold value for protection of human health is based on eight hourly values. According to the Ozone Directive four eight hourly periods have to be considered: 0.00-8.00, 8.00-16.00, 16.00-24.00 and 12.00-20.00.

Based on the averaged diurnal profile of ozone the highest eight hourly values are generally expected for the 12.00-20.00 period; only exceedances of the threshold values for this period are further processed here.

In 1994 exceedances of this threshold value has been observed in all 14 Member States providing data. Maximum concentrations up to 250 µg/m^3 has been observed (see Table 6.20). Figure 6.52 shows the frequency distribution of eight hourly ozone concentrations in excess of the threshold value using so-called Box-Jenkins plots. For each Member State the Box-Jenkins plot indicates the minimum (here the minimum is of course

110 µg/m3), the maximum, the 25 percentile and the 75 percentile value of the exceedances. Although extreme peaks of more than 200 µg/m3 are observed in 7 out of 10 reporting Member States, Figure 6.52 shows that in each Member State for ca. 75% of all exceedances the concentrations are below 165 µg/m3 (that is, 150% of the threshold value).

The geographical distribution of the number of days the threshold value was exceeded is shown in Figure 6.53 for background stations in Figure 6.54 for the urban and unspecified stations.

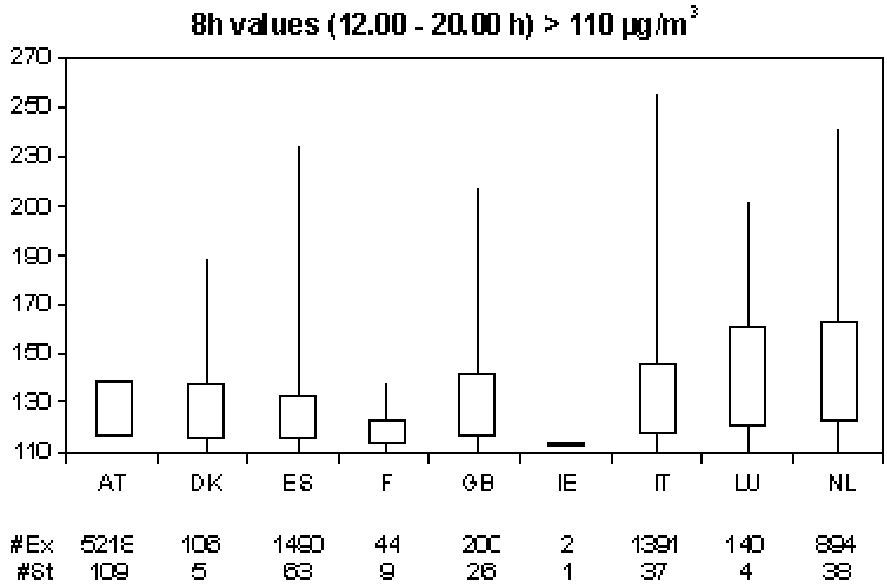


Figure 6.52 Frequency distribution of ozone concentrations (eight hourly values; period 12.00-20.00) in excess of the 110 µg/m3-threshold for hourly values. For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-percentile, the 75-percentile and the maximum value. The data for Belgium did not allow for inclusion in this figure.

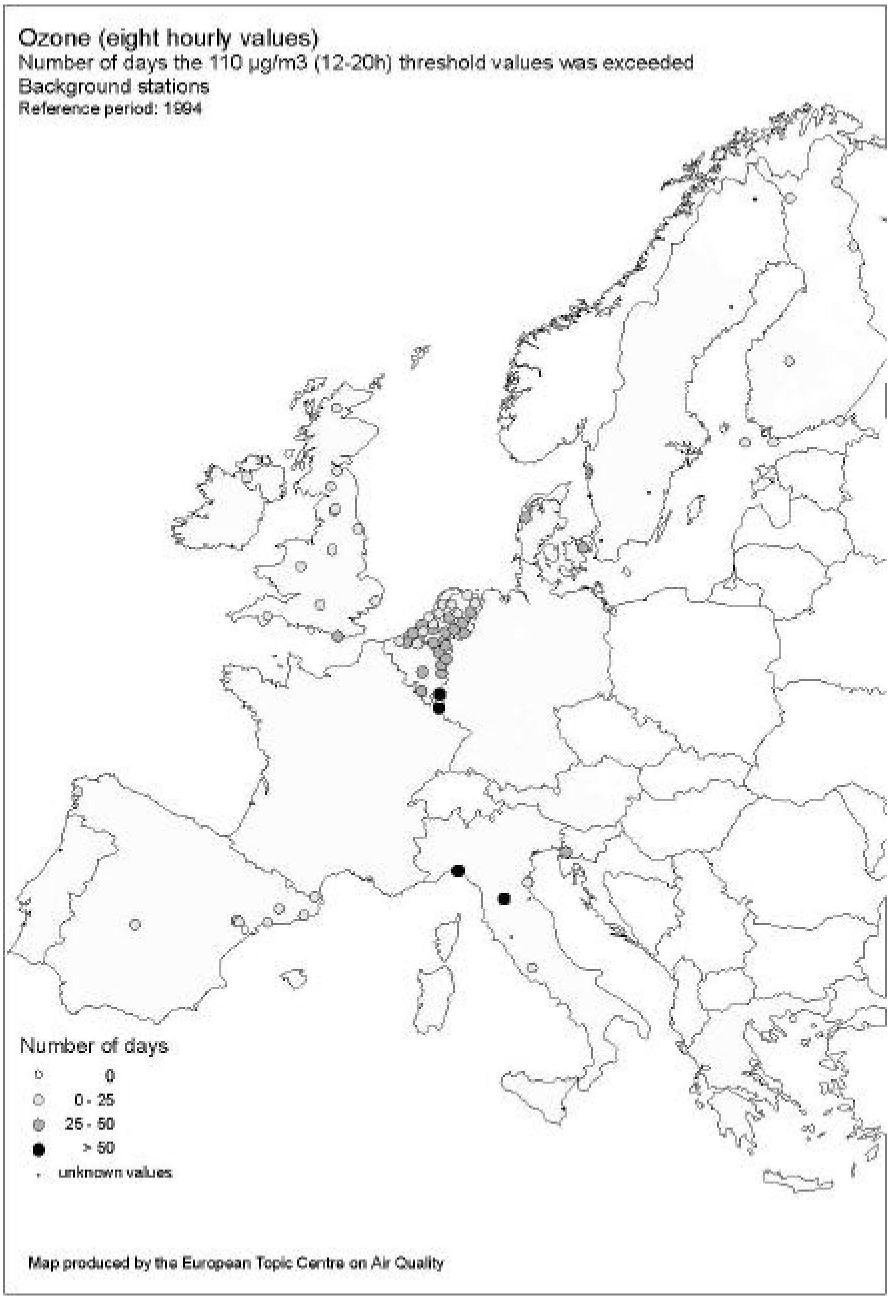


Figure 6.53: Number of exceedances of the threshold value for protection of human health (110 µg/m^3 for eight hourly values) observed at background stations; calendar year 1994; eight hourly averaged values for the period 12.00-20.00.

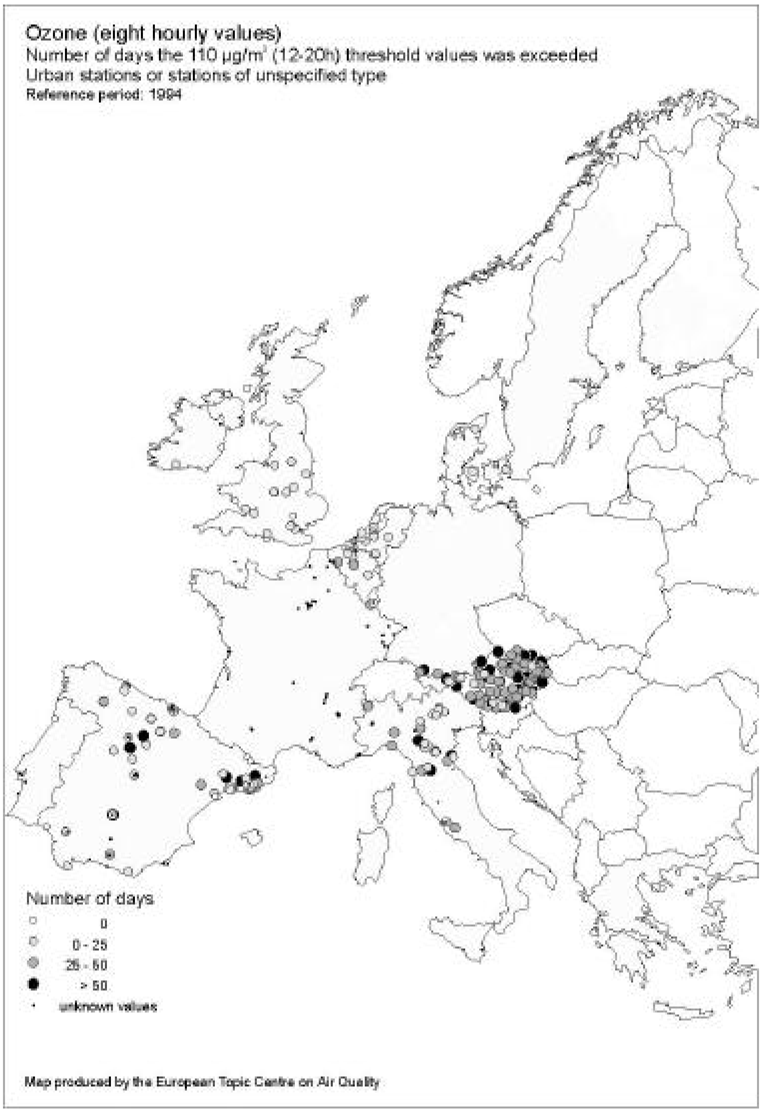


Figure 6.54: Number of exceedances of the threshold value for protection of human health (110 µg/m3 for eight hourly values) observed at urban and unspecified stations; calendar year 1994; eight hourly averaged values for the period 12.00-20.00.

Exceedances most frequently occur in the summer months (April-August). In the southern countries (Italy, Spain) and in Austria exceedances are observed nearly the whole year: from February to October 1994. Note that the phenomenology of ozone peak concentrations strongly depends on the meteorological conditions. The behaviour as found here for 1994 might not be representative for other years.

Exceedances of the threshold values for information and warning of the population

The threshold values for warning the population (360 µg/m3, hourly value) has been exceeded in 1994 once in Greece, Italy and Portugal. All exceedances occurred in the Southern part of Europe. Two exceedance are observed at the end of May. The exceedance in Portugal is observed in January which is, in view of the general behaviour of ozone, quite surprising.

The geographical distribution of the number of exceedances of the threshold value for information of the public (180 µg/m3, hourly value) is presented in Figure 6.56 for background stations and in Figure 6.57 for urban and unspecified stations. Exceedances are observed in 12 of the 14 reporting Member States; only in Finland and Ireland the 180 µg/m3 level has not been reached.

Figure 6.55 shows the frequency distribution of concentrations in excess of the threshold value. Although incidentally the threshold value may be exceeded by more than a factor of 2.5 in almost all of the cases the exceedances are less extreme: The figure shows that on 75% of the days on which the threshold value was exceeded, the level of 225 µg/m3 (that is 125% of the threshold value) has not been reached.

Exceedances are observed during a large part of the year but most frequently and most widely spread geographically during the summer months.

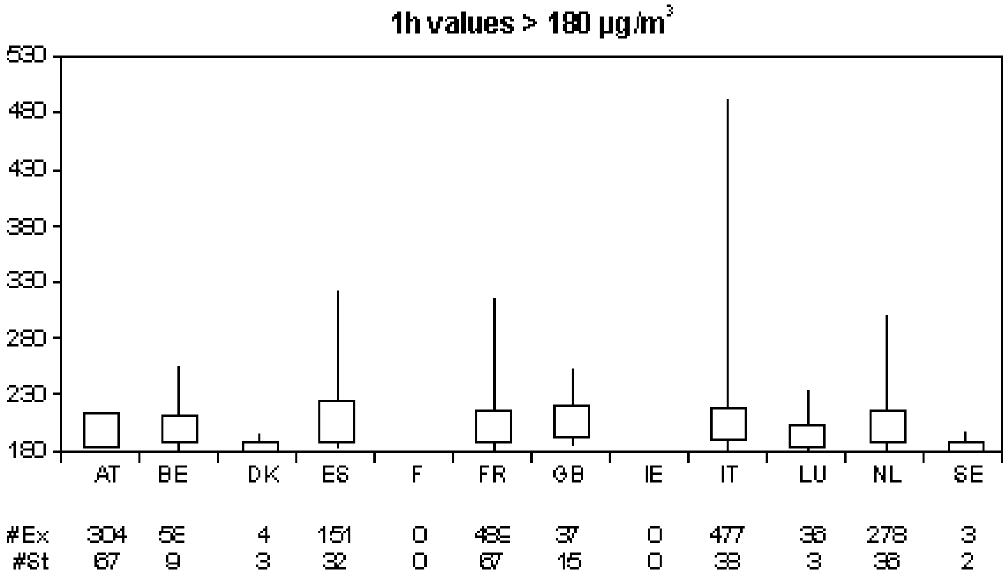


Figure 6.55: Frequency distribution of ozone concentrations (hourly values) in excess of the 180 µg/m3 threshold for hourly values. For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-percentile, the 75-percentile and the maximum value. The data for Belgium did not allow for inclusion in this figure.

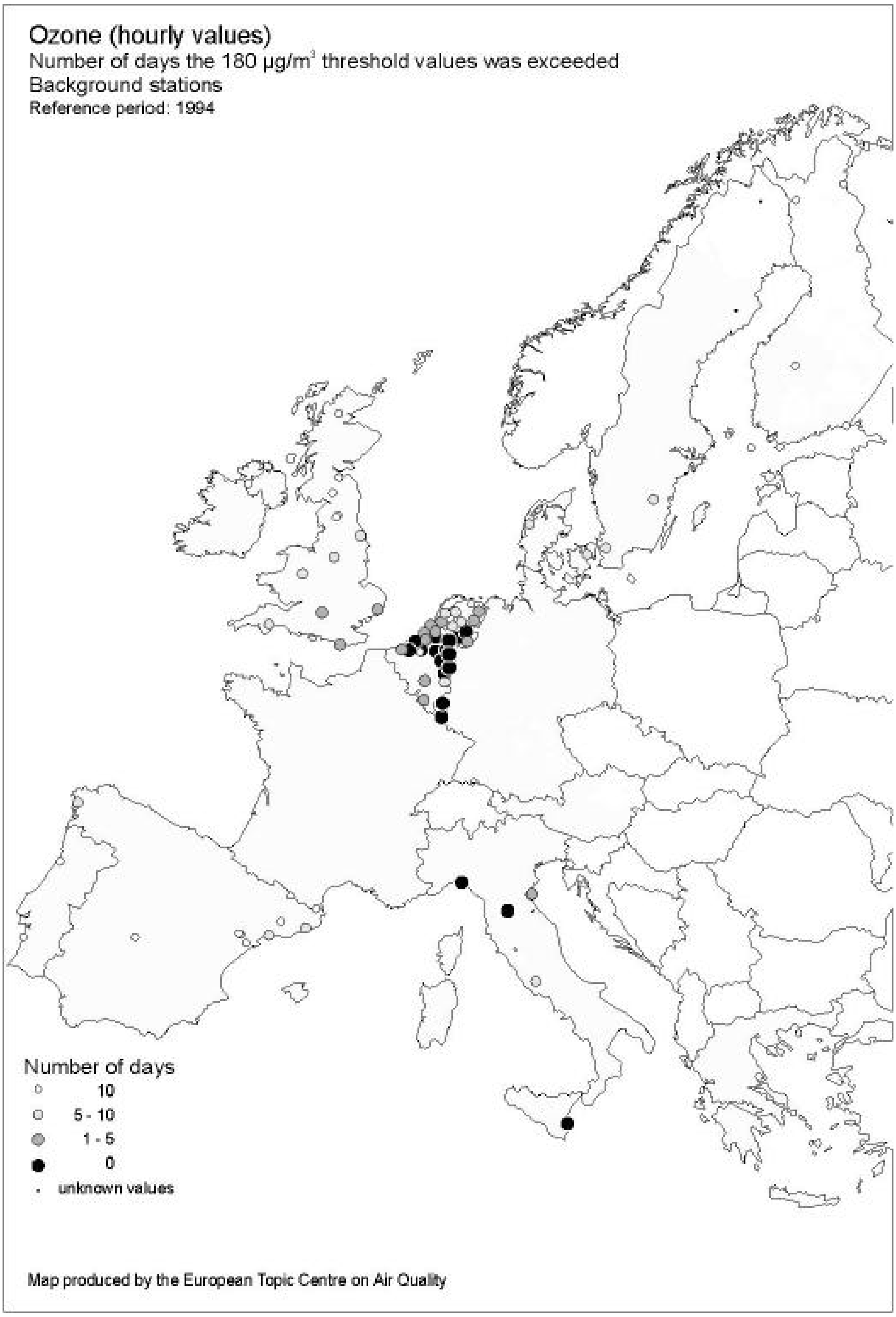


Figure 6.56: Number of exceedances of the threshold value for information of the population (180 µg/m3 for hourly values) observed at background stations; calendar year 1994.

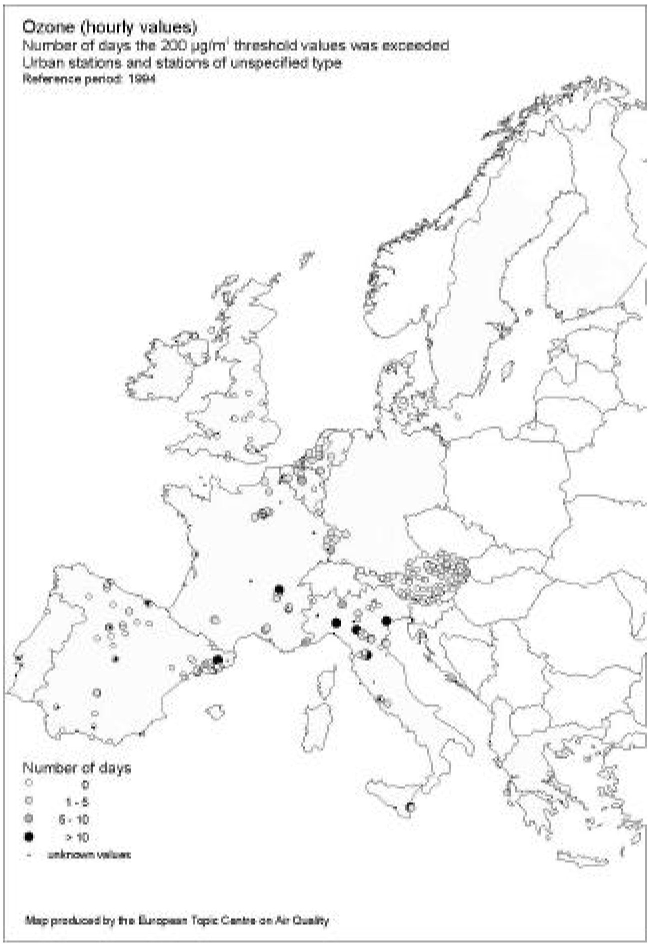


Figure 6.57: Number of exceedances of the threshold value for information of the population (180 µg/m3 for hourly values) observed at urban and unspecified stations; calendar year 1994.

6.5.6 Summer smog episodes in 1994

From the data now available it is clear that exceedances of the threshold value set for information to the public were observed in the southern European Member States (Greece, Italy, Spain) from March onwards. In May this region extended to the north (France, Austria, Luxembourg). Starting at the last week of June, exceedances were also frequently observed in Belgium, United Kingdom, and the Netherlands. More northern countries, Sweden and Denmark, only reported exceedances in the last week of July. This period with frequent exceedances across Europe ended at 5 August 1994. After this date, exceedances were less numerous and again confined to the southern part of Europe (Italy, Spain, Greece and France). These countries reported exceedances till half October.

Table 6. gives a graphical representation of the percentage of stations in every Member State that reported exceedances of the threshold value for population information

(180 $\mu g/m^3$ for hourly values) during the 1994 summer season. Please note that no exceedances were observed in Finland and Ireland. In this period some short periods of several days can be recognised on which exceedances are only observed at a limited number of stations (less than 50%) in one country. These periods with relatively low numbers of exceedances are followed with periods of 4 to 7 days with frequent exceedances in various countries. As an example the maximum hourly ozone concentrations in excess of 180 $\mu g/m^3$ as measured on 27 July 1994 are geographically presented in Figure .

*Table 6.24: Qualitative overview of exceedances of the 180 µg/m³ population information threshold value (1 h) during the period 26 June-8 August 1994. The number of asterisks refers to the percentage of stations in a country which reports and exceedance: *: less than 25%; **, between 25 and 50%, ***: between 50 and 75%; ****: more than 75%. Note that in Ireland and Finland no exceedances are observed in this period.*

Month	Date	Austria	Belgium	Denmark	France	Italy	Luxembourg	the Netherlands	Spain	Sweden	United Kingdom
6	26	*				*					
6	27	*			*	*					
6	28	*	**		*		**	**	*		
6	29	*			*	*			*		
6	30		*		*	*	**		*		
7	1		***		**	*	***	*			**
7	2	*	**		*	*	***	***	*		*
7	3	*	**		*	**	***	**	*		*
7	4	**	*		*	**		*	*		
7	5					**			*		
7	6	*				*					
7	7					*					
7	8					*					
7	9										
7	10				*	*			*		
7	11		*		*	*		***	*		*
7	12				**	*		*	*		***
7	13		**		**	*	***	***	*		
7	14	*	*		*	*		*	*		
7	15	*			*	**	***	*	*		
7	16	*	***		*	**	***	*	**		
7	17	*			*	**	**		*		
7	18	*			*	**			*		
7	19					*			*		
7	20				*						

Table 6.24 (cont.)

Month	Date	Austria	Belgium	Denmark	France	Italy	Luxembourg	the Netherlands	Spain	Sweden	United Kingdom
7	21		*		*			*			*
7	22	*	*		**	*	**	**	*		*
7	23	*	***		**	*	***	**	*		*
7	24	*	**		*	*	***	**	*		**
7	25	*	*		*	*		**	*		*
7	26	**	*	***	**	*	***	**	*		
7	27	**	**		***	*	****	**	*	***	
7	28	**		**	*	*	**	*	*	***	
7	29	*			*	*			*	***	
7	30	*			*	*		**			**
7	31	*			*	*		*			
8	1	*			*	**					
8	2	*			*	**			*		
8	3	*	**		*	**	***	***			
8	4	*	**		*	**	***	****	*		
8	5	**		**	*	***	***	*	*		
8	6	***			**	**			*		
8	7	*			*	*			*		
8	8	*				*			*		

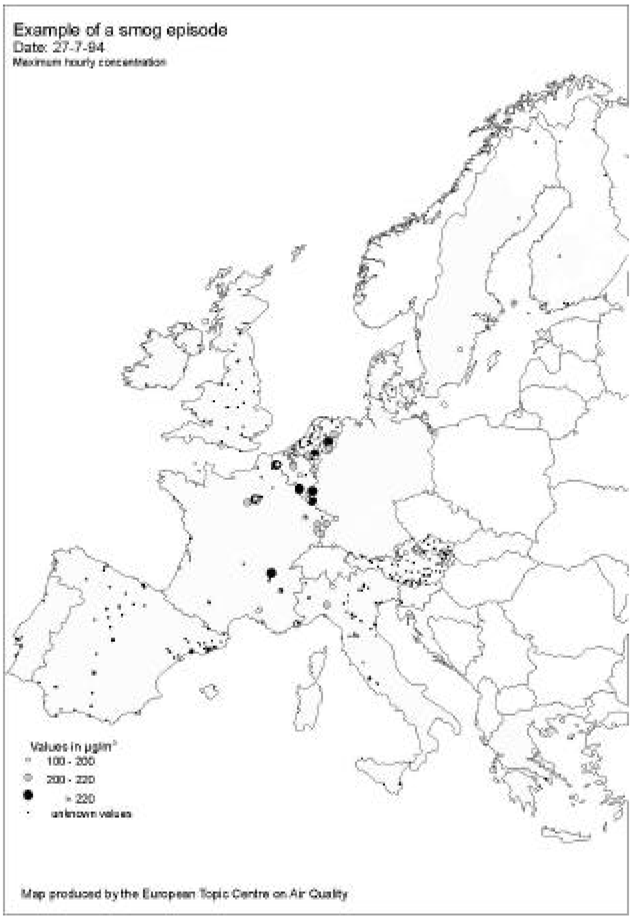


Figure 6.58 Example of an ozone smog episode: hourly ozone concentrations in excess of 180 µg/m3 as measured on 27 July 1994.

6.5.7 Trend 1989-1993

The data reports for the period 1989-1993 are available for 6 Member States and a detailed analysis of ozone exceedances can presently not be made.

The year-to-year variation in 50-percentile values are relatively small when compared to the variations in the 98-percentile values (see Figure and Figure). The 98-percentile values are measured in the summer, typically during periods with hot weather. Ozone is strongly correlated with temperature mainly because the conditions leading to high temperatures (e.g. strong solar radiation, low wind speeds, continental flows) also trigger photochemical formation. Meteorological fluctuations may cause variations in peak ozone levels that are much larger than the variations due to changes in precursor emissions. A yearly fluctuation of ca. 15% in 98-percentile value is not exceptional, see Figure ; according to model calculations a 15% reduction in ozone peak values is expected when commitments to the Sofia Protocol on NO_x emissions and the Oslo Protocol on VOC emission to the international convention on Long-range transport of air pollution are fully implemented.

The yearly fluctuations differ from country to country. In Belgium and the Netherlands similar patterns are found: after two “high” year (1989 and 1990) the period 1991-1993 shows relatively low peak values but increased levels are again observed in 1994. For more northern countries (Denmark, Finland) the 1994-increase is less outspoken or even absent.

The available time series are too short to detect any possible trend in ground level ozone concentrations. Trends in ozone concentrations are expected as a result of trends in precursor emissions in Europe and as a result of the increasing trend in hemispheric background concentrations (Borrell and van den Hout, 1995). The magnitude and even the sign of a possible trend will differ from location to location. No conclusive answers can be given based on the data reported here.

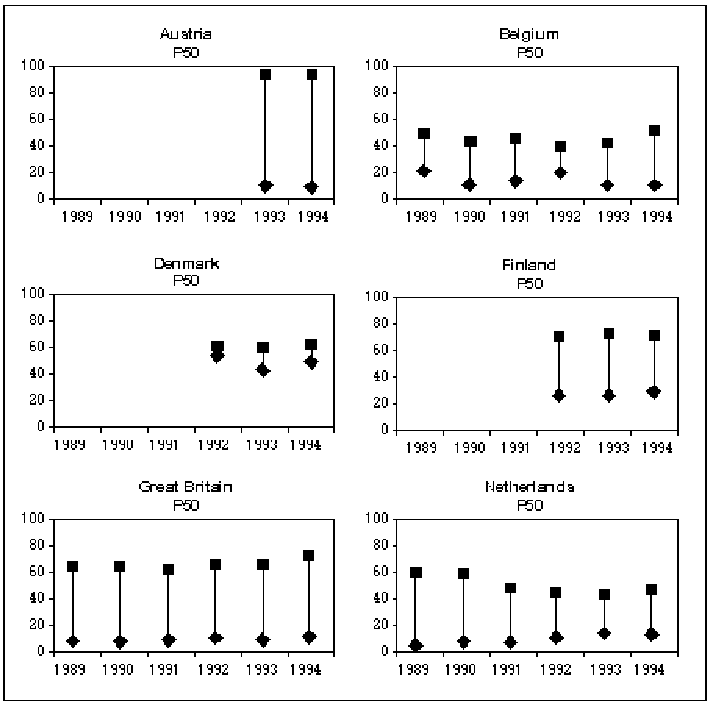


Figure 6.59: *Range in reported 50-percentile values (in µg/m^3, based on hourly concentrations) in Austria, Belgium, Denmark, Finland, Great Britain and the Netherlands in the period 1989-1994.*

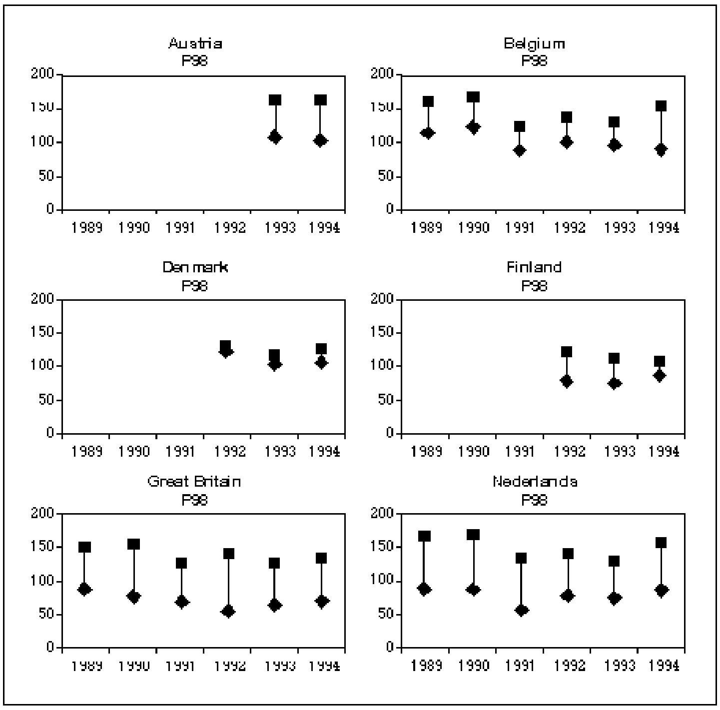


Figure 6.60: Range in reported 98-percentile values (in µg/m^3, based on hourly concentrations) in Austria, Belgium, Denmark, Finland, Great Britain and the Netherlands in the period 1989-1994.

6.6 Lead (Pb)

6.6.1. Behaviour, effects, emissions

Lead is a pollutant in air mainly through its use as an additive to gasoline, in the form of organic lead compounds: tetraethyl and tetramethyl lead. Also, many metal smelters (lead, copper, zinc, iron, steel) emit significant amounts of lead to the atmosphere. Lead occurs in the atmosphere mainly in particulate form (in the fine particle fraction), but a small part occurs in vapour form as organic lead compounds.

The previously very widespread use of lead in gasoline has been substantially reduced in most parts of Europe since early 1980 especially, through the reduction of lead in gasoline, from typically 0.7-0.8 g/l to less than 0.15 g/l, and through the use of lead-free gasoline needed by catalyst cars.

Human exposure to lead is through inhalation of airborne lead and ingestion of lead in foodstuffs and beverages. While most airborne lead is man-made, an appreciable proportion of that in food and water is of natural origin. Nevertheless both deposition of airborne lead, and lead from other man-made sources (e.g. pipes and solders) contribute to dietary intake. Blood lead concentrations are a good indicator of recent exposure to lead from all sources, and adverse health effects tend to increase in severity with increasing blood lead level.

EPA standards are based upon the concept of a relationship between ambient air lead and blood lead concentrations, and presume that a blood lead level of 0.15 µg/ml (mean value for children) can be achieved at an ambient air lead level of 1.5 µg/m^3 .

The most sensitive body systems to the effects of lead are the haematopoietic system, the nervous system and the renal system. In addition, lead has been shown to affect the normal functions of the reproductive, endocrine, hepatic, cardiovascular, immulogic and gastrointestinal systems. The most sensitive group to lead poisoning is children. Some studies indicate that children with high levels of lead accumulated in their baby teeth experience more behavioural problems, lower IQs and decreased ability to concentrate, although these findings are currently controversial.

Examples of some "lowest-observed-effect" levels for children (identified by the EPA) are: disturbance of haem synthesis via enzyme inhibition at 0.1 µg/ml, anaemia at 0.4 µg/ml, encephalopathic symptoms at 0.8 µg/ml.

Lead is generally toxic to both plants and animals, and although no serious effects are generally seen at current environmental levels, it is widely considered prudent to limit further dispersal of lead as far as is possible.

6.6.2. Air Quality Limit and Guide Values

EU Limit value and WHO Guideline value for lead is given in Table . The WHO Guideline value is lower than the EU Limit value by a factor 2-4.

Table 6.25: EU Limit Value for Pb (µg/m^3).
EU Council Directive 82/884/EEC.
WHO Guideline value (µg/m^3).

EU Limit value	Mean of 24h values
Year	2
WHO Guideline value	
Year	0.5-1

6.6.3. Urban and local Pb concentrations

Concentrations

In Appendix B Pb data from 8 countries are given. The stations are ranged according to the annual mean values. The stations with the highest values are given in Table . Figure shows 1993 Pb mean values for selected stations in some European cities.

Mean Pb levels in all cities in Table are well below the EU Limit value and also below the WHO Guideline value. Levels above 0.3 µg/m^3 are measured in some cities in Spain and Italy.

Pb annual mean levels from the selected cities in Figure 5.1/Table 5.2 are shown in Figure .

Table 6.26: Pb yearly mean values for 1993 for selected stations and cities (µg/m^3). (For complete table, see Appendix B).

Country	Name	City Class	Station	Pb 24h values Mean	
Spain	Barcelona	1	Moncada	0.429	
Italy	Genova		XX Settembre	0.42	1
Spain	Barcelona	1	Molina Pl.	0.381	
Italy	Genova		Via Cantore	0.36	1
Spain	Barcelona	1	Prat del Llobregat	0.344	
Spain	Barcelona	1	Poblé nov	0.337	
Italy	Modena		Via Giardini	0.32	1
Italy	Modena		Via Garibaldi	0.28	1
Belgium	Bruxelles	2	IHE Coute rue	0.278	
Belgium	Antwerpen	3	Elizabethziekenhuis	0.251	
Italy	Genova		Villa Raggio	0.25	1
Italy	Modena		Via Cavour	0.24	1
Italy	Forli		Via Le Roma	0.22	
Switzerland	Zürich	4	Schimmelstrasse	0.22	
Italy	Ferrara		Corso Isonzo	0.21	
Italy	Modena (region)		Timaro	0.2	1
Belgium	Antwerpen	3	Kielpark	0.183	
Switzerland	Basel	4	Feldbergstrasse	0.18	
Switzerland	Bern	4	Bern	0.18	
Germany	Duisburg	3	Duisburg-Buchholz	0.17	
Italy	Genova		Rimessa Amt	0.17	1
Italy	Genova		Magazzini Generali	0.17	1
Italy	Genova		Villa Serra	0.17	1
Germany	Dortmund	3	Dortmund-Mitte	0.16	
Italy	Genova		Multedo	0.16	1
Switzerland	Lausanne	4	Lausanne	0.15	

1. Data availability:<75%.

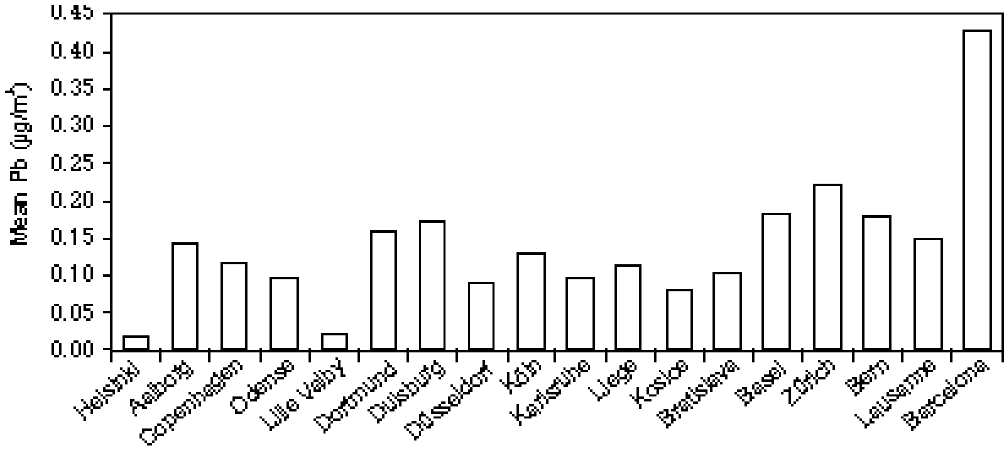


Figure 6.61: Pb yearly mean values for 1993 for selected stations and cities (µg/m3).

Figure 6.62: Pb mean values in selected cities (µg/m3).

Exceedances

In the data material available for this report, there are no exceedances of the EU Limit value or WHO Guideline value for Pb.

Trends

Only Denmark and Belgium have reported updated 1993/94 trends for lead in the APIS system. The trend Figure -Figure show a considerable decrease in Pb levels since the early 1980's due to reduced consumption of leaded petrol.

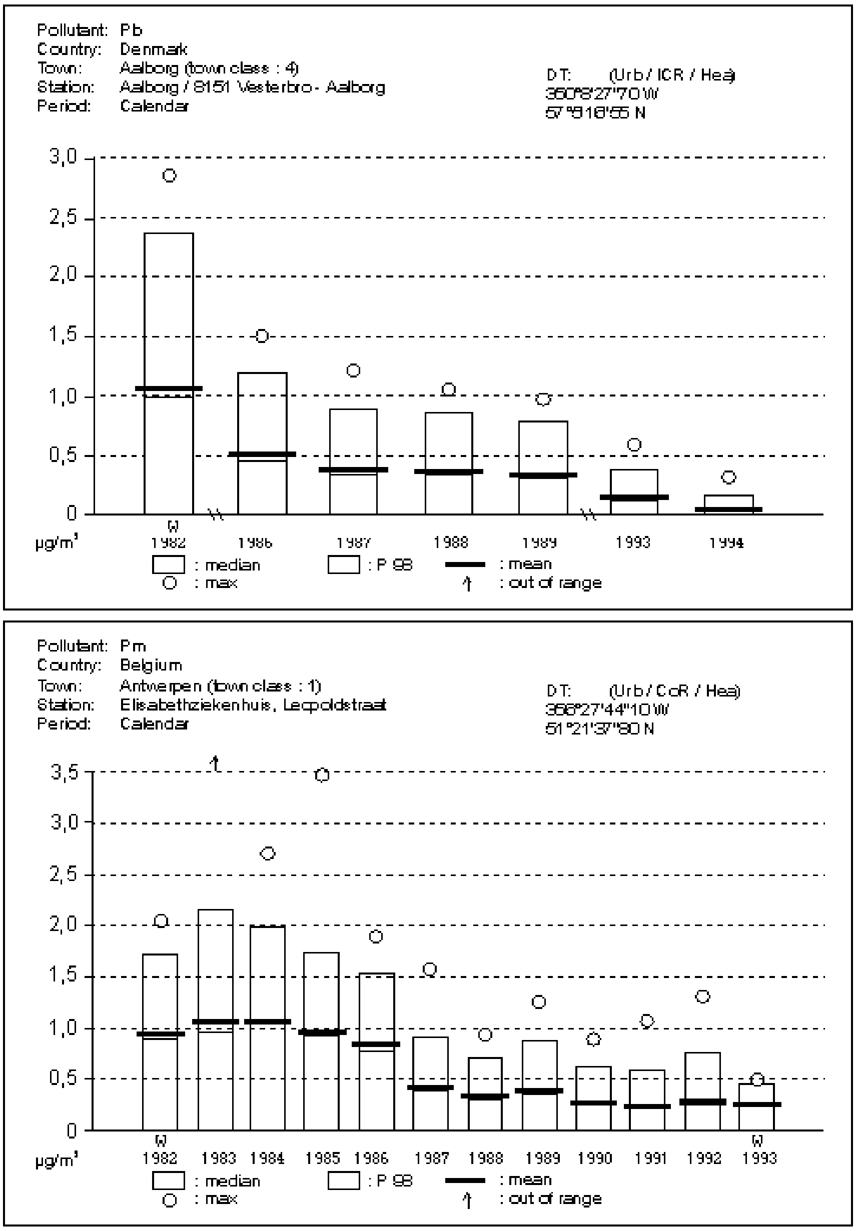


Figure 6.63: Pb trend in Aalborg, Denmark 1982-1994 and Antwerp, Belgium 1982-1993 (µg/m^3). APIS data.

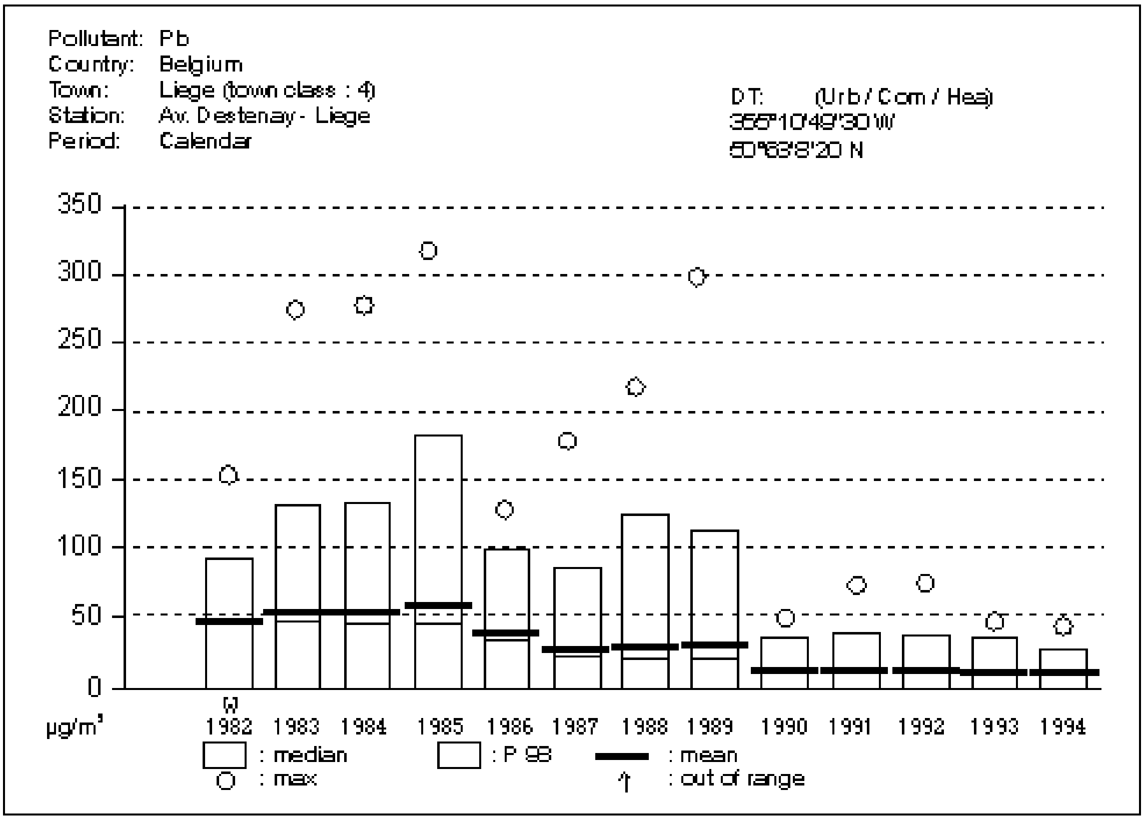


Figure6.64: Pb trend in Liege, Belgium 1982-1994 (µg/m3). APIS data.

6.7 Carbon monoxide (CO)

6.7.1. Behaviour, effects, emissions

Carbon monoxide (CO) exerts its effects on health through its reaction with the haemoglobin of the blood. The affinity of haemoglobin is more than 200 times higher for CO than for oxygen, so that it replaces oxygen in the blood already at low concentrations.

The major sources to CO emissions is combustion of fuels. Poor combustion gives increased CO emissions. In urban areas, road traffic is normally by far the dominant source, and gasoline-powered vehicles (spark ignition engine) is the dominating vehicle group. CO emissions are high at idle and low, intermittent speeds, and decreases rapidly at higher speed. (Emissions increase again substantially at very high speeds, >100 km/h for non-catalyst cars). Other less important sources are biomass combustion, power stations, incineration. CO is slowly oxidised to CO_2 in the atmosphere.

Human health effects range from strokes, unconsciousness and death of parts of the brain and the individual itself at very high exposures (as may occur accidentally e.g. in individual car garages), and to milder, behavioural effects (e.g. impaired learning, reduced vigilance, impaired complex task performance, increased reaction time) that may occur at CO levels that may arise in urban areas close to traffic during periods of poor atmospheric dispersion. Increased risk of certain effects on the cardiovascular system can be expected to begin at levels close to such peak ambient concentrations.

6.7.2. Air Quality Limit and Guide Values

There are no EU Limit or Guide values for CO. WHO Guideline values for CO are given in Table . WHO Guideline values are maximum values.

Table 6.27: WHO Guideline values for CO (mg/m^3).

Averaging time	Mean value
10 min	100[1]
½ h	60[1]
1 h	30[1]
8 h	10

1 Exposure at these concentrations should be for no longer than the indicated times and should not be repeated within 8 hours.

6.7.3. Urban and local CO concentrations

Concentrations

In Appendix B CO data from 12 countries are given. The stations are ranged according to the 98 percentile of hourly values. The stations with the highest values are given in Table . Also the maximum 1h and maximum 8h values are given, if available.

Differences in CO levels are probably due to different exposure to traffic at the monitoring stations. CO levels are shown in Figure -Figure .

Table 6.28: Maximum 1 h, maximum 8 h and 98 percentile 1 h CO values for 1993 for European cities ranged according to the 95 percentile values (µg/m3). (For complete table, see Appendix B).

	City			CO, year, 1h values		
Country	Name	Class	Station	Max. 1h	Max. 8h	98-percentile
Portugal	Lisboa		Benéfica	57.1	18.1	25.3
Portugal	Porto		Fac. Engenharia	38.2	11.4	25.3
Portugal	Faro		Faro	27.4	10.9	21.5
Portugal	Bar./Seixal		Hospital Velho	32.8	11.9	17.9
Greece	Athens	1	Patission 147	33.3 [b]	22.6	15.6
Portugal	Lisboa		Entrecampos	24.3	8.7	14
Greece	Athens	1	Pireas Platia Dimotikou	28.9	18.1	11.5
Germany	Wiesbaden	4	W-Ringkirche			10.3
Portugal	Lisboa		Rua da Prata	16.4	5.2	10.2
Portugal	Lisboa		Casal Ribeiro	14.5	5	10.1
Germany	Braunschweig	4	Bohlweg			9.7
Portugal	Lisboa		Olivais	16.3	3.6	9.4
Spain	Barcelona	1	Molina Pl.	23.8	17.3	8.7
Portugal	Porto		Campo Alegre	8.8	7.8	8
Germany	Hannover	3	Sallstrasse			7.9
Germany	Mainz-Mombach	4	Parcusstrasse			7.45
Portugal	Funchal		Funchal	13.3	3.5	7.3
Greece	Athens	1	Smyrni Cementry	26.9	9.7	7.2
Spain	Madrid	1	Cuatro Caminos	17.2	10.3	7.2
Germany	Düsseldorf	3	Düsseldorf-Mörsenbroich	22.8 [4]		6.8
Germany	Kassel	4	Kassel-Süd			6.8
Portugal	Lisboa		R. Sèculo	12.6	3.1	6.4
Germany	Hannover	3	Göttinger Strasse			6.4
Germany	München	2	Effnerplatz	18.5 [9]		6.3
Germany	München	2	L.Kiesselbach-Platz	21.8 [9]		6.2
Spain	Madrid	1	Plaza España	15.1	8.4	6
Germany	Essen	3	Essen-Ost	17.5 [4]		5.8
Spain	Madrid	1	Carlos V	15.1	8.6	5.8
Germany	München	2	Pasing	21 [9]		5.7
Germany	München	2	Stachus	15.2 [9]		5.7
Germany	München	2	Moosach	19.9 [9]		5.5
The Netherlands	Utrecht		Witte Vrouwenstraat	14.5	9.4	5.5
Germany	Bremen	3	Bremen-Verkehr I			5.5
Finland	Jyväskylä	5	Lyseo	15.6	9.8	5.3
Germany	Ludwigshafen-Frankental	4	Goerdelerplatz			5.25
Portugal	Lisboa		Beato	9.1	3.1	5.1
Germany	Hamburg	2	Stresemannstrasse	9.7	6	5
Germany	Chemnitz		Chemmitz-Mitte 2			4.99
Spain	Madrid	1	Plaza Castilla	11.1	6.6	4.8
Germany	Düsseldorf	3	Düsseldorf-Reisholz	17.3 [4]		4.7
Germany	Essen	3	Essen-Altendorf	15.2 [4]		4.7
Portugal	Lisboa		Chelas	8.1	2.1	4.7
Germany	Essen	3	Essen-Vogelheim	18 [4]		4.6
Germany	Frankfurt	3	Ffm-Höhenstrasse			4.6
Spain	Barcelona	1	Poblé nov	14.2	6.1	4.4
Spain	Madrid	1	Arturo Soria	25.6	10.6	4.3
Germany	Kassel	4	Kassel-Nord			4.3
Germany	Duisburg	3	Duisburg-Walsum	12.4 [4]		4.2
Germany	Leipzig		Leipzig-Mitte 2			4.2
United Kingdom	Belfast	4	Belfast centre	16.9	12.3	4

Re. footnotes: See the full table in Appendix.

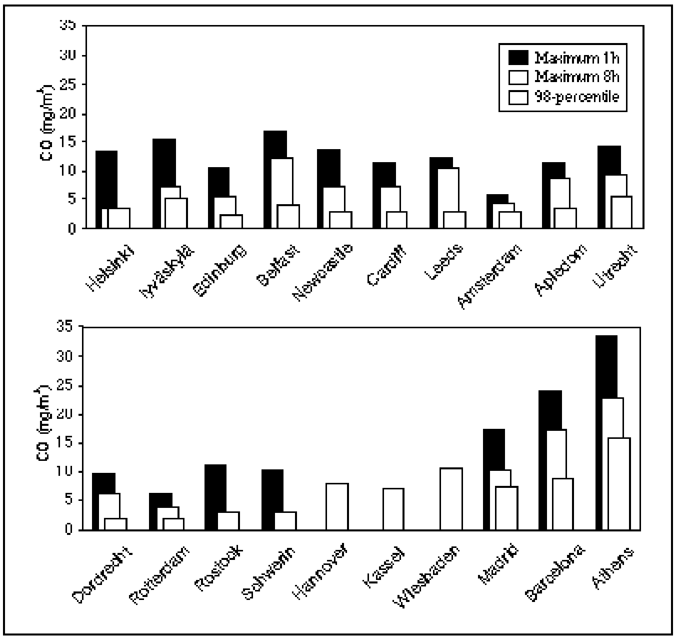


Figure 6.65: Maximum 1 h, maximum 8 h and 98 percentile 1 h CO values for 1993 for selected stations and cities (µg/m3).

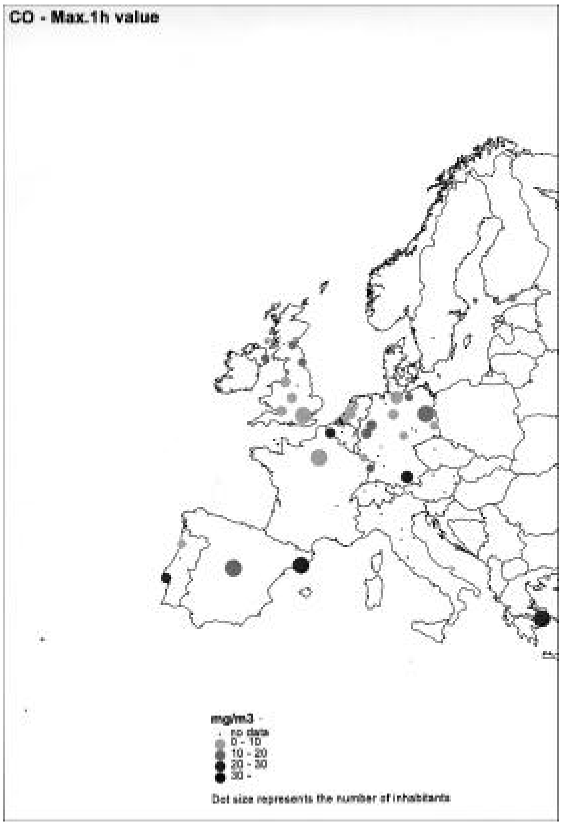


Figure 6.66: CO 1h maximum values in selected cities (µg/m3).

Figure 6.67: CO 8h maximum values in selected cities (µg/m3).

Exceedances

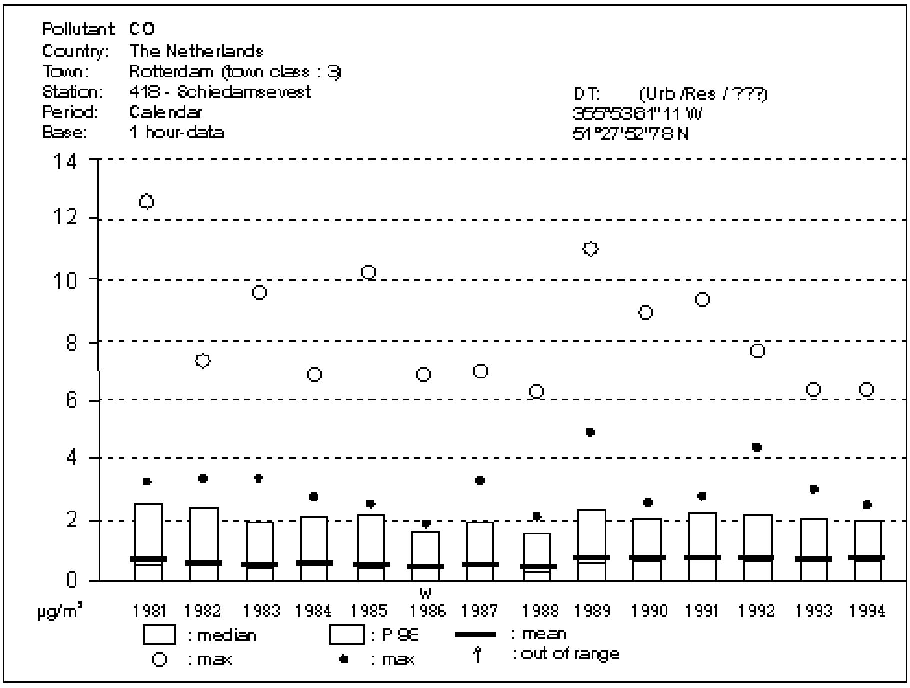
EU has no Limit or Guide values for CO. Table shows stations with exceedances of WHO Guideline values. Exceedances of the WHO Guideline values are reported from Greece, Portugal, Spain and the UK

Table 6.29: Exceedances of WHO Guide Values for CO.

Country	City	Station	**Max. 1h** > 30	**Max. 8h** > 10
Greece	Athens	Patission 147	33.3	22.6
		Pireas Platia Dimotikou		18.1
Portugal	Bar./Seixal	Hospital Velho	32.8	11.9
	Faro	Faro		10.9
	Lisboa	Benéfica	57.1	18.1
	Porto	Fac. Engenharia	38.2	11.4
Spain	Barcelona	Molina Pl.		17.3
	Madrid	Arturo Soria		10.6
		Cuatro Caminos		10.3
United Kingdom	Belfast	Belfast centre		12.3
	Leeds	Leeds centre		10.4

Trends

Trend figures are presented for the Netherlands, Germany (Bremen) and Greece (Figure-Figure). Stations exposed to heavy traffic in Utrecht and Athens show a slightly decreasing trends, except perhaps for maximum 1 h values.



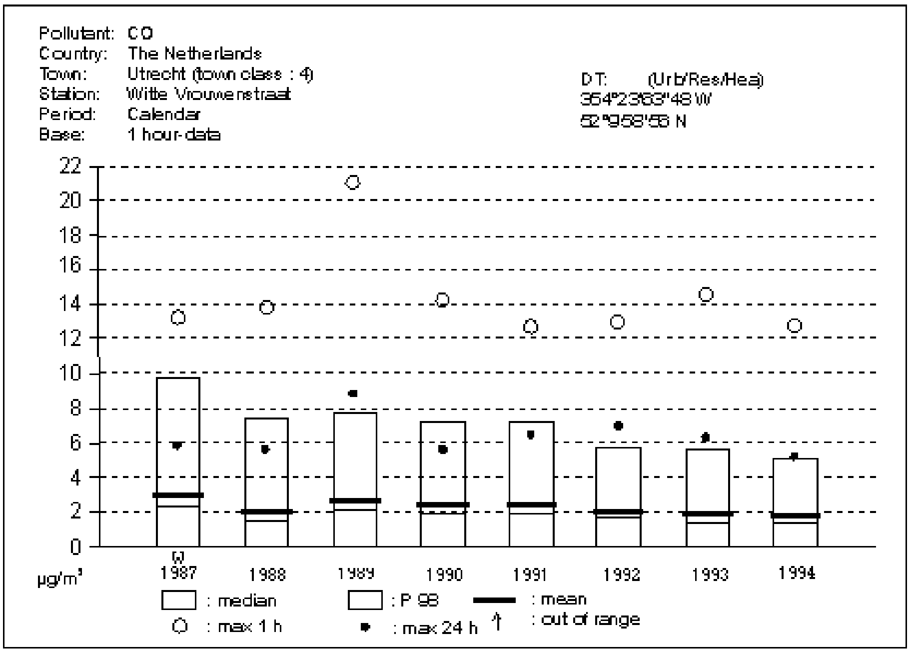


Figure6.68: CO trend in Rotterdam and Utrecht, the Netherlands 1981-1994 (µg/m³). APIS data.

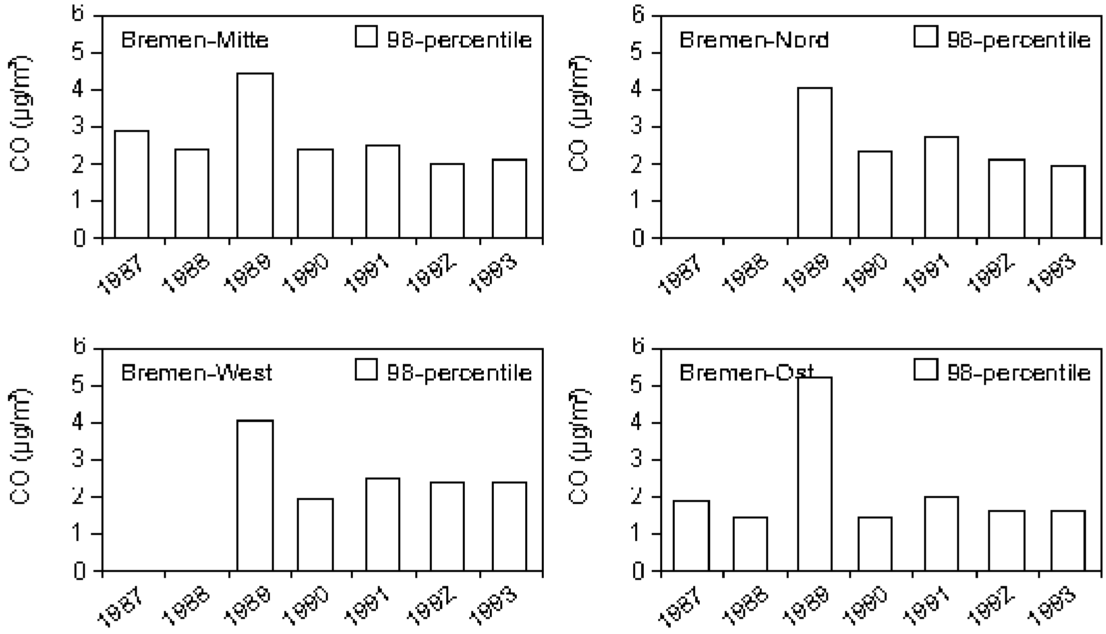


Figure 6.69: CO trend in Bremen, Germany 1987-1993 (µg/m³) 98 percentile 1 h values from Bremen State report.

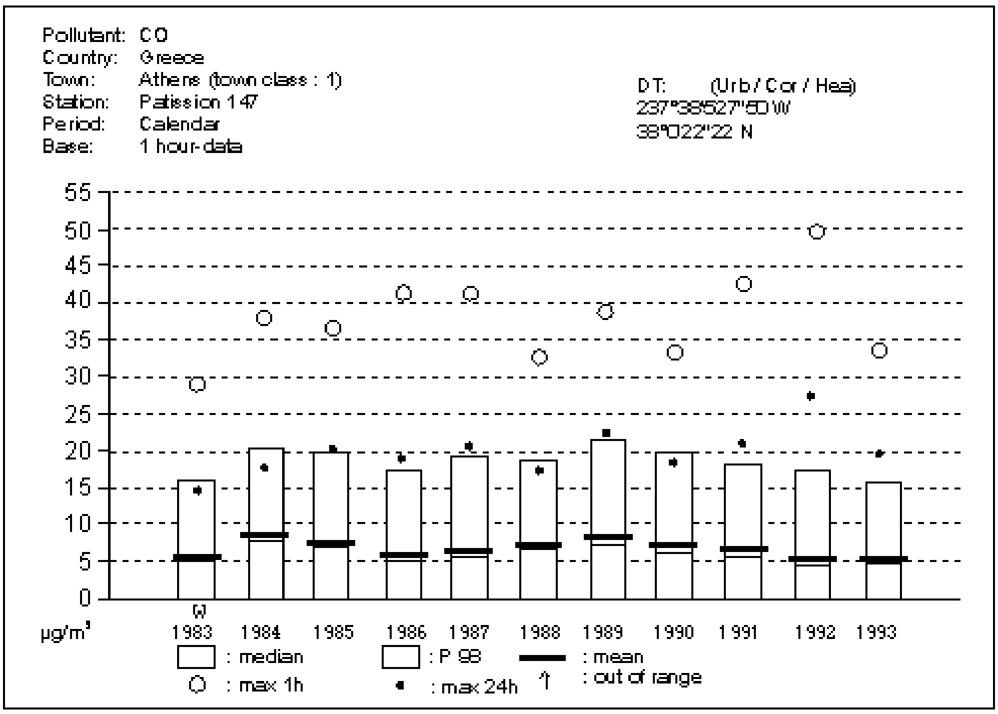


Figure 6.70: CO trend in Greece 1983-1993 (µg/m³). APIS data.

Norsk institutt for luftforskning (NILU)
P.O. Box 100, N-2007 Kjeller - Norway

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European Environmental Agency
Kongens Nytorv 6
DK-1050 COPENHAGEN K
DENMARK

ABSTRACT
Air pollution monitoring data from 21 European countries are summarized, based upon Apis and EoI data and national reports for SO_2, NO_2, black smoke, SPM/TSP/PM_{10}, O_3, CO and Pb. Exceedances of EU Limits, EU Guide Values and WHO Guideline Values are also summarized for each country.

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