European Topic Centre on Air Quality

AIR POLLUTION
BY OZONE IN THE EUROPEAN UNION

Exceedance of Ozone Threshold Values in 1995 and Summer 1996

By

Frank de Leeuw, Rob Sluyter, and Esther van Zantvoort

September 1996

This report was prepared under the supervision of
Gabriel Kielland, Project Manager
European Environment Agency

Cover Design: Folkmann Design and Promotion

Note

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the European Commission or the European Environment Agency concerning the legal status of any country or territory, and the boundaries shown on maps do not imply official endorsement or acceptance.

Cataloguing data can be found at the end of this publication
ISBN 92-9167-074-X

Printed on recycled and chlorine-free bleached paper

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.eu.int
Homepage: http://www.eea.eu.int

TABLE OF CONTENTS

PREFACE

This is a report based upon data collected by the European Commission under Directive 92/72/EEC on air pollution by ozone and presented to the Environment Council in its meeting of October 1996 as two separate reports, one covering the year 1995, the other covering summer 1996. The Commission requested the European Environment Agency to assist in the reporting obligations. The reports were subsequently produced by the European Topic Centre on Air Quality under its agreement with the Agency. In electronic form the separate reports are available at the EEA Homepage on the Internet http://www.eea.dk. A similar report on reported ozone data for the year 1995 was prepared for the Commission to present to the Environment Council in October 1995.

A major achievement with this report has been the timeliness of its delivery. The assessment of ozone episodes in 1996 was based upon data measured only two months earlier, while the usual production time from field measurements to validated assessment reports is rarely less than eighteen months. This has only been possible with the support of the individual contact points within each Member State and the efficient communication established.

The harmful effect of tropospheric ozone on human health and well-being as well as damage to ecosystems is now being recognised as a major concern throughout the Member States of the European Union. The European Community has taken steps to deal with the problem through various Directives including Directive 92/72/EEC on ambient ozone and the Framework Directive 96/62/EEC Directive on ambient air quality assessment and management. The measures necessary to combat pollution is, however, still a responsibility of each Member State and requires political decisions with cost implications and consequences for the development of activities in the society. In this political process basic and reliable information on the extent and severity of the problem is essential.

It is the intention of EEA to continue a yearly reporting and assessment of the ground level ozone situation in Europe in close co-operation with the European Commission and Member States.

Gordon McInnes
Programme Manager

SUMMARY

This report summarises the annual information on exceedances of ozone threshold values during 1995 and gives a first evaluation of the observed exceedances of the thresholds during summer 1996 (April-July). According to the Council Directive (92/72/EEC) on air pollution by ozone, Member States have to provide information on ozone levels (statistical parameters, number and duration of exceedances of specified threshold values) on an annual basis before 1 July of the next year. Additionally, exceedances of the threshold values for population information and warning, as set in the Directive, must be reported to the Commission within one month after occurrence. The analysis presented in this report is based on information for the year 1995 and summer 1996 as far as it was available before 6 August 1996.

The following conclusions are reached:

- Ozone monitoring data for the year 1995 was received from 858 stations within the 15 EU Member States. The quality and quantity of the information supplied by the Member States for 1995 have strongly improved compared to 1994. The preliminary data received for the first four months of Summer 1996 indicate a further increase in the number of operational ozone monitoring stations to a total of 1012 stations.

- Spatial coverage and documentation on monitoring data quality need improvement. Depending on the local situation, the ozone monitoring stations are characterised as rural, urban, street or other (e.g. industrial). The present subset of rural stations is not representative for the land area of the EU: the subset is estimated to cover only 40-50%. The geographical coverage of the rural stations is rather adequate in North West Europe but in other regions gaps are noted. The subset of urban stations is insufficient to estimate the exposure of the population living in cities with more than 25 000 inhabitants: the urban stations cover at 30-35% of the urban population.

- The threshold for warning of the public (360 µg/m^3 as hourly averaged concentration) was exceeded at one station (Coimbra, Portugal) in 1995. During Summer 1996 the threshold was exceeded at three stations: at two stations in Athens (Greece) on 21 May 1996 and at one station in Firenze (Italy) on 13 July 1996.
  Exceedances of the threshold for information of the public (180 µg/m^3 as hourly averaged concentration) were reported for 1995 by all Member States with the exception of Finland. During April-July 1996 this threshold was exceeded in all Member States except Ireland. The number of days on which at least one exceedance was observed ranged from one in Denmark to 41 in France. 48% of all stations reported one or more exceedance.
  For Summer 1996 an initial estimate was made of the percentage of the urban population which was exposed to at least one exceedance of the population information threshold. From all the cities in which at least one monitoring station was operational, 44% (142 cities) reported one or more exceedances. Thirty-one million people (46% of the population in cities with monitors operational) may have been exposed to these exceedances.

- In 1995 the threshold value set for the protection of human health (110 µg/m^3 as 8-hourly averaged concentration) is exceeded substantially and in all Member States. The subset of urban stations is assumed to give representative values for the exposure of an urban population of *c.* 58 million people. 78% of this population is exposed to ozone levels exceeding the threshold during at least one day; 9% is exposed to exceedances during more than 50 days. On average the EU city population is exposed to concentrations above the threshold during 1-2 consecutive days. Maximum episode lengths of 5-8 days were reported.

- The threshold value of daily average concentrations (65 µg/m^3) set for the protection of vegetation is exceeded substantially (by up to a factor 3), widely (in all reporting Member States) and frequently (several Member States report exceedances during more than 150 days at some of their stations). In less than 1% of the area for which the subset of rural stations report representative values, this threshold value is not exceeded; exceedances during more than 150 days are estimated for more than 27% of the area.
  The threshold value of hourly average concentrations (200 µg/m^3) is exceeded largely and widely (reported by 14 Member States) on a limited number of days: in 13% of the mapped area exceedances during more than 5 days are reported.

- For four Member States the percentile values observed in the period 1989-1995 were received. A preliminary analysis indicates that no significant trend in percentile values was observed in this seven year period.

EXCEEDANCE OF OZONE THRESHOLD VALUES IN THE EUROPEAN COMMUNITY IN 1995
Summary based on the information reported in the framework of the Council Directive 92/72/EEC on air pollution by ozone

Report to the Commission by the European Environment Agency
European Topic Centre on Air Quality

Frank de Leeuw
Esther van Zantvoort

September 1996

1. INTRODUCTION

In view of the harmful effects of photochemical pollution in the lower levels of the atmosphere, the Council adopted in 1992 the Directive 92/72/EEC on air pollution by ozone. The Directive came into force on 21 March 1994. It established procedures for harmonised monitoring of ozone concentrations, exchanging of information, communicating and alerting the population regarding ozone and to optimise the action needed to reduce ozone formation.

Article 6 of the Directive specifies how the information on monitoring results must be provided by the Member States to the Commission. Regarding the time frame, two main types of reporting can be distinguished. Information on exceedances of the so-called information threshold (article 6 sub 2) and warning threshold (article 6 sub 3) for the ozone concentration is to be provided shortly after occurrence. Information on the results for a complete calendar year must be provided within six months following the annual reference period (article 6 sub 1). Article 7 of the Directive stipulates that the Commission shall at least once a year evaluate the data collected under the Directive. The present report is the second report of the European Environment Agency (EEA) on annual data received by the Commission; it gives an overview of ozone monitoring results of 1995. An overview of the 1994 annual data has been prepared by the European Topic Centre on Air Quality (de Leeuw *et al.*, 1995; van Zantvoort and Sluyter, 1996).

Following article 7 of the Directive, the Expert Group on Photochemical Pollution was established by the Commission. This group convenes several times per year to coordinate the work within the Member States and the Commission in the framework of the Directive.

The data reported here does not cover all ozone monitoring stations in the European Union. For inclusion in this report, the data must satisfy certain criteria stipulated in the Directive, concerning inter alia measuring methods, sampling methods, station siting, quality assurance and documentation. Formats on the transfer of data have been defined by the Expert Group.

Prior to the current report an overview on ozone threshold exceedances during Summer 1995 (May-July) was presented at the Council meeting of October 1995 (EC, 1995). Background information on the current experience and knowledge concerning the problem of photochemical air pollution, dealing in particular with the phenomenology of ozone, the scientific understanding, as based on experiments and theory, and the insights from modelling studies on the relation between ozone levels and precursor emissions may be found in Borrell and Van den Hout (1995) and Derwent and Van den Hout (1995) and Barrett and Berge (1996).

2. DATA REPORTING

2.1 Introduction

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 value of 1h- and 8h- average concentrations;
- the number, date and duration of periods during which threshold values as presented in Table 1 are exceeded and the maximum concentrations recorded during each occurrence.

In addition to this annual report, Member States must inform the Commission on a monthly basis in case exceedances of the information and warning threshold values are observed. In this report only data reported on an annual basis will be considered.

Table 1. Threshold values for ozone concentrations (in $\mu g/m^3$)

Threshold for:	Concentration	Averaging period
Health protection	110	8 h
Vegetation protection	200	1 h
Vegetation protection	65	24 h
Population information	180	1 h
Population warning	360	1 h

A group of experts from the Members States has followed the practical implementation of the Directive. Among other items this group discussed procedures for data reporting. The formats for information and data exchanges were defined in the document "Council Directive 92/72/EEC on air pollution by ozone. Information and data exchange/formats", Doc.Rev. 11/243/95. In general terms, the requested information consists of two parts:

1. information on stations and measurement techniques (Ozone Directive, article 4.2, indents 1 and 2);
2. information on ozone concentration: annual statistics and threshold exceedances (Ozone Directive, article 6.1).

Based on the experiences in processing the data for the 1994 annual report, the European Topic Centre on Air Quality (ETC-AQ) provided remarks concerning data transmission and suggestions for improvement which were discussed in the Expert Group on Photochemical Pollution. Considering the increasing amount of data requiring processing, and in order to improve the transfer of data relative to the implementation of the Directive, the Commission has prepared an update (April 1996) of the data exchange format. With respect to the transfer of 1995-data, the major changes concern the transfer of additional information:

- type of station: definition of the location of stations as recommended in the draft decision on exchanges of information;
- altitude of stations as recommended by the Expert Group;
- NO_x and VOC data, according to Annex 2.3 of the ozone directive;
- file names: it is recommended to define unique names for all files in order to improve the management and transfer of the data files.

2.2 Data handling

According to the Directive the requested information should have been forwarded to the Commission before 1 July 1996. On 6 August 1996 data from all Member States had been received by DGXI and forwarded to the European Topic Centre on Air Quality (ETC-AQ).

In this report the definition of the data formats as described in the above mentioned document Doc.Rev. 11/243/95 and its April 1996 amendment is used as a reference. If necessary, files were converted at the ETC-AQ for further processing.

After processing the data and calculating various exceedance statistics, the ETC-AQ prepared for each Member State tables as presented in Annex I. The Member States were requested to check these data tables and make annotations if necessary. In case information was lacking, these items were marked and the Member States were requested to provide the missing information. Member States were informed on problems encountered while processing the data. Annotations and additions to the data received before 19 August have been incorporated in this report. Feedback with Spain (incorrect address of contact person) and Italy (data was received too late by the ETC-AQ) failed.

An overview of the data received is presented in Table 2. For 1995 information on ozone concentrations (annual statistics and/or exceedance information) was received for 858 monitoring stations; in 1994, information was received for about 770 stations. For nearly all stations information was submitted on measurement methods, instruments and on calibration procedures. The location of the stations and a description of the immediate and local environments of the monitoring station is less completely available. For Portugal information on 8-hourly average concentrations is lacking. Information on station characteristics (classification, information on immediate environment) is missing for France.

Information on NO_x concentrations was received from 6 Member States; 7 Member States reported on NO_2 concentrations. Information on Volatile Organic Compounds (VOC) was reported by two Member States.

Although fewer problems in data handling were encountered during the preparation of this report compared to the 1994-annual report, a number of remarks and practical suggestions to further optimise the quality of data transmission can be made (see Annex III).

Table 2. Overview of data received by ETC-AQ. For each item the number of Member States and the total number of stations for which data was submitted, are indicated.

Parameter	**Number of Member States**	**Number of stations**
Statistics / percentile values	15	844
Number of exceedances of threshold values	15	812
Longitudinal and latitudinal coordinates	15	855
Surroundings: information on immediate environment	14	745
Information on measurement method	15	831
Information on calibration method	14	720
Type of station (urban, rural, street or other)	14	725
Altitude of the station above sea level (in meter)	15	815
Town where the station is located.	15	832
NO_x statistics	6	97
NO_2 statistics	7	124
VOC statistics	2	11

3. SUMMARY OF REPORTED DATA FOR 1995

The location of monitoring stations used for the implementation of the ozone directive and reporting during 1995 is presented in Map 1. In total information for 858 stations was received. All Member States use the reference method (UV absorption) as prescribed in Annex V of the Ozone Directive, however, at a limited number of stations chemiluminescence is used.

A summary of the maximum concentration measured at any of the reporting stations when exceedance[1] of a threshold value is observed is presented in Table 3. When no exceedances of a threshold was reported, this is indicated with a dash (-).

Exceedance of the threshold value of 360 μg/m^3 for hourly values was observed at one station only:

Country	**Station name & city**	**Date, time**	**Max. conc. (μg/m^3)**
Portugal	Coimbra	26 April 1995, 4.00	365

This exceedance was observed in a period during which exceedances of the 180 μg/m^3 threshold were not reported at any other station in the EU. An explanation of this exceptional level (e.g. local ozone formation, intrusion of stratospheric ozone or malfunc-tioning of the monitoring system) cannot be made without further information on local conditions at the time of exceedance. This study is currently being carried out by Portugal.

As the number of monitoring stations differs widely from country to country, the absolute number of exceedances is less suitable for comparison. Therefore, the concept of "occurrence of exceedances" is introduced here. Occurrence of exceedances is defined as the averaged number of observed exceedances per country, that is, the total number of exceedances summed over all the stations of a country divided by the total number of reporting stations. A summary of occurrence of exceedances is presented in Table 4. Full details on the number of exceedances at the individual stations are presented in Table I.1 of Annex I[2].

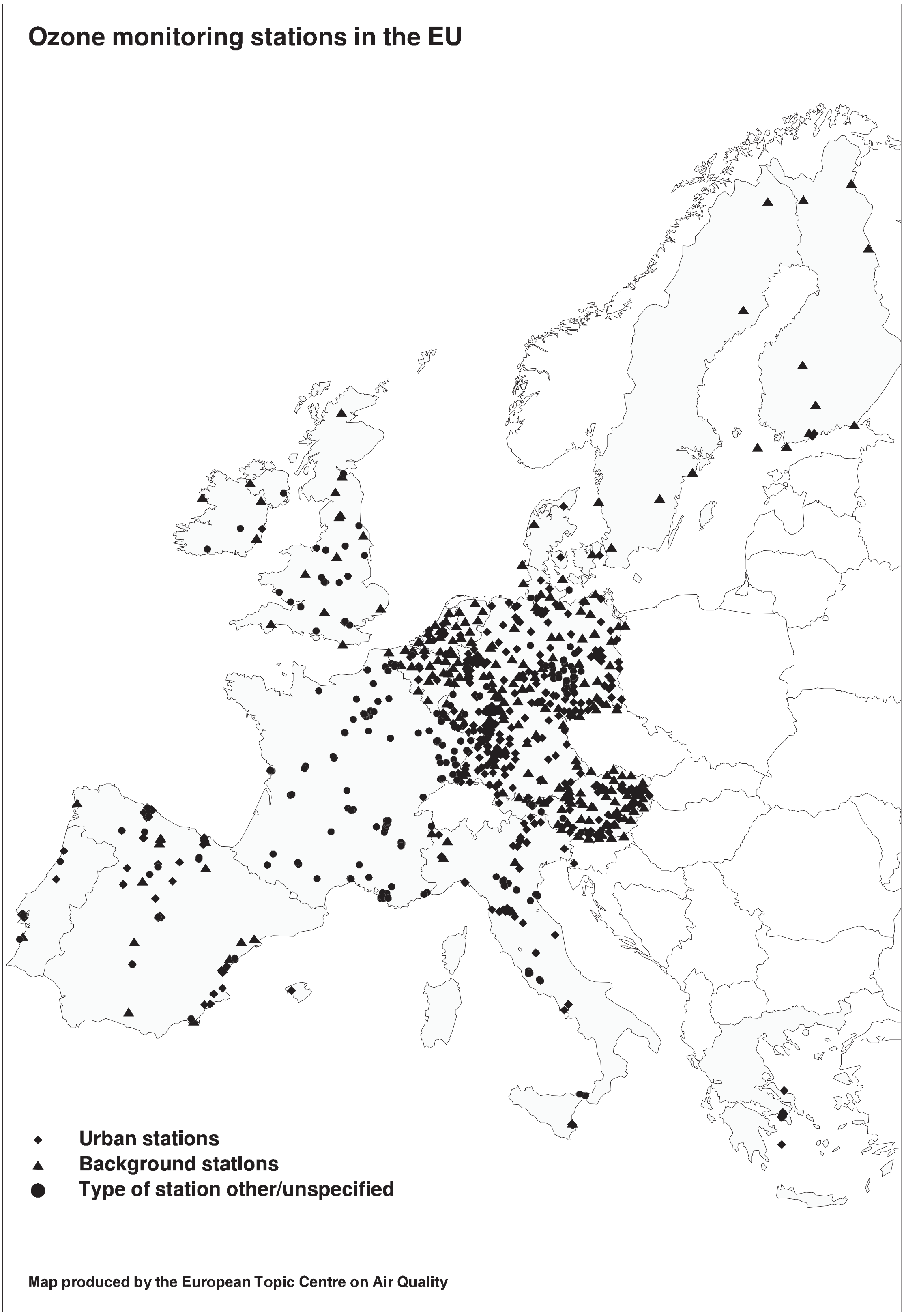
The longest period of consecutive days on which thresholds were exceeded and the average length of an exceedance period are presented in Tables I.2 and I.3 of Annex I.

For each of the Member States the lowest and highest 50-, 98- and 99.9-percentile values observed at individual stations with a data-coverage of 75% or more, are presented in Table 5. In this table, information on the maximum values is also included. Note that the maximum 8-hourly concentration, as reported in Table 5, is based on a moving average and may therefore differ from the values in Table 3 which are based on fixed 8-hourly periods. Detailed information on the percentile values and maximum concentrations observed at individual monitoring stations is given in Annex I, Table I.4.

---

[1] In this report exceedances are counted on a daily basis, that is, a day on which at least one 1h- or 8h-concentration exceeds the threshold value, is marked as an exceedance.

[2] Annex I is only available in computer readable form. In this report a description of the tables in Annex I is provided. Upon request to the ETC-AQ a diskette containing the Annex will be made available.



Map 1. Location of ozone monitoring stations as reported by Member States in the framework of the Ozone Directive for the reference period 1995.

Table 3. Maximum ozone concentrations (in μg/m³) measured during a period of exceedance of threshold values (reference period 1 January - 31 December 1995). A dash (-) indicates that no exceedances were observed at any of the monitoring stations in the Member State. A question mark (?) indicates that exceedances are observed but no information on maximum values is available.

	180 1h	**200 1h**	**360 1h**	**110 8h (a)**	**110 8h (b)**	**65 24h**
AT	260	260	-	190	209	166
BE	284	284	-	242	243	187
DE	293	293	-	227	245	203
DK	202	202	-	179	191	142
ES	292	292	-	164	189	155
FI	-	-	-	131	136	122
FR	319	319	-	234	233	177
GB	268	268	-	244	246	205
GR	352	352	-	155	243	142
IE	232	232	-	175	174	143
IT	300	338	-	227	258	175
LU	253	253	-	190	204	167
NL	279	279	-	195	224	143
PT	365	365	365	?	?	173
SE	206	206	-	183	194	140

(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.

Table 4. Occurrence of exceedances (reference period 1 January - 31 December 1995); n.a. = no information available.

		threshold value (μg/m³)				
	number of stations (c)	**180 1h**	**200 1h**	**110 8h(a)**	**110 8h(b)**	**65 24h**
AT	110	1.2	0.3	33.6	38.7	111.3
BE	20	10.6	4.9	24.7	30.4	45.6
DE	342	5.3	2.2	24.4	33.4	73.3
DK	6	1.0	0.3	6.8	11.5	103.8
ES	86	0.5	0.2	11.3	12.9	52.7
FI	11	0.0	0.0	3.5	4.8	116.0
FR	110	3.4	1.4	20.3	20.3	40.3
GB	32	3.1	1.3	10.8	13.8	58.4
GR	10	18.5	10.2	9.9	53.8	103.2
IE	6	2.2	1.0	15.0	14.3	117.5
IT	68	5.5	2.9	22.8	28.9	45.6
LU	5	8.6	2.6	33.0	31.0	77.8
NL	37	6.9	3.7	14.5	25.5	44.5
PT	9	2.3	1.5	n.a.	n.a.	51.9
SE	6	0.3	0.2	10.8	11.3	138.7
EU-15	858	4.1	1.8	22.1	28.3	70.1

(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) note that small differences in the number of stations reporting for each of the threshold levels may occur.

A further discussion on the reported data for 1995 is given in the following chapters. A short comparison between the ozone levels in 1994 and 1995 will be given in paragraph 4.5. Percentile values for previous years (1989-1995) were reported by four Member States and are briefly discussed in paragraph 4.6.

Table 5. Range in reported 50-, 98- and 99.9-percentile values and maximum observed values (based on hourly and moving eight-hourly average concentrations) observed at individual monitoring stations in Member States (in μg/m³), period 1 January - 31 December 1995; n.a.= no information available.

1995	1h-P50		1h-P98		1h-P99.9		1h-MAX	
range	min	max	min	max	min	max	min	max
AT	9	96	88	153	117	201	128	260
BE	27	50	126	167	187	235	214	284
DE	9	92	70	182	113	242	148	293
DK	45	63	104	112	156	183	177	202
ES	11	78	34	141	56	232	62	292
FI	34	70	79	116	100	133	109	147
FR	13	81	70	170	112	265	30	319
GB	14	68	72	160	116	244	28	268
GR	18	59	79	173	101	275	110	352
IE	48	72	100	125	n.a.	n.a.	160	233
IT	7	69	64	179	107	246	95	338
LU	16	62	87	167	149	210	178	253
NL	17	53	86	153	164	232	175	279
PT	10	90	32	137	57	227	81	365
SE	57	67	93	117	115	183	122	206

1995	8h-P50		8h-P98		8h-P99.9		8h-MAX	
range	min	max	min	max	min	max	min	max
AT	13	95	81	148	109	183	119	211
BE	27	55	114	152	168	219	184	251
DE	15	91	62	177	104	232	130	267
DK	45	63	98	107	139	168	164	189
ES	11	77	31	138	47	159	41	188
FI	34	70	74	113	91	131	99	137
FR	14	81	65	155	94	225	28	241
GB	16	68	66	156	102	238	24	252
GR	20	59	72	155	89	223	98	259
IE	47	71	94	120	n.a.	n.a.	145	190
IT	44	44	146	146	n.a.	n.a.	66	244
LU	19	62	77	164	131	200	146	205
NL	19	53	79	140	141	214	156	227
PT	10	91	30	144	54	205	61	226
SE	56	67	90	114	112	171	114	194

4. DISCUSSION

4.1 Geographic coverage of monitoring stations

For 1995 information for 858 stations was received; for nearly all of them (855) geographical coordinates are available. For the interpretation of ozone data it is essential to have an indication of the direct surroundings of the station as the ozone concentration may be strongly influenced by local conditions. For example, the ozone concentrations may be scavenged by locally emitted nitrogen oxides or by enhanced dry deposition as might be the case under a forest canopy; see Annex II for a brief discussion on ozone phenomenology. For 725 stations (85%) information on immediate surroundings is available.

According to the submitted information on station type and characteristics, a distinction between background (or rural), urban, street and other stations has been made, see Table 6. Map 2 shows the location of background monitoring stations. Tentatively, the area for which the measurements at these stations are assumed to be representative is indicated with a circle using a radius of 100 km. This “radius of representativeness” might be different for the various regions in Europe - it might even depend on the wind direction - and should be based on more detailed analysis of the ozone phenomenology at the stations. Although the identification of the background stations is far from complete and the radius of representativeness may differ from the assumed 100 km, Map 2 suggests that the present set of stations covers 40 to 50% of the land area of the EU. As is shown in Map 2 the geographical coverage of background stations is rather adequate in Northwest Europe but in other regions, in particular in France, Italy and Greece, gaps are noted.

Table 6. Classification of ozone stations according to their direct surroundings as rural, urban, or street station; ‘other’ indicates both other station types (e.g. in industrial areas) and stations for which no information of station type is available.

MS	rural	urban	street	other/ unknow n
AT	59	34	12	5
BE	12	7	0	1
DE	95	166	47	34
DK	3	3	0	0
ES	13	6	52	15
FI	9	1	1	0
FR	0	0	0	110
GB	13	2	0	17
GR	0	6	4	0
IE	3	1	0	2
IT	7	33	6	22
LU	2	0	3	0
NL	26	3	8	0
PT	1	1	4	3
SE	6	0	0	0
EU	249	263	137	209

Map 2. Location of background ozone monitoring stations. Tentatively the area for which the ozone measurements might be representative is indicated with a circle with a radius of 100 km.

It has been attempted to quantify the coverage of the monitoring stations for urban areas as is relevant for population exposure. According to information obtained from the Eurostat population database, there are in the EU about 2000 cities with more than 25 000 inhabitants. It is estimated that from a total EU population of *c*. 362 million, *c*. 195 million people live in these cities with more than 25 000 inhabitants. Summation of the number of inhabitants of all the cities in which at least one ozone station is operational and has been reported to the EC in 1995, leads to a total of approximately 58 million, that is, only for 30% of the total urban population (equivalent to 16% of the total EU population) an estimate of ozone exposure can be made.

Although the uncertainties in the present set of station descriptions and the large number of stations for which a description of immediate surrounding is lacking preclude any firm conclusion, clearly the set of urban stations in the national networks is not representative for the total urban population in the EU. Conclusions concerning the exposure of urban population to high ozone levels should therefore be seen as tentative.

4.2 Annual statistics, 1995

The geographical distribution of 98-percentile values calculated on the basis of hourly concentrations is presented in Map 3 for background stations and in Map 4 for urban, street and other stations.

Similar to the observations in 1994 (de Leeuw *et al.*, 1995) the 98-percentiles at background stations in general show low values in the Scandinavian countries, and an increase from northwest to central Europe. In particular for the stations in Austria, the elevated location of the monitoring stations may play a role. For summer 1993 and 1994 similar patterns were estimated from measurements made within the framework of EMEP (Hjellbrekke, 1996). However, the relatively low values observed in the EMEP data over the Iberian peninsula are not fully supported by the present observations which might be caused by differences in year, in averaging period and in set of reporting stations.

For urban and ‘other’ stations (Map 4) no large scale concentration gradient in 98-percentiles is recognised; high values are observed all over the continent. The local conditions (at stations downwind of the urban area relatively high ozone values might be observed whereas at stations with NO_x sources such as traffic in their immediate surrounding relatively low ozone levels will be measured, see Annex II) seems to be more important than European-wide smog episodes. For example, in Athens the observed 98-percentile values of hourly average concentrations ranges from 79 on station Patission to 173 $\mu g/m^3$ on station Marousi. The interaction with (local) NO_x emissions (see also Annex II) is shown in the observed NO_2 concentration: at Patission the highest yearly average NO_2 concentration (95 $\mu g/m^3$) is observed whereas at Marousi one of the lowest NO_2 yearly average was observed (36 $\mu g/m^3$).

The 98-percentile values based on moving eight-hourly average concentrations show a strong correlation with the hourly 98-percentile: on average, 8-h percentiles are about 5% lower, see Figure 1. The geographical distribution of the 8-h percentile values is very similar to the distribution of the 1-h percentile values.

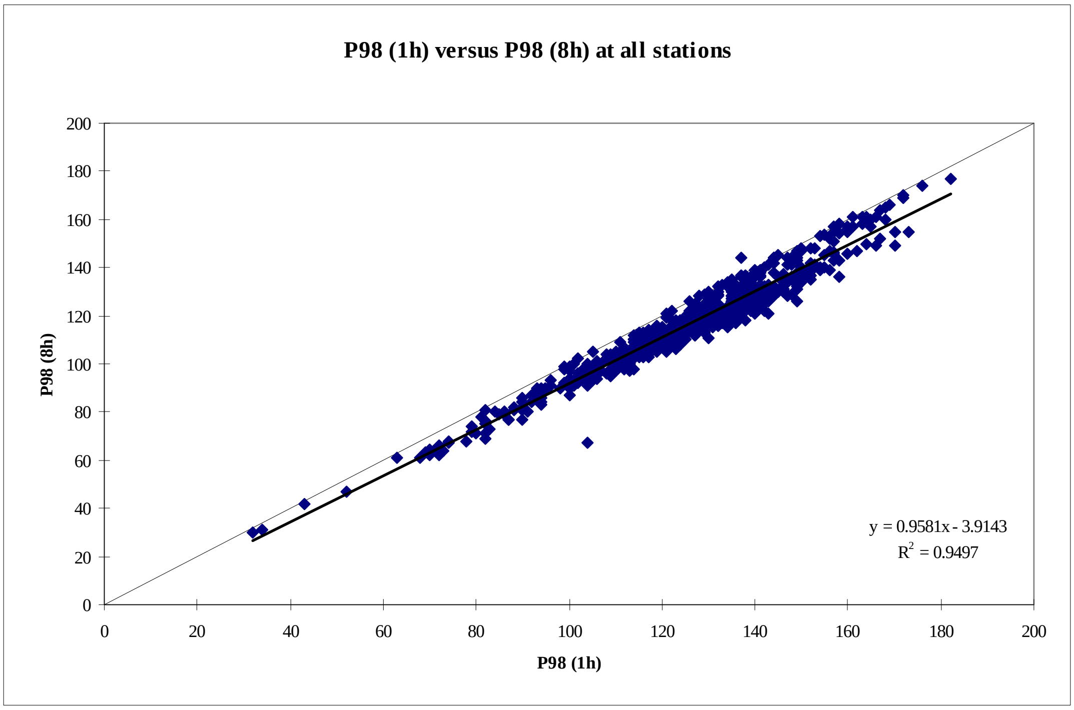
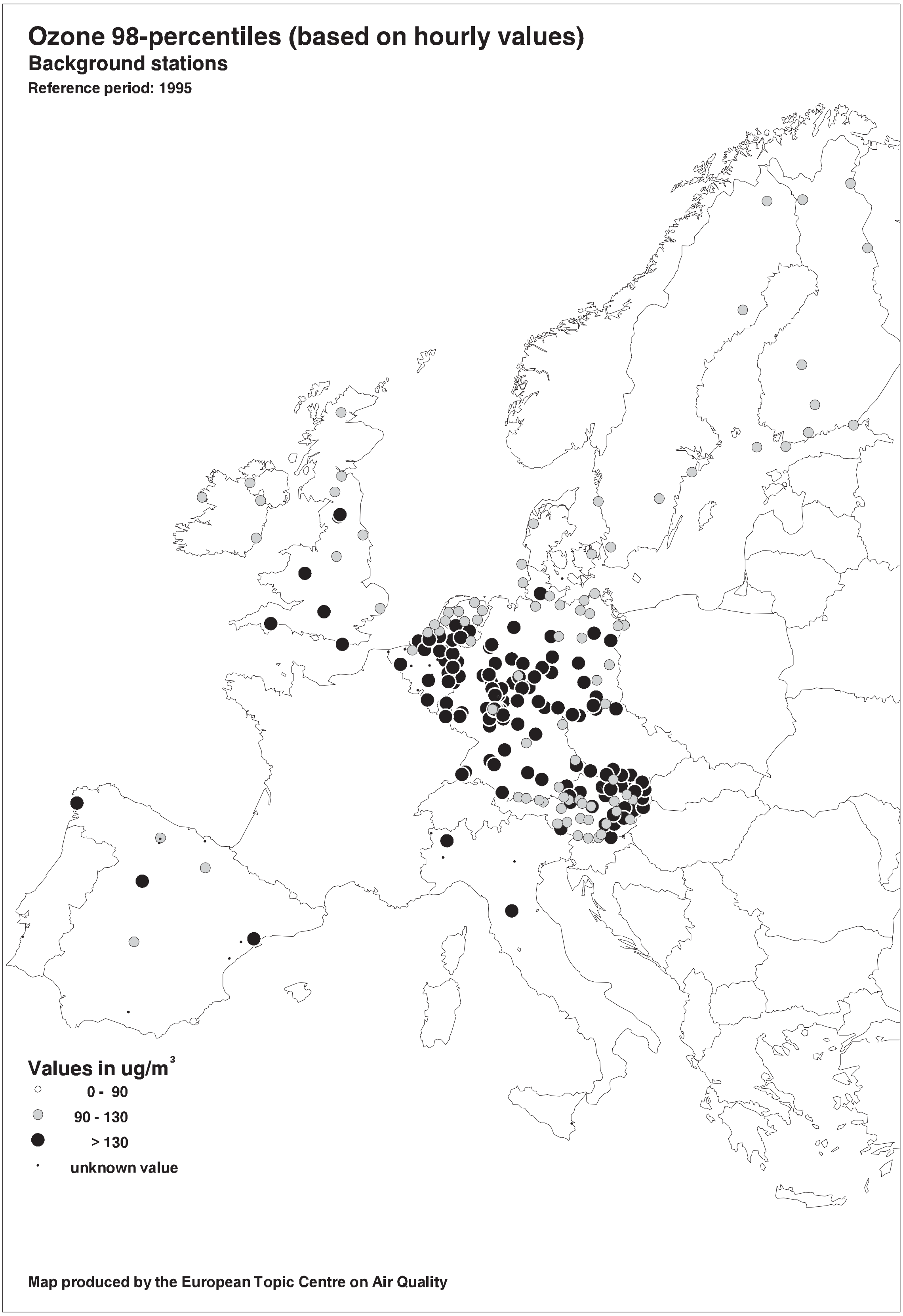
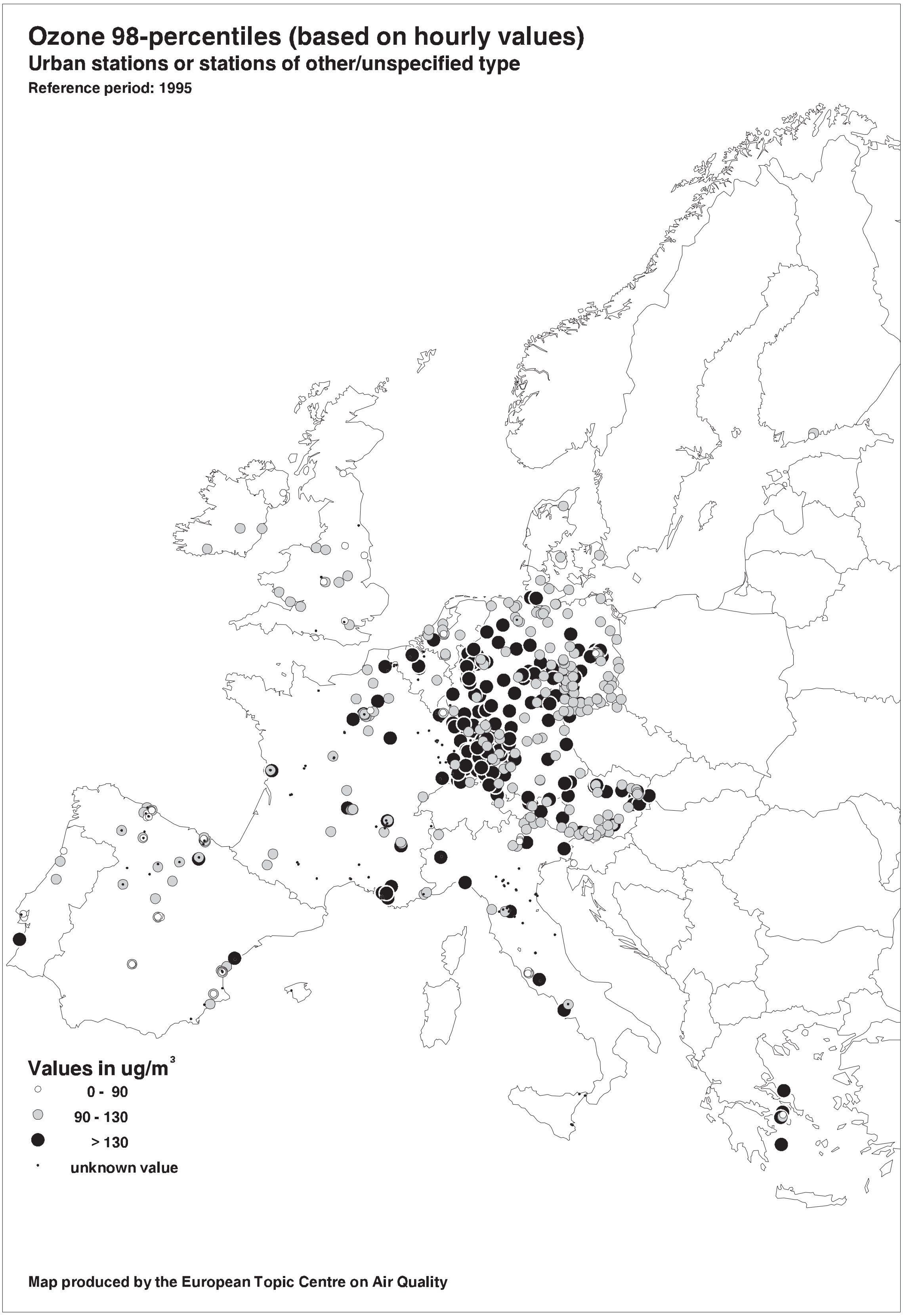


Figure 1. Relation between 98-percentiles values based on hourly concentrations and 8-hourly concentration at all reporting stations (in μg/m³; 1 January-31 December 1995).



Map 3. 98 percentiles (based on hourly concentrations; μg/m^3) measured at background stations, period 1 January- 31 December 1995.



Map 4. 98 percentiles (based on hourly concentrations; $\mu g/m^3$) measured at urban, street and other stations, period 1 January - 31 December 1995.

4.3 Exceedances of thresholds in 1995

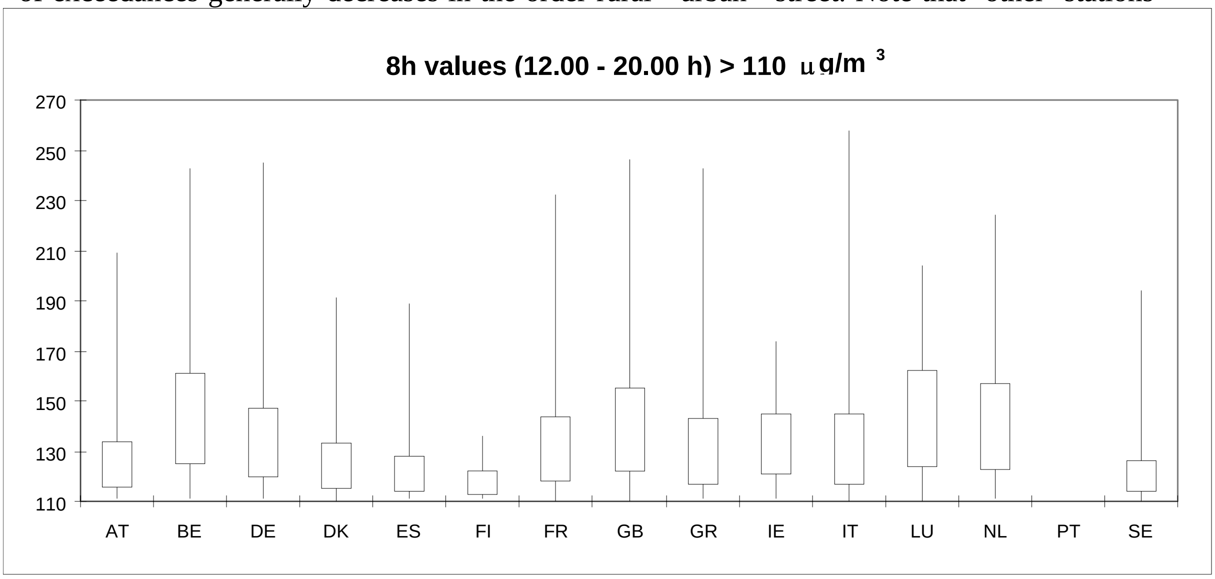
The threshold value for protection of human health (110 μg/m^3) is based on eight-hourly values. According to the Ozone Directive, four eight-hourly periods have to be considered: 0.00-8.00; 8.00-16.00, 16.00-24.00 and 12.00-20.00.

Based on the average diurnal profile of ozone (see Annex II) the highest eight-hourly values are generally expected for the 12.00-20.00 period; only exceedances of the threshold values for this period have been considered here.

In 1995 exceedances of this threshold value were observed in all Member States; for Portugal no information on exceedances is available but according to maximum reported values (Table 5) one or more exceedances must have been observed. In 7 Member States maximum concentrations exceeding twice the threshold value were observed (see Table 3).

Figure 2 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/m^3), the maximum, the 25 percentile and the 75 percentile value of the concentrations during exceedance. Although extreme peaks of more than 200 μg/m^3 are observed in 9 out of 14 reporting Member States, Figure 2 shows that, in each Member State, less than 25% of all exceedance concentrations are above 165 μg/m^3 (that is, 150% of the threshold value).

The geographical distribution of the number of days the threshold value was exceeded is shown in Map 5 for background stations and in Map 6 for urban, street and other stations. A comparison of Map 5 and 6 shows that exceedances are more frequently observed at rural stations. This is also demonstrated more clearly in Figure 3 where for each station type (rural, urban and street stations) the average number of exceedances is plotted. The average occurrence of exceedances generally decreases in the order rural - urban - street. Note that ‘other’ stations



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	4254	607	11429	69	1035	53	1966	441	538	86	1273	155	945	n.a.	68
#st	110	20	342	6	80	11	97	32	10	6	44	5	37	4	6

n.a = number of exceedances not available

Figure 2. Frequency distribution of ozone concentrations (eight-hourly values; period 12.00-20.00) in excess of the 110 μg/m^3-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 Portugal did not allow for inclusion in this figure.

and stations for which the type has not been specified are not presented in Figure 3.

Of the total EU urban population, about 58 million people live in cities with one or more ozone monitoring stations reporting in the framework of the Ozone Directive. The number of days on which this population is exposed to ozone levels exceeding the 110 μg/m^3 threshold values ranges from zero days (for 18% of the population, see Figure 4) to more than 50 days (for 9% of the population). On average the EU city population is exposed to concentrations above the threshold during 1-2 consecutive days. Maximum episode lengths of 5-8 days were reported.

These results should be interpreted with great care. The observations at the present set of urban stations might not be representative for the total urban population; only 30% of the urban population lives in a city “covered” by an ozone monitoring station, and information on urban situation is scarce or even lacking in some member states (in nine Member States the number of operational urban monitoring stations is three or less). Although more quantitative conclusions can not be drawn at this stage, it is likely that a substantial fraction of the urban population is frequently exposed to high ozone levels.

In rural areas the number of exceedances is higher than in urban regions, see Figure 3. It is estimated that in *c.* 90 % of the area for which information is available (see Map 2) the threshold value is exceeded at least on one day in 1995. The fraction of the rural population living in this exposed area can not be quantified as yet.

Exceedances most frequently occur in the summer months (May - August). In the winter months (January-March and September - December) exceedances were observed very occasionally.

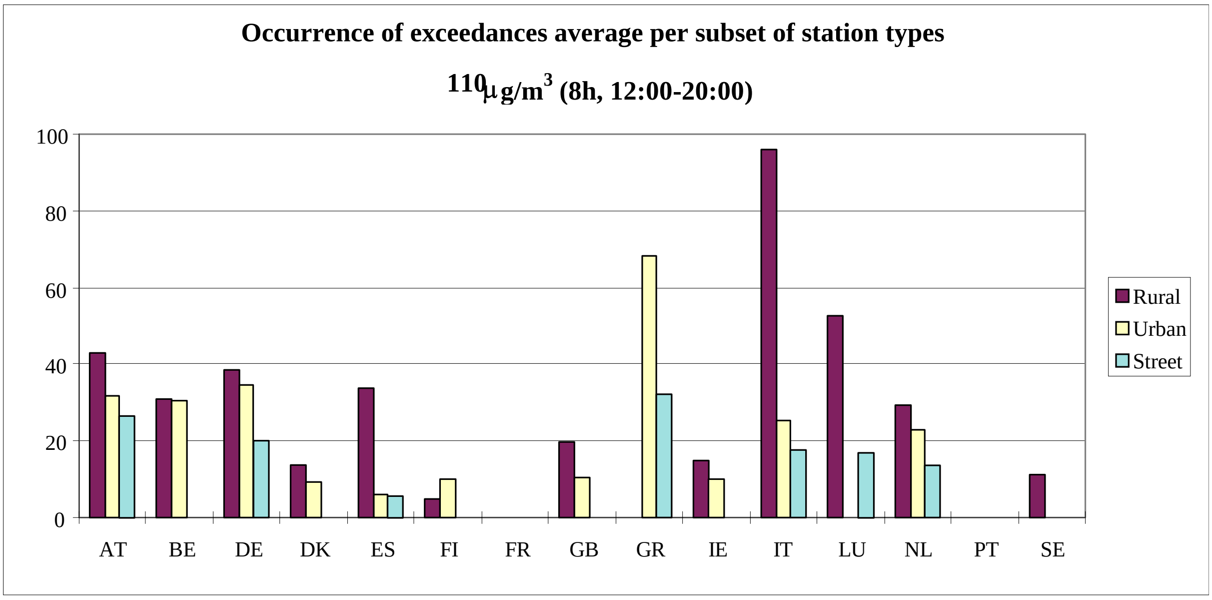


Figure 3. The occurrence of exceedances of the threshold value for protection of human health (110 μg/m^3 for eight-hourly values) average over all reporting rural, urban, and street stations.

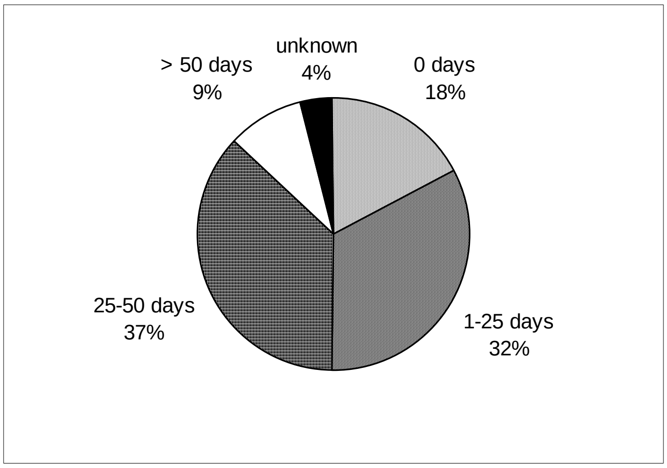
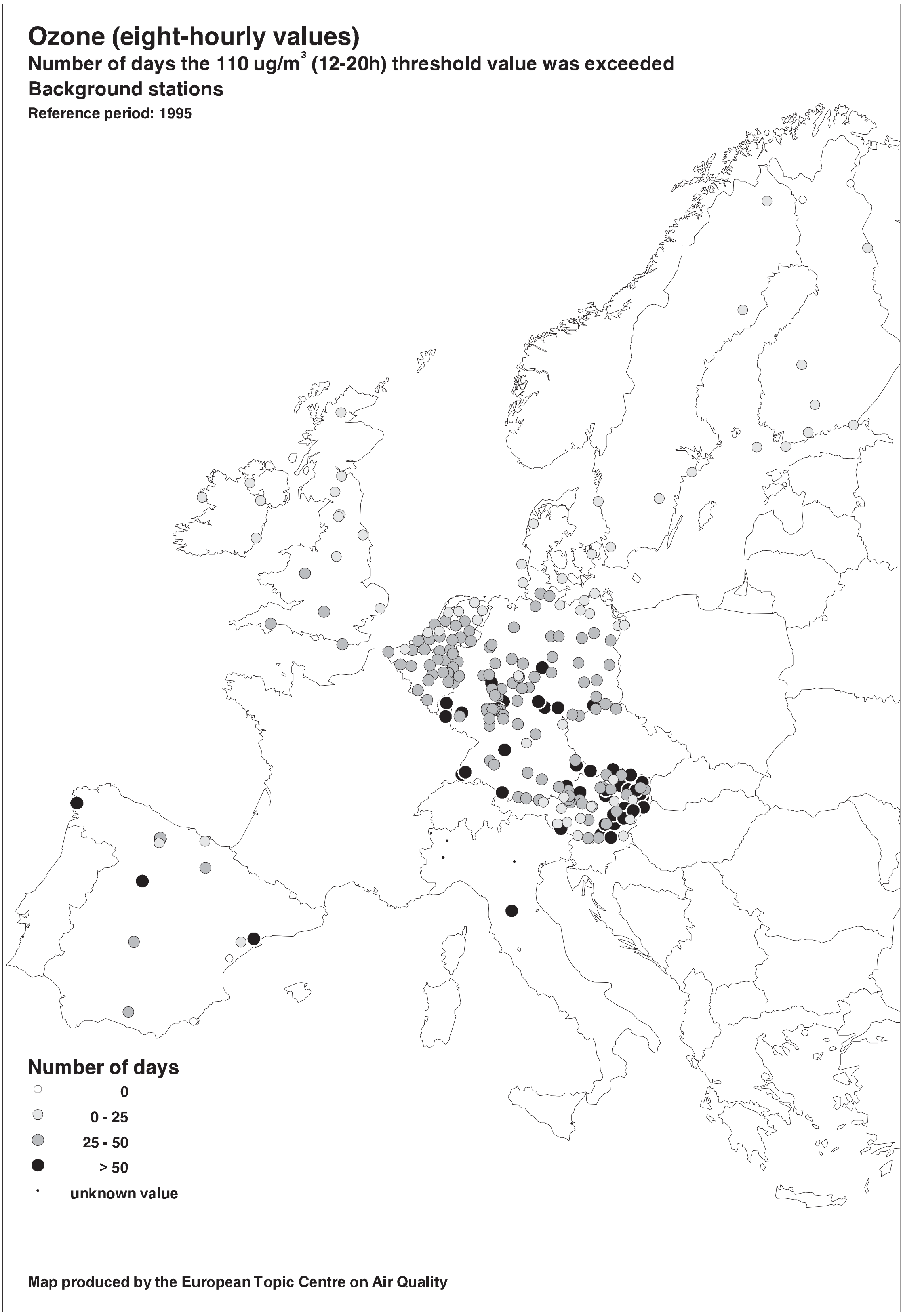
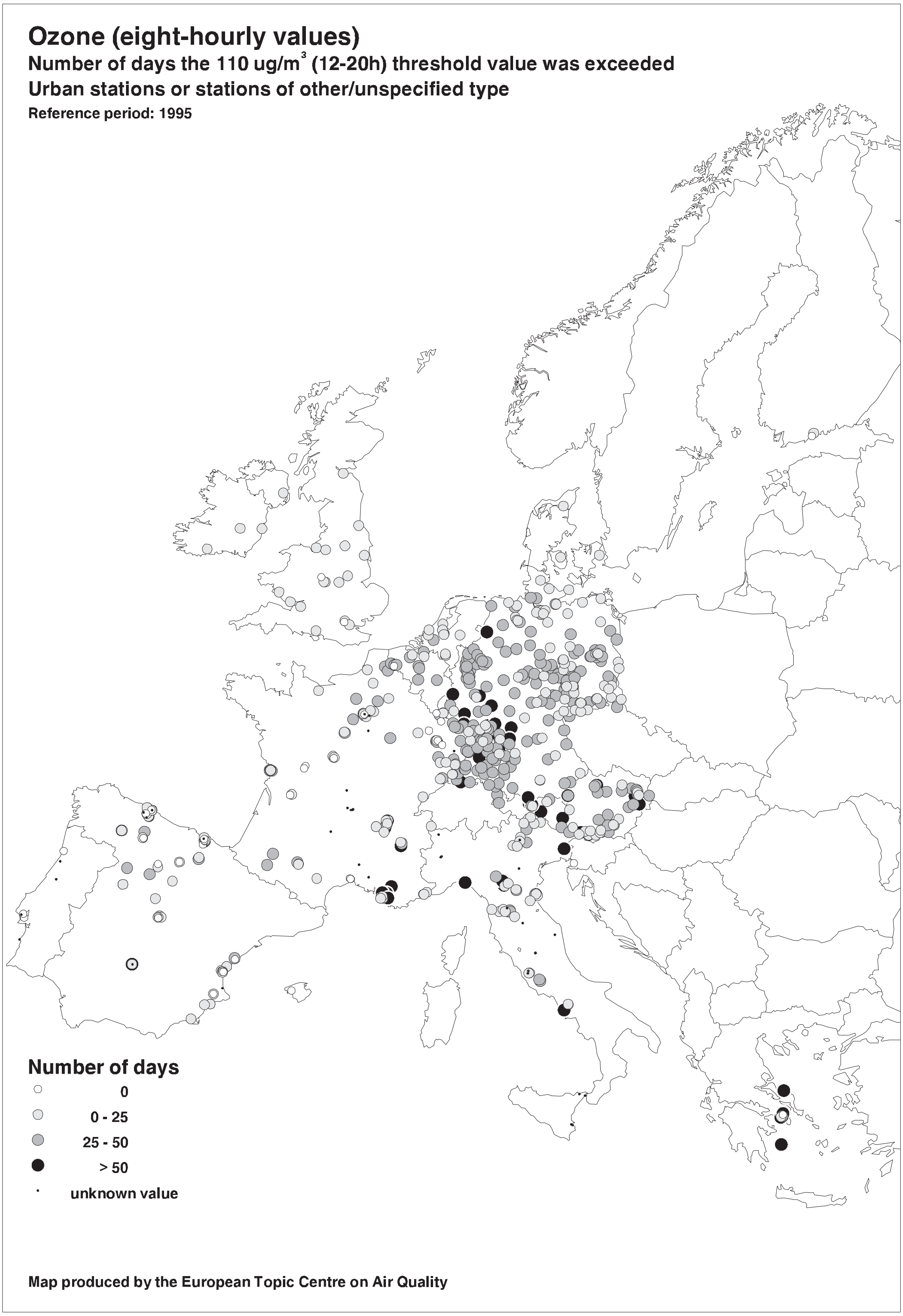


Figure 4. Number of exceedances (in days) and frequency distribution of urban population exposed to eight-hourly concentrations exceeding 110 $\mu g/m^3$, 1 January -31 December 1995. Note that information on ozone exceedances which has been made available within the framework of the ozone directive, is estimated to be representative for a total urban population of 58 million (that is, 30% of the EU population living in cities with more than 25 000 inhabitants and 16% of the total population in the EU).



Map 5. Number of exceedances of the threshold value for protection of human health (110 $\mu g/m^3$ for eight hourly values) observed at background stations; 1 January - 31 December 1995; eight hourly average values for the period 12.00-20.00.



Map 6. Number of exceedances of the threshold value for protection of human health (110 $\mu g/m^3$ for eight-hourly values) observed at urban, street and other stations; 1 January - 31 December 1995; eight-hourly average values for the period 12.00-20.00.
Exceedances of the threshold values for information and warning of the population.

In 1995, the threshold values for warning of the population (360 μg/m^3, hourly value) were exceeded once at the station Coimbra in Portugal, on 26 April. An explanation of this exceedance can not be given.

The geographical distribution of the number of exceedances of the threshold value for information of the public (180 μg/m^3, hourly value) is presented in Map 7 for background stations and in Map 8 for urban, street and other stations. Exceedances are observed in 14 Member States; only in Finland the 180 μg/m^3 level has not been reached. Similar to the exceedances of the threshold values of 8-hourly average concentrations, the threshold values for public information more frequently occur at rural stations than at urban or street stations. For the urban stations an overview of the number of exceedances weighted according to the population of the city, is presented in Figure 5. From these limited data, it seems likely that about 60% of the urban population is exposed to ozone concentrations exceeding 180 μg/m^3 for one or more days.

Figure 6 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, in almost all of the cases the exceedances are less extreme: Figure 6 shows that on 75% of the days on which the threshold value was exceeded, the level of 250 μg/m^3 (that is 150% of the threshold value) was not reached in nearly all Member States.

Exceedances are observed during a large part of the year but occur most frequently and geographically most wide-spread during the summer months. Figure 7 shows the total number of exceedances (summed over all reporting stations) per day. Note that in Figure 7 a large number of exceedances does not necessarily imply a large geographical extent of a smog episode. The differences in spatial density of the monitoring networks in the Member States are so large that there will be no clear relation between total number of exceedances and geographical extent. After four winter months with only occasional exceedances, the first smog episode is observed in the beginning of May (in particular 5-7 May). After a second episode - mainly covering Germany - in the third week of May and a low-ozone period in the beginning of June, there is a two month period with frequent exceedances of the 180 μg/m^3. In September-December only a few exceedances are observed.

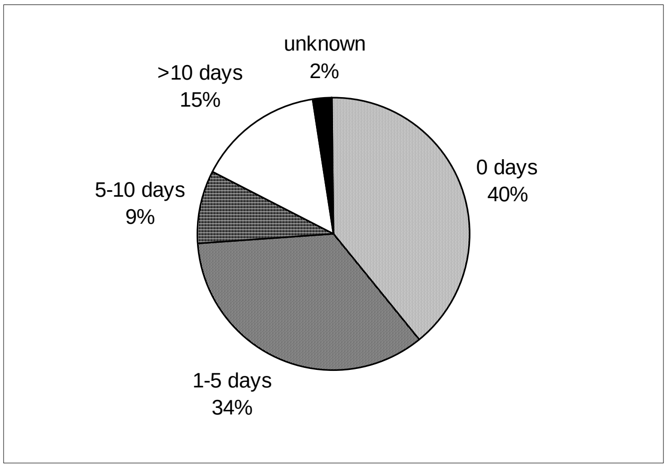
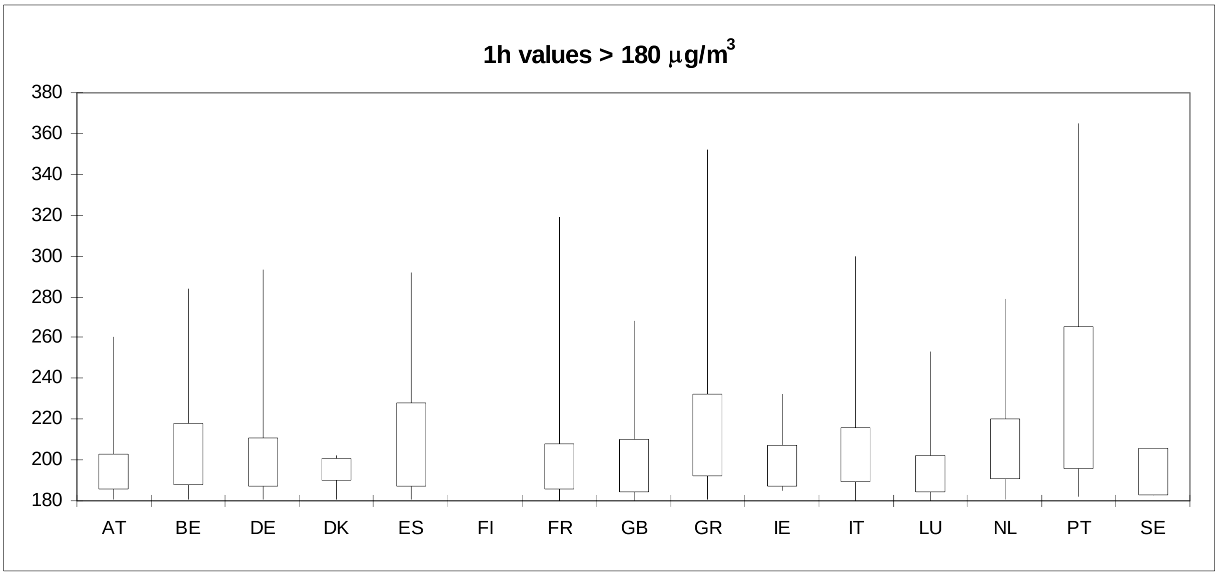


Figure 5. Number of exceedances (in days) and frequency distribution of urban population exposed to hourly ozone concentrations exceeding 180 μg/m^3, 1 January - 31 December 1995.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	128	211	1804	6	40	0	374	99	185	13	295	43	257	18	2
#st	110	20	342	6	86	11	110	30	10	6	54	5	37	8	6

Figure 6. Frequency distribution of ozone concentrations (hourly values) in excess of the 180 µg/m^3 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.

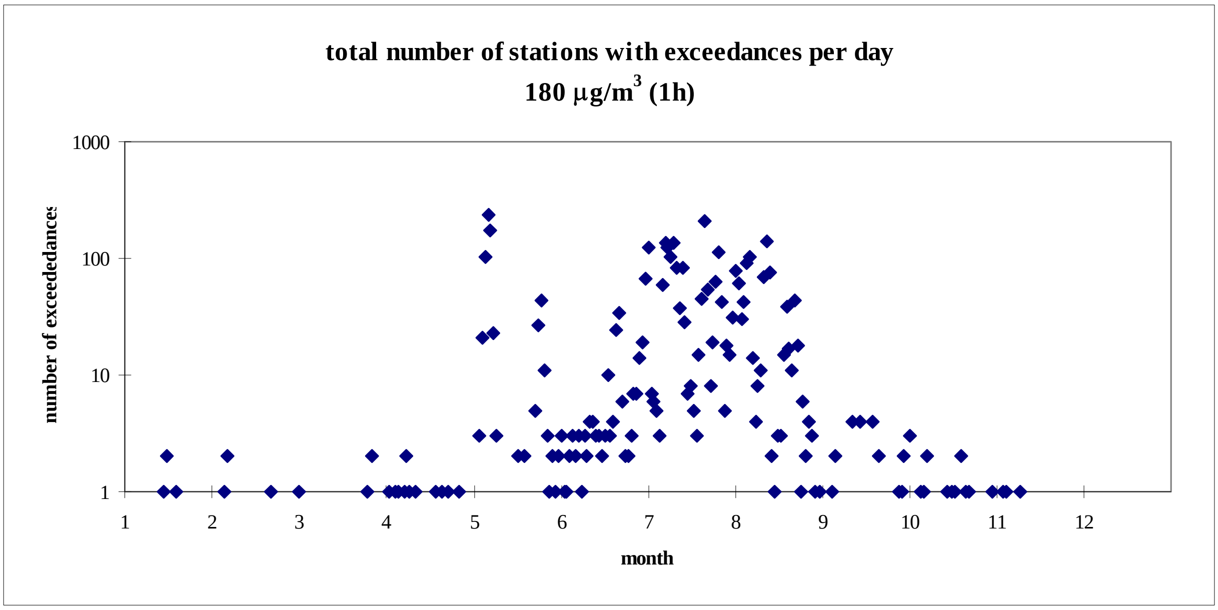
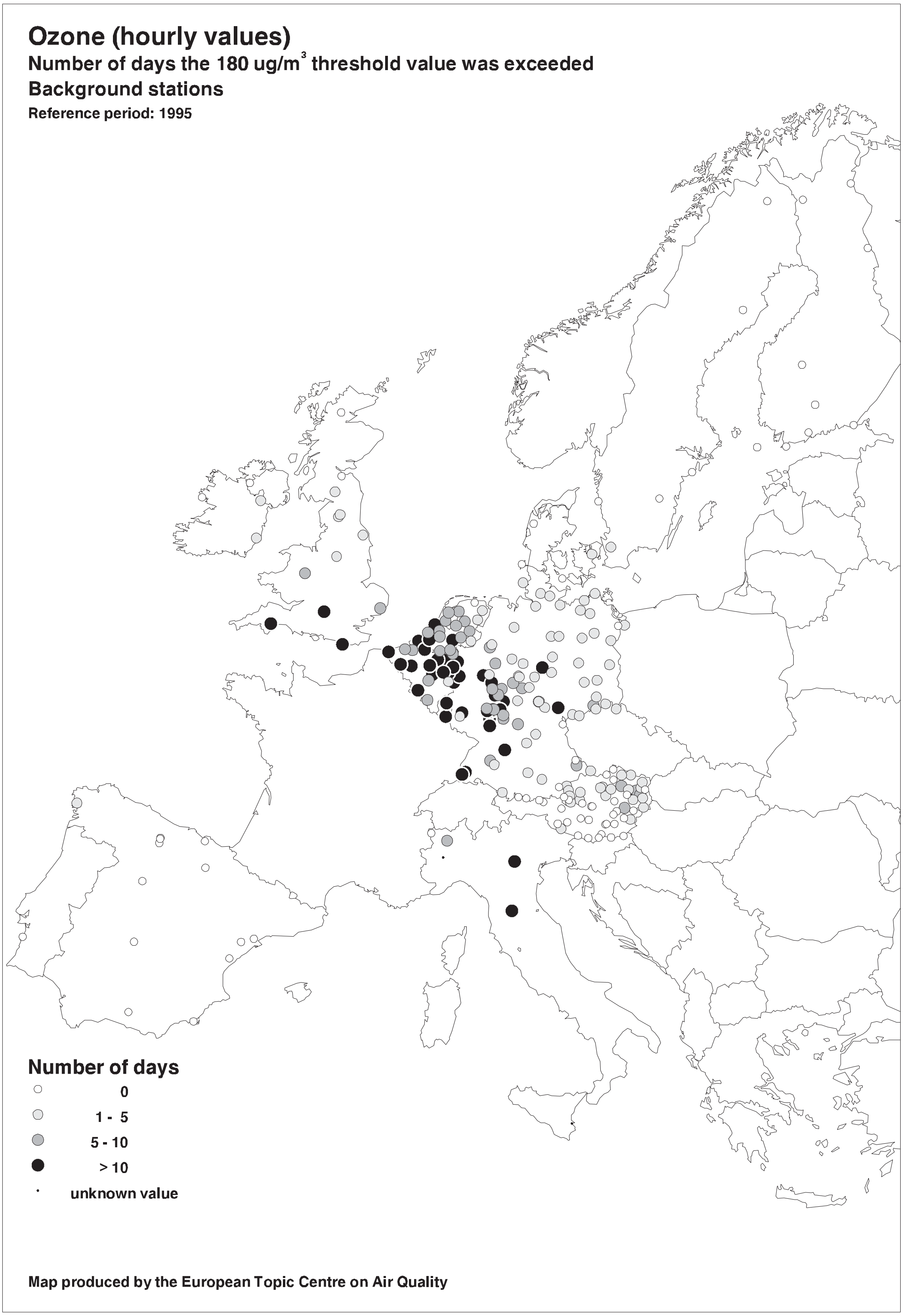
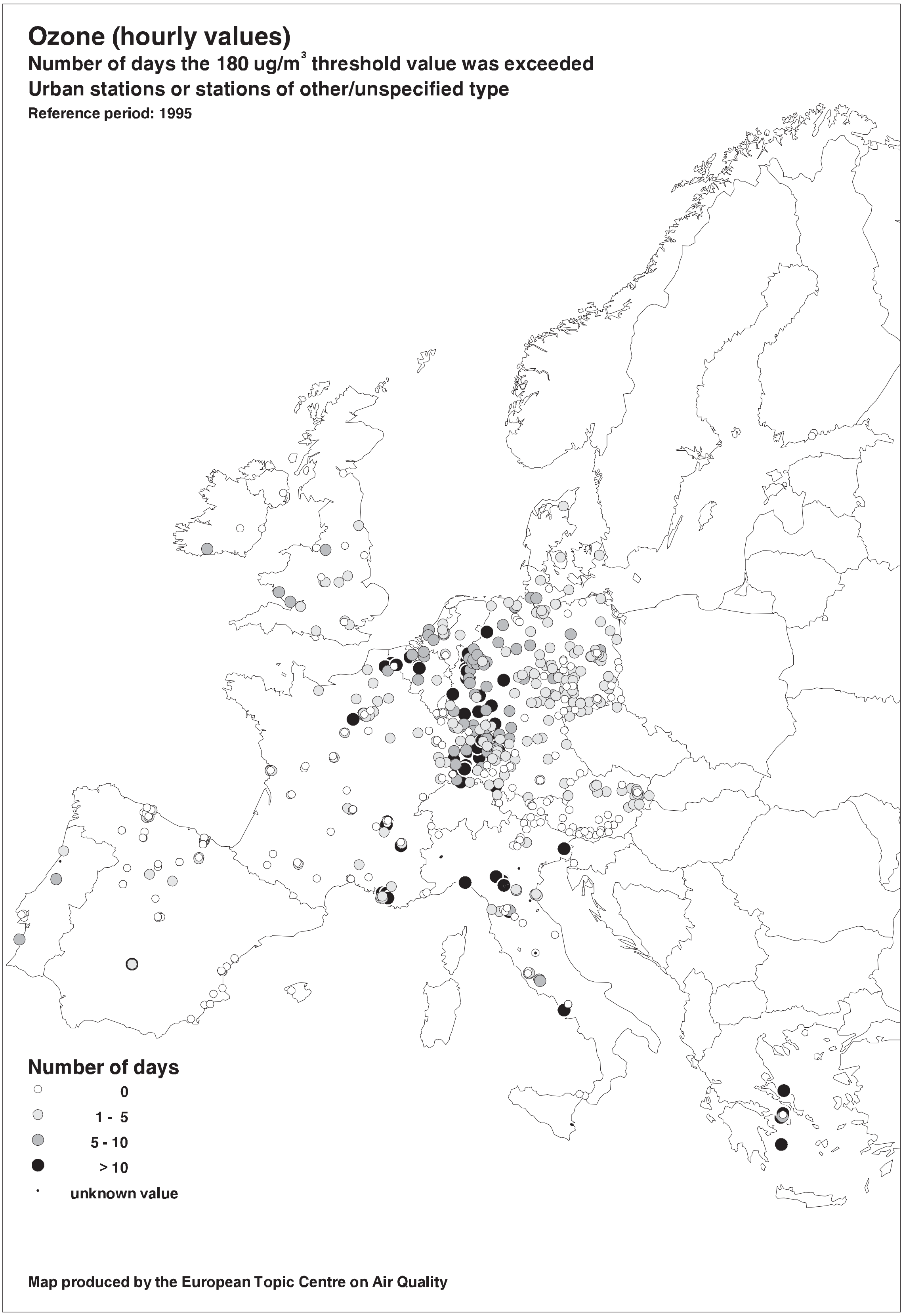


Figure 7. Total number of exceedances (summed over all 858 operational stations) of the ozone threshold value for information (180 µg/m^3); 1 January - 31 December 1995. Note the logarithmic scale.



Map 7. Number of exceedances of the threshold value for information of the population (180 $\mu g/m^3$ for hourly values) observed at background stations;1 January - 31 December 1995.



Map 8. Number of exceedances of the threshold value for information of the population (180 $\mu g/m^3$ for hourly values) observed at urban, street and other stations; 1 January - 31 December 1995. Exceedance of daily threshold value for protection of vegetation

As Table 4 shows, exceedances of the daily threshold of 65 μg/m^3 were observed frequently in all reporting countries. Stations where the threshold was exceeded on more than 100 days in 1995 are located all over the EU. The geographical distribution of the number of exceedance of the daily threshold is presented in Map 9 for the background stations and on Map 10 for the urban and other stations. In Map 9 an attempt has been made to quantify the area where exceedances are observed. For the background stations a representative radius of 100 km is assumed, see also Map 2. When the “representative areas” of two or more stations overlap, the number of exceedances in this location is estimated by a distance-weighted interpolation. In less than 1% of the total area “covered” by the rural stations (1 460 000 km^2) the 65 μg/m^3 level is not exceeded. In 19% of the area the 65 μg/m^3 level is exceeded on 1-75 days and in 74% of the area on more than 75 days. For 6% of the “covered” area no information is available. Exceedances during more than 150 days are reported both by northern and southern Member States (see Map 9).

For exceedances of a daily average concentration the differences between rural and urban stations are more pronounced than is the case for hourly concentrations, see Figure 8. In urban areas the low concentrations during the night (caused by interaction with NO_x emissions) reduce the daily average concentrations; in rural areas the decrease in ozone concentrations during the night is generally less strong.

Figure 9 shows the frequency distribution of daily values in excess of 65 μg/m^3. Although extreme values of more than 200 μg/m^3 are observed, in nearly all Member States (except Luxembourg) for 75% of the exceedances the daily average concentrations falls between 65 and 98 μg/m^3 (that is 150% of the threshold value). Although the exceedances are most frequently observed in the period March to September, see Figure 10, daily values above 65 μg/m^3 are observed in all reporting Member States also during the winter months (January-February and October-December 1995). The low number of exceedances in June is ascribed to the cold and rainy weather conditions in NW Europe; a similar dip in June is found for the exceedances of other threshold values, see Figure 7.

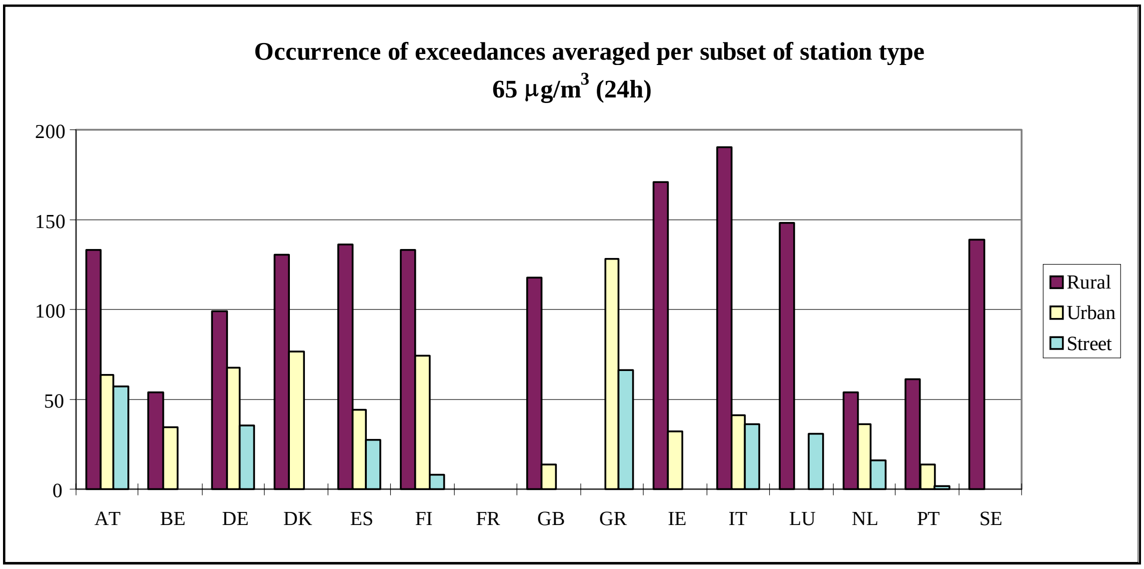
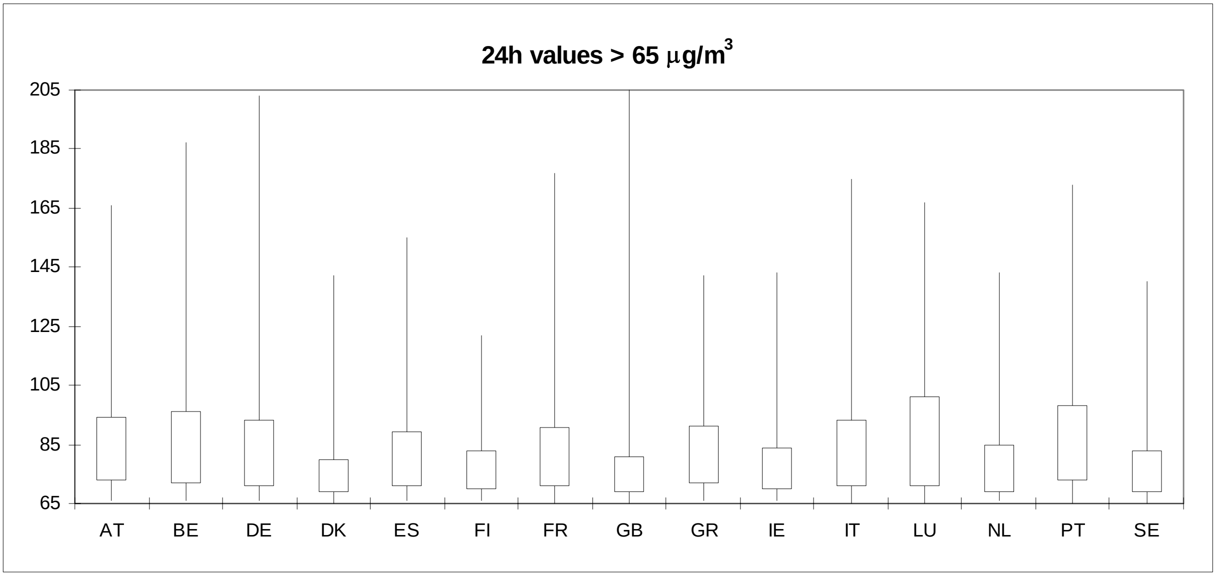


Figure 8. The occurrence of exceedances of the threshold value for protection of vegetation (65 μg/m^3 as daily value) averaged over all reporting rural, urban and street stations.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	12245	911	25052	623	4212	1276	3949	1868	1032	705	2008	389	1646	467	832
#st	110	20	347	6	80	11	98	32	10	6	44	5	37	9	6

Figure 9. Frequency distribution of ozone concentrations (24h values) in excess of the 65 µg/m³ threshold for daily 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.

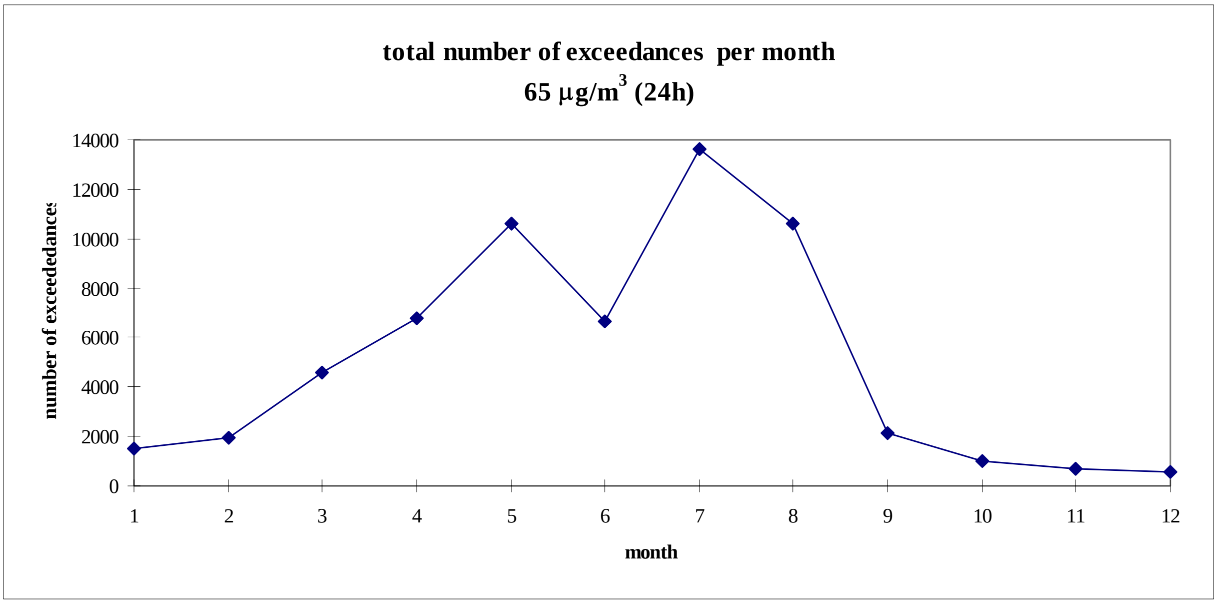
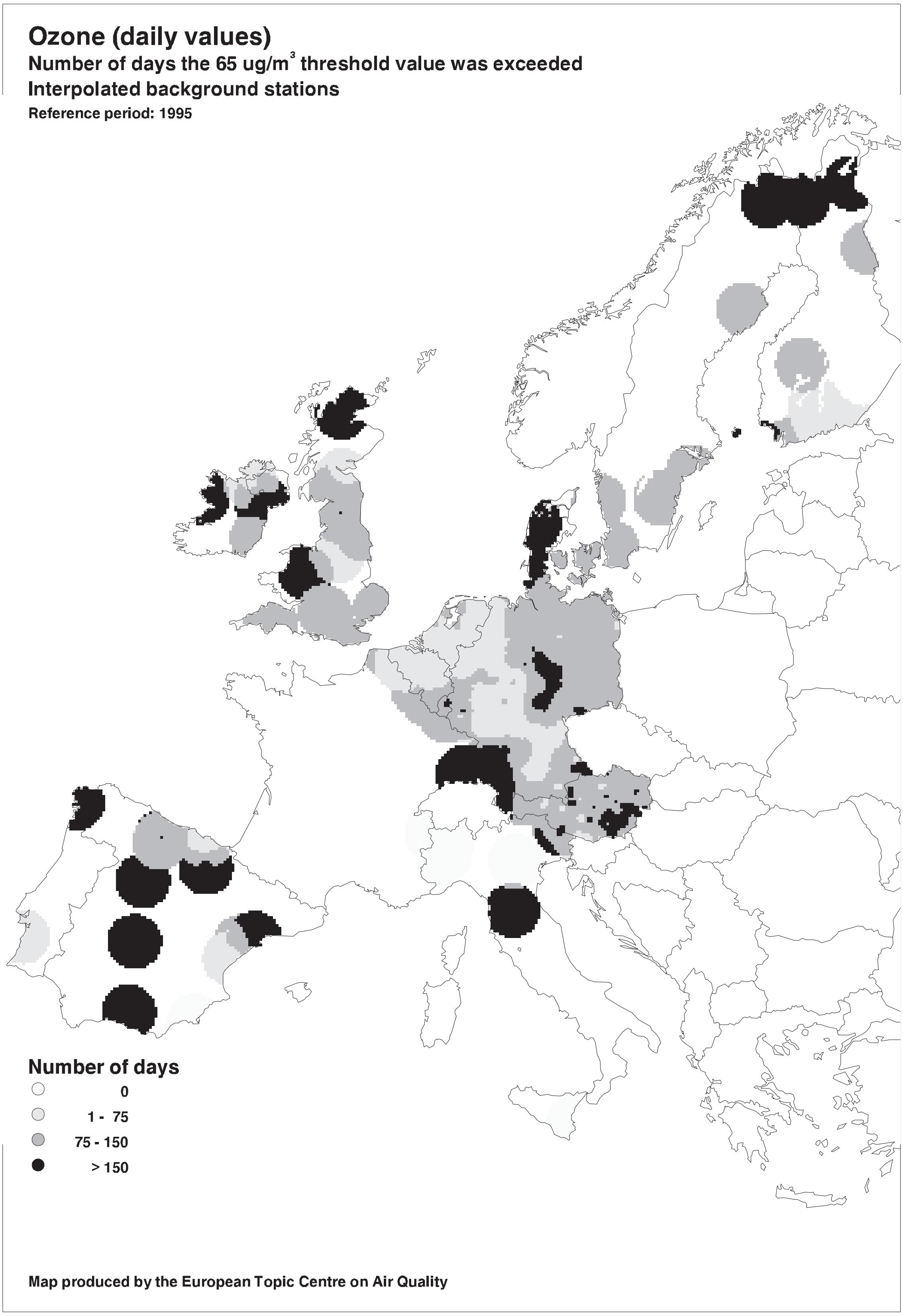
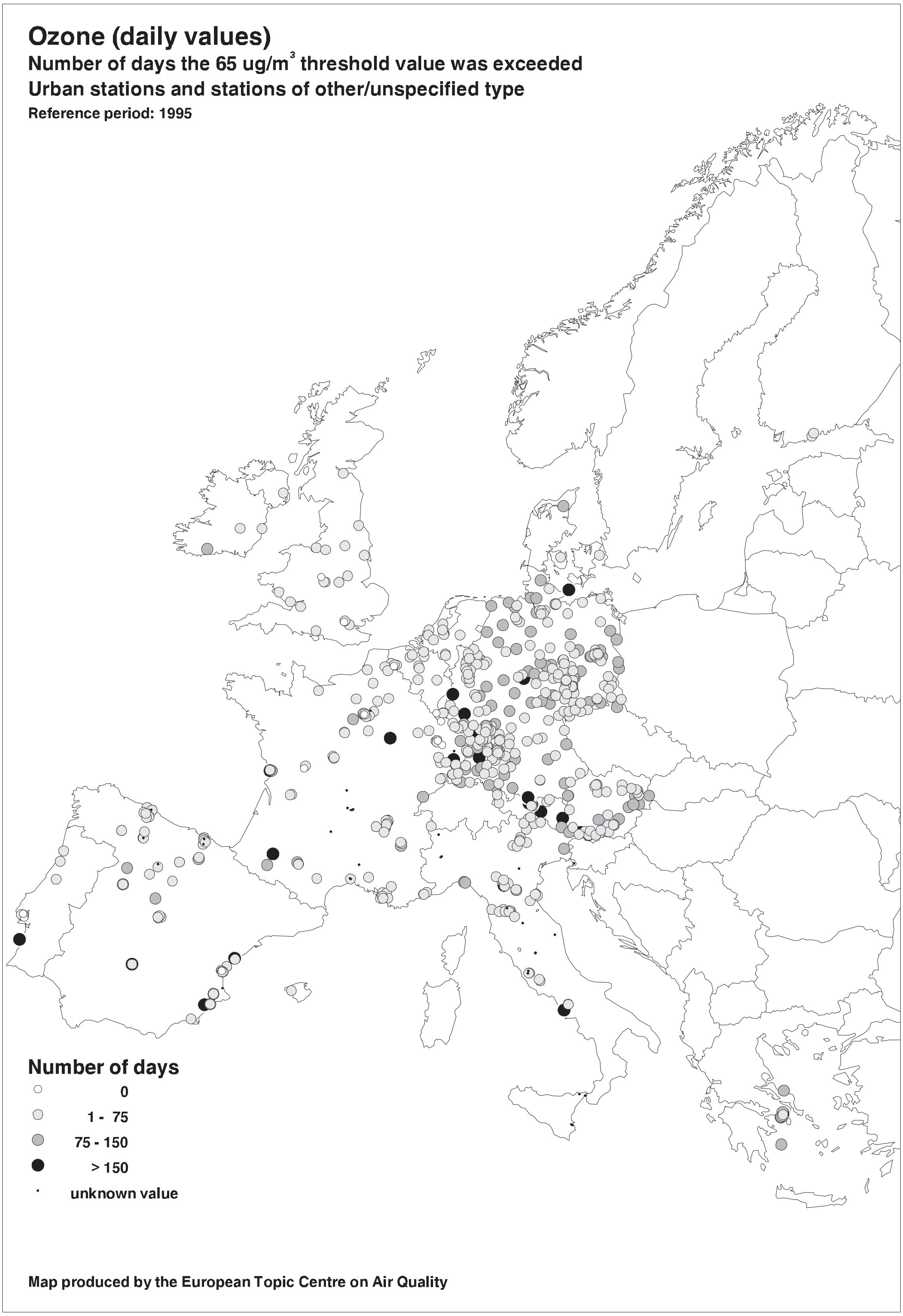


Figure 10. Total number of exceedances (summed over all stations) of the threshold value for protectio of vegetation (65 µg/m³ for daily averages).



Map 9. Number of exceedances of the threshold value for vegetation (65 $\mu g/m^3$ for daily values) observed at background stations; 1 January - 31 December 1995. Data is interpolated using inverse distance weighting and a cut-off distance of 100 km.

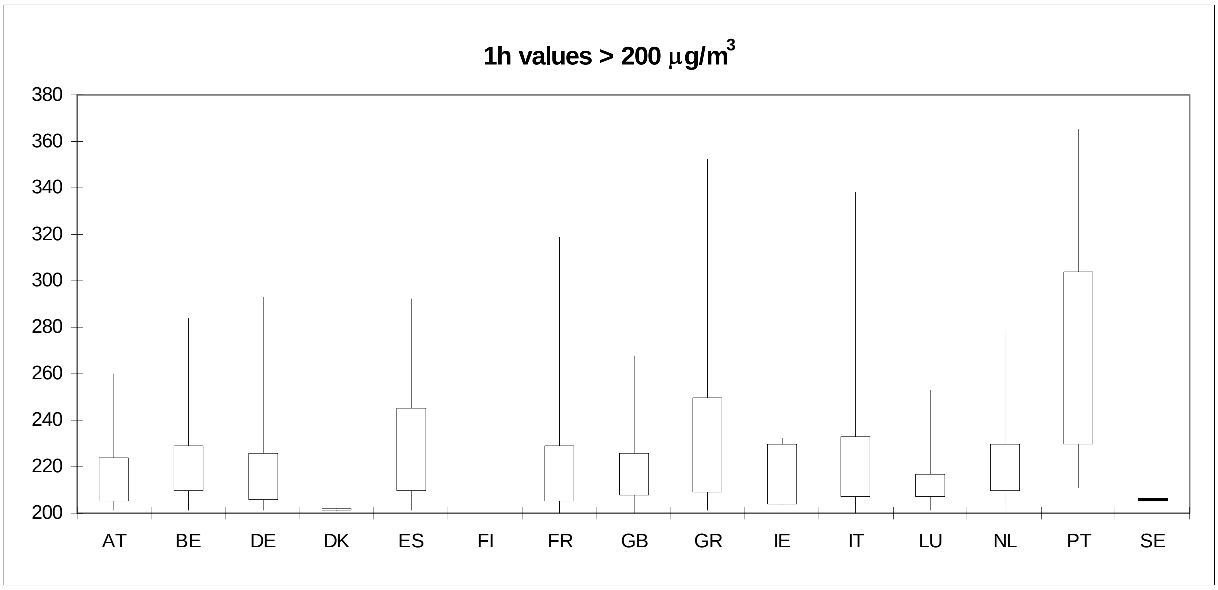


Map 10. Number of exceedances of the threshold value for vegetation (65 $\mu g/m^3$ for daily values) observed at urban and unspecified stations;1 January - 31 December 1995.
Exceedance of hourly threshold value for protection of vegetation

Exceedances of the hourly threshold values for protection of vegetation (200 μg/m^3) are reported by all Member States with the exception of Finland, see Table 4. The geographical distribution of the number of days on which this hourly threshold value was exceeded is presented in Map 11 for background stations and Map 12 for urban street and other stations. The maps show that above ca. 60^0 N this threshold value was not exceeded in 1995; in England, BeNeLux and Germany frequent exceedances are observed. On the Iberian peninsula no exceedances are observed.

In 61% of the rural regions where data from representative monitoring stations is reported (see Map 2) no exceedances of the 200 μg/m^3 threshold value were observed; in 26% of the area an exceedance is observed during 1-5 days whereas exceedances during more than 5 days occur in 13% of the mapped area.

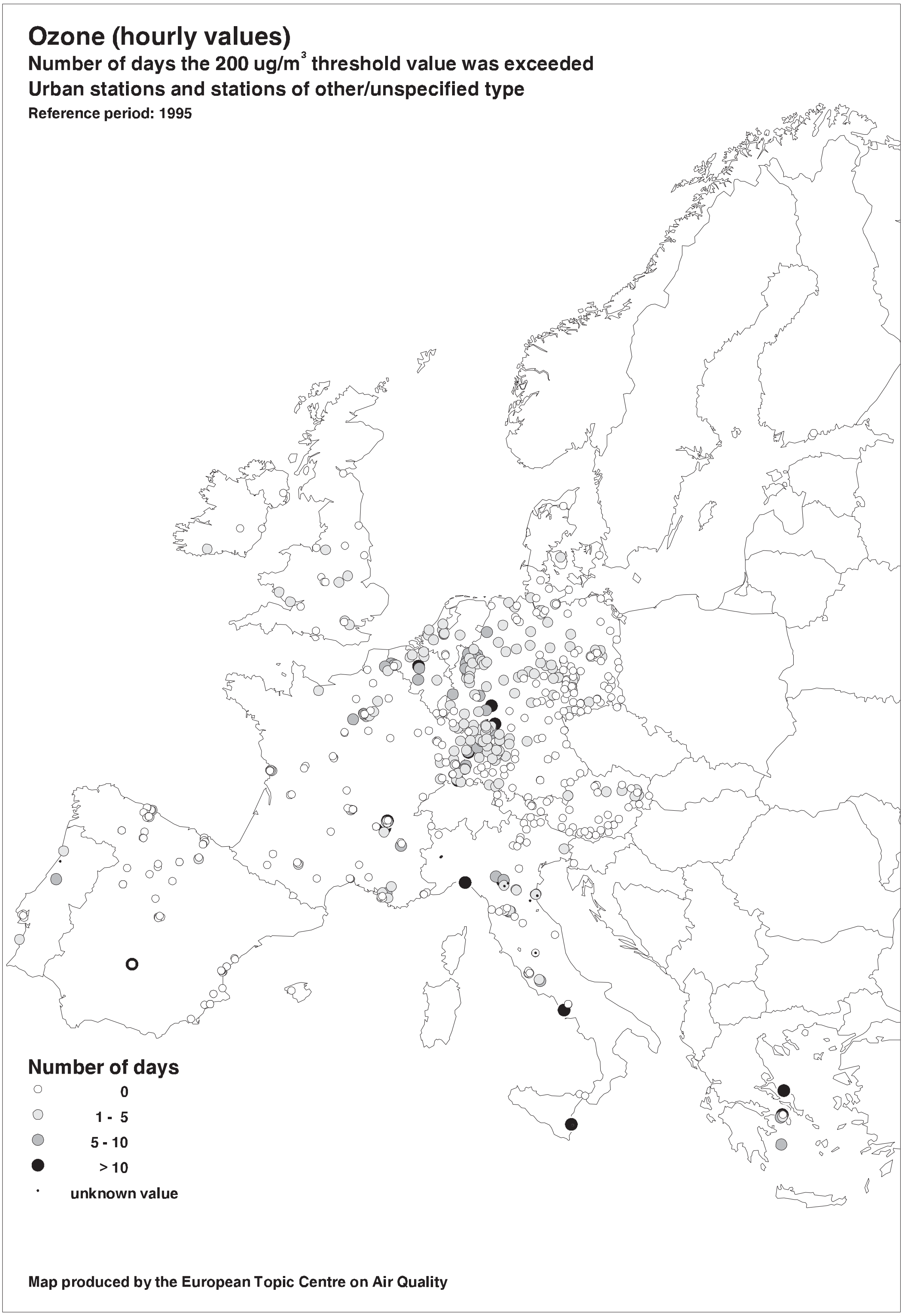
The frequency distribution of exceedances of the hourly threshold is presented in Figure 11. For ca. 75% of the exceedances the ozone levels falls between 200 and 250 μg/m^3 (that is 125% of the threshold value).



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#ex	37	98	745	2	17	0	154	40	102	6	166	13	136	12	1
#st	110	20	342	6	86	11	110	32	10	6	57	5	37	8	6

Figure 11. Frequency distribution of ozone concentrations (hourly values) in excess of the 200 μg/m^3-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.

Map 11. Number of exceedances of the threshold value for vegetation (200 $\mu g/m^3$ for hourly values) observed at background stations;1 January - 31 December 1995. Data is interpolated using inverse distance weighting and a cut-off distance of 100 km.



Map 12. Number of exceedances of the threshold value for vegetation (200 $\mu g/m^3$ for hourly values) observed at urban, street and other stations; 1 January - 31 December 1995.

4.4 Summer smog episodes in 1995

A first analysis of the episodes during summer 1995 has been presented by the EC (EC, 1995). From the data now available it is clear that exceedances of the threshold value set for information to the public were occasionally observed in January - April in the Southern Member States (Greece, Italy, Portugal and Spain). During the first week of May smog was observed in nearly the whole EU: in the period 5-7 May only Finland, Greece and Portugal did not report exceedance of the 180 $\mu g/m^3$ level.

June started as a “low ozone” month although in Greece and Italy on nearly every day one or more stations reported an exceedance. Starting in the last week of June, exceedances were frequently observed in the EU except in the Nordic Countries. The period with frequent violation of the threshold value across Europe ended in the last week of August. During the last four months of 1995, exceedances were less numerous and again confined to the southern part of Europe.

Table 7 gives a graphic 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 1995 summer season. Note that in this period no exceedances were observed in Finland. In July-August some short periods of several days can be recognised during which exceedances are only observed in a few Member States (e.g. 15-19 July). On the other hand there are also periods during which smog is widespread over Europe, e.g. 1 August. As an example the maximum hourly ozone concentrations in excess of 180 $\mu g/m^3$ as measured on 1 August are geographically presented in Map 13.

*Table 7. Qualitative overview of exceedances of the 180 μg/m³ population information threshold value (1h) during the period 6 July - 28 August 1995. The number of asterisks refers to the percentage of stations in a country that reports an exceedance: *: at least one station but less than 25%; **, between 25 and 50%, ***: between 50 and 75%; ****: more than 75%.. The number of reporting stations is indicated above the Country Code.*

		110	20	342	6	86	11	110	32	10	6	54	5	37	8	6
m	d	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
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		*	*		*		*				*	*			
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									**						
8	9					*				***					*	
8	10		*	*				*	*			*		*		
8	11	*	**	*				*	**			*	*	**		
8	12	*	***	*				*	*	*		*	**	****		
8	13			*	**	*						*		*		*
8	14											*				
8	15									*						
8	16							*								
8	17							*	*							
8	18		*	*		*		*	*	**				*		
8	19		**	*				*	*					*	*	
8	20			*				*	*	*	*				*	
8	21			*				*	*	**						
8	22	*	**	*		*		*	*	**			*	*		
8	23			*		*						*				
8	24							*								
8	25							*		**		*				
8	26											*				
8	27							*				*				
8	28									**						

Map 13. Example of an ozone smog episode: hourly ozone concentrations in excess of 180 $\mu g/m^3$ as measured on 1 August 1995.

4.5 Comparison with 1994

In comparison with 1994 the quality and quantity of the information submitted by the Member States in the framework of the Ozone Directive have substantially improved. The data is nearly complete (see Table 2). Suggestions for further improvement of the data transmission are made in Annex III.

With respect to the ozone exceedance no clear differences between the years can be seen. This is caused partly by the fact that the information for 1994 was incomplete, partly by the changes in or extension of the national ozone monitoring networks. Most Member States reported a small increase in the occurrence of exceedances for the vegetation related threshold value of 65 $\mu g/m^3$. However, in Finland, Ireland and Portugal a very strong increase is found. To a large extent this will be caused by the increase in the number of stations reported.

The occurrence of exceedances of the 110 $\mu g/m^3$ level for 8-hourly average concentrations increased slightly in most countries. Notable exceptions are found for Austria, Germany, Denmark, and Finland. The change in occurrence of exceedances of the hourly threshold values of 180 and 200 $\mu g/m^3$ varies from country to country: in six MS an increase, in five MS a decrease in the number of exceedances of 200 $\mu g/m^3$ is found whereas in two MS this number remains constant. For the 180 $\mu g/m^3$ level a similar result is obtained: increases in occurrence of exceedances in five MS, decreases in seven MS and constant in one MS.

Examination of the results per Member State showed that only in Austria the number of exceedances of all threshold values decreases. In Germany a decrease is observed for 1h and 8h values but for the 24h value an increase is observed. An increase in the number of exceedances for all threshold values is found in Belgium and Luxembourg, the United Kingdom and Ireland. For Ireland the increase might result from the extension of the monitoring network. For the other Member States both upward and downward fluctuations are found.

4.6 Data reported for 1989-1995

The data reports for previous years are available for various Member States: for Austria for the period 1993-1995, for Denmark and Finland information for 1992-1995 is available. For the period 1989-1995 data reports are available for four Member States (Belgium, Luxembourg, the Netherlands and United Kingdom), see Figure 12. In discussing the time series of 50 and 98 percentile, the reader must be aware that the network (number and location of stations, measuring method etc.) might have been changed during the years.

The year-to-year variation in 50-percentile values is relatively small when compared to the variations in the 98-percentile values (see Figure 12). Peak values of ozone are 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.

The yearly fluctuations differ from country to country. In Belgium, Luxembourg and the Netherlands similar patterns are found: after two “high” years (1989 and 1990) the period 1991-1993 shows relatively low peak values but increased levels are again observed in 1994. In contrast to Luxembourg and the Netherlands where peak values in 1995 are lower than in 1994, in Belgium and the United Kingdom the 98-percentile value even further increased in 1995.

The available time series are too short to detect any possible trend in ground level ozone concentrations in the EU. Trends in ozone concentrations are expected to result from trends in precursor emissions in Europe and from 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. In a study of trends in concentrations of ozone and related species in the Netherlands and nearby countries, Roemer (1996) concluded that the ground level oxidant (sum of ozone and NO_2) concentrations have decreased significantly in the Netherlands from 1981 to 1994 with an average decrease of about 1% per year. For Germany a slightly downward (northern part) or slightly upward (southern part) trend was noted but probably none of these trends are significant at the 95% confidence interval (Roemer, 1996). Based on the data reported here in the framework of the Ozone Directive, no conclusive answers can be given.

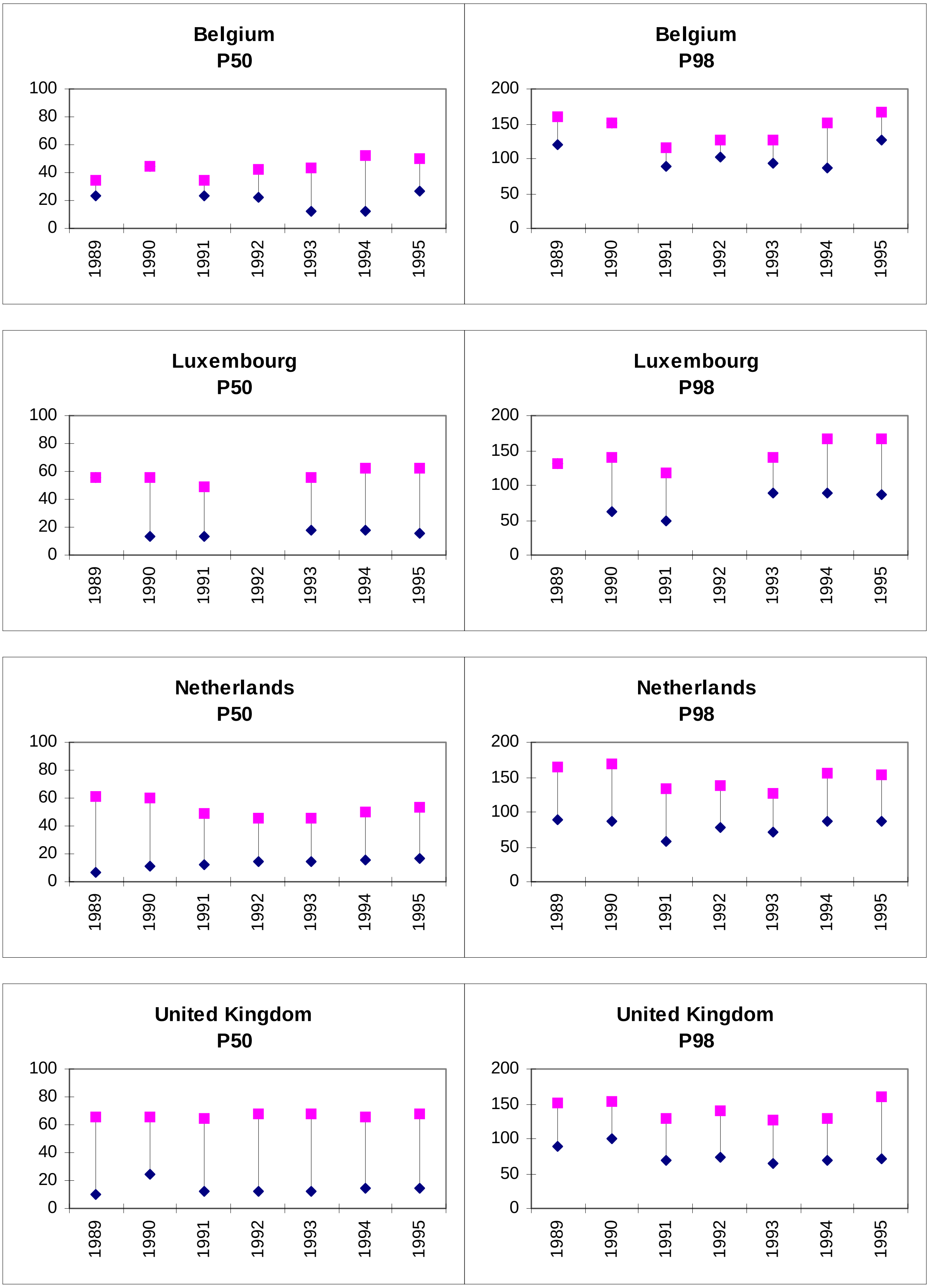


Figure 12. Range in reported 50-percentile values (in µg/m³, based on hourly concentrations) and 98-percentile values (in µg/m³, based on hourly concentrations) in Belgium, Luxembourg, the Netherlands and United Kingdom in the period 1989-1995.

5. CONCLUSIONS AND RECOMMENDATIONS

1. **Data for 1995 were received by the European Commission from 15 Member States for 858 monitoring stations.**

The quality and quantity of the information supplied by the Member States for 1995 is strongly improved compared to 1994. The improved formats for reporting have resulted in a good harmonisation of the data reports although in some cases deviations from the formats occurred. Suggestions for further improvement of data transmission are presented in Annex III.

2. **The spatial coverage and quality documentation of the data need improvement.**

Depending on the local situation, the ozone monitoring stations are characterised as rural, urban, street or other (e.g. industrial). The present subset of rural stations is not representative for the land area of the EU: the subset is estimated to cover only 40-50%. The subset of urban stations is insufficient to estimate the exposure of the population living in all cities with more than 25 000 inhabitants: the urban subset covers at most 30% of the urban population. Spatial coverage and documentation of the monitoring data quality need improvement if the level of protection of human health and ecosystems in Europe to elevated ozone levels is to be fully assessed. Member States are encouraged to reconsider their ozone measuring networks in the light of the spatial coverage of ozone monitoring stations. It is recommended to improve the documentation on the representativity and on the surroundings of the existing stations.

3. **The threshold value set for the protection of human health was exceeded substantially in all Member States.**

The threshold value of 110 µg/m^3 (8h-average) was exceeded substantially (in *c.* 25% of the reported exceedances the 8h-average concentrations exceeded 165 µg/m^3). The subset of urban stations is assumed to give representative values for the exposure of an urban population of approximately 58 million people. 18% of this population is not exposed to ozone levels exceeding the threshold whereas 9% is exposed to exceedances during more than 50 days. The number of exceedances averaged over all stations in each Member State varies from 5 to 54 with an average of 28 for the EU-15.

4. **The threshold values set for the protection of vegetation were exceeded substantially and in almost all the EU Member States.**

The threshold value of 65 µg/m^3 (24h-average) is reported to be exceeded substantially (by up to a factor 3), widely (in all reporting Member States) and frequently (several Member States report exceedances during more than 150 days at some of their stations). In less than 1% of the area for which the subset of background stations reports representative values, this threshold value is not exceeded; exceedances during more than 150 days are estimated for more than 27% of the area. The threshold value of 200 µg/m^3 (hourly average) is exceeded largely and widely (reported by 14 Member States) on a limited number of days.

5. **The threshold value for information of the population was exceeded in almost all the EU Member States during a limited number of days.**

Exceedance of the information threshold value of 180 µg/m^3 (1 h average) was reported for stations in 14 Member States. For one station an exceedance of the warning level of 360 µg/m^3 (1h average) was reported.

6. **It is recommended to improve the reporting of ozone precursors (NO_x, NO_2 and VOC).**

NO_x measurements should be co-located with the ozone monitoring stations as NO_x can be used as an indicator of the station representativity. Moreover, precursor concentrations will be needed for testing of compliance with VOC and NO_x emission reduction programs.

REFERENCES

Barrett K. and Berge E. (eds.) (1996) Transboundary air pollution in Europe. Part 1: Estimated dispersion of acidifying agents and of near surface ozone. EMEP/MSC-W Report 1/96. The Norwegian Meteorological Institute, Oslo, Norway.

Borrell, P. and D. van den Hout (1995) Tropospheric ozone - a review of current understanding. Doc.Ref XI/363/95. European Commission, Brussels.

De Leeuw F., Sluyter R. Van Zantvoort E. and Larssen S. (1995) Exceedance of Ozone threshold values in the European Community in 1994. Summary based on the information reported in the framework of the Council Directive 92/72/EEC on air pollution by ozone. European Topic Centre on Air Quality.

Derwent, D. and D. van den Hout (1995) Computer modelling of ozone formation in Europe. Doc.Ref XI/364/95. European Commission, Brussels.

EC (1994). Information Document concerning Air Pollution by Ozone - Overview of the situation in Europe during Summer 1994. European Commission, Brussels.

Hjellbrekke A.-G. (1996) Ozone measurements 1993-1994. EMEP/CCC Report 1/96, NILU, Kjeller, Norway.

Roemer M. (1996) Trends of tropospheric ozone over Europe. Thesis, University of Utrecht.

Van Zantvoort E. and Sluyter R. (1996) Annex to the report: Exceedance of Ozone threshold values in the European Community in 1994. Summary based on the information reported in the framework of the Council Directive 92/72/EEC on air pollution by ozone. European Topic Centre on Air Quality.

ANNEX I

Observed exceedances of ozone threshold values and annual statistics in 1995 at individual monitoring stations reporting in the framework of the Council Directive 92/72/EEC on air pollution by ozone

Information on ozone exceedances and concentrations for the individual stations reporting in the framework of the Ozone Directive is available in computer readable form only. Upon request a diskette containing the following tables is available:

Table I.1 Number of days on which exceedances of threshold values (180 $\mu g/m^3$ and 200 $\mu g/m^3$ for hourly values; 110 $\mu g/m^3$ for 8-hourly values and 65 $\mu g/m^3$ for daily values) were observed at reporting monitoring stations, period 1 January- 31 December 1995.

Table I.2 The longest period of consecutive days on which exceedances of threshold values were observed at reporting monitoring stations, period 1 January - 31 December 1995.

Table I.3 Average length (in days) of periods of consecutive days on which exceedances of threshold values were observed at reporting monitoring stations, period 1 January-31 December 1995.

Table I.4 Annual statistics (percentiles and maximum values) of hourly and moving eight hourly ozone concentrations for reporting monitoring stations; all concentrations in $\mu g/m^3$; period: 1 January - 31 December 1995.

Table I.5 Annual statistics (averaged, 50-, 95- and 98- percentile values) of hourly NO_x concentrations for reporting monitoring stations; all concentrations in $\mu g/m^3$; period: 1 January - 31 December 1995.

Table I.6 Annual statistics (averaged, 50-, 95- and 98- percentile values) of hourly NO_2 concentrations for reporting monitoring stations; all concentrations in $\mu g/m^3$; period: 1 January - 31 December 1995.

Notes to the Tables

Table I.1

Exceedances of the threshold value of 360 $\mu g/m^3$ for hourly values were observed at one station:

Country	Station name & city	Date, time	Max. conc. ($\mu g/m^3$)
Portugal	Coimbra	26 April 1995, 4.00	365

In Table I.1 it is also indicated when no exceedance of (one or more) threshold value was observed at the station. This information has not been submitted by the Member States and is inferred from the available data. In cases where the information was insufficient for an unambiguous answer a “?” is printed.

Explanations of headings of Table I.1

codcou	country code
stanamename of monitoring station	
incod	code number of monitoring station
ville	city where station is located
180 (1)	number of days on which the 180 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded
200 (1)	number of days on which the 200 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded
110 (8a)	number of days on which the 110 $\mu g/m^3$ threshold values for the non-overlapping 8 hourly values between 0.00-8.00, 8.00-16.00 and 16.00 and 24.00 has been exceeded
110 (8b)	number of days on which the 110 $\mu g/m^3$ threshold values for the 8 hourly values between 12.00-20.00 has been exceeded
65 (24)	number of days on which the 65 $\mu g/m^3$ threshold values for the 24 hourly values has been exceeded
% 1h val	percentage of valid 1h average values

Table I.2:
Explanations of headings of Table I.2

codcou	country code
stanamename of monitoring station	
incod	code number of monitoring station
ville	city where station is located
180 (1)	longest period (in days) during which the 180 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded
200 (1)	longest period (in days) during which the 200 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded
110 (8a)	longest period (in days) during which the 110 $\mu g/m^3$ threshold values for the non-overlapping 8 hourly values between 0.00-8.00, 8.00-16.00 and 16.00 and 24.00 has been exceeded
110 (8b)	longest period (in days) during which the 110 $\mu g/m^3$ threshold values for the 8 hourly values between 12.00-20.00 has been exceeded
65 (24)	longest period (in days) during which the 65 $\mu g/m^3$ threshold values for the 24 hourly values has been exceeded
% 1h val	percentage of valid 1h average values

Table I.3

Explanations of headings of Table I.3:

codcou	country code
stanamename of monitoring station	
incod	code number of monitoring station
ville	city where station is located
180 (1)	average length of period (in days) during which the 180 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded
200 (1)	average length of period (in days) during which the 200 $\mu g/m^3$ threshold values for 1h average concentrations has been exceeded
110 (8a)	average length of period during (in days) which the 110 $\mu g/m^3$ threshold values for the non-overlapping 8 hourly values between 0.00-8.00, 8.00-16.00 and 16.00 and 24.00 has been exceeded
110 (8b)	average length of period (in days) during which the 110 $\mu g/m^3$ threshold values for the 8 hourly values between 12.00-20.00 has been exceeded
65 (24)	average length of period (in days) during which the 65 $\mu g/m^3$ threshold values for the 24 hourly values has been exceeded
% 1h val	percentage of valid 1h average values

Table I.4

Explanations of headings of Table I.4:

codcou	country code
stanamename of monitoring station	
incod	code number of monitoring station
ville	city where station is located
1h P50	50 percentile of hourly values ($\mu g/m^3$)
1h P98	98 percentile of hourly values ($\mu g/m^3$)
1h P99.9	99.9 percentile of hourly values ($\mu g/m^3$) (additional information)
1h MAX	maximum value of hourly value ($\mu g/m^3$)
% 1h val	percentage of valid 1h average values
8h P50	50 percentile of eight hourly values ($\mu g/m^3$, calculated as a moving average)
8h P98 98	percentile of eight hourly values ($\mu g/m^3$)
8h P99.9	99.9 percentile of eight hourly values ($\mu g/m^3$, additional information)
8h MAX	maximum value of eight hourly value ($\mu g/m^3$)
% 8h val	percentage of valid 8h average values ($\mu g/m^3$)

Table I.5

Explanations of headings of Table I.5

codcou	country code
stanamename of monitoring station	
incod	code number of monitoring station
ville	city where station is located
AVER	yearly average NO_x concentration ($\mu g/m^3$)
PARP50	50-percentile of hourly NO_x concentration ($\mu g/m^3$)
PARP90	90-percentile of hourly NO_x concentration ($\mu g/m^3$)
PARP95	95-percentile of hourly NO_x concentration ($\mu g/m^3$)
% val	percentage of valid 1h average values

Table I.6

Explanations of headings of Table I.6

codcou	country code
stanamename of monitoring station	
incod	code number of monitoring station
ville	city where station is located
AVER	yearly average NO_2 concentration ($\mu g/m^3$)
PARP50	50-percentile of hourly NO_2 concentration ($\mu g/m^3$)
PARP90	90-percentile of hourly NO_2 concentration ($\mu g/m^3$)
PARP95	95-percentile of hourly NO_2 concentration ($\mu g/m^3$)
% val	percentage of valid 1h average values

ANNEX II

Phenomenology of ozone concentrations

For a better understanding of the report, some of the main characteristics of ambient ozone are summarised here. For more advanced information on ozone and its photochemical formation the reader is referred to information documents provided by DGXI (Peter Borrell and Dick van den Hout, "Tropospheric ozone: a review of current understanding", Doc.Ref XI/363/95; Dick Derwent and Dick van den Hout, "Computer modelling of ozone formation in Europe", Doc.Ref. XI/364/95) and to reports prepared in the framework of UN-ECE Convention on long-range transport of air pollution and EUROTRAC[3].

Ozone is a secondary air pollutant formed in the atmosphere under the influence of sunlight. Ozone formation occurs at all levels in the atmosphere, from ground level up to the stratosphere. Here the discussion is limited to ozone at ground level. It has been shown that under the present conditions in Europe the ozone exposure of humans, vegetation and materials leads to adverse effects.

The precursors of the ozone formation are Volatile Organic Compounds (VOC), carbon monoxide (CO) and nitrogen oxides (NO_x). VOC and CO act as "fuel" as they are oxidised in the process; the nitrogen oxides play an important role as "catalysts": they are not 'consumed' in the formation process but are essential for the continuation of the process. However, nitrogen oxides are consumed in side reactions by which they are further oxidised to nitric acid or nitrates. For the continuation of the photochemical oxidation process a continuous injection of nitrogen oxides is therefore necessary.

The ozone formation takes place on various time and spatial scales: on the local scale as in urban areas such as Athens or Milan, on the regional scale as is demonstrated by the photochemical episodes in Central and Northwest Europe and on the hemispheric/global scale. Highly reactive VOCs are important precursors on the local and regional scale whereas the less reactive, relatively long-lived VOCs such as methane contribute to ozone formation on the global/hemispheric scale.

The role of nitrogen oxides is complex and may be different at various distances from the source. In heavily populated areas the ozone concentrations may be lower than the regional concentrations due to chemical scavenging by local nitrogen oxide emissions. This scavenging is presented by the chemical reaction:

$$O_3 + NO \rightarrow NO_2 + O_2 \qquad \text{(R1)}$$

Nitrogen dioxide (NO_2) formed in this reaction can be seen as 'potential ozone' as in the photolysis of NO_2, nitrogen monoxide, NO, and ozone are produced:

$$NO_2\ (+\ O_2) \rightarrow O_3 + NO \qquad \text{(R2)}$$

[3] see e.g. EUROTRAC, Annual Report 1993, International Scientific Secretariat; Garmisch-Partenkirchen, December 1994 and EMEP/MSC-W, European Transboundary Acidifying Air Pollution, Report 1/96 and Report 2/96.

As both the time scales of the NO-scavenging reaction (R1) and of the NO_2 photolysis are relatively short, an equilibrium between the three components will be established:

$$O_3 + NO \leftrightarrow NO_2 + O_2 \qquad \text{(E1)}$$

Note that the sum of O_3 and NO_2 (frequently indicated as *oxidant* or *Ox*) is constant. Knowledge on simultaneously measured NO_x concentrations in general and NO_2 concentration in particular is therefore important for interpretation of ozone levels. The oxidant levels are spatially less variable than the ozone levels. A mapping procedure based on oxidant levels is therefore preferred.

The time scales of photochemical ozone formation are generally longer than the time scale associated with the above reaction R1 and R2 and close to NO_x sources a decrease in ozone concentrations may be observed. In Figure II.1 the ozone concentration in an air parcel passing a NO_x source is schematically presented.

One of the consequences of this interaction with NO_x is that the representativeness of ozone monitoring stations depends strongly to what extent the station is influenced by local NO_x sources: concentrations measured at a station in a traffic situation will be representative for its direct surroundings only (e.g. less than a few 100 m) whereas a background station may measure concentrations representative for an area of several tens of kilometres. The information requested in Article 4 of the Directive should form the basis on which a representative area for each of the monitoring stations could be defined.

At ground level ozone concentrations generally show a strong diurnal variation. At night concentrations are low, both caused by removal by dry deposition and by titration by NO-emissions. In the morning concentrations increase, caused not only by the sun-light induced photochemical formation but also by the downward mixing of higher, ozone-rich layers. In the afternoon both processes will become less important and concentrations will decrease again when the loss processes dominate. The maximum concentration is frequently found in the late afternoon, around 16.00. For the eight hour periods reported in the framework of the Ozone Directive, the highest value will generally be observed between 12.00 and 20.00.

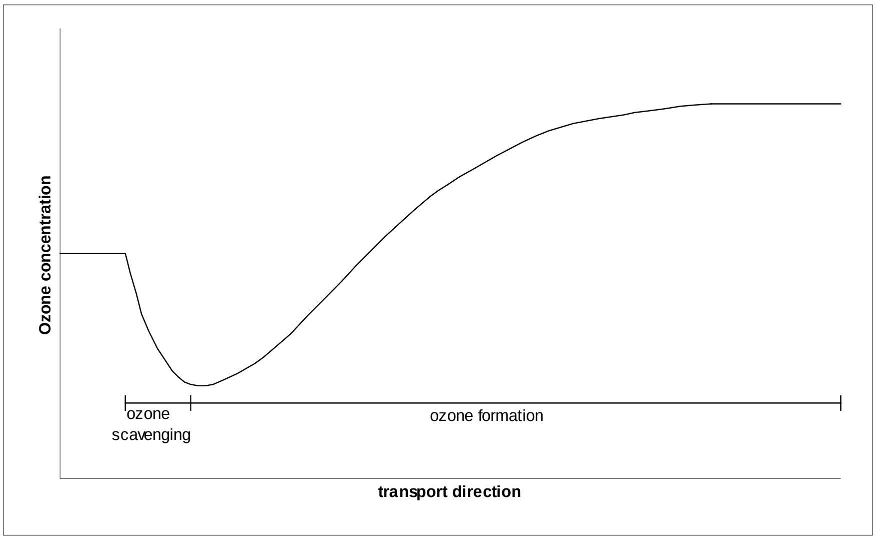


Figure III.1 Schematic presentation of ozone concentrations downwind of a large NO_x source where ozone scavenging will take place.

ANNEX III

Remarks concerning data transmission and suggestions for improvement

During the preparation of this report several ‘problems’ were encountered while processing the data. These problems and other remarks concerning data transmission are summarised below.

- The definition of *exceedance* is ambiguous: seven countries reported an exceedance when the ozone concentration *equals* the threshold value, the other countries indicated only when concentrations are *greater than* the threshold value. The latter definition is preferred.

- From the available information it is not always clear whether no exceedances were observed at a station. In order to estimate the size of attainment areas, it is recommended to report (in computer readable form) explicitly results from stations where no exceedances are observed.

- Information on data coverage (fraction of time with valid measurements) is presented for hourly values and for the moving eight hourly values; it is recommended to give it also on a daily basis. Criteria for the calculation of valid eight hourly and daily values should be given. Following the criteria for the validity of the calculation of percentile values (see Annex III of the Ozone Directive), it could be considered that at least 6 and 18 valid hourly values, distributed uniformly throughout the period in question, should be available for calculation of a valid eight hourly or daily average value, respectively.

- For feedback on possible errors encountered during the processing of the data it is recommended to identify a contact person at the national institute responsible for data submissions.

- The code for erroneous or missing data for the station elevation (- 1) is confusing as an elevation below sea level (small negative values) may occur. It is recommended to use the error code - 999.

- VOC data was submitted by 2 Member States only. According to the proposed format Italy submitted statistical information on daily average concentrations of total Non Methane Hydro Carbons (NMHC) at two stations; for one station averaging time was 1 hour. The Netherlands submitted data (for 8 stations yearly average values based on an averaging time of one week) of 47 individual organic compounds using a different format. A further harmonisation on VOC-data transmission is to be discussed.

- In the reporting of NO_x concentrations there is confusion about the units. It is recommended to report NO_x concentrations (defined as the sum of NO and NO_2 concentrations) in ppb-units and NO_2 in $\mu g/m^3$.

OVERVIEW OF THE SITUATION IN THE EUROPEAN UNION DURING THE 1996 SUMMER SEASON (APRIL-JULY)

Information Document concerning Air Pollution by Ozone

Report to the Commission by the European Environment Agency
Topic Centre on Air Quality

Rob Sluyter
Esther van Zantvoort

September 1996

riivm

1. INTRODUCTION

Ozone is a strong photochemical oxidant which may cause serious health problems and damage to materials and crops. Human exposure to elevated levels of ozone concentrations can give rise to decreases in lung function and inflammatory responses. Symptoms observed are cough, chest pain, difficulty in breathing, headache and eye irritation. Both laboratory and epidemiological data indicate large variations between individuals in response to episodic O_3 exposure, the effects seem to be more pronounced in children than in adults [1]. The World Health Organization (WHO) recommends a 1h guide value of 150-200 µg/m^3 [2] above which symptoms and damage to respiratory functions can be expected to occur.

In view of the harmful effects of photochemical pollution, the Council adopted in 1992 Directive 92/72/EEC on air pollution by ozone [3]. The Directive defined threshold values, established procedures for harmonised monitoring, for collecting and exchanging data and for information of the public when exceedances of threshold values occur.

The thresholds set by the Directive are presented in Table 1. As far as data reporting is concerned, two types of reporting can be distinguished according to Article 6 of the Directive:

1. Exceedances of the population information and warning thresholds (date, time, duration and maximum concentration) must be reported to the Commission within one month after occurrence (data is not necessarily validated);
2. Exceedances of all threshold values including some additional statistics (percentiles, maxima) must be provided within 6 months after the end of a calendar year (validated data).

Table 1. Threshold values for ozone concentrations set in Directive 92/72/EEC

Threshold for:	**Concentration (in µg/m^3)**	**Averaging period (h)**
Health protection	110	8
Vegetation protection	200	1
Vegetation protection	65	24
Population information	180	1
Population warning	360	1

According to Article 7 of the Directive, the Commission prepares a report summarising all the information transmitted by the Member States at least once a year. The report for the 1995 calendar year will become available together with this document [4].

In this document a first assessment is made of the 1996 summer season, based only on the exceedances of the population information and warning thresholds for ozone, which were transmitted by the Member States after the end of each month. The report is mainly intended to provide fast feedback to the Member States on their data. It also enables the Member States to compare the levels observed in the past summer season with those observed in other Member States.

2. AVAILABILITY OF DATA

According to the Directive, exceedances of the population information and warning thresholds are to be transmitted to the Commission within one month following the observation. On the basis of experience gained with the ozone data reporting in 1995, the Commission updated the formats to be used and gave additional guidelines to ensure successful transmission of data [5]. In this report, the definition of data formats as described in the above mentioned guideline document is used as reference. If necessary, files were converted at the European Topic Centre on Air Quality (ETC-AQ) for further processing. In this report all data received by he Commission (DGXI) and forwarded to the ETC-AQ not later than 15 September 1996 have been included in the analysis.

For all 15 EU Member States, information concerning the observation of exceedances during the months April-July 1996 is available. Only for Spain, no information for July was received in time for this report. Table 2 presents an overview of observed exceedances per country per month.

Table 2: Overview of observed exceedances per month per country. yes: exceedance of the population information threshold reported, no: no exceedance reported, ?: no reporting received.

	April	**May**	**June**	**July**
AT	yes	yes	yes	no
BE	no	no	yes	yes
DE	yes	yes	yes	yes
DK	no	no	yes	no
ES	yes	yes	yes	?
FI	no	no	yes	yes
FR	yes	yes	yes	yes
GB	no	yes	yes	yes
GR	yes	yes	yes	yes
IE	no	no	no	no
IT	yes	yes	yes	yes
LU	no	no	yes	no
NL	no	no	yes	yes
PT	no	no	yes	yes
SE	yes	yes	yes	no

Member States were requested to check the information made available to the Commission on ozone monitoring sites implemented in the framework of the Directive. For the interpretation of ozone data it is essential to have information on the direct surroundings of the station since the ozone concentration may be scavenged by locally emitted nitrogen oxides or by enhanced dry deposition that might occur for example under a forest canopy[4]. Member States were requested to classify their stations as street, urban background[5] or rural stations as a first description of the environment of the stations. Map 1 presents the location of all ozone monitoring stations (street and urban background taken together as 'urban') which were scheduled to be operational during the 1996 summer season, based on the information supplied by the Member States. 1012 ozone monitoring sites are operational in the framework of the Directive. This amounts to an increase

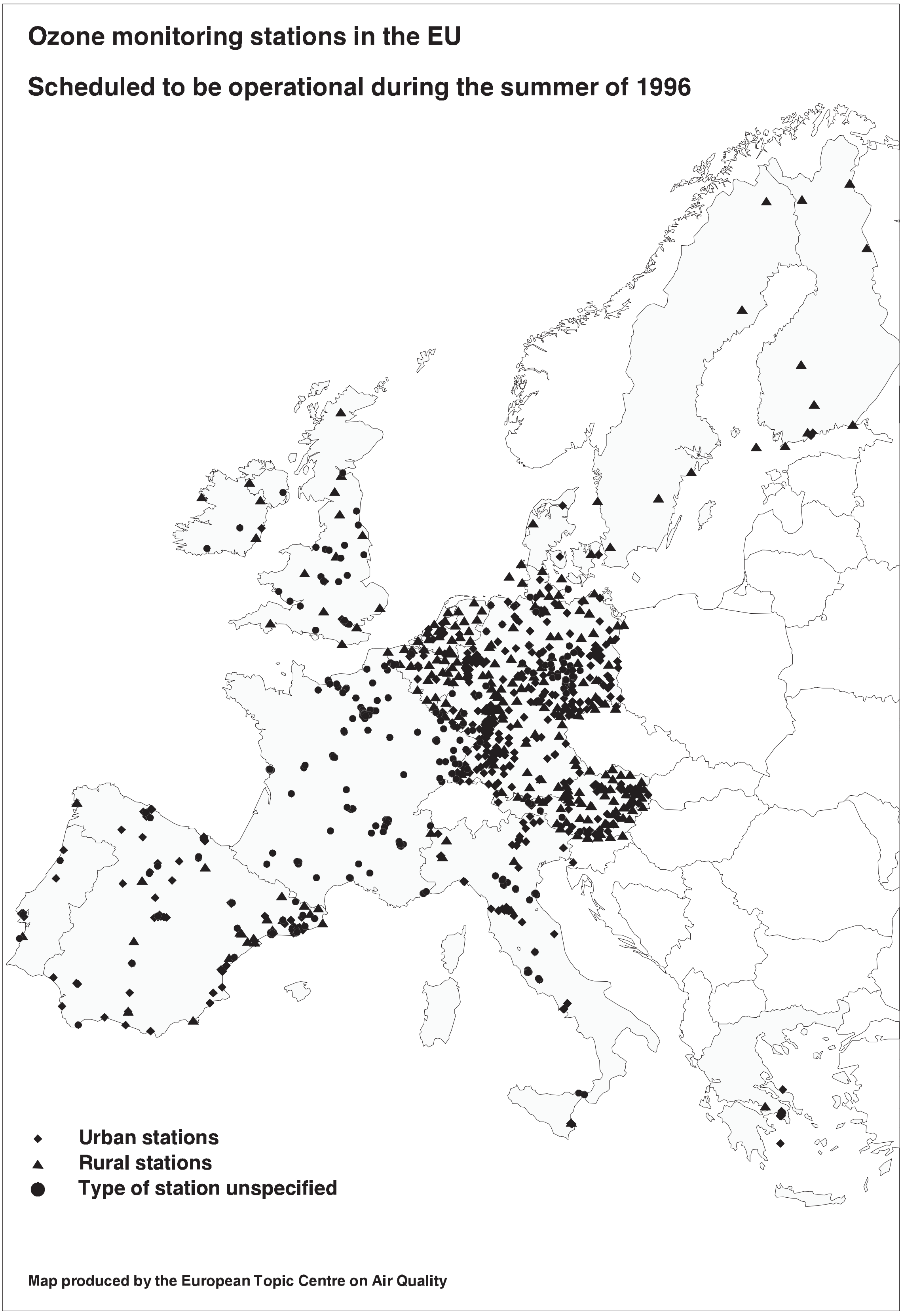
[4] An introduction to ozone phenomenology can be found in 'Concern for Europe's Tomorrow [WHO, 1].
[5] Urban background: station located in the build-up area of the city but not directly influenced by emission sources such as traffic or industry.

of 154 stations since 1995. From the 1012 ozone monitoring stations, 272 stations are situated in rural areas, 283 stations in urban background environments, 163 are street stations and for 294 stations the monitoring environment was not specified.

Note that since only exceedances of thresholds was reported, it is not clear that stations were operational continuously. It is possible that ozone concentrations exceeded a threshold at a site but was not reported because the monitoring station was temporarily out of operation[6].

In this report exceedances are counted on a daily basis, that is, a day on which a threshold is exceeded at least once, is calculated as one exceedance day. Note that information presented in this document is not necessarily based on validated monitoring data and hence should be considered preliminary.

[6] The annual report [4] gives information on the percentage of time stations were operational, most stations score >90%.



Map 1: Ozone monitoring stations implemented in the framework of Directive 92/72/EEC on air pollution by ozone, scheduled to be operational during 1996.

3. SUMMARY OF DATA REPORTED FOR SUMMER 1996

The threshold for warning of the public (1h> 360 µg/m^3) was exceeded at three stations during summer 1996 (Table 3):

Table 3: Observed exceedances of the threshold for warning of the public (1h concentration > 360 µg/m^3) during summer 1996 (April-July).

Country	City	Station	Maximum observed hourly concentration (µg/m^3)	Date, time
Greece	Athens	Marousi	361	21-5-96,
Greece	Athens	Liosia	391	21-5-96,
Italy	Firenze	Settignano	387	13-7-96, 9.00

Both the Athens and Firenze (Florence) episode will be described in more detail in Chapter 4. Table 4 presents a general overview of the observed exceedances of the threshold for information of the public during April-July 1996 on a country by country basis[7]. As the number of stations differs widely from country to country, the absolute number of exceedances is less suitable for comparison. As in the annual ozone report [4], the concept of 'occurrence of exceedances' is used here. Occurrence of exceedances is defined as the total number of exceedances summed over all stations divided by the number of stations.

Table 4: Summary of exceedances of the threshold for information of the public (1h concentration > 180 µg/m^3) during summer 1996 (April-July) on a country by country basis.

	Nr. of stations[8]	Nr. of stations with exceedance	Nr. of days with exceedance[9]	maximum observed concentr. (µg/m^3)	averaged maximum concentr. (µg/m^3)	Occurrence of exceedances[10]	average duration of exceedances (hour)
AT	114	52 (46%)	18	225	191	0.9/1.9	3.4
BE	22	12 (55%)	6	244	200	1.2/2.3	3.9
DE	386	229 (59%)	29	271	196	1.6/2.7	3.0
DK	6	1 (17%)	1	198	198	0.2/1.0	3.0
ES	132	31 (24%)	27	323	202	0.8/3.2	2.3
FI	11	1 (1%)	2	190	186	0.2/2.0	1.0
FR	155	56 (36%)	41	273	199	1.4/3.9	2.5
GB	42	23 (55%)	11	244	194	0.9/1.7	2.8
GR	11	9 (82%)	40	*391*	235	9.3/11.3	2.9
IE	6	0 (0%)	0	-	-	-	-
IT	69	36 (57%)	39	*387*	206	2.8/5.3	2.9
LU	5	2 (40%)	4	199	190	1.2/3.0	2.0
NL	38	31 (82%)	8	265	200	2.4/3.0	3.3
PT	9	3 (33%)	5	251	202	0.6/1.7	1.4
SE	6	3 (50%)	5	212	194	1.2/2.3	4.0
EU	1012	489 (48%)		391	200	1.5/3.1	2.9

[7] Note that in all tables and figures presented, information for July from Spain has not been included.
[8] Number of stations implemented in the framework of the Ozone Directive
[9] The number of days on which at least one exceedance was observed.
[10] Left figure: averaged over all implemented stations, right figure: averaged over all stations which reported at least one exceedance.

In northern and western Europe, the weather conditions during the 1996 summer season were on average less favourable for the formation of ozone then during the 1995 summer season. This year, cool and relatively clean Atlantic air masses prevailed on many days. In 1995 a number of heat-waves was recorded and especially July was very hot and sunny. As a result, less exceedances was reported this summer (*April-July*) than in the same period last year. In the Mediterranean region of southern Europe, frequent exceedances were observed during the stable, warm and sunny summer months.

Ireland was the only Member State where the threshold for the information of the public was not exceeded. In other countries, the number of days on which at least one exceedance was observed ranged from one in Denmark to 41 in France. 48% of all stations reported one or more exceedance. During the same period in 1995, 59% of all stations reported one or more exceedance. On average 3.1 exceedances occurred this year on stations that recorded at least one exceedance. During summer 1995 on average 5.0 exceedances were recorded. The average maximum hourly concentration during an exceedance of the threshold this year was 200 $\mu g/m^3$ which is slightly lower than last year (EU average 1995: 203 $\mu g/m^3$). An exception is Greece, where the average maximum rose from 219 to 235 $\mu g/m^3$. The average length of an exceedance period was 2.9 hours (3.5 hours in 1995). However, from Table 4 it is clear that there is quite a large difference in the average episode length between the Member States.

Table 5 summarises the exceedances on a month by month basis. June had the highest number of stations reporting exceedances and the highest occurrence. This is mainly due to one ozone episode in the beginning of June in NW-Europe (see also Chapter 5).

Table 5: Summary of exceedances of the threshold for information of the public (1h concentration > 180 $\mu g/m^3$) during summer 1996 (April-July) on a month by month basis.

	Nr. of stations with exceedance[11]	**maximum observed concentration ($\mu g/m^3$)**	**averaged maximum concentration ($\mu g/m^3$)**	**Occurrence of exceedances**[12]	**average duration of exceedances (hr)**
April	135 (13%)	254	190	0.2/1.8	3.0
May	134 (13%)	391	208	0.2/1.4	3.0
June	388 (38%)	387	201	0.8/2.1	3.0
July	112 (11%)	323	202	0.2/2.1	2.6

In Figure 1 the number of days per month is presented on which at least at one station in a country was recorded an exceedance. Again, the relative abundance of exceedances in June is striking. Figure 2 presents the occurrence of exceedances per country on a month by month basis. No monthly pattern is apparent. Exceedances in June were observed on many stations, the occurrence in this month is not significantly different from that in other months. Exceedances in Greece and Italy were observed on a limited number of stations; this explains the relative high occurrence of exceedances in these countries.

[11] The theoretical maximum is 1012 stations (all stations which were scheduled to be operational during summer 1996).

[12] Left figure: averaged over all implemented stations, right figure: averaged over all stations which reported at least one exceedance.

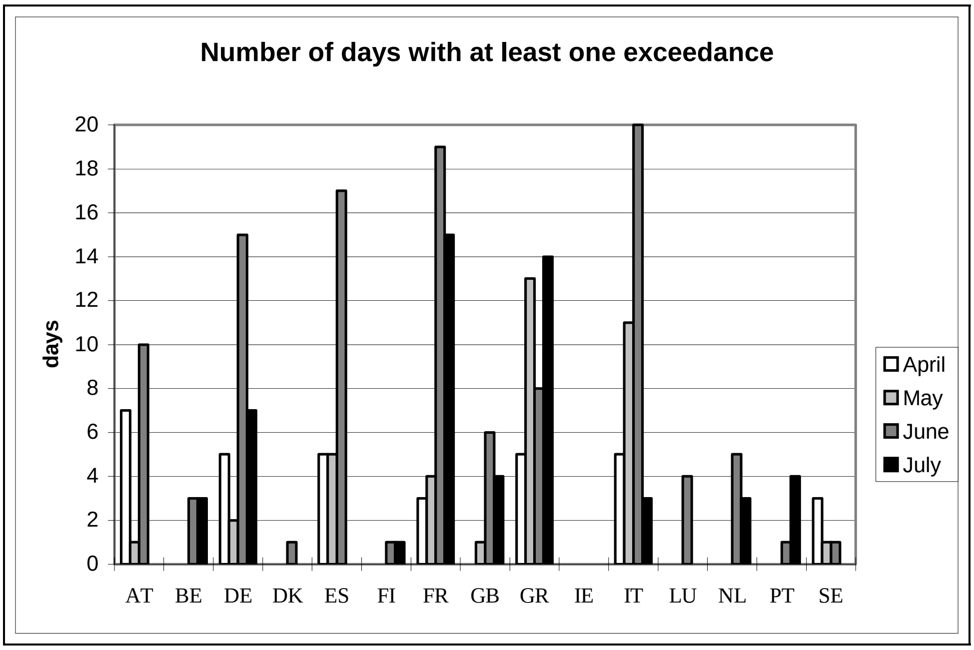


Figure 1: Number of days on which at least one exceedance of the threshold value for information of the public (1h concentration > 180 µg/m³) was observed per country and per month during summer 1996.

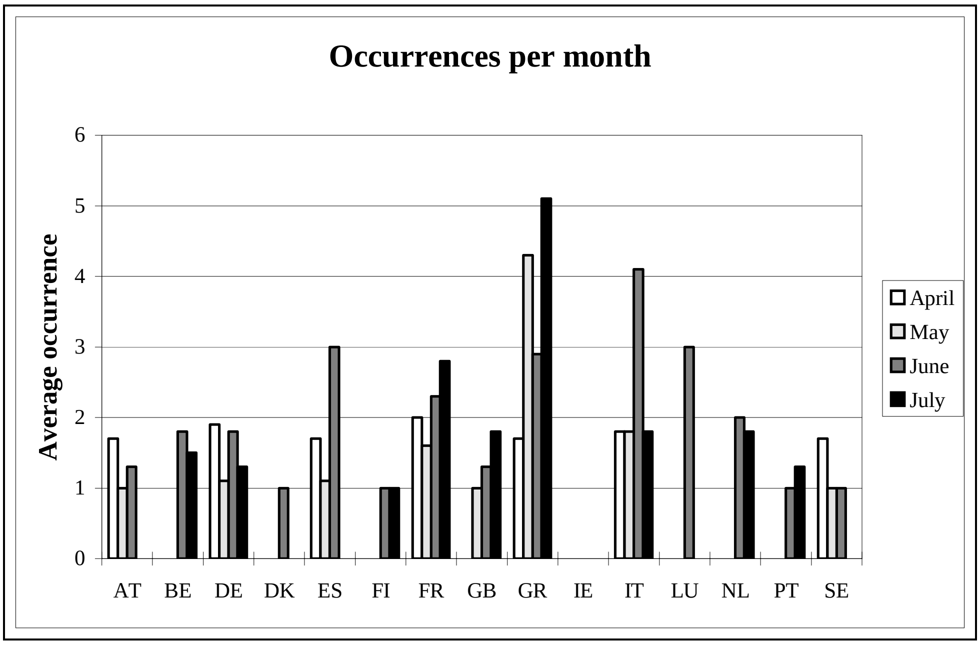


Figure 2: Occurrence of exceedances (in days) of the threshold value for information of the public (1h concentration > 180 µg/m³) per country on a month by month basis during summer 1996.

The average occurrence of exceedances (in days) in each country of the threshold for information of the public by station type (rural, urban and street) is presented in Figure 3. The occurrence of exceedances generally decreases in the order rural-urban-street. Stations for which the type was not specified are not presented in this figure.

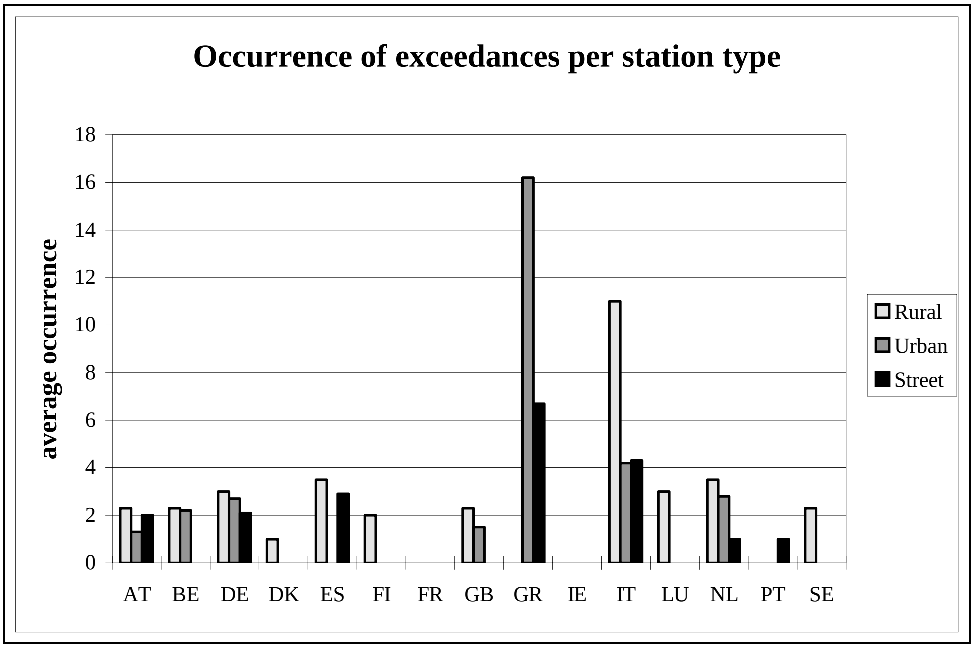
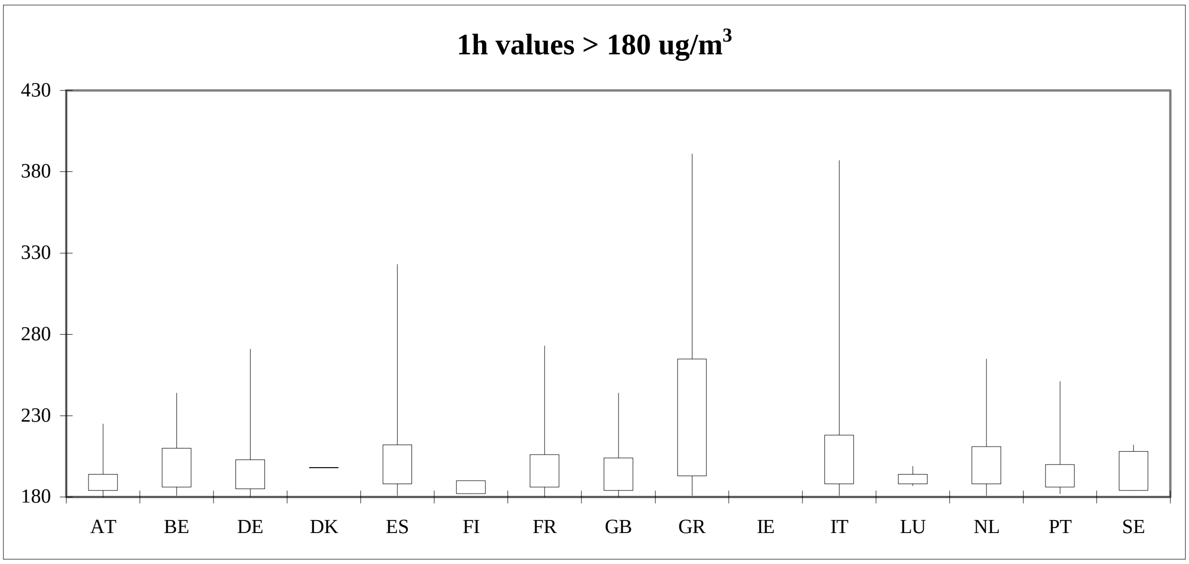


Figure 3: Average occurrence of exceedances (in days) of the threshold for information of the public (1h concentration > 180 µg/m^3) by station type (rural, urban and street) and country.

Figure 4 shows the frequency distribution of hourly ozone concentrations in excess of the threshold value using Box-Jenkins plots. For each Member State the Box-Jenkins plot indicates the minimum (here the minimum is 180 µg/m^3), the maximum, the 25 percentile and the 75 percentile value of the exceedances. The figure shows that during 25% of all observed exceedances, the maximum hourly concentration recorded was just above the 180 µg/m^3 threshold. 75% of all maximum exceedances recorded were below 208 µg/m^3. During the same period last year, the 75 percentile was ca. 6% higher.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#Ex	99	27	607	1	99	2	217	38	102	0	191	6	92	5	7
#St	114	22	386	6	132	11	155	42	11	6	69	5	38	9	6

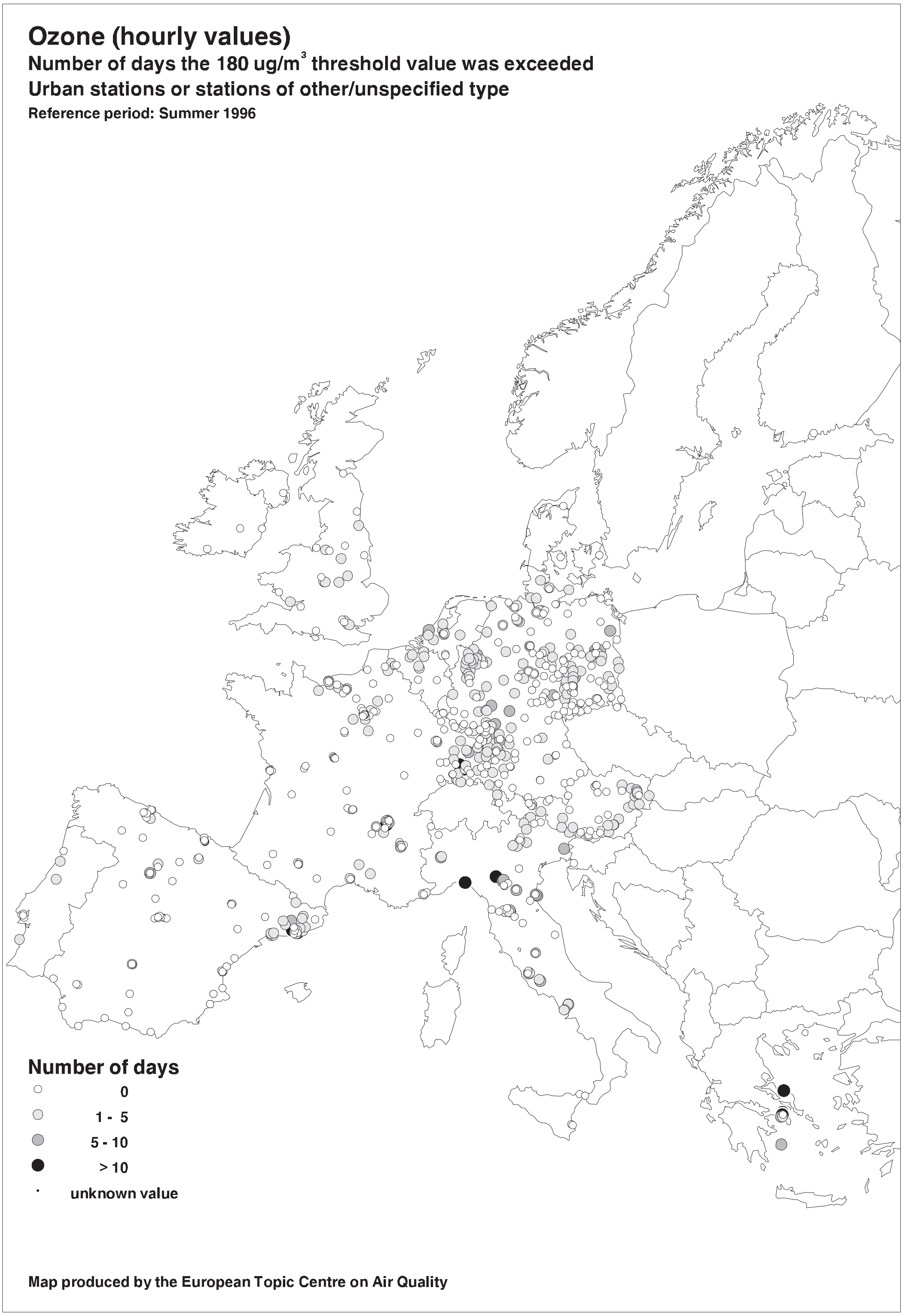
Figure 4: Frequency distribution of ozone concentrations in excess of the 180 $\mu g/m^3$-threshold for hourly values (April-July 1996). For each country the total number of observed exceedances is given in row '#Ex', the number of stations is given in row '#St'. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-Percentile, the 75-percentile and the maximum value.

Geographical distribution

Maps 2 and 3 show the geographical distribution of the number of days on which the threshold value for information of the public was exceeded for urban[13] and background stations, respectively. Exceedance data for urban stations are presented as dots. The exceedance data for rural stations are interpolated using simple inverse distance weighting and a tentatively estimated 'radius of representativeness' of 100 km. Note that this radius might be different for the various regions in Europe. Calculation should be based on more detailed analysis of the ozone phenomenology at the stations in future.

No simple spatial structure is visible as far as exceedances at urban stations are concerned. Note that information for July from Spain is missing, that the reporting period is only 4 months and stations of unspecified type are also plotted in this map. The interpolated exceedance map for rural locations is too fragmented to draw firm conclusions on spatial patterns. The rural stations cover approximately 47% of the EU territory. The area where exceedances were observed, calculated on basis of the interpolated map, is approximately 48% of the total area covered by background stations which is estimated at 23% of the total EU territory.

[13] Exceedances reported from stations of unspecified type are also plotted in this map.



Map 2: Number of exceedances of the threshold value for the information of the public (1h > 180 µg/m^3) observed at urban stations and stations of unspecified type. Summer 1996 (April-July).

Map 3: Number of exceedances of the threshold value for the information of the public (1h > 180 µg/m³) observed at background stations. Summer 1996 data (April-July), interpolated using inverse distance weighting and a cut-off distance of 100 km.

4. MAIN OZONE EPISODES

Ozone formation and destruction is dependent on emissions, concentrations and ratios of precursors (mainly VOC, CO and NO_X), and on the amount and intensity of sunlight. Important in this respect is the role of nitrogen oxide emissions. In urban areas, the ozone concentrations may be lower than the rural ('background') concentrations due to chemical scavenging by local nitrogen oxide emissions (see for example Figure 3, which shows that the occurrences of exceedances are in general the highest at rural stations).

Episodes, periods with elevated ozone levels, will mainly occur during periods of warm sunny weather. In the Mediterranean countries, having prolonged spells of hot and sunny weather during the summer, ozone can quickly be formed and high levels can occur on many days and in the vicinity of urban centres. In northern Europe the build up of ozone is slower due to the more moderate weather conditions. Here, highest levels will generally be found outside cities.

Figure 5 presents a graphical representation of the percentage of stations in every Member State that reported exceedances of the threshold value for population information (180 μg/m^3 for hourly values) during the 1996 summer season.

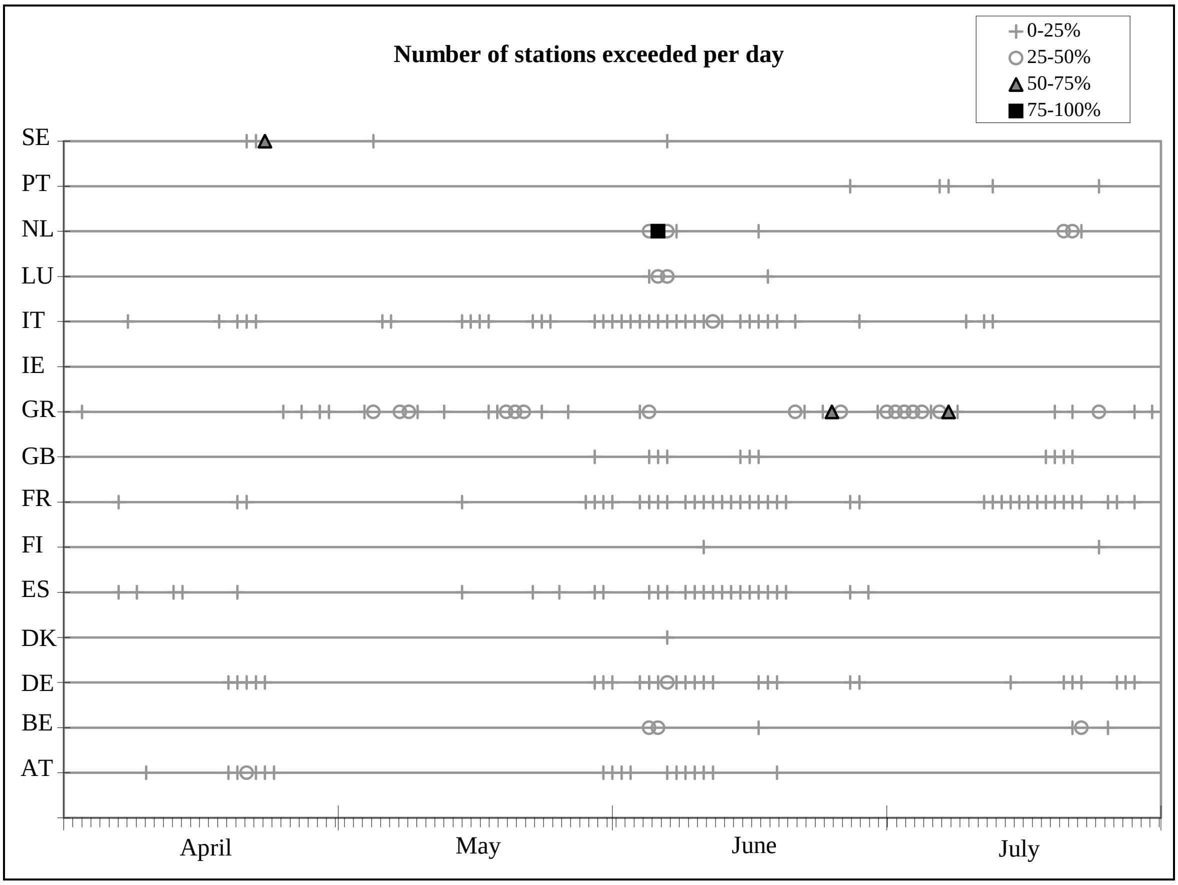
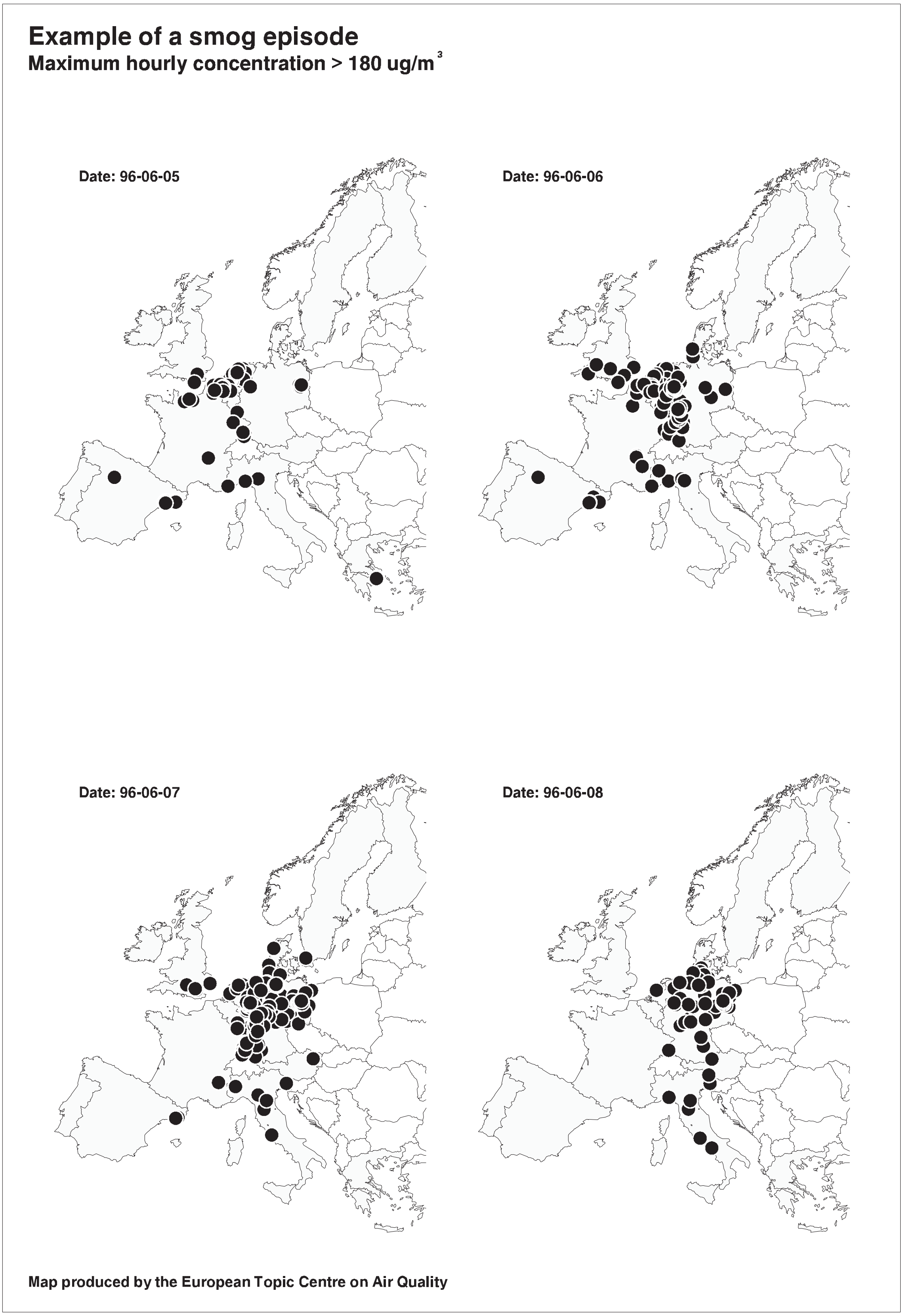


Figure 5: Qualitative overview of exceedances of the 180 μg/m^3 population information threshold value (1h) during the period 1 April - 30 July 1996. The symbols represent the percentage of stations that observed at least one exceedance of the threshold for the information of the public during a particular day

From Figure 5 it is clear that the number of episodes covering extended areas of the European territory was limited during summer 1996. As already mentioned in Section 3, weather conditions in western and northern Europe were often unfavourable for the build-up of ozone. On many days cool and relatively clean Atlantic air masses prevailed in northern and western European countries. Frontal activity could often be found in the Alps region. One of the most widespread northern European episodes this summer occurred 5-8 June 1996. Map 4 presents an overview of the sites that observed an exceedance during this period. In the text box, the conditions leading to this episode are described in more detail. In contrast, in southern Europe frequent exceedances are observed throughout the reporting period.

The episode of 5-8 June 1996

On the first days of June, a high pressure cell formed over western Europe. On 4 June, this pressure cell dominated the weather north of the Alps. On that day, the air mass present north of the Alps could be characterised as relatively clean and cool Atlantic air. On 5 June, the centre of the high pressure cell was situated near the Baltic States. In western Europe, a light SE-circulation set in which started to transport the air mass, which had been present for a few days over the Continent, to the North Sea basin. Under the influence of the intense solar radiation, surface temperatures reached summerly values and exceedances were observed in BeNeLux, northern France and southern UK. Hardly any exceedance was observed in Germany on 5 June where cool Atlantic air was still present. On 6 June, temperatures reached 30°C in many places and the area where exceedances occurred extended to include the western part of Germany and parts of Denmark. The number of exceedances in the eastern part of Germany was still limited. On 7 June a cold front, behind which cooler and cleaner air moved in, reached the western part of the UK; exceedances in the UK were limited to the south-eastern part of the country. In the hot air preceding the cold front (34°C was reached for example in the Netherlands), thunderstorms developed during the day in France and Belgium. Although there was no change in air mass, the thunderstorms and more generally the build-up of clouds ended the episode in France and Belgium. Further east, the area where ozone levels reached the threshold now included eastern and northern parts of Germany and the southern tip of Sweden. On 8 June, the cleaner Atlantic air behind the cold front reached France, BeNeLux and SW-Germany and subsequently no more exceedances were observed in these regions. On 9 June, the cleaner and cooler air covered the whole of Europe north of the Alps and no further widespread exceedances were reported.
Note that during the whole period the weather was warm and sunny in southern Europe and (occasional) exceedances were also reported from Spain, Italy and Greece.



Map 4: Example of a smog episode: stations that reported an hourly ozone concentration in excess of 180 µg/m^3, 5-8 June 1996 (all station types).

Figure 6 and 7 present the maximum hourly ozone values recorded in the Athens conurbation (Greece) and in Firenze (Florence, Italy), as examples of 'local' ozone episodes in the Mediterranean region. Both in Athens and Firenze, the threshold for warning of the public (1h >360 µg/m^3) was exceeded. Note that other stations in and around Athens did not report exceedances during this period. More information on the specific conditions leading to these particular episodes is not yet available to the authors of this report.

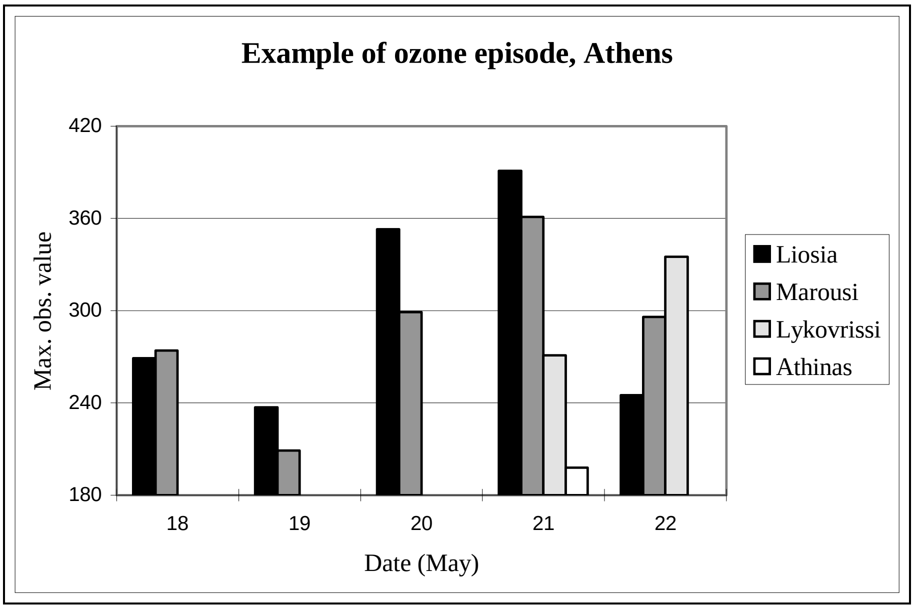


Figure 6: Example of a local ozone episode, Athens 18-22 May 1996. Maximum observed 1h values (µg/m^3) on stations in the Athens conurbation that observed an exceedance of at least 180 µg/m^3 (1h).

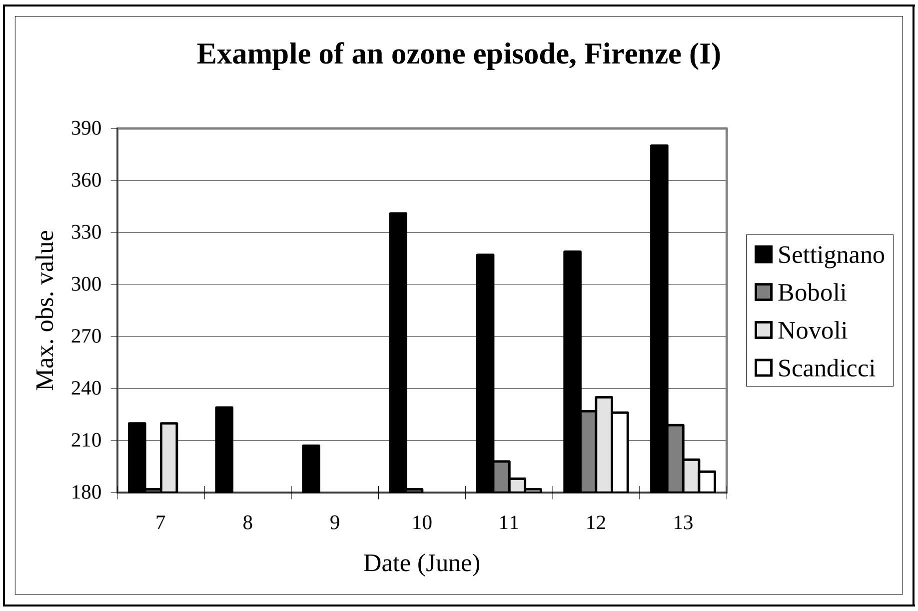


Figure 7: Example of a local ozone episode, Firenze (Florence) (I),7-13 June 1996. Maximum observed 1h values (µg/m^3) on stations that observed an exceedance of at least 180 µg/m^3 (1h).

5. POPULATION EXPOSURE TO EXCEEDANCES

The actual outdoor exposure of the population to ozone is difficult to estimate. In addition to estimating the spatial distribution and time variation of the ozone concentration, the location and physical activity level of the population should be known. Since detailed data about these variables is not available, the description of exposure must be limited to estimating the number of people that possibly experienced ('were potentially exposed to') at least one exceedance of ozone concentrations above the information threshold value during summer 1996.

For rural areas, the number of people exposed to at least one exceedance could not be calculated. The interpolated exceedance 'field' (Map 3) is too fragmented. Moreover, no rural population database is available at the moment.

For urban areas, using a Geographical Information System, the location of urban stations was combined with an urban population database provided by Eurostat [6]. This database lists ca. 2100 cities in the EU with more than 25 000 inhabitants. It is estimated that from a total EU population of ca. 362 million, ca. 195 million people live in these cities. Approximately 66 million people live in cities in which at least one ozone station was operational during the 1996 summer season (34% of the total EU urban population or 18% of the total EU population). 142 cities reported at least one exceedance of the population information threshold value. Approximately 31 million people in these cities (46% of the urban population living in cities with operational monitors) were potentially exposed to at least one exceedance. The urban exposure estimates are presented in Figure 8.

The results should be interpreted with great care. In many cities, only one station is operational and exceedances at such a station were attributed to the whole urban population. The current description of station types is imprecise and for a substantial number completely missing. Nevertheless, it is obvious that urban population exposure estimates cannot be based on monitoring results alone, since monitoring stations cover only 34% of the total urban population.

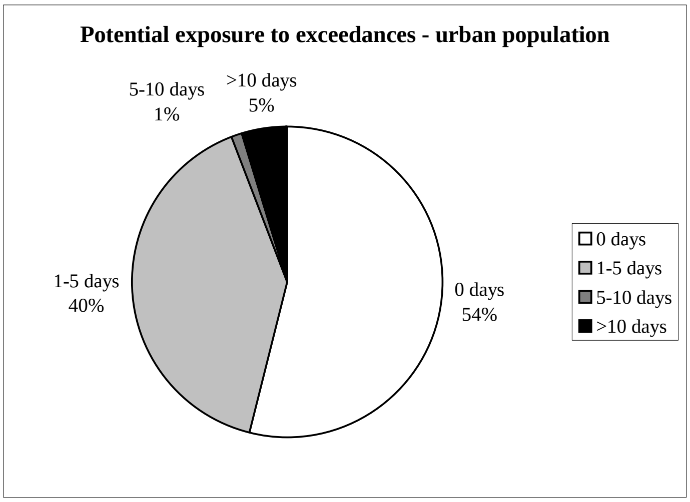


Figure 8: Number of exceedances (in days) and frequency distribution of urban population potentially exposed to hourly ozone concentrations exceeding 180 µg/m^3, April-July 1996. (Representative for an urban population of 66 million (34% of the EU urban population) living in cities with more than 25 000 inhabitants; 18% of the total EU population).

6. CONCLUSIONS

This report presents a first evaluation of the reported exceedances of the threshold value for information and warning of the public during summer 1996.

Information on the occurrence of exceedances was received from all EU Member States for the months April, May, June and July, except for July from Spain. The quality of the information supplied was greatly improved compared to earlier years. Improvements can be made for a number of countries as far as characterisation of stations is concerned and timely reporting of observed exceedances. 1012 monitoring stations were scheduled to be operational this summer, an increase of 154 stations since last year.

The threshold for warning the public (1h > 360 $\mu g/m^3$) was exceeded at three stations during summer 1996; at two stations in Athens (Greece) on 21 May 1996 and at one station in Firenze (Florence, Italy) on 13 July 1996.

The threshold for information of the public (1h > 180 $\mu g/m^3$) was exceeded in all Member States except for Ireland. The number of days on which at least one exceedance was observed ranged from one in Denmark to 41 in France. 48% of all stations reported one or more exceedance. On average 3.1 exceedances occurred this year on stations that recorded at least one exceedance. The average length of an episode was three hours.

The number of stations that reported an exceedance, the occurrence of exceedances at those stations and maximum concentrations during episodes this year were lower then during the 1995 summer season. This difference can mainly be attributed to year-to-year weather variability. Especially in northern and western Europe, the weather conditions during the 1996 summer season were on average less favourable for high ozone levels than during the 1995 summer season. This year, cool and relatively clean Atlantic air masses prevailed on many days. By contrast in 1995, a number of heat-waves was recorded and especially July was very hot and sunny.

A first estimate was made of the percentage of the urban population exposed to at least one exceedance of the population information threshold. Approximately 66 million people live in 322 cities (with more than 25 000 inhabitants) in which one or more ozone stations were operational during the 1996 summer season (34% of the total EU urban population or 18% of the total EU population). 142 cities reported at least one exceedance of the population information threshold value. Approximately 31 million people in these cities were potentially exposed to at least one exceedance. However this estimate should be interpreted with great care. In many cities, only one station is operational and exceedances at such a station were attributed to the whole urban population. The current description of station types is unprecise and for a substantial number completely missing. Nevertheless, it is obvious that urban population exposure estimates cannot be based on monitoring results alone, since monitoring stations cover only 34% of the total urban population.

REFERENCES

World Health Organization (1995): Concern for Europe's tomorrow. Health and the environment in the WHO European region. WHO European Centre for Environment and Health.

World Health Organization (1987): Air quality guidelines for Europe. WHO, Copenhagen, regional publications, European series No. 23.

Council Directive 92/72/EEC on air pollution by ozone.

De Leeuw, F., E. van Zantvoort: Exceedance of ozone threshold values in the European Community in 1995. Summary based on the information reported in the framework of the Council Directive 92/72/EEC on air pollution by ozone. European Topic Centre on Air Quality.

European Commission, (Doc.XI.D3/PP D(96)): Information document prepared by EC-DGXI/D3 to the expert group on photochemical air pollution concerning the transfer of ozone exceedance files.

EUROSTAT digital population database.