Topic report No 10/2000

Air pollution by ozone in Europe in 1998 and summer 1999

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1. Preface

This report is based upon data submitted to the European Commission under Directive 92/72/EEC on air pollution by ozone. The Commission had requested the European Environment Agency (EEA) to assist in this reporting. The voluntary submission to the EEA of information on ozone levels by other European countries have made it possible to present an ozone assessment on a wider European scale. The data collection in Phare countries was greatly facilitated by the Phare Topic Link on Air Quality. Two separate reports, one covering the year 1998, the other covering summer 1999, were originally produced by the European Topic Centre on Air Quality under contract to the EEA. These reports were presented to Member States at their meeting under the Directive in October 1999.

In this topic report, the annual 1998 and summer 1999 reports as presented to the Commission are reproduced here in an updated version. New information which became available after the preparation of the initial separate reports to the Commission has been included in this topic report. The differences in available data, the set of threshold values, the number of stations, the location of stations and the status of the information (based on validated 1998 data and non-validated 1999 data) justifies such an approach.

A major asset of this report is the timeliness of its initial delivery as a draft report to the Commission to present to the countries each autumn. The assessment of ozone episodes in summer 1999 was based upon data made available by the end of September 1999, a delay of one to six months, while the normal production time from field measurements to validated assessment reports is rarely less than eighteen months. This timely reporting has only been possible with the support of the individual contact points within each Member State and the efficient communication established.

The harmful effects of tropospheric ozone on human health and well-being as well as damage to ecosystems is now recognised as a major concern throughout the European Union. The European Community has taken steps to address the problem through Directive 92/72/EEC on ambient ozone, Directive 96/62/EEC on ambient air quality assessment and management (the Air Quality Framework Directive), and development of an ozone daughter Directive, as well as the decision to develop a Community strategy for the reduction of ozone pollution. The measures necessary to abate pollution remain however a responsibility of each Member State and require political decisions with cost implications and consequences for the development of activities in the society. In this political process objective and reliable information on the extent and severity of the issue is essential.

It is the intention of EEA to continue yearly reporting and assessment of ground level ozone in Europe in close cooperation with the European Commission, EU Member States and other countries.

Gordon McInnes
Programme manager

2. Summary

This report summarises the annual information on ozone monitoring stations and exceedances of ozone threshold values during 1998 and gives a first evaluation of the observed exceedances of the thresholds during summer 1999 (April-August). According to the Council Directive 92/72/EEC on air pollution by ozone, EU 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 for the year 1998 presented in this report is based on information made available before 15 August 1999. By then, information for the calendar year 1998 had been received from all Member States and, on a voluntary basis, from 10 other European countries (Czech Republic, Estonia, FYROM, Latvia, Lithuania, Norway, Poland, Slovakia, Slovenia and Switzerland). Information on the situation in Bulgaria was received more than one month later; as far as possible the Bulgarian data was included in the current version.

For the summer 1999 period, all 15 EU Member States provided information on the observed exceedances in time (the deadline for transmitting data was set at 13 September 1999), or indicated that no exceedances were observed. It is greatly appreciated by the Commission that Member States were able to transmit August exceedance data before the formal deadline as set in the Directive. In addition, the 10 other European countries listed above reported on the summer ozone situation. This information has also been included in this report.

From an evaluation of the exceedances and annual statistics, the following conclusions are drawn:

- In 1998 the threshold value set for the protection of human health (110 $\mu g/m^3$ for 8-hourly average concentrations) was exceeded substantially and in all reporting countries. On average, this threshold is exceeded on more than 24 days per year at each station.
- In 1998 the threshold value of daily average concentrations set for the protection of vegetation (65 $\mu g/m^3$) is exceeded substantially (by up to a factor 3), widely (in all reporting countries) and frequently; at 94 stations (about 10 % of the reporting stations) located in 13 different countries exceedances were reported during more than 200 days.
  The threshold value of hourly average concentrations set for the protection of vegetation
  (200 $\mu g/m^3$) is exceeded largely and widely (reported by 11 EU Member States and in four other European countries) on a limited number of days. On average, 2.2 exceedance days per station were reported for monitoring stations in EU Member States.
- In 1998 the threshold value for providing information to the population (180 $\mu g/m^3$ for hourly values) was exceeded during a limited number of days in 18 countries, of which 11 are EU Member States. In EU Member States a total of 5283 exceedance days (on average 3.9 days per station) were reported. During Summer 1999 the number of days on which at least one exceedance was observed in the EU ranged from 2 in Luxembourg to 68 in Italy. 27 % of all stations reported one or more exceedance. On average, 4.3 exceedances

occurred this summer at stations which recorded at least one exceedance; the average exceedance duration was 2.8 hours. The average maximum hourly concentration during an exceedance of the threshold this year was 202 µg/m^3.

- In 1998 exceedance of the threshold value for warning of the population (360 µg/m^3 for hourly values) was reported from nine stations of which eight stations are located in three Member States. For three stations in the Athens conurbation, four stations in Italy (Castenaso, 10 km east of Bologna; Cormano in the outskirts of Milan; Riccione along the coast of the Adriatic Sea, south of Rimini and Busto Palermo located in region Lombardia north-west of Milan), one station in France (Notre Dame de Gravenchon, halfway between Le Havre and Rouen) and one station in Bulgaria (AMS Rakovsky in Dimitrovgrad) exceedance of the warning level was reported. No exceedance of the warning threshold was reported in Summer 1999.
- Information on annual statistics (percentile values) and on exceedances of ozone for the year 1998 were received from a total of 1400 stations within the EU and from 130 stations in other countries. During summer 1999 a comparable number of stations was operational.
- Spatial coverage and documentation on monitoring data quality has improved compared to previous reporting periods but still needs further improvement as specified in earlier reports. 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 geographical coverage of the rural stations is rather adequate in north-west and central Europe but in other regions gaps are noted.

DISCLAIMER
THE INFORMATION PRESENTED IN PART II, *INFORMATION DOCUMENT CONCERNING AIR POLLUTION BY OZONE*, IS PARTLY BASED ON NON-VALIDATED MONITORING DATA AND HENCE SHOULD BE REGARDED AS PRELIMINARY

Part I:

Exceedance of EC ozone threshold values in Europe in 1998

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
Annemarieke Camu

30 September 1999

1. Introduction

Ozone, O_3, is a strong photochemical oxidant, which causes serious health problems and damage to materials and ecosystems. Human exposure to elevated levels of ozone concentrations can give rise to inflammatory responses and decreases in lung function. Symptoms observed are cough, chest pain, difficulty in breathing, headache and eye irritation. Both laboratory and epidemiological data indicates large variations between individuals in response to episodic ozone exposure, the effects seem to be more pronounced in children than in adults. Studies indicate that exposure to ozone concentrations in the range 160-360 $\mu g/m^3$ for a period of 1-8 hours – concentrations often observed in ambient air over Europe – reduces various pulmonary functions. During a 3-year study small but consistent decrements in lung function in a cohort of school children living in north-east Austria, were observed. These effects were associated with long-term ambient ozone exposure (Frischer *et al.*, 1999).

Ozone exposure of ecosystems and agricultural crops results in visible foliar injury and in reductions in crop yield and seed production. For vegetation a long-term, growing season averaged exposure rather than a episodic exposure is of concern. Adverse effects on vegetation can be noted at relatively low ozone levels. Within the framework of the UN-ECE Convention on Long-range Transboundary Air Pollution the critical level[1] for ozone is expressed as the accumulated ozone exposure above a threshold of 40 ppb (corresponding with 80 $\mu g/m^3$). Guideline values of this accumulated ozone exposure of 3000 ppb.h and 10,000 ppb.h are given for crops and forest, respectively. The World Health Organization Regional Office for Europe Europe (WHO) came forward with similar guidelines (WHO, 1996b).

It is known that ozone affects materials such as natural and synthetic rubbers, coatings and textiles. However, there are today serious gaps in knowledge on the mechanisms of damage, the attribution of ozone to damage in comparison to other factors and the economic evaluation of such damage. As far as understood there is no 'no-effect level' of ozone for material corrosion; it is assumed that dose-response relations for materials are linear or nearly linear under ambient conditions. Synergistic effects of ozone in combination with the acidifying components SO_2 and NO_2 have been reported to lead to increased corrosion on building materials like steel, zinc, copper, aluminium and bronze.

In view of the harmful effects of photochemical pollution in the lower levels of the atmosphere, the Council adopted in 1992 Directive 92/72/EEC on air pollution by ozone. The Directive came into force in March 1994. It established procedures for harmonised monitoring of ozone concentrations, for exchange of information, for communication with and alerting of 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 within one month

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[1] Critical levels are defined as concentrations of pollutants in the atmosphere above which direct adverse effects on receptors, such as plants, ecosystems or materials may occur according to present knowledge (Bull, 1991).

after occurrence. Information on exceedances of all threshold values given in Article 6 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 gives an overview of ozone monitoring results of 1998. Similar overviews for the period 1994-1997 have been prepared by the European Topic Centre on Air Quality (de Leeuw *et al.*, 1995; 1996; 1997; 1999). Prior to the current report an overview on ozone threshold exceedances during Summer 1998 (April-August; based on partially validated data) has been presented to the Commission (de Leeuw *et al.,* 1999).

Harmful ozone concentrations are observed over the whole of Europe. Formation of ozone takes place at various space and time scales: the high emission density of reactive precursors in urbanised areas might lead to high ozone levels within the city or at short distances downwind. But ozone precursors may also be transported over distances of hundreds to thousands kilometres, resulting in ozone formation far from the sources. For improving the insight in current ambient ozone levels over Europe, countries outside the European Union have been requested by the European Environment Agency (EEA) to provide information on ozone exceedances in line with the Ozone 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 on Photochemical Pollution. This group, established by the Commission following Article 7 of the Directive, had several meetings to coordinate the work within the Member States and the Commission in the framework of the Directive.

Background information on the current experience and knowledge concerning 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), Derwent and Van den Hout (1995), Jonson *et al.,* (1999). An overview of the situation within the European Union can be found in *Tropospheric ozone in the European Union. The consolidated report* (Beck *et al.*, 1999) which has been prepared following Article 8 of the Directive. In the process of preparing the new ‘Ozone Daughter Directive’, a comprehensive review of almost all aspects concerning ozone pollution is currently prepared by an expert group established by the European Commission. This so-called *Position Paper on Ozone* will be published in 1999. Some aspects of the ozone phenomenology are briefly discussed in Annex II.

A proposal for a new ozone daughter directive under the air quality framework directive (96/62/EC) has been put forward by the Commission (proposal COM(99)125). In this new proposal long-term objectives and target values for the protection of human health and vegetation are defined based on the revised guidelines of WHO (WHO, 1996). The target values should be attained, as far as possible, in 2010. In addition, the proposed ozone directive sets information and general alert thresholds. Whereas for humans an exposure period 8 hours is considered, for the protection of vegetation the relevant period extends over the whole growing season (three months). Based on the gap between current ozone levels and the targets, one might say that the targets for protection of vegetation will be more difficult to meet than the human health related targets.

2. Data reporting

2.1. Introduction

According to the Ozone Directive, 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 ozone 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 based on validated data, 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. The monthly reports for summer 1998, which were not necessarily completely validated, have been reported before (de Leeuw *et al.,* 1999).

Table 1. Threshold values for ozone concentrations (in $\mu g/m^3$) set in Directive 92/72/EEC

threshold for:	concentration	averaging period
health protection	110	8 h
vegetation protection	200	1 h
	65	24 h
population information	180	1 h
population warning	360	1 h

A group of experts from the Members States have followed the practical implementation of the Directive. Among other items this group discussed procedures for data reporting. The formats for information and data exchanges have been 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 measurements 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, as well as the improvement of the transfer of data relating to the implementation of the Directive, the Commission has prepared an update (April 1996) of the data exchange format. The major changes concern the transfer of additional information:

- type of station: definition of the location of stations as recommended in the Decision on Exchanges of Information (97/101/EC);
- 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.

For submission of the 1998 data no further modifications in data requirements and data exchange formats have been made. Non-EU countries have been requested to submit their data in agreement with these data exchange formats. Information submitted using the Air Quality DEM (*Date Exchange Module*, a software tool developed by ETC/AQ (Sluyter and Schoorl, 1999) to facilitate data flows under the Exchange of Information Decision 97/101/EC) is accepted as well.

2.2. Data handling

According to the Ozone Directive the requested information over 1998 should have been forwarded to the Commission before 1 July 1999. All data forwarded by the Commission and received at the European Topic Centre on Air Quality (ETC/AQ) before 14 August 1999 has been processed is this report. In this report the definition of the data formats as described in the 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.

Non-EU Member States were contacted by the European Environment Agency, through the Phare Topic Link on Air Quality or, in case of Switzerland, directly and requested to voluntarily submit data following the standard formats on data exchange. Information has been received from Switzerland, Czech Republic, Estonia, Lithuania, Latvia, FYROM, Norway, Poland, Slovakia and Slovenia. After the closing date for data submission for the report to the Commission information from Bulgaria has been received. For technical reasons, the Bulgarian stations have not been included the maps.

The summary of received information presented in Table 2 shows that the information for the EU is nearly complete. However, analysing the data revealed a number of errors, ambiguities or missing data.

From France, information on geographical location was not received for all reporting stations. Information on additional monitoring stations was extracted, as far as possible, from data delivered for the 1997 annual report. The information on exceedances submitted by France did not include information on exceedances during the 8h periods. Information on exceedances of the hourly thresholds of 180 and 200 $\mu g/m^3$ was received for the summer period only. Various minor points were clarified by contacting the French data supplier.

From Italy, a file containing station characteristics was not included in the submitted information. As far as possible this information was extracted from information recently submitted to AIRBASE. Also in case of Italy it was shown that bilateral contact with the data supplier is essential for clarifying ambiguities.
Some errors were detected in the data received from the Netherlands, which were corrected after consultation with the data supplier. There was also some (minor) lack of clarity in the Norwegian data. A quick response from the data supplier at NILU solved this point.

A *Measurement techniques file* was not received for several countries; in these cases, the information received in 1998 was assumed to be valid.

Table 2. Summary of information received for 1998

country	station info	meas. tech	statistics	exceedance	NO_2	NO_x	VOC
Austria	✓	✓	✓	✓	×	×	×
Belgium	✓	✓	✓	✓	✓	×	✓
Denmark	✓	✓	✓	✓	×	×	×
Finland	✓	✓	✓	✓	✓	✓	×
France	×(3)	×	✓(5)	✓(6)	×	×	×
Germany	✓	×	✓	✓	×	×	×
Greece	✓	✓	✓	✓	✓	✓	×
Ireland	✓	✓	✓	✓	×	×	×
Italy	×(7)	×	✓	✓	×	×	×
Luxembourg	✓	✓	✓	✓	✓	✓	✓
The Netherlands	✓	✓	✓	✓	✓	✓	✓
Portugal	✓	×	✓	✓	✓	✓	×
Spain	✓	✓	✓	✓	×	×	×
Sweden	✓	✓	✓	✓	×	×	×
United Kingdom	✓	✓	✓	✓	✓	✓	✓ (1)
Bulgaria	×	×	✓	✓(9)	✓	✓(8)	✓
Czech Republic	✓	✓	✓	✓	✓	✓	×
Estonia	✓(2)	×	×	✓(2)	×	×	×
F.Y.R. of Macedonia	✓	✓	×	✓	×	×	×
Latvia	✓	✓	✓	✓	×	×	×
Lithuania	✓	✓	✓	✓	✓	✓	×
Norway	✓	×	✓	✓	×	×	×
Poland	×(4)	×	✓	✓	×	×	×
Slovakia	✓	✓	✓	✓	×	×	×
Slovenia	✓	✓	×	✓	×	×	×
Switzerland	✓	✓	✓	✓	✓	✓	✓

✓: delivered;
×: not delivered;
(1) file contains no data and/or no information;
(2) data delivered in a format deviating from agreed formats; conversion by ETC/AQ;
(3) information on station not delivered; data delivered for the 1997-annual report used;
(4) station information not delivered but extracted from statistic file;
(5) data for hourly averaged concentrations delivered in a format deviating from agreed formats; conversion by DGXI;
(6) only exceedances of thresholds of 180, 200 and 360 µg/m3 (1h; period 1 April – 31 August) and 65 µg/m3 (24h) are reported;
(7) station information not delivered but extracted from statistic file and from AIRBASE;
(8) only NO data submitted;
(9) only exceedances of thresholds of 180 and 360 µg/m3 are reported.

Voluntary data on precursor concentrations was received for seven Member States and four additional countries.

For 1998 information on ozone concentrations (annual statistics and/or exceedance information) were received for 1540 monitoring stations of which 1400 were located in EU Member States.

Figure 1 shows the number of stations reported since the first reporting year 1994. Compared to 1997, the increase in the number of EU-stations is mainly due to increases in the southern countries (France, Italy, and Spain).

While processing the data it was noted that for a limited number of stations conflicting information was submitted. For the stations listed in Table 3, no exceedances of the 180 µg/m³ and/or 200 µg/m³ level were reported while the maximum concentration is in excess of both 180 µg/m³ and 200 µg/m³. Due to time constraints and because only minor corrections are expected when the exceedance data for these stations has been updated, the data suppliers have not been contacted on this point.

Table 3. Stations not explicitly reporting exceedances but with a maximum concentration in excess of the threshold levels

Country	Station name	180 µg/m³ threshold	200 µg/m³ threshold	max. 1h conc (µg/m³)
Austria	Sulzberg	×	✓	188
France	Martigues La Gatasse	×	×	245
France	Auribeau Mourre-Nègre	×	×	240
France	30030	×	×	208
France	Avicen	×	✓	182
Italy	Aosta (Mont Fleury)	×	×	247
Italy	Belluno – La Cerva	×	×	296
Italy	Martellago	×	×	292
The Netherlands	Wieringerwerf	✓✓	×	259
The Netherlands	Amsterdam-Florapark	×	✓	182

✓: correctly no exceedances reported;
✓✓: exceedances reported ;
×: exceedances expected but not reported.

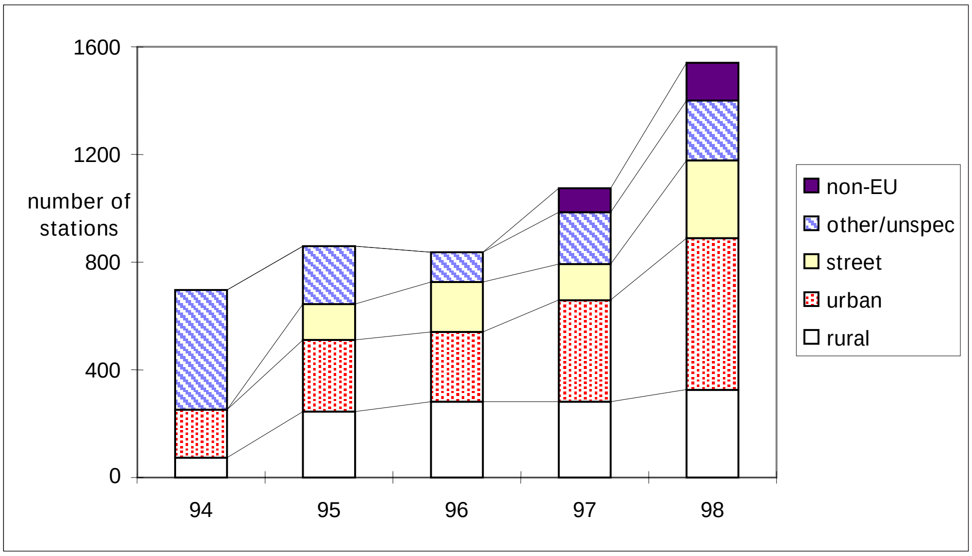


Figure 1. Number of stations reporting ozone data within the framework of the ozone directive. For stations in non-EU countries a station classification is known but not resolved in this figure for clarity.

3. Survey of reported data for 1998

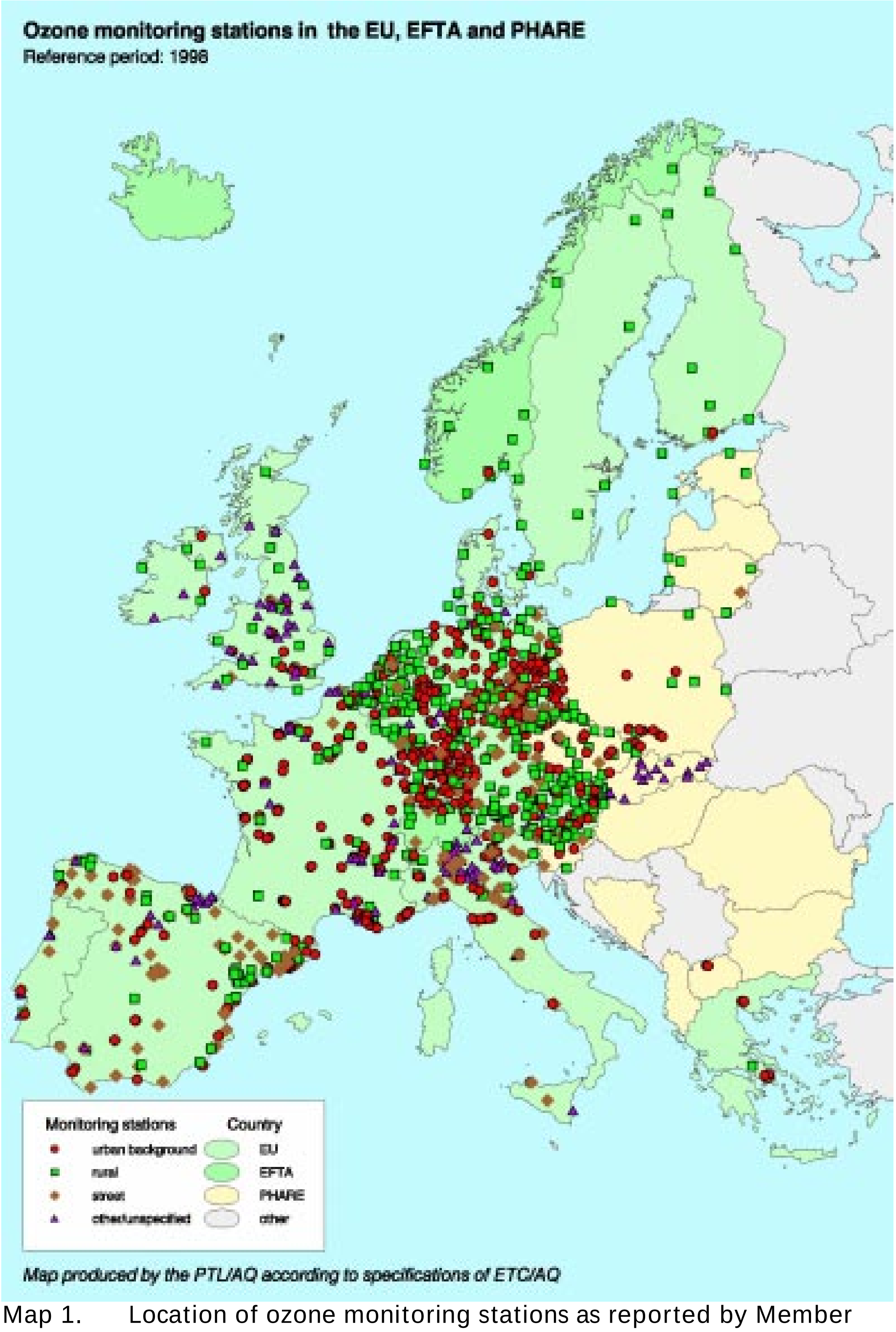
The location of monitoring stations in EU Member States which are used for the implementation of the ozone directive and which are reporting over 1998, is presented in Map 1. Stations located in other European countries, which have reported ozone data on a voluntary basis, are shown as well. In total information for 1400 stations in 15 Member States has been received; for 140 stations in the reporting non-EU countries information has been received. Nearly all reporting countries use the reference method (UV absorption) as prescribed in Annex V of the Ozone Directive. However, at a limited number of German stations chemiluminescence is used. Information on the analytical method is incomplete or not given at all for stations in France, Italy, Bulgaria, Norway and Poland.
In 1998 for nine stations exceedances of the threshold value of 360 $\mu g/m^3$ for hourly values were reported (Table 4). In contrast to the 1998 summertime exceedances in France and Greece, exceedances at the Italian stations were not reported previously and they are therefore not included in the first assessment of the 1998 summer season (de Leeuw *et al.,* 1999).

Exceedances of the threshold value for warning of the public were exceeded regularly in the Athens conurbation (in 1994, 1996, 1997). The exceedances in Athens in July 1998 are examples of a local ozone episode, which occurs frequently in the urbanised Mediterranean region. The exceedances during the beginning of August are examples of a continental-scale episode covering large parts of Europe; for a more extensive description of these episodes, see de Leeuw *et al.* (1999). The exceedances in October are again limited to the Athens conurbation. In the period 9-11 October, 2-7 stations in and around Athens reported exceedances of the 180 $\mu g/m^3$ threshold; no other country reported an exceedance of this threshold during this month.

The newly reported exceedances in Italy in May, June and July have a more meso-scale character. Geographically the episodes appear to be limited to Italy. With the exception of Switzerland where 2-4 of the 13 stations report exceedances of the 180 $\mu g/m^3$ threshold, in none of the other countries high levels were observed during this period. In time the episodes extend from 1 to 6 days: from 20 to 24 July, 30-60 % of the Italian ozone stations reported exceedances of the 180 $\mu g/m^3$ threshold.

A summary of the maximum concentrations measured at each of the reporting stations where exceedance of a threshold value is observed is presented in Table 5. 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. When no exceedances of a threshold have been reported by a country, this is indicated with a dash (-).

The maximum concentrations reported here are substantially higher than the maximum values reported for 1997 by EMEP (Hjellbrekke, 1999). Differences in monitoring period (1998 was a high-ozone year compared to 1997) can only partly explain the difference. The EMEP sub-set of stations might not be indicative for the worst air quality situations for ozone.



Map 1. Location of ozone monitoring stations as reported by Member States in the framework of the Ozone Directive for the reference period 1998. Stations for which other European countries submitted information are also shown.

Table 4. Reported exceedances of the threshold for warning of the public (1h concentration exceeding 360 µg/m^3); reference period 1 January – 31 December 1998.

country	station name & city	date	time & duration	max conc
Italy	Riccione Lungamare Liberta	21-5-98	14.00; 1 h	387
Italy	Castenaso	20-6-98	15.00; 1 h	363
Greece	Marousi, Athens	2-7-98	13.00; 3 h	421
Greece	Lykovrissi, Athens	2-7-98	13.00; 5 h	410
Greece	Marousi, Athens	3-7-98	12.00; 2 h	401
Greece	Lykovrissi, Athens	3-7-98	12.00; 3 h	425
Italy (1)	Busto Palermo	24-7-98	12.00; 2 h	443
Italy (1)	Busto Palermo	24-7-98	17.00; 2 h	414
Greece	Lykovrissi, Athens	29-7-98	13.00; 1 h	367
France	Notre Dame de Gravenchon, Le Havre	7-8-98	11.00; 1 h	405
Italy	Cormano 1	10-8-98	14.oo; 1 h	365
Greece	Liosia, Athens	10-10-98	15.00; 1 h	365
Greece	Marousi, Athens	10-10-98	14.00; 1 h	389
Greece	Lykovrissi, Athens	10-10-98	14.00; 2 h	463
Bulgaria	AMS Rakovsky, Dimitrovgrad	4-11-98	16.00; 1 h	365

(1) As exceedances are counted on a daily basis, these two non-continuous periods form only one exceedance.

Table 5. Maximum ozone concentrations (µg/m^3) measured during a period of exceedance of threshold values (period 1 January – 31 December 1998). A dash (–) indicates that no exceedances have been observed; and indicates that no data is available. Exceedances of the 180 µg/m^3 level are based on (a) three non-overlapping values or (b) the mean value between 12-20 h.

	180 (1h)	200(1h)	360(1h)	110(8h-a)	110(8h-b)	65(24h)
Austria	283	283	–	184	204	170
Belgium	259	259	–	191	213	160
Denmark	–	–	–	136	144	110
Spain	328	328	–	197	211	180
Finland	–	–	–	160	159	131
France	405	405	405	na	na	173
Germany	286	286	–	236	236	206
Greece	463	463	463	286	334	164
Ireland	–	–	–	149	151	120
Italy	443	443	443	279	389	212
Luxembourg	230	230	–	198	208	166
The Netherlands	262	262	–	198	231	132
Portugal	259	259	–	259	259	108
Sweden	–	–	–	139	144	121
United Kingdom	240	240	–	168	203	128
Bulgaria	365	na	365	na	na	na
Czech Republic	246	246	–	197	202	170
Estonia	na	na	na	154	154	131
Lithuania	–	–	–	137	156	117
Latvia	–	–	–	120	129	104
F.Y.R. of Macedonia	253	253	–	na	na	na
Norway	–	–	–	139	132	139
Poland	247	247	–	183	197	152
Slovenia	187	–	–	176	172	152
Slovakia	197	–	–	173	170	161
Switzerland	313	313	–	220	263	182

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 average 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 6. However, Table 6 has to be interpreted carefully, as there are additional reasons, which hamper a comparison between the countries. Firstly, the local environment (in particular NO_x sources) influences the ozone levels; the differences between countries partly result from the differences in the fraction of street, urban and rural stations. Secondly, about 20 % of the reporting stations show a data time capture of less than 75 % (or data capture is not known); this might result in an underestimation of the number of exceedances. Also the differences in definition of an exceedance (some countries count an exceedance when the concentration is greater than the threshold value, other countries count it when the concentrations is equal to or greater than the threshold) may introduce difference in occurrence of exceedances.

Table 6. Occurrence of exceedances (OoE; in days) and average concentration during exceedance (C-aver in µg/m³) reference period 1 January – 31 December 1998. na = no data available.

		threshold value (in µg/m³)					
	number of stations (b)	180-1h OoE	180-1h C-aver	110-8h(a) OoE	110-8h(a) C-aver	65-24h OoE	65-24h C-aver
Austria	114	1.2	195.4	38.2	126.3	125.7	85.7
Belgium	27	3.2	197.6	15.9	133.8	52.1	79.1
Denmark	7	0	-	6.1	120.9	94.4	75.8
Finland	10	0	-	8.4	120.1	125.7	79.4
France	254	3.1	198.1	na	na	79.9	82.4
Germany	393	2.6	198.9	21.9	132.4	64.0	80.1
Greece	14	15.3	229.7	58.1	134.3	83.0	84.5
Ireland	6	0	-	1.6	119.5	87.3	77.6
Italy	176	15.8	202.7	59.1	141.1	85.0	87.8
Luxembourg	5	3.4	194.0	22.4	135.5	84.2	81.9
The Netherlands	39	1.9	197.5	8.8	132.3	28.4	75.1
Portugal	13	1.2	199.6	5.5	158.0	21.1	76.0
Spain	265	1.0	197.9	21.6	126.1	74.0	83.9
Sweden	6	0	-	5.3	120.9	119.7	76.7
United Kingdom	72	0.2	195.1	3.0	124.5	38.0	74.2
Bulgaria	10	6.1	231.3	na	na	na	na
Czech Republic	52	1.7	193.1	34.9	128.5	128.5	84.2
Estonia	3	na	na	8.7	131.6	119.7	80.2
Lithuania	6	0	-	8.3	125.3	57.6	76.3
Latvia	1	0	-	10.0	122.9	90.0	75.4
F.Y.R. of Macedonia	2	2.0	205.2	na	na	na	na
Norway	14	0	-	3.2	121.7	122.4	89.3
Poland	19	1.8	192.3	32.6	127.8	107.6	82.1
Slovenia	5	1.0	182.8	50.4	125.6	115.4	90.5
Slovakia	15	0.3	188.0	19.3	123.8	66.6	78.9
Switzerland	13	10.5	199.8	68.7	137.3	160.2	88.3

(a) based on the eight hourly value between 12.00-20.00.

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

Adverse effects of ozone on human health and vegetation will not only depend on the frequency by which a threshold is violated but also on the severity of the exceedance. The severity of an exceedance can be expressed by the average concentrations during an exceedance period, see Table 6. The data suggests that in southern countries (Greece, Italy, Portugal) the concentrations are generally much higher during an exceedance than in the northern countries. The exposure of humans or vegetation depends, however, both on frequency and severity of exceedances. As an approximation of the exposure we can calculate an *exceedance rate* which is defined as:

$$ER = \sum_{i}^{NET} (C_{i,max} - T) \cdot \left(\frac{d+1}{2}\right) \cdot AV$$

where the summation is now over the total number of exceedance *NET* and *d* is the duration of the exceedance expressed in number of averaging periods, *AV* (de Leeuw *et al.,* 1999). The ER is expressed in *concentration* x *time* units, for example in *ppm.h* or $mg.h.m^{-3}$.

For each of the countries the lowest and highest 50-, 98- and 99.9-percentile values observed at individual stations are presented in Table 7. In this table information on the maximum values is also included. Note that the maximum 8-hourly concentration, as reported in Table 7, is based on a moving average and may therefore differ from the values in Table 5, which are based on fixed 8-hourly periods. From Estonia, FYROM and Slovenia no statistical information has been received. France, Bulgaria and Latvia have not submitted percentile values for moving eight-hourly concentrations. Full details on percentile values and the number of exceedances at the individual stations is presented in Tables I.3 of Annex I[2]. For more than 80 % of the stations the requirement of data capture of 75 % or more is fulfilled.

As ozone concentrations show a high auto-correlation in time, the correlation between 1-h and 8h percentile values is no surprise. Median values for hourly and moving 8-hourly concentrations are very similar. The 98-percentile for 8h values is generally about 10 % lower than the corresponding 1-h value although this ratio is slightly different for the various types of stations and has also a meteorological dependence. Detailed information on the percentile values and maximum concentrations observed at individual monitoring stations is given in Annex I, Table I.3.

For a large number of countries additional statistical information on NO_x, NO_2 and VOC concentrations has been received. This information is primarily used here for the classification of stations. Being precursors of ozone, information on ambient levels of NO_x and VOC is essential to evaluate the effectiveness of ozone abatement strategy. The information voluntarily submitted in the framework of the Ozone Directive is, however, not sufficient for such an evaluation. The inhomogenity in data over the last years, the limited time series and generally lack of information on the local environment of the stations, hamper an analysis of a possible trend in precursor NO_x and VOC emissions. As the reported NO_2 and O_3

[2] Annex I is only available in computer readable form. In the previous report (de Leeuw *et al.*, 1999) a detailed description of the tables in Annex I is provided (also available from the ETC/AQ web-site: http:\\www.etcaq.rivm.nl. Upon request to the ETC/AQ a diskette containing the Annex will be made available (e-mail address: frank.de.leeuw@rivm.nl; fax + 31 30 228 75 31).

concentrations are not measured simultaneously, it is not possible to improve the insight in spatial variability of ozone concentration based on mapping of oxidant (sum of NO_2 and ozone) concentrations. Oxidant concentrations are representative for a larger area since oxidant is less dependent on local condition and meteorological conditions than either ozone or NO_2 (see also Annex II). An overview of the reported NO_x, NO_2 and VOC concentrations is given in Table I.4 and I.5 of Annex I.

Table 7A. Range in reported 50-, 98- and 99.9-percentile values and Maximum observed values (based on hourly average concentrations, period: 1998) observed at individual monitoring stations in reporting countries (in µg/m^3); na = range in percentile values not available; Latvia submitted information for one station only. The 99.9 percentile value is additional information submitted on a voluntary basis.

1998	1h-P50		1h-P98		1h-P99.9		1h-MAX	
	min	max	min	max	min	max	min	max
Austria	17	99	96	153	122	208	99	283
Belgium	26	60	96	132	147	201	173	259
Germany	14	89	62	161	90	234	70	286
Denmark	49	67	89	105	116	137	145	156
Spain	8	109	19	163	33	240	32	328
Finland	34	74	79	112	100	156	116	169
France	16	90	75	159	118	224	70	331 (1)
Greece	16	71	90	170	112	379	129	463
Ireland	48	78	76	102	na	na	112	170
Italy	4	82	43	243	63	301	84	443
Luxembourg	24	65	77	139	122	198	138	230
The Netherlands	17	51	72	110	127	210	152	262
Portugal	2	51	39	122	59	188	75	259
Sweden	53	62	99	105	124	136	128	155
United Kingdom	8	72	46	110	70	170	74	240
Bulgaria	6	17	95	241	134	333	80	365
Czech Republic	20	80	87	149	133	203	155	246
Estonia	na	na	na	na	na	na	na	na
Lithuania	13	62	58	110	113	153	123	172
Latvia	55	-	127	-	139	-	144	-
F.Y.R. of Macedonia	na	na	na	na	na	na	na	na
Norway	47	70	86	109	96	128	101	140
Poland	25	68	94	144	125	186	140	247
Slovakia	27	55	77	129	114	173	123	197
Slovenia	na	na	na	na	na	na	na	na
Switzerland	21	85	124	186	160	260	166	313

(1) At station Notre Dame de Gravenchon an hourly maximum of 405 µg/m^3 has been measured but for this station percentile values have not been submitted.

Table 7B. Range in reported 50-, 98- and 99.9-percentile values and maximum observed values (based on moving eight-hourly average concentrations, period: 1998) observed at individual monitoring stations in reporting countries (in µg/m^3); na = range in percentile values not available; Latvia submitted information for one station only. The 99.9 percentile value is additional information submitted on a voluntary basis.

1998	8h-P50		8h-P98		8h-P99.9		8h-MAX	
	min	max	min	max	min	max	min	max
Austria	21	100	85	151	111	180	95	209
Belgium	28	59	91	128	133	189	137	213
Germany	17	88	56	159	77	220	66	240
Denmark	49	67	86	102	109	129	113	146
Spain	9	110	18	161	26	188	22	222
Finland	34	74	74	110	87	153	98	160
France	na	na	na	na	na	na	60	239
United Kingdom	8	72	42	108	62	160	68	202
Greece	18	70	81	160	na	na	103	354
Ireland	47	79	73	100	na	na	97	156
Italy	6	83	38	217	56	266	58	389
Luxembourg	26	65	70	137	103	191	116	210
The Netherlands	19	51	67	104	111	183	118	227
Portugal	3	52	31	122	56	173	58	182
Sweden	53	61	96	105	118	132	124	149
Bulgaria	na	na	na	na	na	na	na	na
Switzerland	25	85	112	173	149	238	159	263
Czech Republic	20	80	83	147	121	187	130	209
Estonia	na	na	na	na	na	na	na	na
Lithuania	14	61	52	105	105	145	118	160
Latvia	na	na	na	na	na	na	na	na
F.Y.R. of Macedonia	na	na	na	na	na	na	na	na
Norway	47	69	84	108	94	125	98	129
Poland	26	68	85	142	108	174	123	204
Slovenia	na	na	na	na	na	na	na	na
Slovakia	27	55	72	120	99	155	104	176

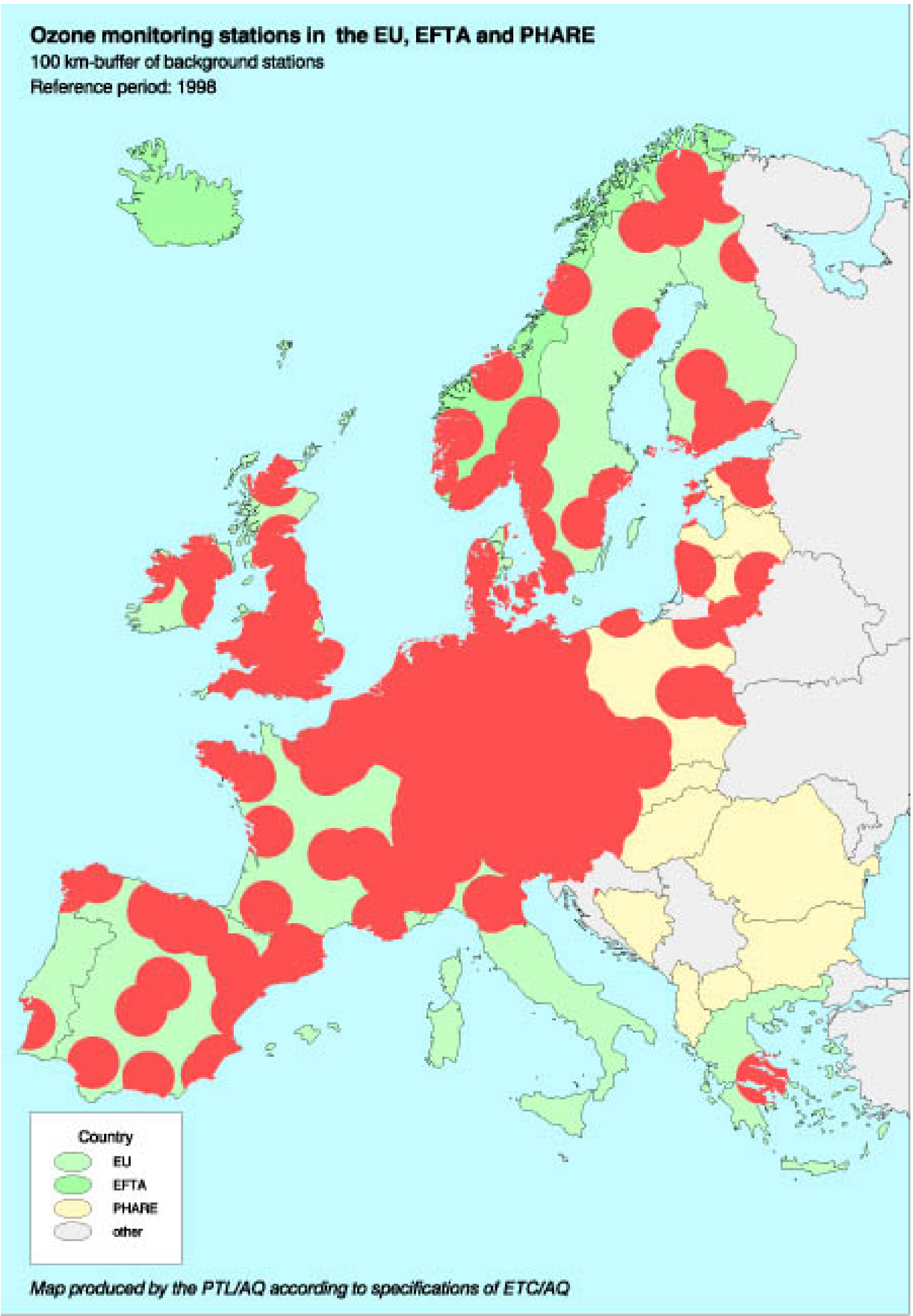
4. Discussion

4.1. Geographical coverage of monitoring stations

For 1998 information from 1400 stations in EU Member States and 140 stations in eleven other European countries has been received; for nearly all of them geographical coordinates are available. For the interpretation of ozone data it is essential to have an indication of the immediate surroundings of the station since the ozone concentration may be strongly influenced by local conditions. For example, ozone 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 the majority of stations information on immediate surroundings has been made available.

Map 2 shows the location of rural 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 rural 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 large parts of the land area in the reporting countries. As is shown in Map 2 the geographical coverage of rural stations is rather adequate in north-west and central Europe but in southern and most northern regions gaps are noted. In Scandinavia the coverage by rural stations appears to be inadequate but the small gradients in ozone concentrations over this region suggest a larger radius of representativeness than the assumed 100 km might be appropriate.

To compare the monitoring results in the various countries it is important that in the national or regional networks similar criteria are used to classify the stations. Further work on harmonisation of station classification schemes is undertaken by ETC/AQ in cooperation with DGXI (Larssen et al., 1998) and is foreseen to be addressed by an EU Technical Working Group on Exchange of Information lead by Germany. A second requirement for obtaining European wide comparable results is the harmonisation of air quality measurements. This work is conducted on behalf of the Commission by the European Reference Laboratory of Air Pollution (ERLAP) at the Joint Research Centre in Ispra (De Saeger et al., 1997).



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

4.2. Annual statistics, 1998

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

Similar to the observations in previous years (de Leeuw *et al.*, 1999) the 98-percentiles at rural stations show in general low values in the Nordic countries, and an increase from north-west to central Europe. Similar patterns have been estimated from measurements made within the framework of EMEP (Hjellbrekke, 1999). In particular for the stations in Austria and Switzerland, the elevated location of the monitoring stations may play a role, see also Figure 2, which shows a tendency toward increasing 98-percentile-values with increasing altitudes. For urban and street stations the altitude does not appear to be an important factor since other factors are dominating at this type of stations.

For urban and 'other' stations (Map 4) high 98-percentile values of 130 $\mu g/m^3$ or more are frequently observed south of the 50 degree latitude. The local conditions appear to be more important than Europe-wide smog episodes: 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 surroundings relatively low ozone levels will be measured (see Annex II).

The 98-percentile values based on moving eight-hourly average concentrations show a strong correlation with the hourly 98-percentile values: on the average, 8h percentiles are about 7 % lower than the corresponding 1h value. The factual relation between the two statistics depends on the type of the stations and has also a meteorological dependence. The geographical distribution of the 8h percentile values is very similar to the distribution of the 1-h percentile values.

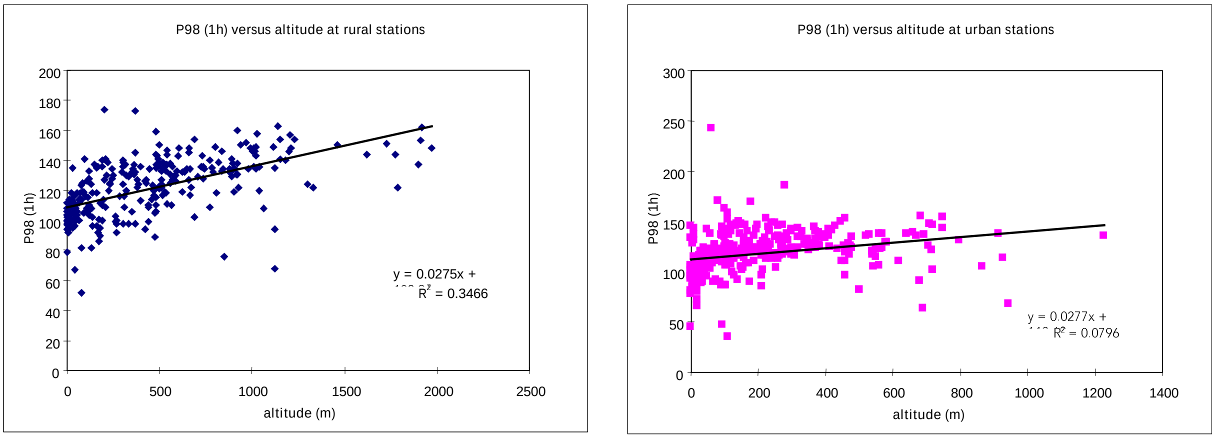
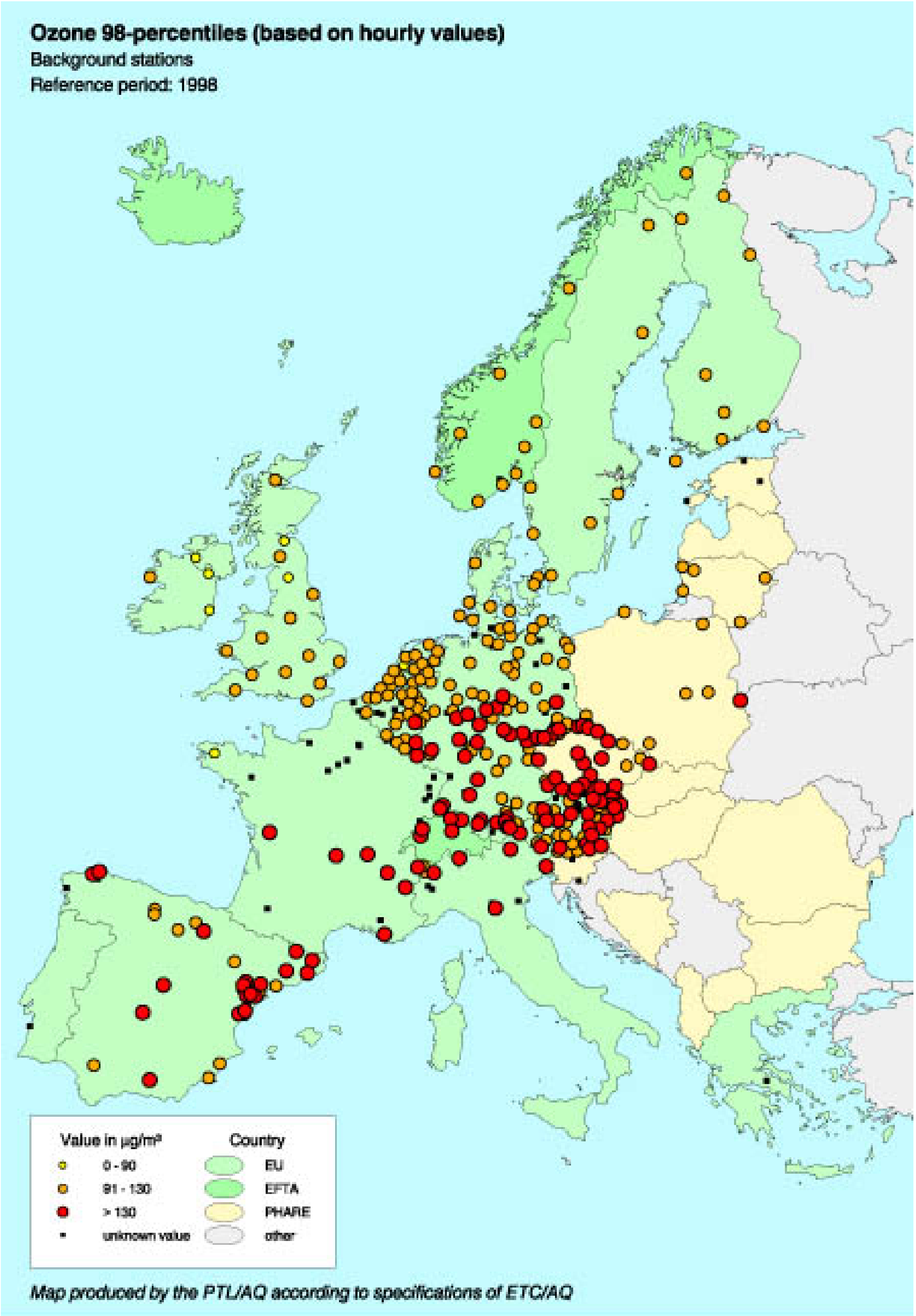
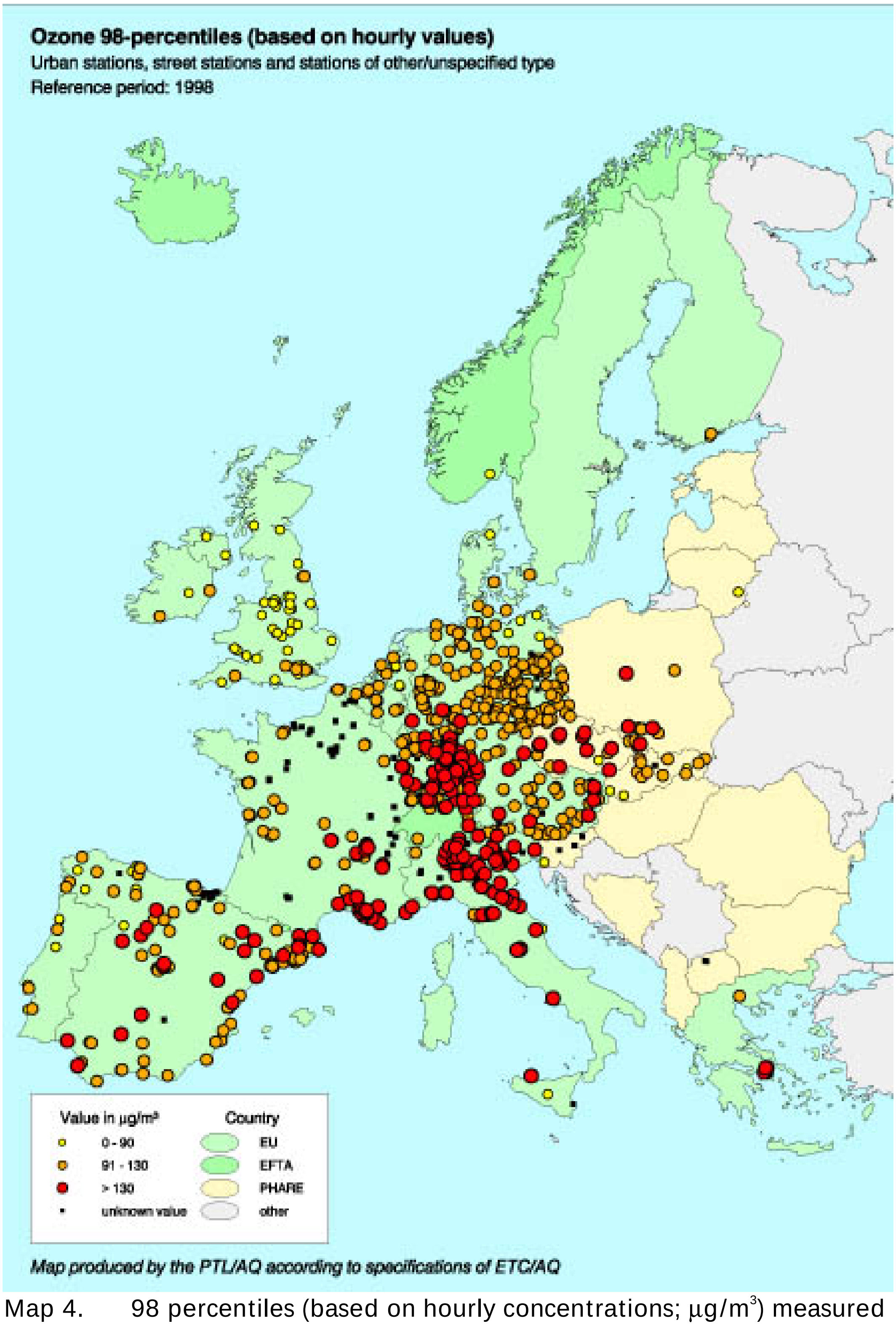


Figure 2. 98 percentile values (reference period 1 January – 31 December 1998) in relation to the altitude of the monitoring stations; left: rural stations; right: urban stations.



Map 3. 98 percentiles (based on hourly concentrations; µg/m^3) measured at rural stations, period 1 January- 31 December 1998.



Map 4. 98 percentiles (based on hourly concentrations; µg/m³) measured at urban, street and other stations, period 1 January- 31 December 1998.

4.3. Exceedances of thresholds in 1998

4.3.1. Exceedances of the threshold value for protection of human health

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 and only exceedances of the threshold values for this period have been considered here.

In 1998 exceedances of this threshold value have been reported by 23 countries. France did not submit information on exceedances for this threshold but, judging the information submitted on maximum values for the moving 8h average concentration, this threshold is also frequently exceeded in France: at 136 out of 147 reporting stations the maximum concentration is in excess of 110 µg/m^3. Bulgaria and FYROM provided only information on exceedances of the hourly thresholds. A quick survey of the data shows that the 110 µg/m^3 8h threshold is more frequently exceeded than the 180 µg/m^3 1h threshold (see Table 6); it is therefore expected that also in Bulgaria and FYROM exceedance has occurred. Figure 3 shows the frequency distribution of eight-hourly ozone concentrations in excess of the 110 µg/m^3 threshold value using Box-Jenkins plots. For each country 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 peaks of more than 220 µg/m^3 are observed in 5 reporting countries, Figure 3 shows that, in nearly all countries, in 75 % of all exceedance situations, the concentrations are below 165 µg/m^3 (that is, below 150 % of the threshold value).

The geographical distribution of the number of days the threshold value was exceeded is shown in Map 5 for rural stations and in Map 6 for urban, street and other stations. A comparison of Map 5 and Map 6 shows that exceedances are generally more frequently observed at rural stations.

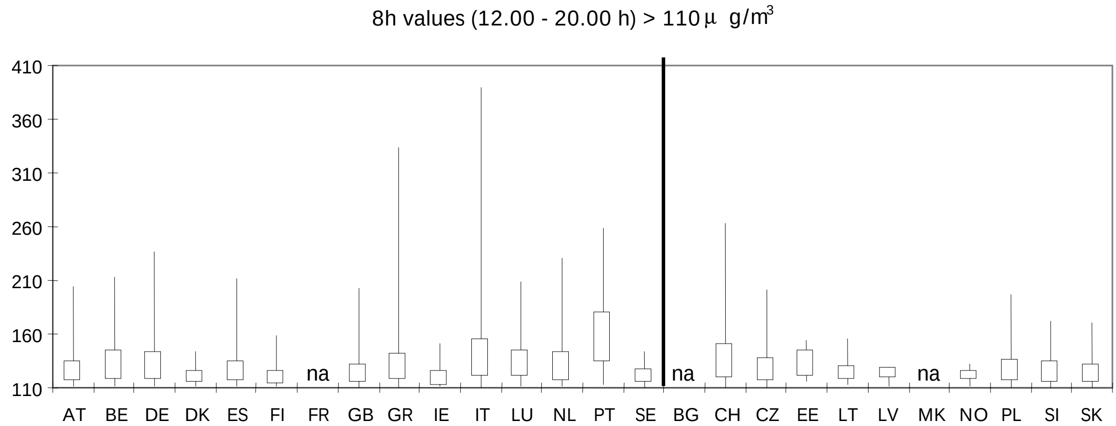


Figure 3. Frequency distribution of ozone concentrations (eight-hourly values; period 12.00-20.00; 1 Jan. – 31 Dec. 1998) in excess of the 110 µg/m3 threshold for hourly values. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-Percentile, the 75-percentile and the maximum value (in µg/m3).

Exceedances most frequently occur in the summer months; in the periods 13-20 May and 7-12 August the most widespread ozone episodes occurred. How widespread ozone episodes are, is further illustrated in Figure 4 which presents a histogram of the daily count of the number of Member States with at least one station reporting an exceedance. On 285 days in 1999 there was at least one station in one Member State reporting an exceedance.

In the 1997 annual report an attempt was made to evaluate the ozone data submitted under the current directive against the proposed threshold values of the new directive (de Leeuw *et al.,* 1999). The analysis showed that, due to the differences in the definitions of the threshold values, the information collected under the current ozone directive is not adequate to assess exceedances of proposed threshold values or the revised WHO ozone guidelines.

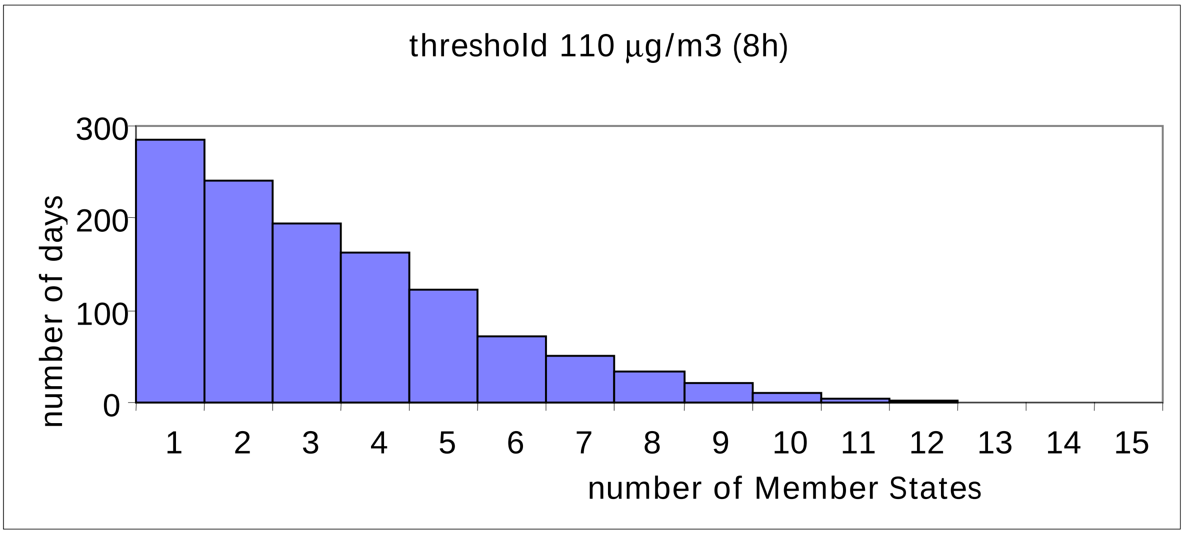


Figure 4. Number of days as function of the minimum number of Member States where at least one exceedance of the threshold value of 110 µg/m^3 was observed (for example, on 162 days the threshold was exceeded in at least 4 Member States); period 1 January- 31 December 1998. Note that information from France has not been included.

Nevertheless, in order to give the best possible approximation of exceedances of the threshold value for the protection of human health (120 µg/m^3 for moving 8h values) the exceedances reported for the 8h period between 12.00 and 20.00 has been used. In this way, information on exceedances of the 120 µg/m^3 level is available for 1241 stations, one out of every three stations the 8h-average concentration between 12.00 and 20.00 is in excess of 120 µg/m^3 on more than 20 days. As ozone concentrations generally reach their maximum in the late afternoon, the average concentration over the period 12.00-20.00 is expected to be a good approximation of the highest daily 8h values calculated from a moving average. Figure 5 shows a European wide exceedance of this threshold value. However, evaluation of hourly data has shown that when comparing the number of exceedance days calculated from moving 8-hourly means with such based on the fixed 12-20 h period, the latter is about 15 % lower, in urban areas even 25 %.

Figure 5 might therefore give an underestimation of the exceedances of the proposed threshold value.

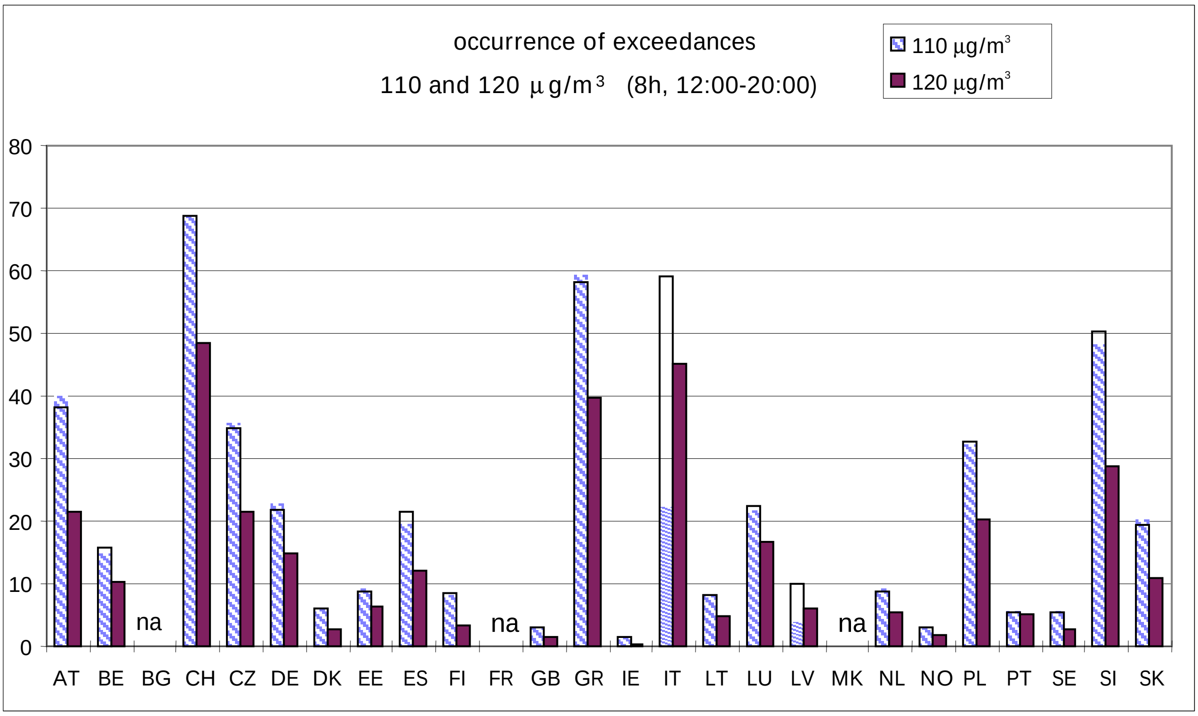
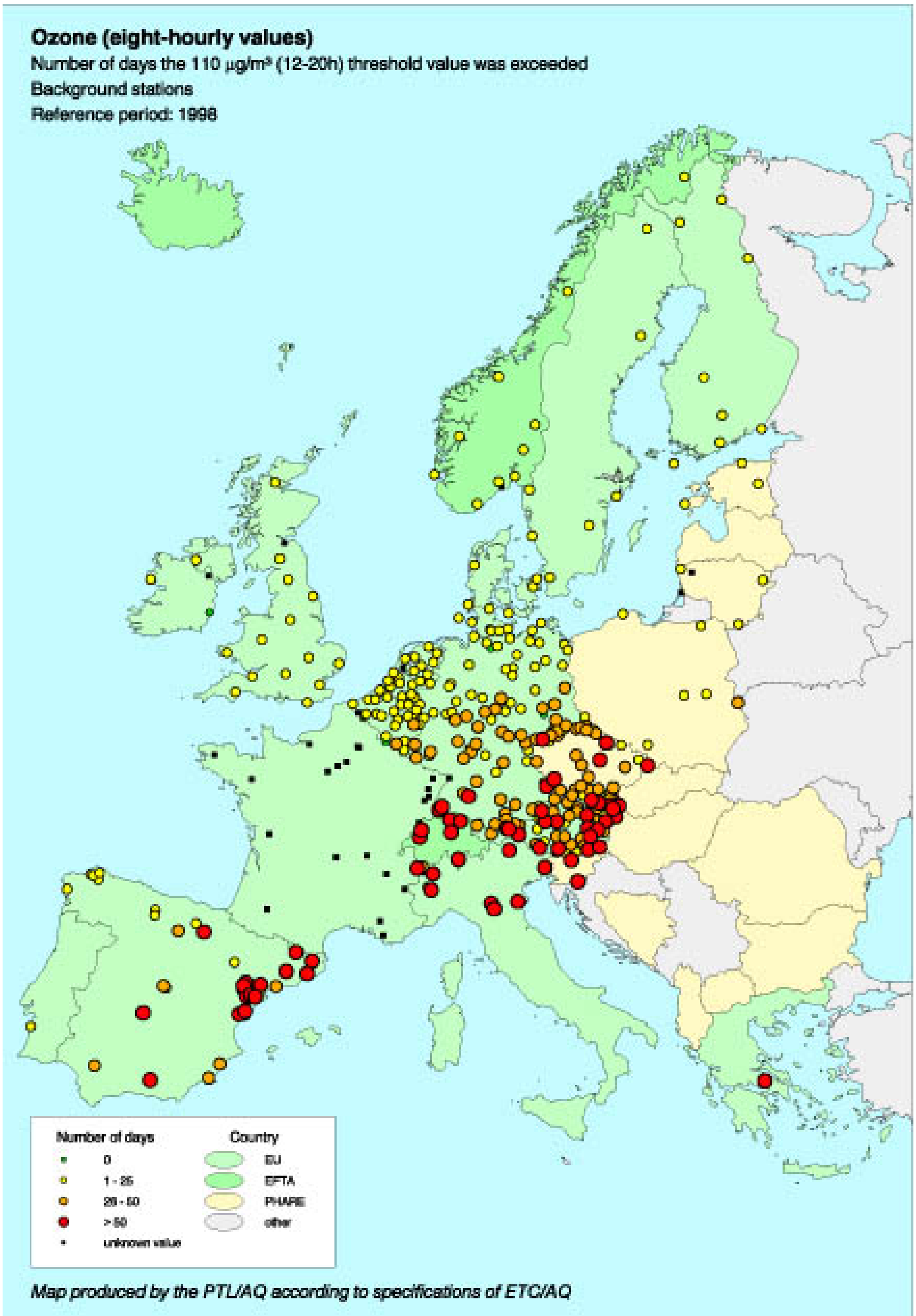
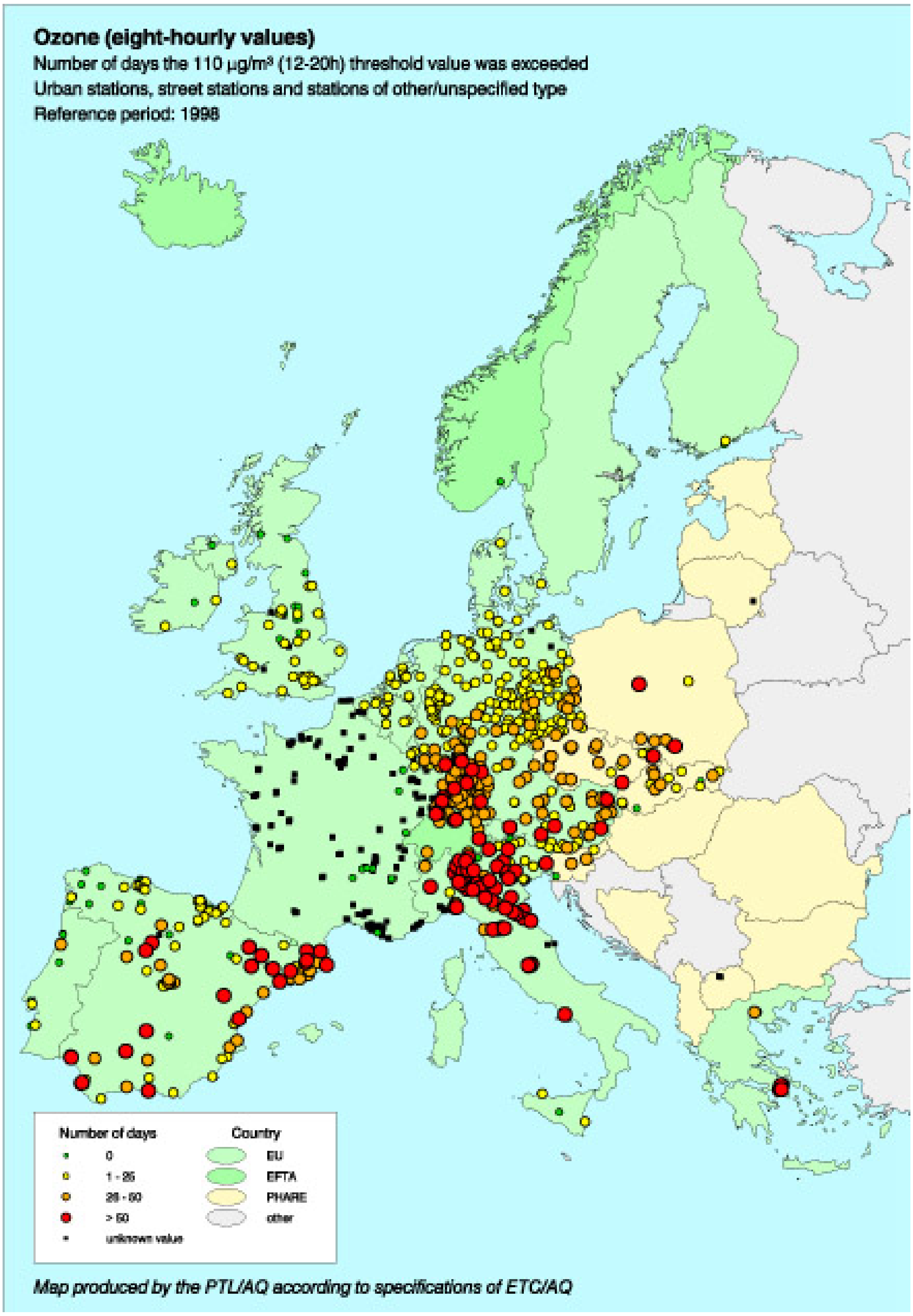


Figure 5. Comparison between the occurrence of exceedances of the current threshold value for protection of human health (110 µg/m³, averaged between 12.00 and 20.00) and the proposed threshold value (120 µg/m³ for moving 8hourly values; calculations are, however, based on ozone concentrations reported for the fixed time period 12.00-20.00h, see text), averaged over all stations; period 1 January – 31 December 1998.



Map 5. Number of exceedances of the threshold value for protection of human health (110 µg/m^3 for eight hourly values) observed at rural stations; 1 January – 31 December 1998; 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 µg/m^3 for eight-hourly values) observed at urban, street and other stations; 1 January – 31 December 1998; eight-hourly average values for the period 12.00-20.00.

4.3.2. *Exceedances of the threshold values for information and warning of the population*

The threshold value for warning of the population (360 µg/m^3, hourly value) was exceeded in 1998 at nine stations, see Chapter 3.

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 rural stations and in Map 8 for urban, street and other stations. Exceedances were reported for 18 countries (11 Member States). The remaining countries did not explicitly report exceedances but, based on the additional information provided, it can be concluded that exceedances indeed did not occur. An exception is Estonia for which the additional information does not enable a firm conclusion to be drawn.

Figure 7 shows the frequency distribution of concentrations in excess of the threshold value for information of the public. Although the threshold value is exceeded by more than a factor of two, in almost all of the cases the exceedances were less extreme: Figure 7 shows that in all Member States except Greece on 75 % of the days on which the threshold value was exceeded, the level of 240 µg/m^3 (that is 33 % above the threshold value) was not reached.

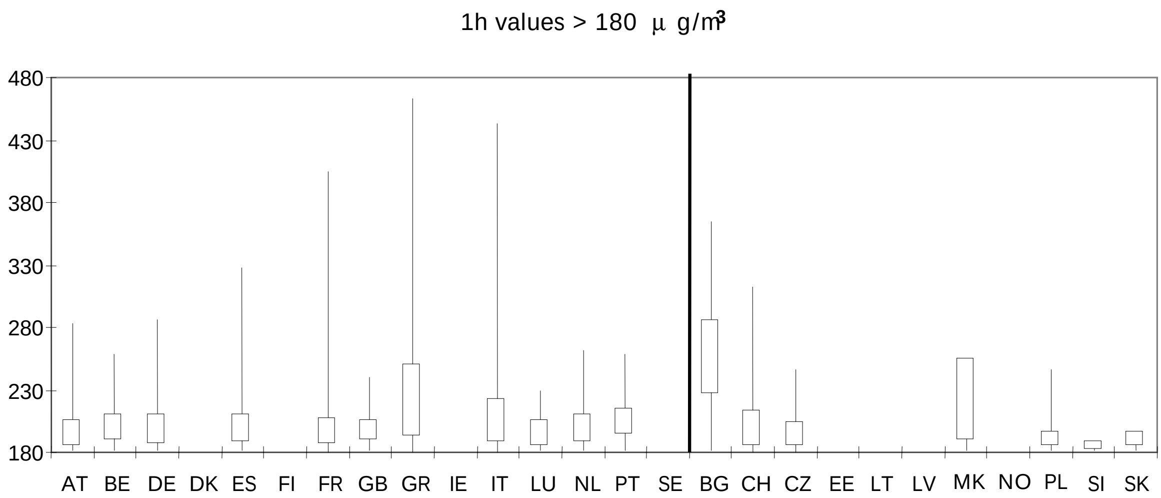
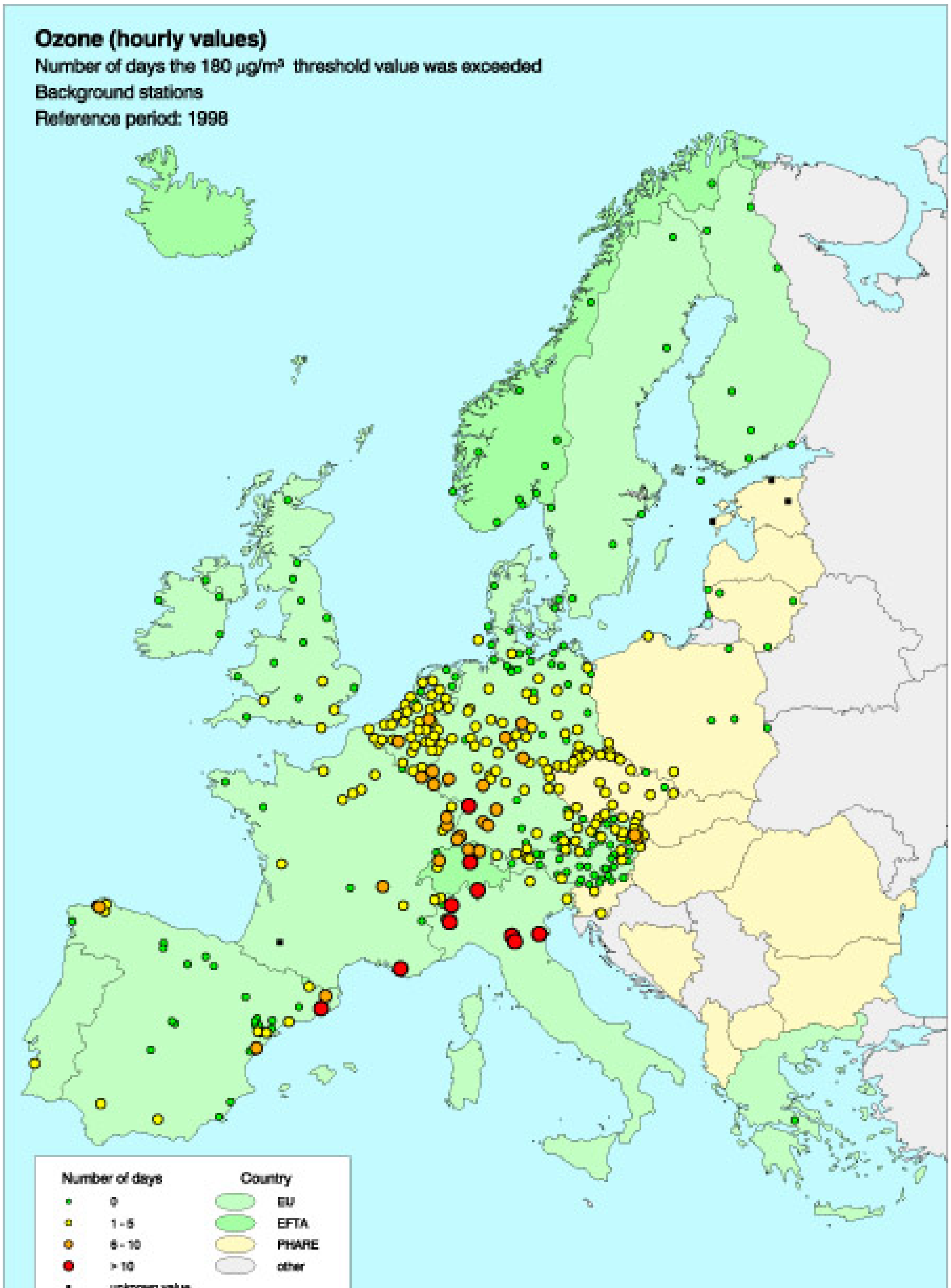
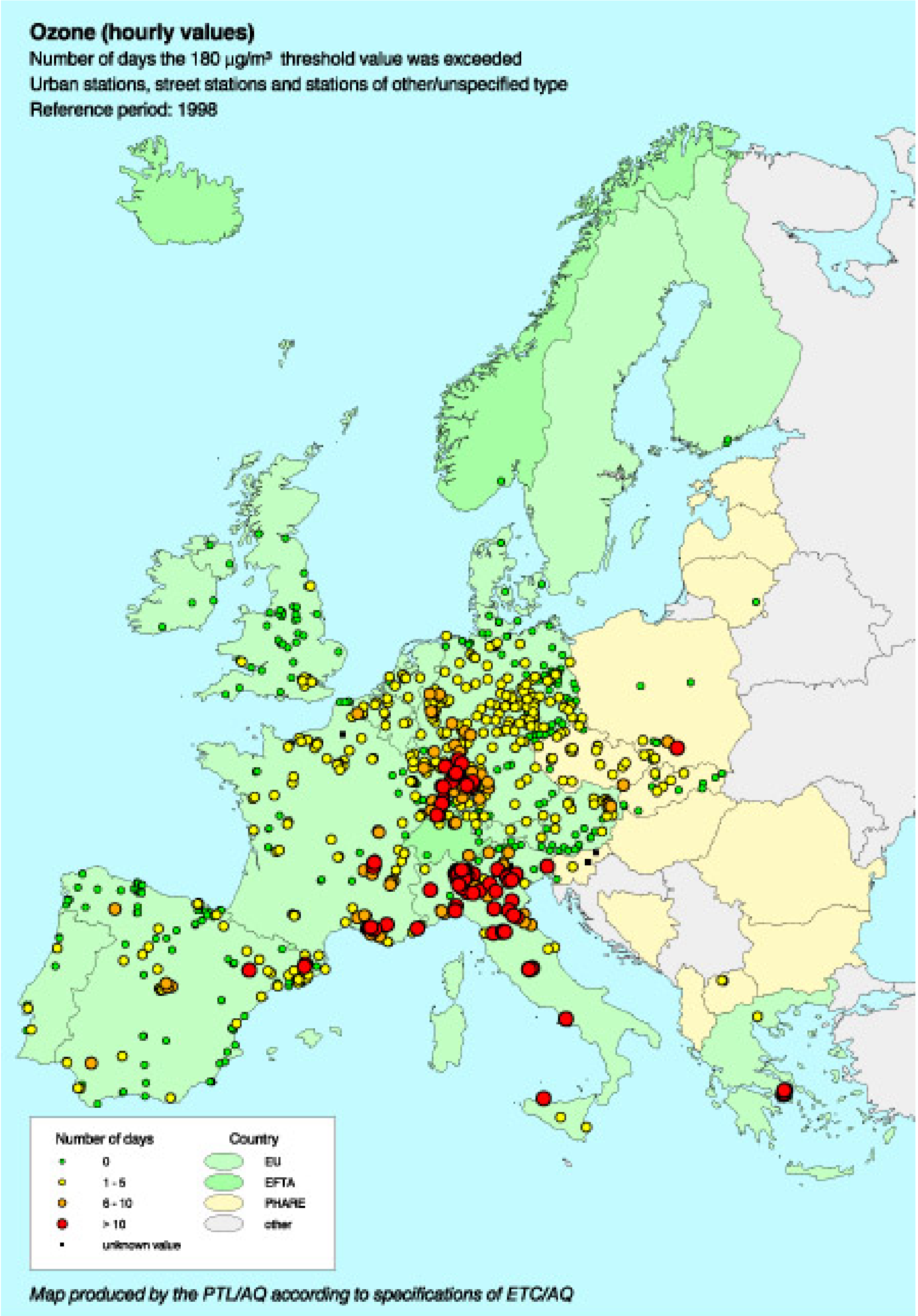


Figure 6. Frequency distribution of ozone concentrations (1h values; 1 January – 31 December 1998) in excess of the 180 •g/m3 threshold for hourly values. Frequency distributions are presented as Box-Jenkins plots indicating the minimum ,the 25-percentile, the 75-percentile and the maximum.



Map 7. Number of exceedances of the threshold value for information of the population (180 µg/m³ for hourly values) observed at rural stations; 1 January – 31 December 1998.



Map 8. Number of exceedances of the threshold value for information of the population (180 µg/m³ for hourly values) observed at urban, street and other stations; 1 January – 31 December 1998.

4.3.3. Exceedances of the daily threshold value for protection of vegetation

As Table 6 shows, exceedances of the daily threshold of 65 µg/m^3 for protection of vegetation were frequently observed in all reporting countries; the average daily concentrations during exceedance were frequently above 80 µg/m^3. Every day in 1998 this threshold value was exceeded in at least 4 Member States.

The geographical distribution of the number of exceedances of the daily threshold value is presented in Map 9 for the rural stations. In Map 9 an attempt has been made to quantify the area where exceedances are observed. For the rural stations a representative radius of 100 km has been 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.

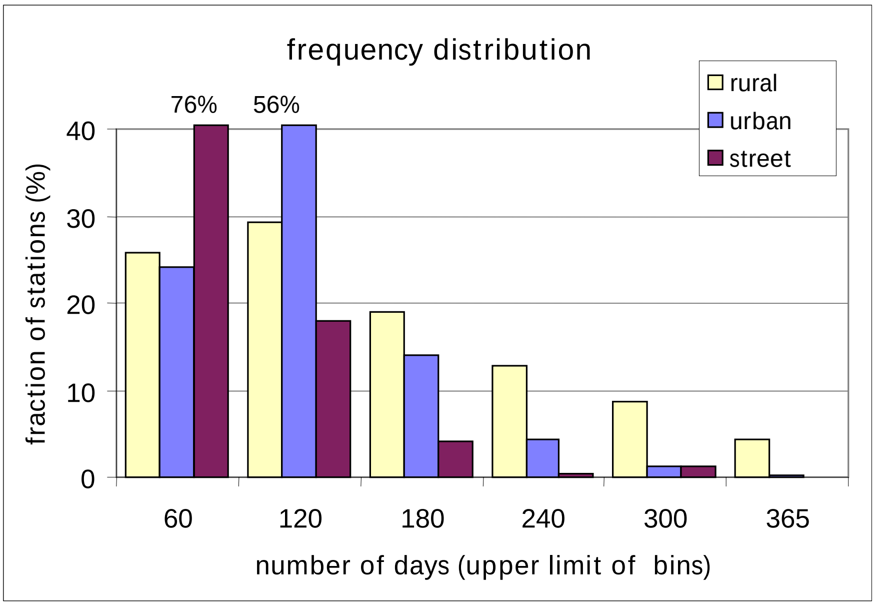


Figure 7. Frequency distribution of the number of exceedance days of the threshold value for protection of vegetation (65 µg/m^3, 24h) for street, urban and rural stations; reference period 1 January – 31 December 1998.

For exceedances of a daily average threshold value the differences between rural and urban stations are more pronounced than is the case for hourly threshold values. 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. In north-west Europe, however, the high NO_x emission density might also cause some quenching of ozone at rural sites which explains the relatively low number of exceedances in this region compared both to north and south Europe. The different behaviour of ozone concentrations at different types of stations is further illustrated in the frequency distribution of the number of exceedance days (Figure 7). At the majority of street stations the threshold value was exceeded on less than 60 days whereas more than 50 % of the urban stations fall in the class of 60 to 120 exceedance days. The rural stations fall in the high-end of the frequency distribution with 45 % of the exceedances observed during more than 120 days.

Figure 8 shows the frequency distribution of daily values in excess of 65 µg/m^3. Although high values of more than 200 µg/m^3 were observed, in all countries except Slovenia for 75 % of the exceedances the daily average concentration falls between 65 and 98 µg/m^3 (that is, below 50 % of the threshold value). The exceedances are most frequently observed during the growing season (May-July): more than 45 % of the exceedances were reported in this three-month period. However, about 20 % of the exceedances occurred during the winter months (January to March and October to December).

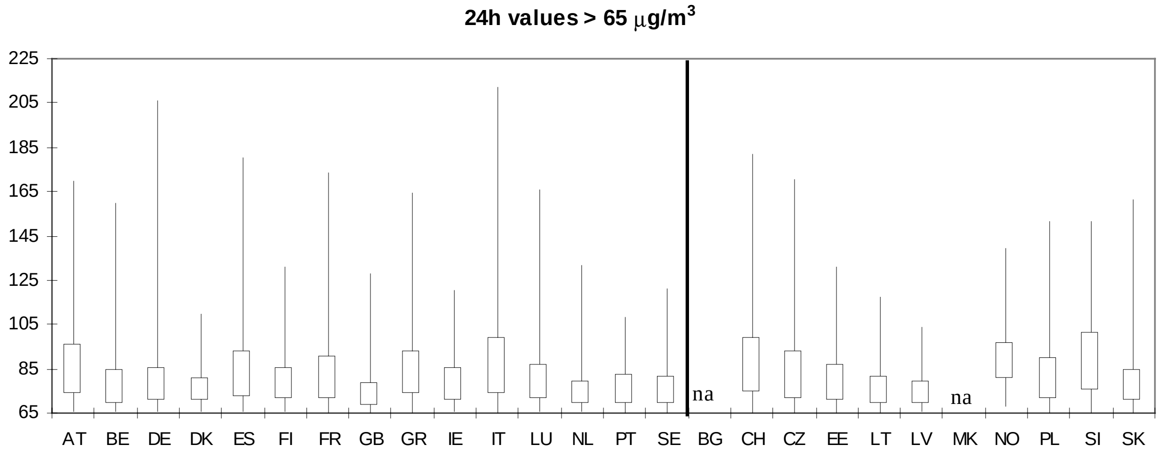
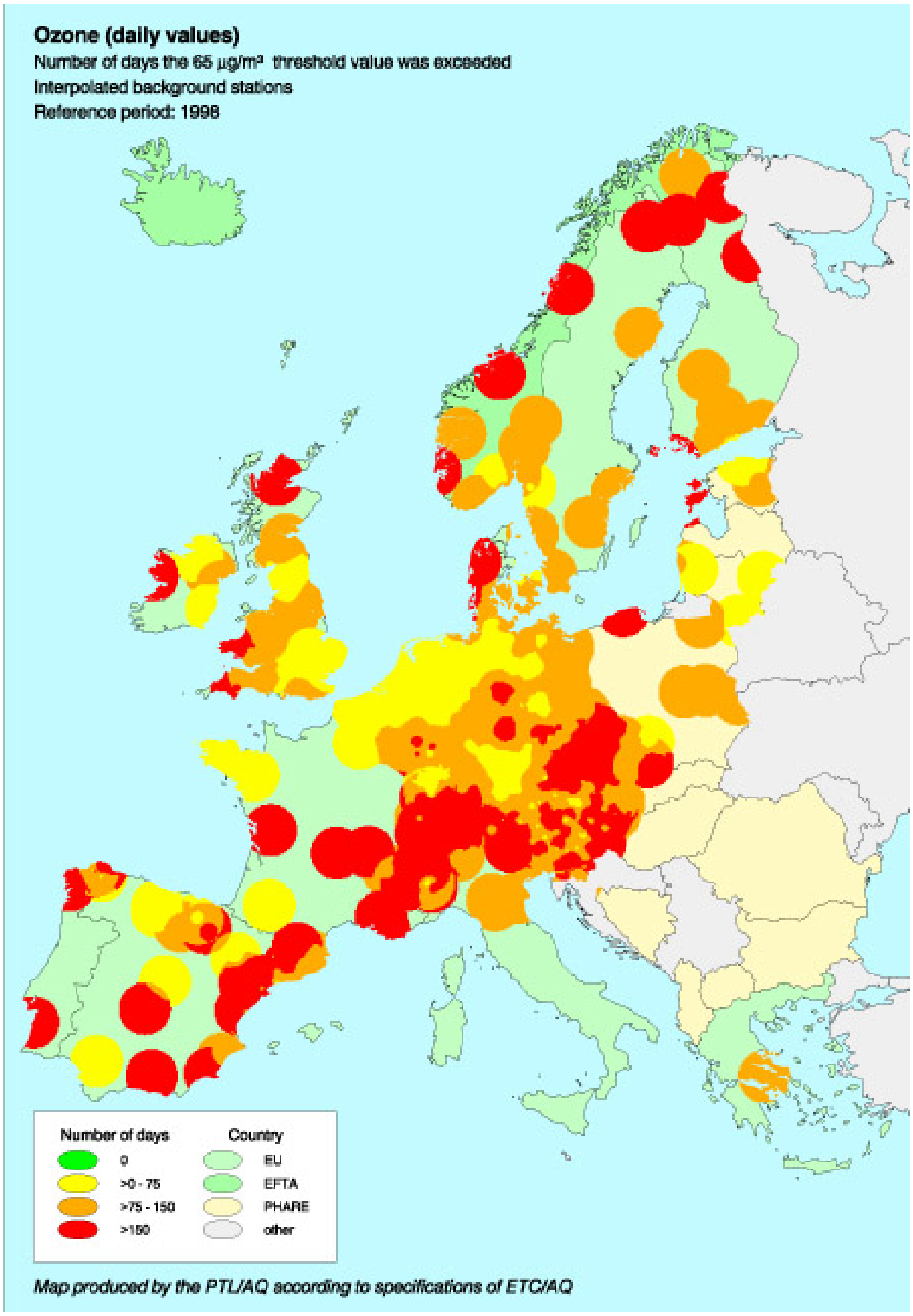


Figure 8. Frequency distribution of ozone concentrations (24h values; 1 January - 31 December 1998) in excess of the 65 µg/m^3 threshold for daily values. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-percentile, the 75-percentile and the maximum value of concentrations above the threshold value.



Map 9. Number of exceedances of the threshold value for vegetation (65 µg/m³ for daily values) observed at rural stations; 1 January – 31 December 1998. Data is interpolated using inverse distance weighting and a cut-off distance of 100 km.

4.3.4. Exceedance of the hourly threshold value for protection of vegetation

Exceedances of the hourly threshold value for protection of vegetation (200 µg/m³) were reported by 11 Member States. No exceedances were observed in Denmark, Finland, Ireland and Sweden, see Table 5. The geographical distribution of the number of days on which this hourly threshold value was exceeded is presented in Map 10 for rural stations. The map shows that above approximately 55^0 N this threshold value was not exceeded.

The frequency distribution of exceedances of the hourly threshold are presented in Figure 9. For about 75 % of the exceedances the ozone levels fall between 200 and 275 µg/m^3.

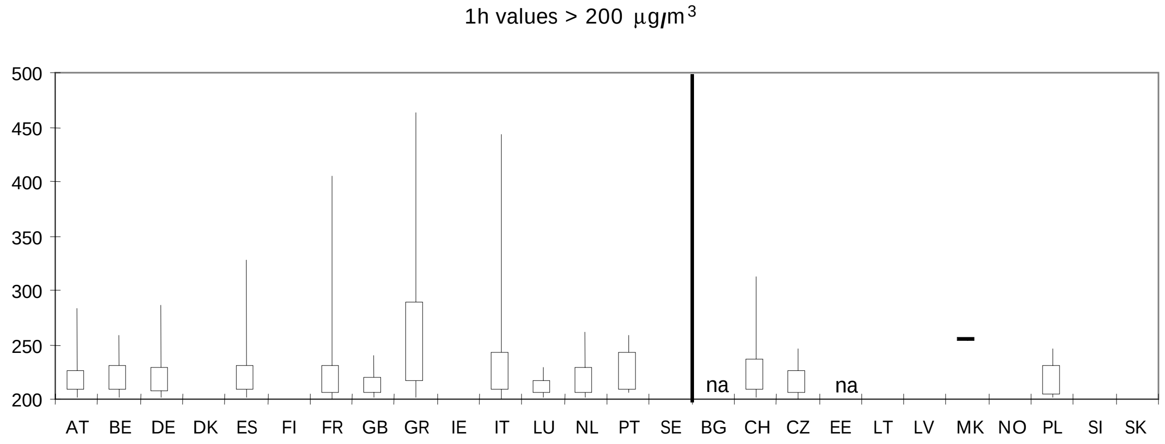
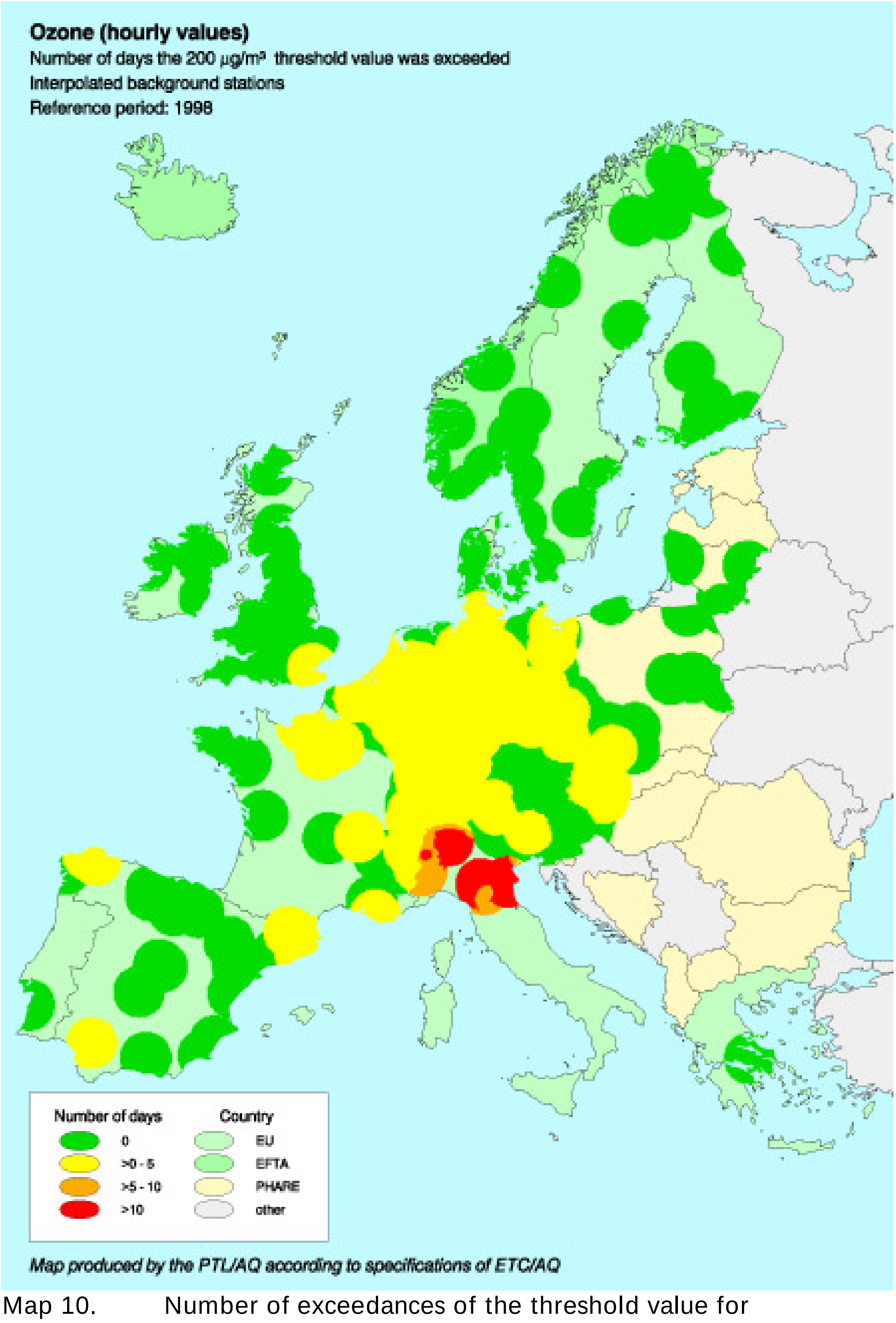


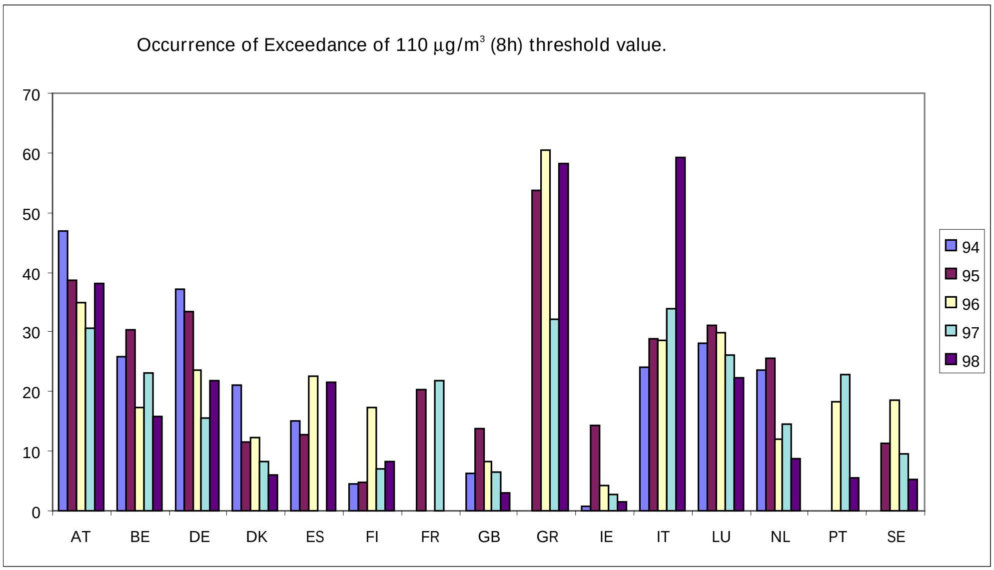
Figure 9. Frequency distribution of ozone concentrations (hourly values; 1 January – 31 December 1998) in excess of the 200 µg/m^3 threshold for hourly values. Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25-percentile, the 75-percentile and the maximum value.



Map 10. Number of exceedances of the threshold value for vegetation (200 µg/m^3 for hourly values) observed at rural stations; 1 January – 31 December 1998. Data is interpolated using inverse distance weighting and a cut-off distance of 100 km.

4.4. First analysis of data reported for 1994-1998

The time series reported in the framework of the Ozone Directive, now covering a period of five years (1994-1998), are still too short or too variable in terms of monitoring network configuration (number of stations, locations) to give conclusive answers on a possible ozone trend in the whole of the EU.
Figure shows the number of occurrence of exceedance (that is, the average number of exceedances per station) for the 110 µg/m^3 and the 65 µg/m^3 threshold level over the five year period. On the basis of the exceedances of the 110 µg/m^3 threshold, 1998 is a year with generally a moderate number of exceedances. For nine countries the 110 µg/m^3 level was exceeded less in 1998 than in 1997 although some countries (e.g. United Kingdom, Italy) show a sharp increase.



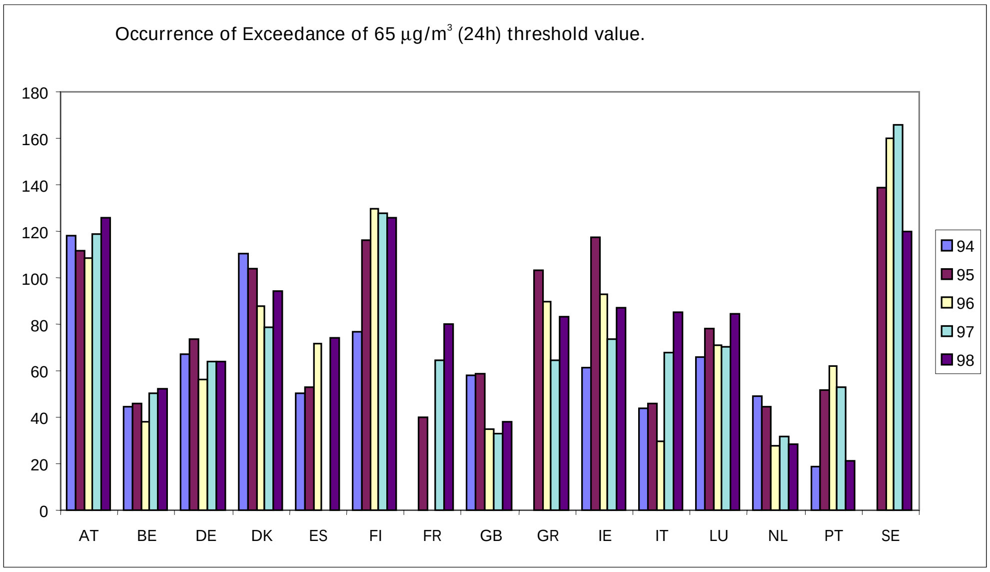


Figure 10. Occurrence of exceedances (number of days) of threshold values of 110 (8h) and 65 (24h) µg/m^3 in EU Member States during the period 1994-1997

A different picture is found for exceedances of the daily threshold of 65 μg/m^3. Here, 1998 is a year with a relatively high number of exceedances. For a number of countries (Austria, Belgium, Spain, France, Italy, Luxembourg) 1998 is even the year with the highest number of exceedances over the five year period. However, for four countries the situation improved in 1998 when compared to 1997. A more in depth analysis, taking into account the information on exceedances at individual stations is necessary to explain these results. Reliable information on the type of stations is needed here as a different trend for street and rural stations, induced by different impacts of changes in traffic-related NOx emissions, might not be excluded.

Acknowledgement
The authors are indebted to Hana Livorova and Jaroslav Fiala at the PHARE Topic Link on Air Quality at the Czech Hydrometeorological Institute for the cartographic contributions and further GIS support.

5. Conclusions

1. **Data on ozone concentrations and exceedances for 1998 was received by the European Commission from all Member States. In addition, information for 11 other European countries were received.**
   The 15 EU Member States provided information on ozone concentrations for in total 1400 monitoring stations. Bulgaria, Switzerland, the Czech Republic, Estonia, Lithuania, Latvia, FYROM, Norway, Poland, Slovakia and Slovenia provided information on ozone concentrations for a total of 140 stations.

2. **The threshold value set for the protection of human health was exceeded substantially in all reporting countries.**
   The threshold value of 110 µg/m^3 (8h-average) was exceeded substantially. The threshold was exceeded on an average of 25 days at each reporting station and during an exceedance the average concentration was about 130 µg/m^3.

3. **The threshold values set for the protection of vegetation were exceeded substantially and in almost all EU Member States.**
   The threshold value of 65 µg/m^3 (24h-average) was reported to be exceeded substantially (by up to a factor 3), widely (in all reporting countries) and frequently (nearly all countries report exceedances during more than 100 days at one or more of their stations). The threshold value of 200 µg/m^3 (hourly average) was exceeded largely and widely (in total 15 countries, 11 EU Member States) on a limited number of days.

4. **The threshold value for warning of the population was exceeded at eight stations in three Member States. The threshold value for information of the population was exceeded in almost all EU Member States during a limited number of days.**
   For three stations in the Athens conurbation, four stations in Italy (Castenaso, 10 km east of Bologna; Cormano in the outskirts of Milan; Riccione along the coast of the Adriatic Sea, south of Rimini and Busto Palermo located in region Lombardia north-west of Milan), one station in France (Notre Dame de Gravenchon, halfway between Le Havre and Rouen) and one station in Bulgaria (AMS Rakovsky in Dimitrovgrad) exceedances of the warning level of 360 µg/m^3 (1h average) was reported. Exceedance of the information threshold value of 180 µg/m^3 (1h average) was reported for stations in 18 countries, 11 of which were EU Member States.

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Annex I: Observed exceedances and annual statistics

Observed exceedances of ozone threshold values and annual statistics in 1998 at individual monitoring stations reporting in the framework of the Council Directive 92/72/EEC on air pollution by ozone.

Information on exceedances and concentrations of ozone and its precursors for the individual stations in EU Member States and several other European countries reporting in the framework of the Ozone Directive over the period 1 January 1998 – 31 December 1998 is available in computer readable form only; see for a detailed description of the annex de Leeuw *et al.* (1999). The information on exceedances will also become available from AIRBASE.

In the framework of the Council decision on Exchange of Information (Council Decision 97/101/EC) the Member States will report hourly ozone concentration for (a selection of) the reporting stations. This hourly data will become available from the EEA-ETC/AQ database AIRBASE.

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, its photochemical formation and its precursors the reader is referred to documents provided by DGXI (Borrell and van den Hout, 1995; Derwent and van den Hout,1995; Beck *et al*., 1999) and to reports prepared in the framework of UN-ECE Convention on long-range transport of air pollution (Hjellbrekke, 1999; Jonson *et al.,* 1999) and EUROTRAC (see e.g. Borrel *et al.,*1997; Hov, 1997). 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 'fuels' 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 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:

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

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 independant of the equilibrium. 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; at larger distances to the source the ozone levels will increase again. 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 rural station may measure concentrations representative for an area of several tens of kilometres. The information requested for 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 according to reaction R1. 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.

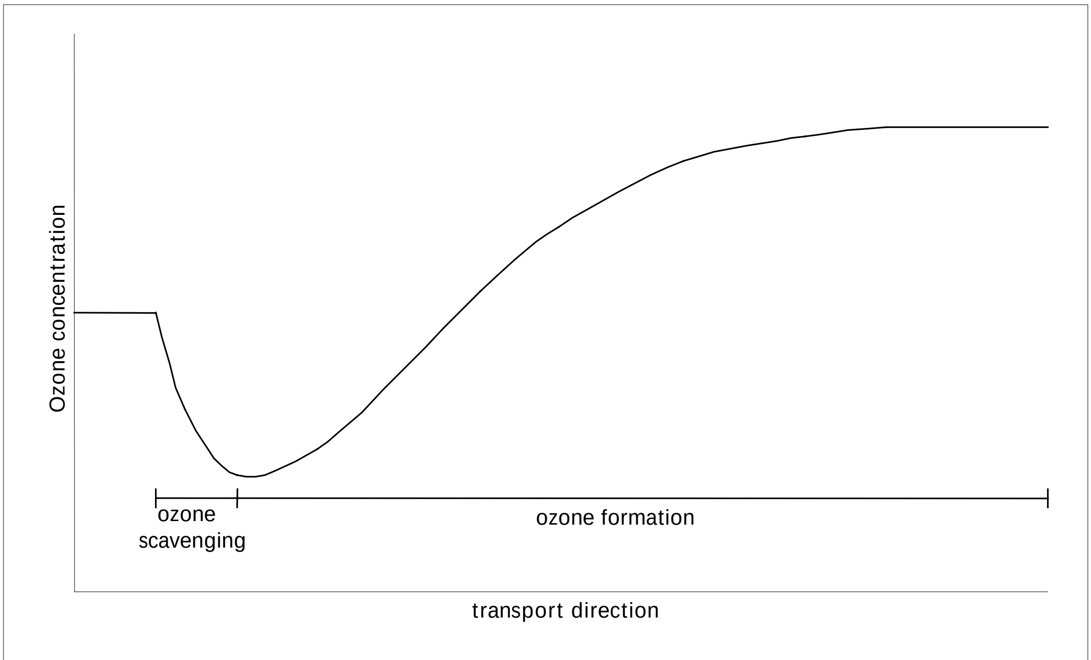


Figure II.1 Schematic presentation of ozone concentrations downwind of a large NO_x source where ozone scavenging will take place.

Part II:

Air Pollution by Ozone in the European Union – Overview of the 1999 summer season (April-August)

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

Rob Sluyter
Annemarieke Camu

30 September 1999

1. Introduction

Ozone is a strong photochemical oxidant, which may cause serious health problems and damage to materials and ecosystems. 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 indicates large variations between individuals in response to episodic O_3 exposure; the effects appear to be more pronounced in children than in adults. Studies indicate that exposure to ozone concentrations in the range 160-360 $\mu g/m^3$ for a period of 1-8 hours reduces various pulmonary functions.

In view of the harmful effects of photochemical air pollution, the European Council adopted in 1992 Directive 92/72/EEC on air pollution by ozone. 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 $\mu g/m^3$)	averaging period (h)
health protection	110	8
vegetation protection	200	1
	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 1998 calendar year is included as part of this combined report (De Leeuw and Camu, 1999).

In this report a first assessment is made of the 1999 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.

It should be noted that information presented in this report is not necessarily based on validated monitoring data and hence should be considered as preliminary. 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 on Photochemical Pollution. This group, established by the Commission under Article 7 of the Directive, had several meetings to coordinate the work within the Member States and the Commission in the framework of the Directive.

Detailed background information on current experience and knowledge concerning 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), Derwent and Van den Hout (1995), Jonson *et al.,* (1999). An overview of the situation within the European Union can be found in *Tropospheric ozone in the European Union. The consolidated report* (Beck *et al.*, 1998) which has been prepared following Article 8 of the Directive. In the process of preparing the new 'Ozone Daughter Directive', a comprehensive review of almost all aspects concerning ozone pollution has been prepared by an expert group established by the European Commission. This so-called *Position Paper on Ozone* will be published in 1999.

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.

All 15 EU Member States provided information on the observed exceedances on time (the deadline for transmitting data was set at 13 September 1999), or indicated that no exceedances were observed. It is greatly appreciated by the Commission that Member States were able to transmit August exceedance data before the formal deadline as set in the Directive. In addition, this year for the first time, 10 other European countries (Czech republic, Estonia, F.Y.R. of Macedonia, Latvia, Lithuania, Norway, Poland, Slovak Republic, Slovenia and Switzerland) provided information on observed exceedances.

In contrast to earlier years all files transmitted were formatted according to the prescribed Commission requirements. No conversion was necessary and data could be directly processed. As was the case in 1997 and 1998, EU Member States Ireland, Denmark, Finland and Sweden did not record any exceedance of the 180 $\mu g/m^3$ threshold in 1999. In addition, no exceedances were observed in Estonia, Latvia, Lithuania, Norway and Slovenia. Table 2 presents an overview of observed exceedances per country per month.

Table 2. Overview of observed exceedances per month per country in 1999. p: exceedance of the population information threshold reported, -: no exceedance reported[3].

	April	May	June	July	Aug.
Austria	-	p	-	p	p
Belgium	-	p	-	p	p
Denmark	-	-	-	-	-
Finland	-	-	-	-	-
France	-	p	p	p	p
Germany	p	p	p	p	p
Greece	p	p	p	p	p
Ireland	-	-	-	-	-
Italy	-	p	p	p	p
Luxembourg	-	-	p	-	-
The Netherlands	-	p	p	p	p
Portugal	-	-	p	p	p
Spain	-	p	p	p	p
Sweden	-	-	-	-	-
United Kingdom	-	p	p	p	p
Czech Republic	p	p	-	-	p
Estonia	-	-	-	-	-
F.Y.R. of Macedonia	-	-	-	p	p
Lithuania	-	-	-	-	-
Latvia	-	-	-	-	-
Norway	-	-	-	-	-
Poland	-	-	-	p	p
Slovakia	p	p	-	-	-
Slovenia	-	-	-	-	-
Switzerland	-	p	p	p	p

[3] France and Italy submitted information on observed exceedances for only part of their operational ozone stations.

EU Member States were requested to check and, if necessary, update 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 immediate surroundings of the station since ozone may be scavenged by locally emitted nitrogen oxides or by enhanced dry deposition which might occur for example under a forest canopy. Member States were requested to classify their stations as street, urban background[4], rural or industrial stations as a first description of the environment of the stations.

Only France transmitted information on their operational stations. For other EU countries, the 1998 station configuration has been used throughout this report, merged with the list of stations reporting exceedances during the past summer season. Other European countries provided environmental descriptions of their operational stations.

Map 1 presents the location of all ozone monitoring stations (street and urban background taken together as ‘urban’) assumed to be operational during the 1999 summer season.

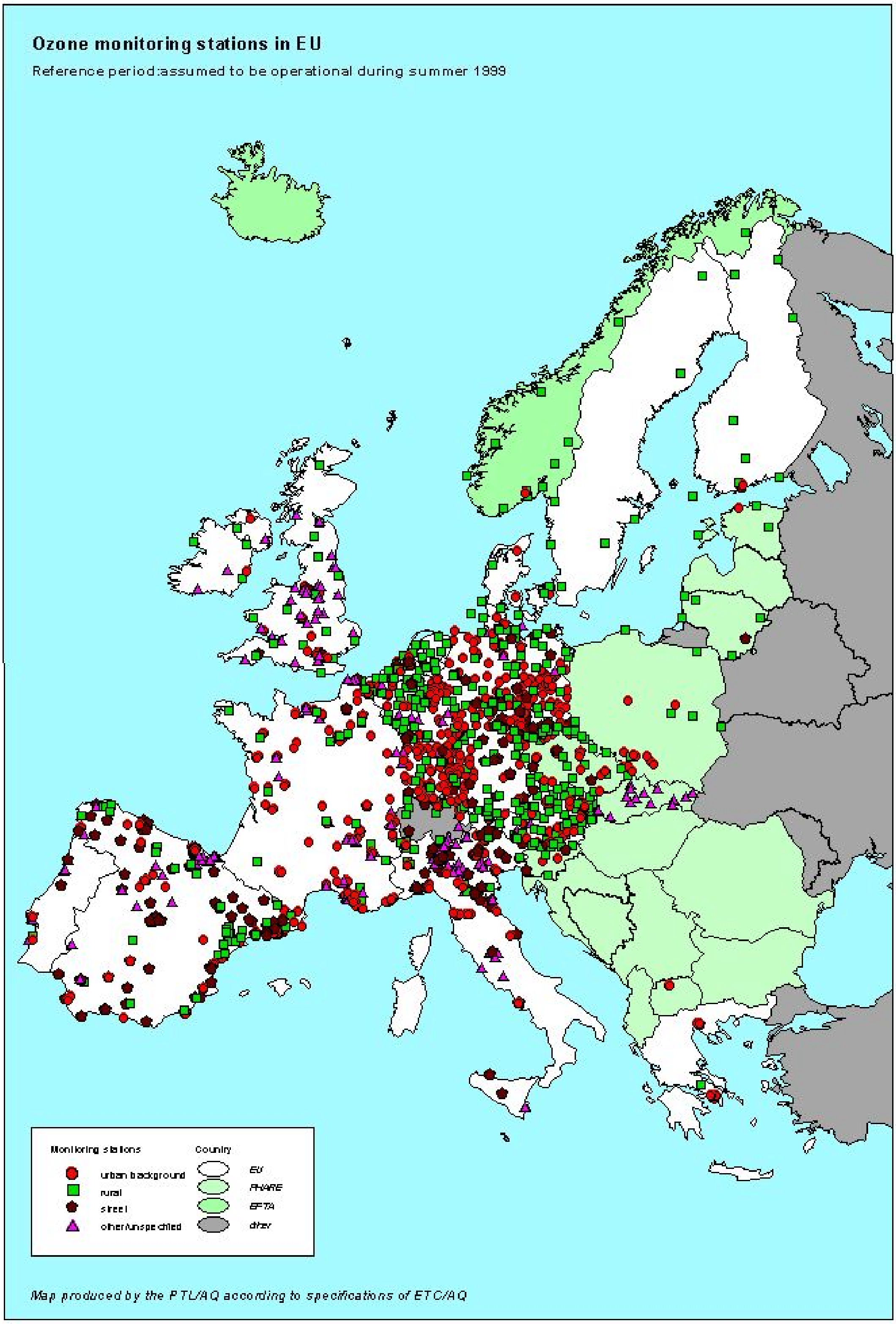
1451 ozone monitoring sites are assumed to be operational in the framework of the Directive. From these, 325 stations are situated in rural areas, 569 stations in urban background environments, 48 are street stations and 119 stations were characterised as industrial stations or the monitoring environment was not specified. The number of operational stations is slightly higher then in 1998[5], the number of stations which were not characterised decreased by more than 50 % compared to 1998. In addition, 129 ozone monitoring sites are assumed to be operational in other European countries (59 rural, 45 urban background, 9 street, 16 industrial or unspecified).

It should be noted that, as only exceedances of thresholds were reported, it is not clear whether stations were operational continuously during summer 1999. It is possible that ozone concentrations exceeded a threshold at a site but this 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.

[4] Urban background: station located in the built-up area of the city but not directly influenced by emission sources such as traffic or industry.

[5] The number of Italian stations has increased from 65 to 189. As a result, statistics presented in this report for Italy cannot be compared to those published in last year’s report.

[6] The 1998 annual report [De Leeuw and Camu, 1999] 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, assumed to be operational during 1999. Stations for which non-EU countries submitted information are presented as well.

3. Summary of data reported for summer 1999

The threshold for warning of the public (1h> 360 µg/m^3) was not exceeded in the European territory during summer 1999.

During the summers of 1996, 1997 and 1998 the threshold for warning of the public was exceeded at only a few stations in Southern Europe.

Table 3 presents a general overview of the observed exceedances of the threshold for information of the public during April-August 1999 on a country by country basis. 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 (De Leeuw and Camu, 1999), 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 3. Summary of exceedances of the threshold for information of the public (1h concentration greater than 180 µg/m^3) during summer 1999 (April-August) on a country-by-country basis.

	No of stations[I]	No of stations with exceedance	No of days with exceedance[II]	Max. observed concentr. (µg/m^3)	Average max. concentr. (µg/m^3)[IV]	Occurrence of exceedances[III]	Average duration of exceedances (hour)
Austria	114	15 (13 %)	8	224	198	0.2/1.8	1.7
Belgium	30	21 (70 %)	11	230	193	1.7/2.4	2.9
Germany	396	89 (22 %)	19	219	188	0.4/1.6	1.8
Denmark	7	0	0	<180	<180	-	
Spain	268	38 (14 %)	40	*341*	199	0.4/2.6	1.9
Finland	10	0	0	<180	<180	-	
France	279	80 (29 %)	42	277	196	0.8/2.9	2.2
United Kingdom	72	30 (42 %)	9	228	193	0.9/2.1	2.5
Greece	15	9 (60 %)	53	304	208	7.4/12.3	2.2
Ireland	6	0	0	<180	<180	-	
Italy	189	83 (44 %)	*68*	339	*206*	4.9/11.0	3.3
Luxembourg	5	2 (40 %)	2	203	190	0.6/1.5	2.3
The Netherlands	39	19 (49 %)	7	251	192	0.7/1.5	1.9
Portugal	18	8 (44 %)	10	242	199	1.1/2.4	2.2
Sweden	6	0	0	<180	<180		
EU	*1451*	*394 (27 %)*		*341*	*202*	*1.2/4.3*	*2.8*
Switzerland	13	6 (46)	24	253	201	3.2/6.8	3.2
Czech Republic	51	7(14 %)	21	222	193	0.4/3.1	2.8
Estonia	4	0	0	<180	<180	-	
Lithuania	5	0	0	<180	<180	-	
Latvia	1	0	0	<180	<180	-	
F.Y.R. of Macedonia	2	2(100 %)	2	189	186	1.0/1.0	1
Norway	14	0	0	<180	<180	-	
Poland	19	3(16 %)	10	200	189	0.7/4.7	2.3
Slovenia	5	0	0	<180	<180	-	
Slovakia	15	2(13 %)	6	206	188	0.4/3.0	2.0

I Number of stations implemented in the framework of the Ozone Directive

II The number of days on which at least one exceedance was observed

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

IV Average of all maximum concentrations recorded during exceedances.

Of the EU Member States Denmark, Finland, Ireland and Sweden did not observe exceedances of the population information threshold during summer 1999. Nor did these countries report any exceedance during the 1997 and 1998 summer seasons. Of the other countries Estonia, Lithuania, Latvia, Norway and Slovenia did not observe exceedances of the population information threshold during summer 1999.

In other EU countries, the number of days within the April-August period of 153 days on which at least one exceedance of the population information threshold was observed ranged from 2 in Luxembourg to 68 in Italy. 27 % of all stations reported one or more exceedance. Last year, the number of stations and days on which exceedances were observed was higher in many Northern and Western European countries, with exception of the United Kingdom[7]. On average 4.3 exceedances occurred in summer 1999 at stations which recorded at least one exceedance. The average maximum hourly concentration during an exceedance of the threshold in 1999 was 202 µg/m^3. In other non-EU countries, 16 % of all stations reported one or more exceedance.

Table 4 summarises the exceedances on a month by month basis. July had the highest number of stations reporting exceedances and the highest occurrence, mainly due to one period at the end of the month with favourable ozone formation conditions (this episode extended into the first days of August and is described in detail in Chapter 4). The average duration of exceedances and maximum observed values also reached a peak in July[8].

Table 4. Summary of exceedances of the threshold for information of the public (1h concentration > 180 µg/m^3) during summer 1999 (April-August) on a month by month basis in the European Union. Figures between brackets include non EU countries.

	Nr. of stations with exceedance[I]	maximum observed concentration (µg/m^3)	average maximum concentration (µg/m^3)[II]	Occurrence of exceedances[III]	average duration of exceedances (hr)
April	4 (6)	239 (239)	204 (191)	0.0/1.3 (0.0/2.3)	1.6 (2.2)
May	51 (58)	275 (275)	200 (202)	0.1/1.7 (0.1/1.9)	2.1 (2.2)
June	186 (188)	339 (339)	200 (206)	0.3/2.2 (0.3/2.2)	2.6 (2.6)
July	296 (305)	341 (341)	202 (208)	0.6/2.8 (0.6/2.9)	3.0 (3.1)
August	162 (172)	304 (304)	202 (205)	0.2/2.1 (0.2/2.1)	2.5 (2.5)

I The theoretical maximum is 1451 stations (EU stations only) and 1580 stations (including non EU countries)(all stations which are assumed to be operational) during summer 1999 and for which data was transmitted).

II Average of all maximum concentrations recorded during exceedances.

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

7 Almost all exceedances are normally observed during the April-August period, with the exception of some occasional exceedances in the Mediterranean region during spring and fall. In 1999, weather conditions favorable for the build-up of ozone extended into September in large parts of Northern and Western Europe. As a consequence, exceedances of the information of the public threshold have been observed in September in a number of countries. However, these exceedances are not included in this report.

8 The average maximum in April was higher then in July but based on a small number of four exceedances only.

Figure 1 presents the number of days per month on which at least at one station in a country an exceedance was recorded. Figure 2 presents the occurrence of exceedances per country on a month by month basis. In all countries, the number of days on which exceedances were recorded was highest in July. The average occurrence of exceedances shows no obvious dependence on the month of observation.

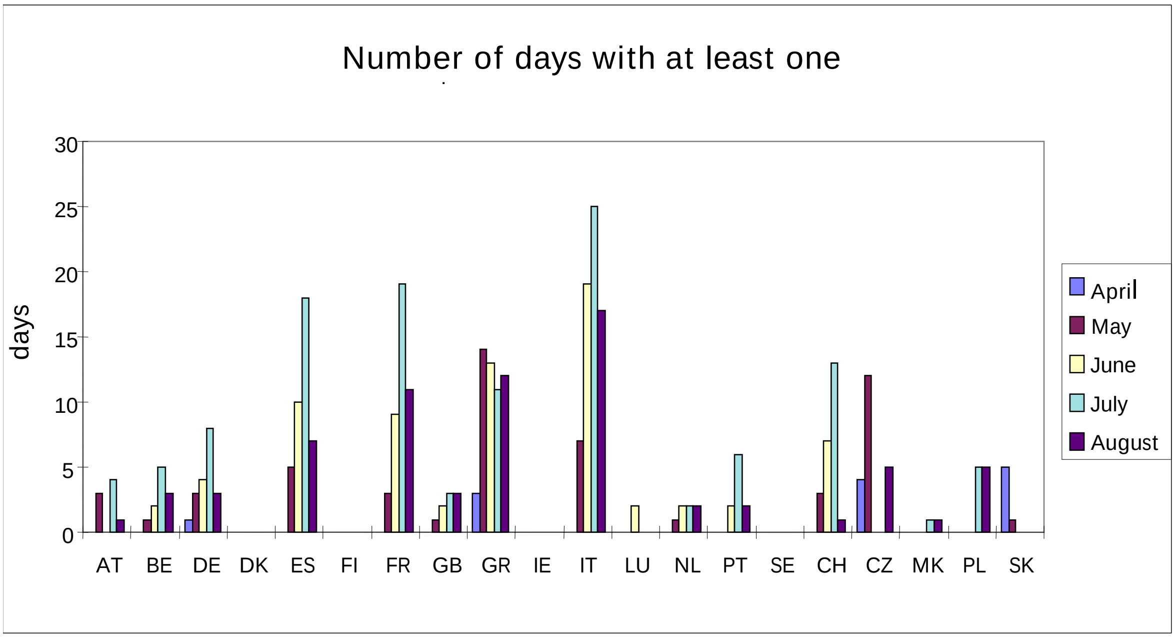


Figure 1. Number of days on which at least one exceedance of the threshold value for information of the public (1h concentration > 180 µg/m³) was observed per country and per month during summer 1999. Finland, Denmark, Sweden and Ireland did not report exceedances. .(Non EU countries reporting no exceedances are not visualised

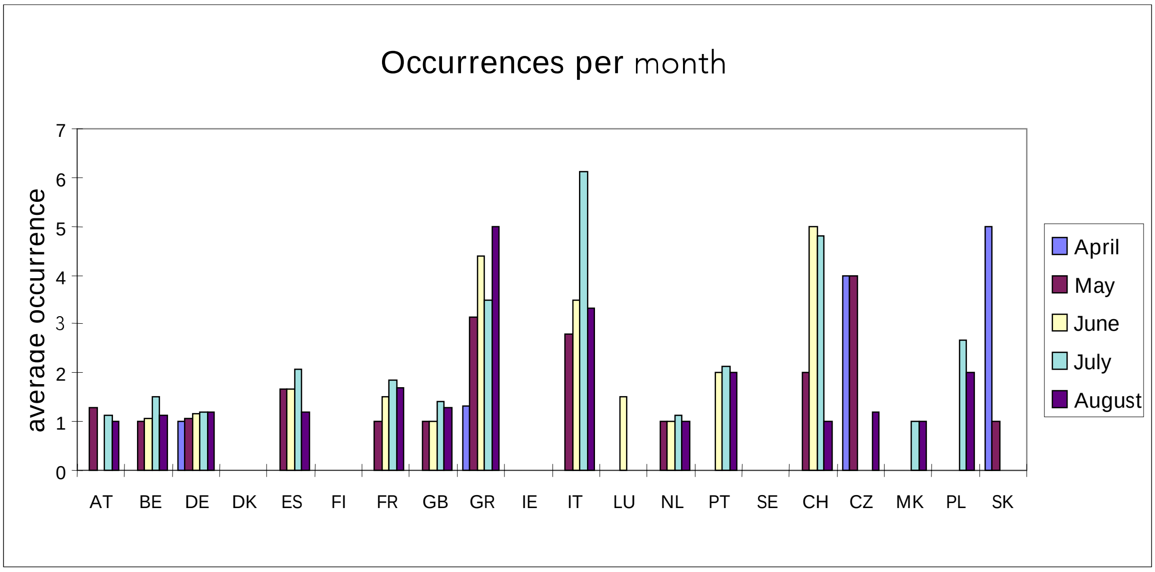


Figure 2. Occurrence of exceedances of the threshold value for information of the public (1h concentration > 180 µg/m³) per country on a month by month basis during summer 1999. Finland, Denmark, Sweden and Ireland did not report exceedances.(Non EU countries reporting no exceedances are not visualised).

The average occurrence of exceedances (in days) of the threshold for information of the public by station type (rural, urban and street in each country) is presented in Figure 3. Stations for which the type was not specified are not included in this figure. The average occurrence rate is expected, according to ozone phenomenology, to decrease in general in the order rural-urban-street. For some countries, this order of decrease is suggested for street stations vs. urban stations. In other countries, this relation is not visible or even contradicted.

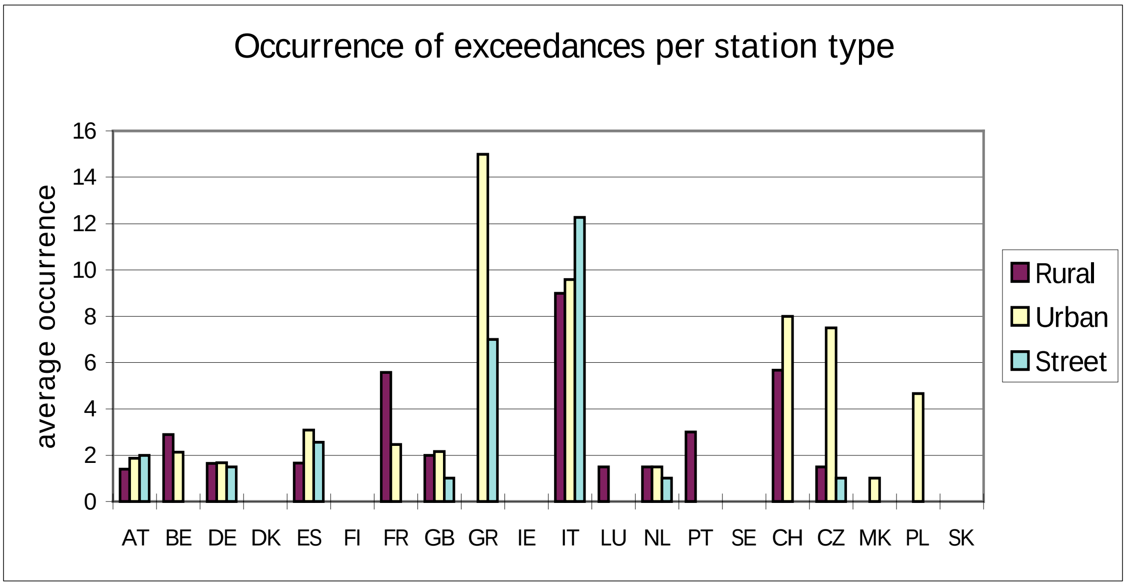
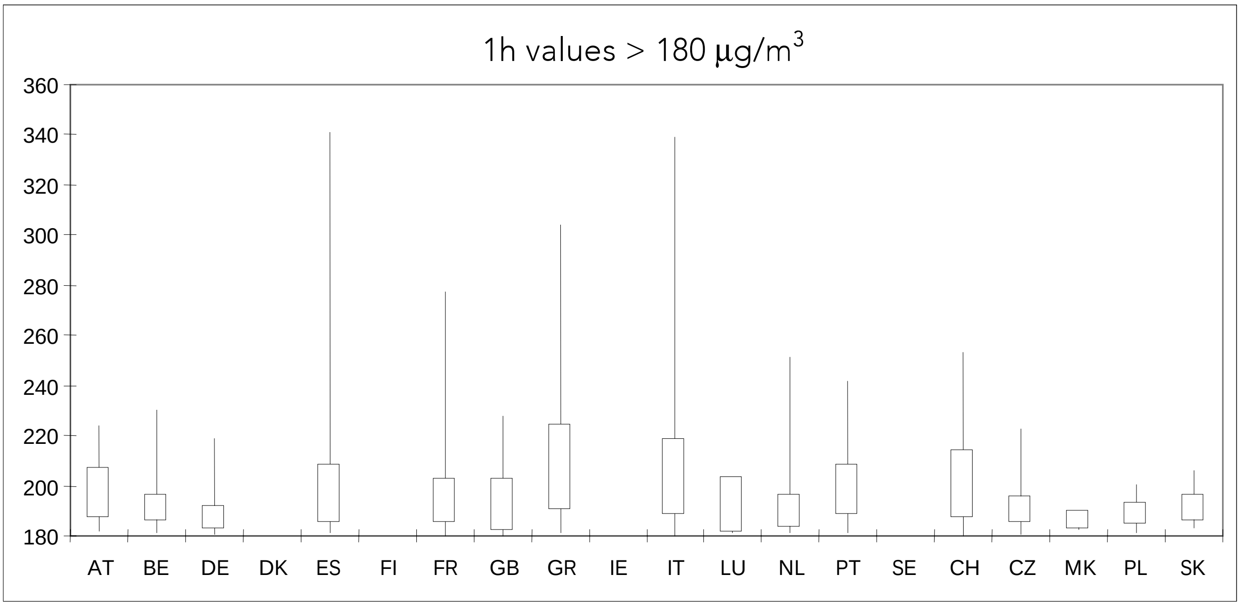


Figure 3: Average occurrence of exceedances (in days) of the threshold for information of the public (1h concentration > 180 µg/m^3) by station type (rural, urban and street) and country during summer 1999. Finland, Denmark, Sweden and Ireland did not report exceedances. (Non EU countries reporting no exceedances are not visualised).

Figure 4 shows the frequency distribution of hourly ozone concentrations in summer 1999 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 concentrations in excess of the threshold value of 180 µg/m^3. 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 in the EU were below 205 µg/m^3, which is rather low compared to the 75 percentile in earlier years.



	AT	BE	DE	DK	ES	FI	FR	GB	GR	IE	IT	LU	NL	PT	SE
#Ex	27	50	144	0	97	0	229	62	111	0	912	3	28	19	0
#St	15	21	89	.	38	.	80	30	9	.	83	2	19	8	.

	CH	CZ	MK	PL	SK
#Ex	41	22	2	14	16
#St	6	7	2	3	2

Figure 4. Frequency distribution of ozone concentrations in excess of the 180 µg/m^3 threshold for hourly values (April-August 1999). Frequency distributions are presented as Box-Jenkins plots indicating the minimum, 25-Percentile, 75-Percentile and maximum values. (Non EU countries reporting no exceedances are not visualised).

3.1 Geographical distribution of exceedance days

Maps 2 and 3 present the geographical distribution of the number of days on which the threshold value for information of the public was exceeded for urban[9] and rural stations, respectively. Exceedance data for urban stations is presented as dots. The exceedance data for rural stations is interpolated using simple inverse distance weighting and a provisionally estimated ‘radius of representativeness’ of 100 km. Note that this radius might actually be different for the various regions in Europe.

The geographical distribution of exceedances observed in summer 1999 at urban stations and stations of unspecified type in Northern and Western Europe is not comparable to that observed during the summer seasons of the previous four years. In previous years, the number of exceedances rose from zero in the Scandinavian countries, Baltic States and Ireland to a maximum in Southern Germany. This year, many stations in this region, the eastern part of Germany and Austria did not report a single exceedance of the threshold value. The zone with

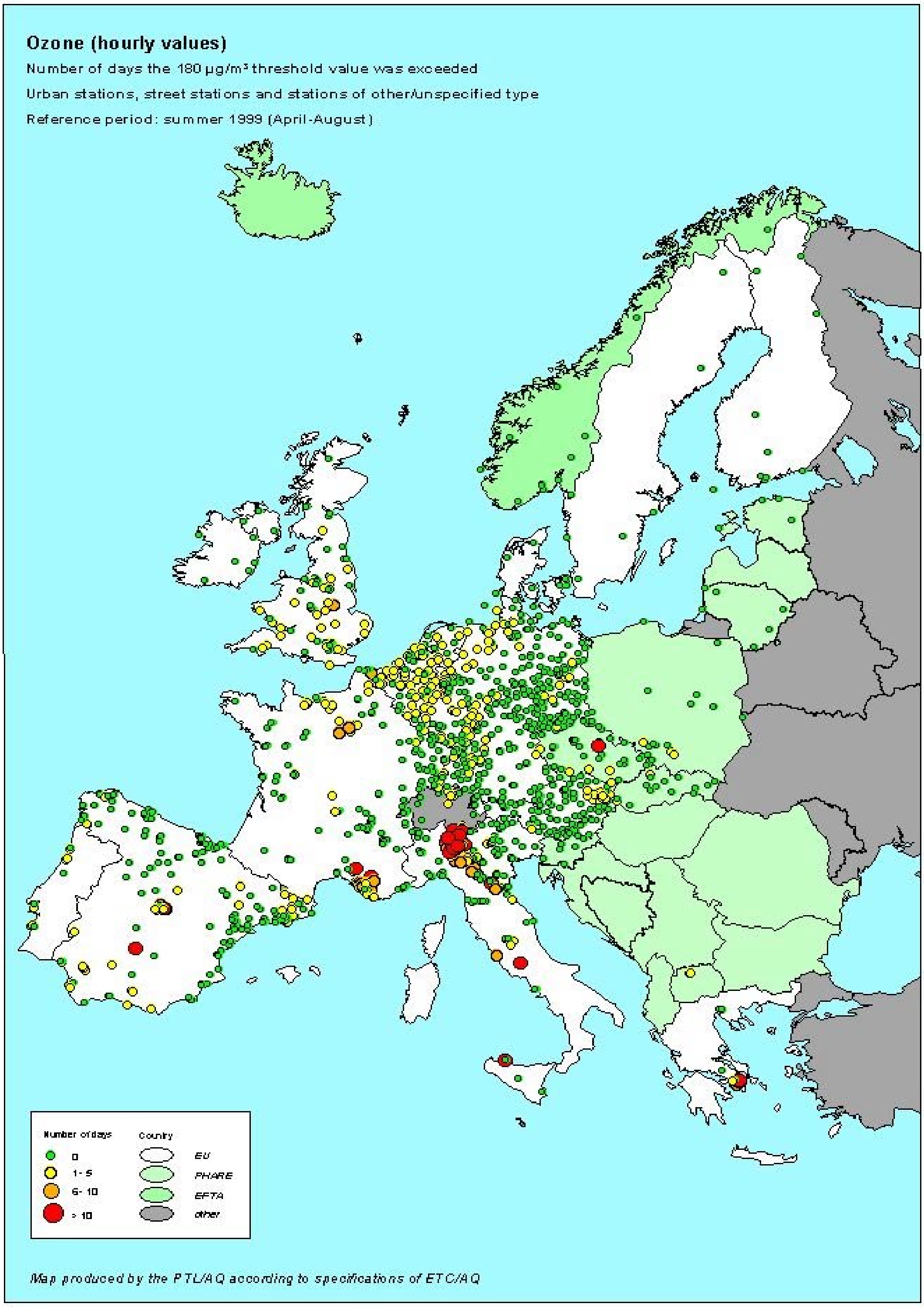
[9] Exceedances reported from stations of unspecified type are also plotted in this map.

must abundant exceedances in summer 1999 was situated over the United Kingdom, Benelux and the northern part of France.

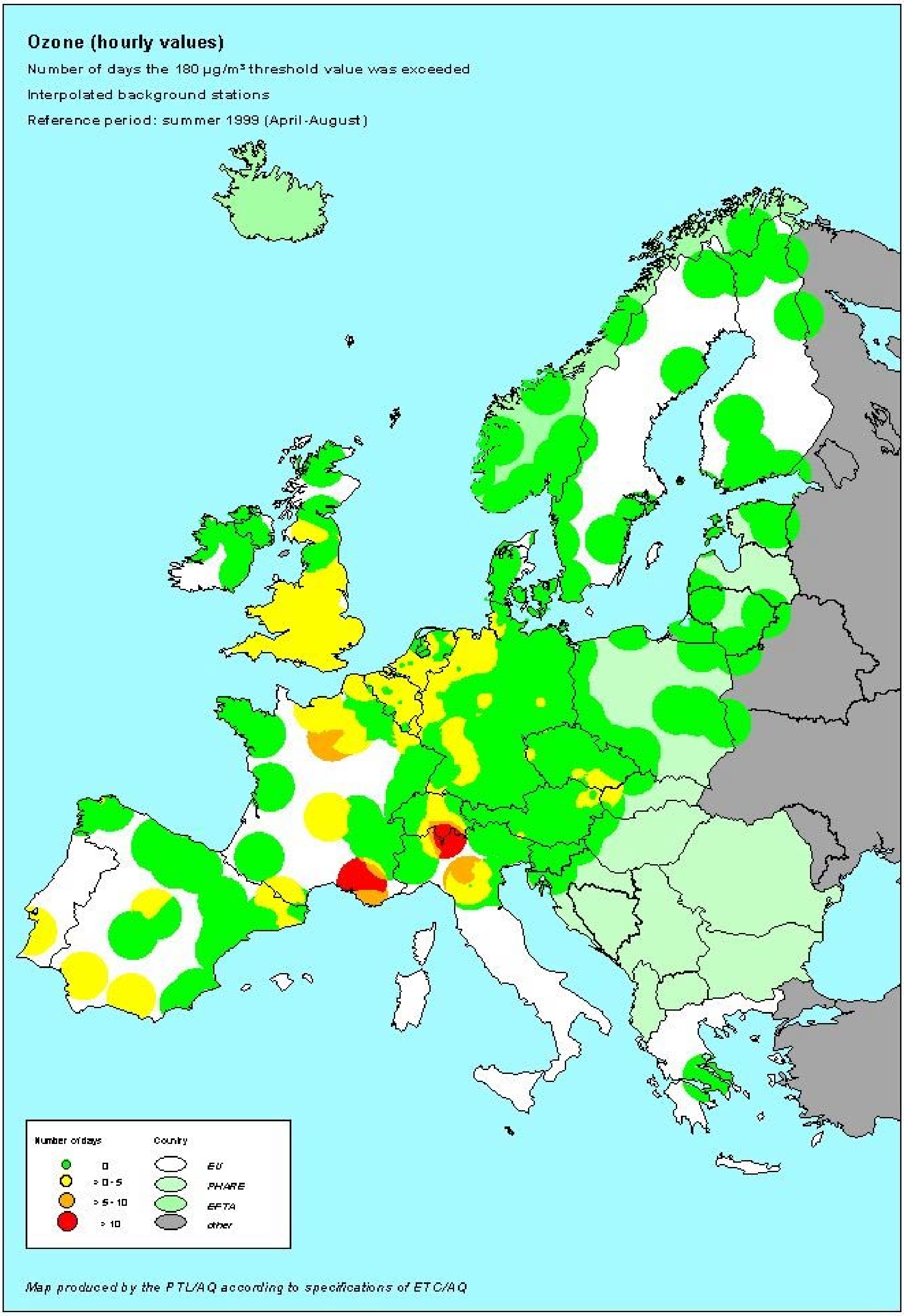
The spatial pattern found in summer 1999 can be explained most probably by the meteorological conditions favourable for the build-up of ozone (warm and sunny) in July and August (theoretically the months likely to have most abundant exceedances). The dominating high pressure cell in summer 1999 was located from western France to Scotland and Norway, resulting in north-easterly circulations transporting relatively clean air towards the south over the eastern half of the European Union. Air masses tended to become stagnant over the United Kingdom, northern France and the Benelux.

No consistent spatial pattern is apparent in the Mediterranean region. Many stations did not report exceedances, while other stations reported more than 10 exceedances.

The spatial pattern of exceedances observed in summer 1999 at background stations (interpolated field) is not similar to the field observed in the previous summers and largely follows the pattern as described for urban stations and stations of unspecified type. It should be noted that the number of background stations in several countries is by far not sufficient to draw any conclusion on the background ozone concentration field.



Map 2. Number of exceedances of the threshold value for the information of the public (1h > 180 µg/m^3) observed at urban/street stations and stations of unspecified type in the EU and other countries. Summer 1999 (April-August).



Map 3. Number of exceedances of the threshold value for the information of the public (1h > 180 µg/m^3) observed at background stations. Summer 1999 data (April-August), interpolated using inverse distance weighting, cut-off distance of 100 km.

3.2 Comparison of exceedance in 1999 with earlier years

Exceedances observed in the EU during the 1999 summer period were compared to exceedances observed during the same period in 1998, 1997, 1996 and 1995[10]. Figure 5.a presents the average exceedance duration[11] of the population information threshold, Figure 5.b presents the average occurrence and Figure 5.c the average maximum concentration observed during exceedances.

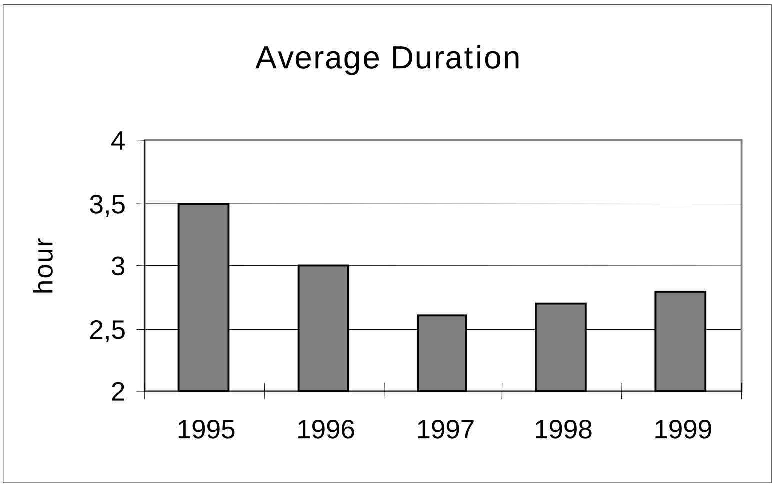


Figure 5.a. Average duration in hours of exceedance during the summer period (April-August, French and Italian data was not included in 1995 and 1996).

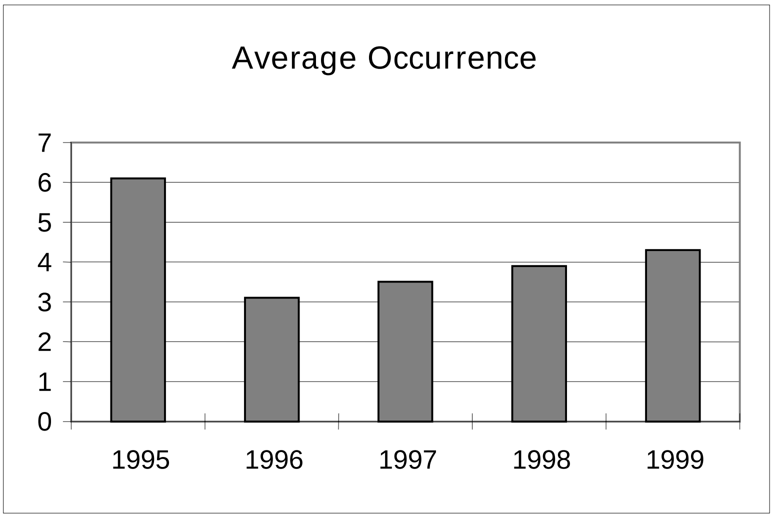


Figure 5.b. Average occurrence (number) of exceedances at stations which reported at least one exceedance during the summer period (April-August, French and Italian data was not included in 1995 and 1996).

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[10] 1995, 1996, 1997, 1998: Validated exceedance statistics as transmitted by Member States were used for this purpose.

[11] Averaged over all stations which reported at least one exceedance.

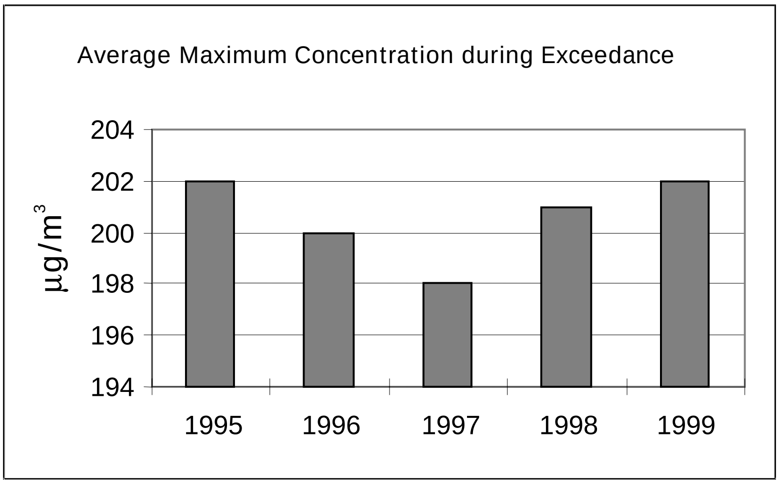


Figure 5.c. Average maximum concentration (µg/m^3) observed during exceedances during the summer period (April-August, French and Italian data was not included in 1995 and 1996)

All three indicators show some upward trend since 1997. However, it is not possible to assess a statistically significant trend in the number, duration and severity of exceedances of the threshold for information of the public which in its turn would indicate a possible trend in precursor emissions, because:

- As indicated, French and Italian data was not included in the 1995 and 1996 data analysis. From a comparison for 1997 with the indicators calculated with and without the French data, it is expected that the average duration, occurrence and maximum would increase for 1995 and 1996 if Italian and French data was included.
- High ozone levels (in this case exceedances of the population information threshold) are mainly observed during periods with warm and sunny weather. Especially in western and northern Europe, the year-to-year variations in meteorological conditions favorable for high ozone levels are large. The resulting variations in exceedance statistics can obscure a possible trend due to changes in precursor emissions. It is at the moment not possible to correct for this variability on a country by country basis nor for the complete EU territory;
- Exceedance statistics are available for only five years which is a relatively short time period for the assessment of statistically significant trends;
- The number of stations implemented in the framework of the Ozone Directive increased by almost 50 % during the period 1995-1999. The increased territorial coverage can have implications for the number of exceedances observed, especially since the increase is not the same for all countries reporting. Also, a changing ratio between the number of rural and urban/street stations can have implications for the number of observed exceedances since peak ozone levels will on average be lower in urban areas then in rural areas.
- The information presented in this section is based only on sites reporting exceedances of the threshold for information of the public and does not provide complete information on ozone levels observed in the European Union.

4. Main ozone episodes

Ozone formation and destruction is dependent on emissions, concentrations and ratios of precursors (mainly VOC, NO_x, and CO), and on the amount and intensity of sunlight. Particularly important in this respect is the role of nitrogen oxide emissions. In urban areas, ozone concentrations may be lower then 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 highest at rural stations).

Episodes, periods with increased ozone concentrations, mainly occur during periods of warm sunny weather. In the Mediterranean countries, which have prolonged spells of hot and sunny weather during the summer, ozone can be formed quickly and high concentrations 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 are usually found downwind of cities. Figure 6 presents a graphical representation of the percentage of stations in every country that reported exceedances of the threshold value for population information (180 $\mu g/m^3$ for hourly values) during the 1999 summer season.

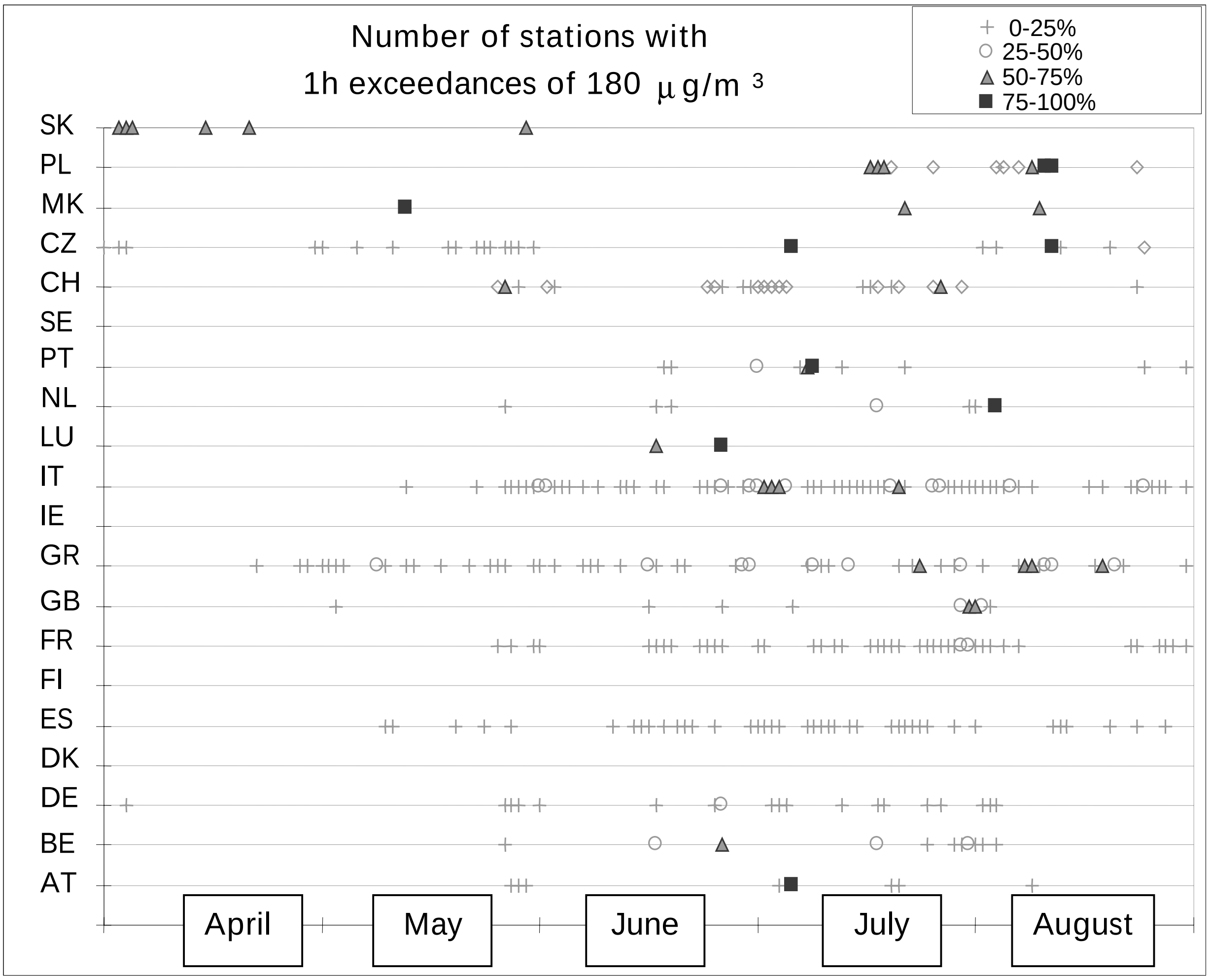
From Figure 6 it is clear that the number of episodes covering extended areas of the European territory was limited during April-August 1999. As already mentioned in Section 3, weather conditions in western and northern Europe were often unfavourable for the build-up of ozone.

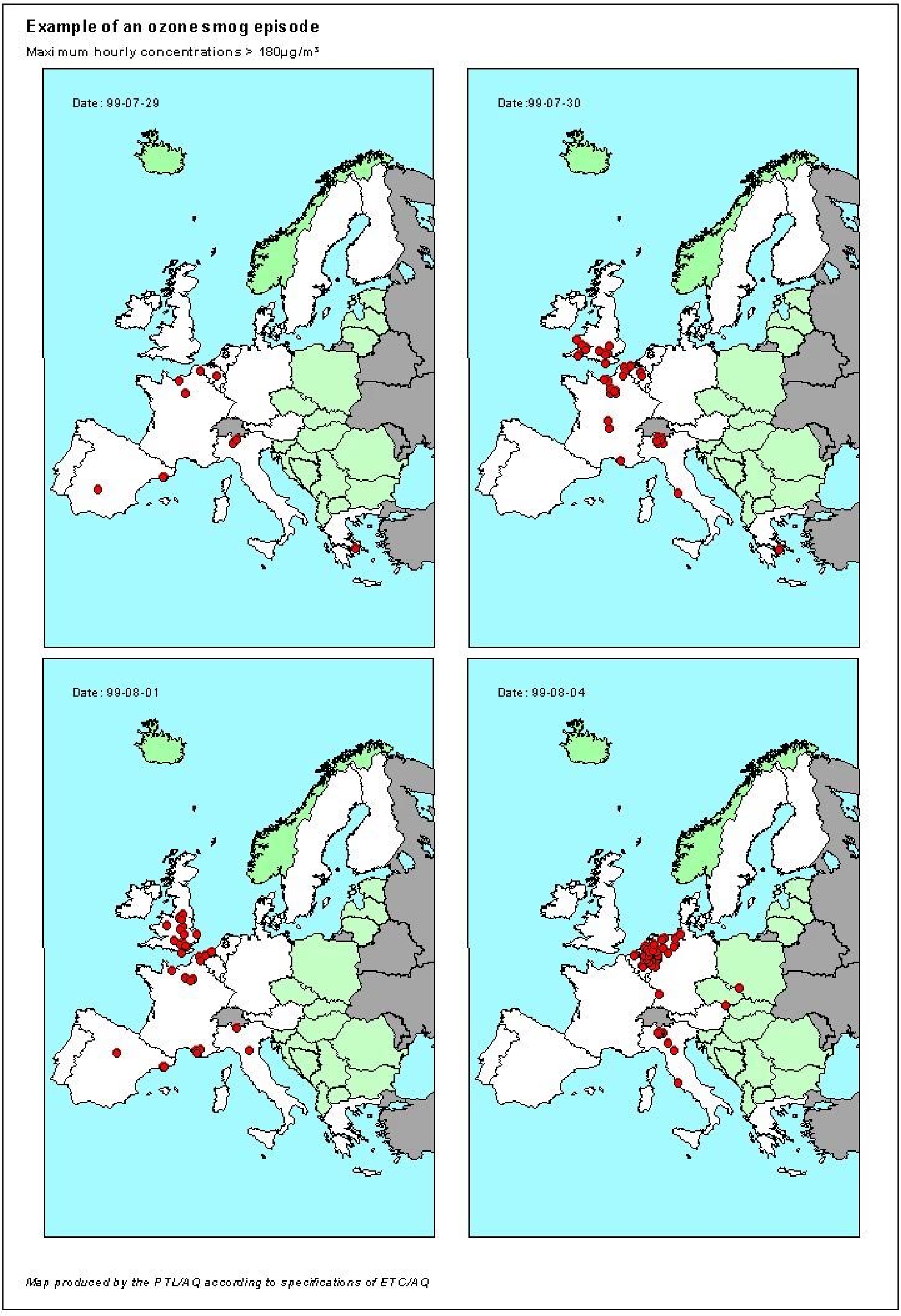
The episode of 29 July – 4 August 1999

During the last week of July, a strong high pressure cell formed north of the Azores and gradually took position north of Scotland. A period of warm, sunny and stable weather set in over Northern and Western Europe, frontal systems and associated unstable wet weather was found over the Alps. The air masses transported over large parts of the European Union north of the Alps originated over Scandinavia and could be characterised as relatively clean. These air masses became stagnant over the UK, Benelux and northern France on 29 July. In combination with the build-up of precursors pollutants, this resulted in ozone concentrations exceeding the 180 $\mu g/m^3$ threshold in this area. The synoptical situation remained more or less the same until 3 August, and subsequently exceedances were reported from the UK, Benelux and France during these days. On the 4th of August, a depression south west of Ireland started to transport relatively clean Atlantic air over the UK and France. This ended the episode in these countries. Parts of Belgium, the Netherlands and north western Germany remained in the stagnant polluted air with warm and sunny conditions; exceedances were widely spread in this area. On 5 August, the cleaner Atlantic air reached Germany, the Netherlands and Belgium and ended the episode.

The most geographically extended northern European episode in summer 1999 occurred between 29 July and 4 August. Map 4 presents an overview of the sites where exceedances were observed on 29 and 30 July, 1 and 4 August 1999. In the text box, the conditions leading to this episode are described in more detail. In contrast, in southern Europe exceedances were observed frequently throughout the reporting period.

Figure 6. Qualitative overview of exceedances of the 180 µg/m³ population information threshold value (1h) during the period April – August 1999. The symbols represent the percentage of stations which observed at least one exceedance of the threshold for the information of the public during a particular day.





Map 4. Example of a smog episode: stations which reported an hourly ozone concentration in excess of 180 µg/m^3, 29 July -4 August 1999 (all station types).

Figure 7 presents the maximum hourly ozone values recorded on the Saronno Sc.Moro monitoring station (near Milan, Italy) from 1 June – 31 August 1999 on days when the threshold for information of the public (1h >180 µg/m^3) was exceeded, as an example of frequent exceedances on a local scale in the Mediterranean region.

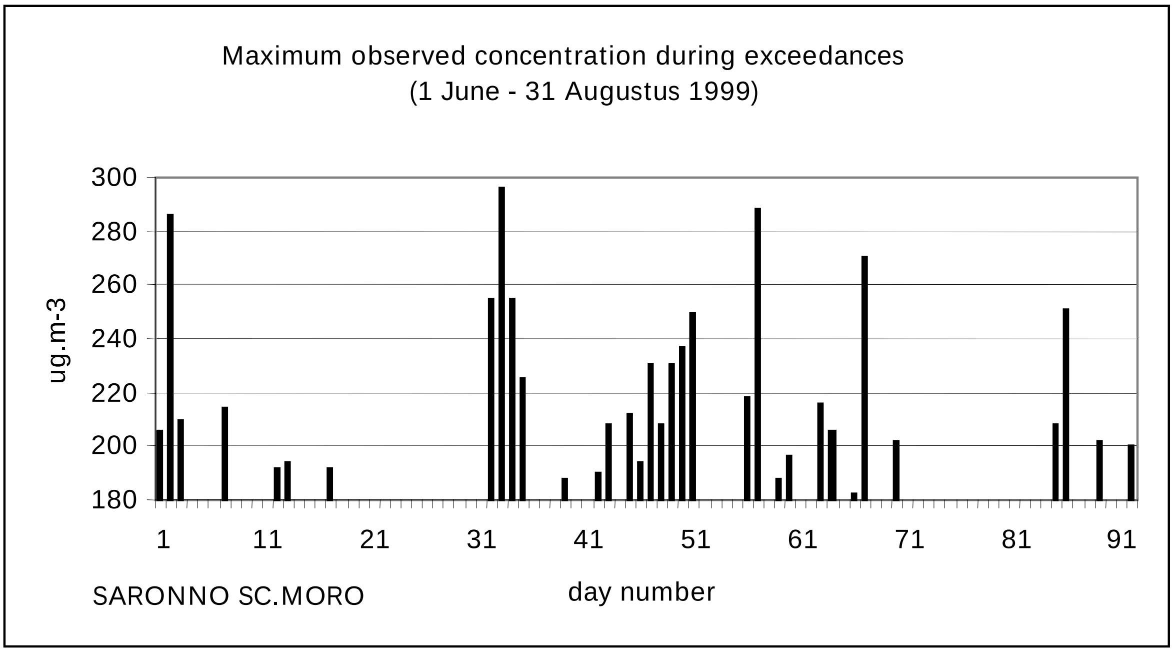


Figure 7. Example of frequent exceedances of the public information threshold value. Maximum observed 1h values (µg/m^3) on the Saronno Sc.Moro monitoring station (near Milan, Italy, 1 June – 31 August 1999) on days when the concentration rose to at least 180 µg/m^3 (1h).

5. Conclusions

This report presents a first evaluation of the reported exceedances of the threshold values for information and warning of the public during summer 1999 (April-August). Information is based on monitoring data which is not completely validated and hence the conclusions drawn should be considered as preliminary.

Information on the occurrence of exceedances was received from all EU Member States and for ten other countries (Czech republic, Estonia, FYROM, Latvia, Lithuania, Norway, Poland, Slovak Republic, Slovenia and Switzerland) for the months April, May, June, July and August. The quality of the exceedance information supplied was good and according to EU specifications. Improvements can be made for a number of countries as far as characterisation of stations is concerned. 1580 monitoring stations were assumed to be operational in summer 1999.

The threshold for warning of the public (1h > 360 $\mu g/m^3$) was not exceeded in the European territory during the 1999 summer season.
The threshold for information of the public (1h > 180 $\mu g/m^3$) was exceeded in all EU countries with the exception of Ireland, Denmark, Sweden and Finland. The same countries did not report any exceedance during the 1997 and 1998 summer season. In addition, no exceedances were observed in Estonia, Latvia, Lithuania, Norway and Slovenia in 1999.

In other EU countries, the number of days on which at least one exceedance was observed ranged from 2 in Luxembourg to 68 in Italy. 27 % of all stations reported one or more exceedance. On average 4.3 exceedances occurred in summer 1999 at stations that recorded at least one exceedance, with an average duration of 2.8 hours. The average maximum hourly concentration during an exceedance of the threshold this summer was 202 $\mu g/m^3$.

The spatial pattern of exceedances observed this summer in Northern and Western Europe is not comparable to that observed during the summer seasons of the last four years. In previous years, the number of exceedances rose from zero in the Scandinavian countries and Ireland to a maximum in Southern Germany. This year, many stations in this region, the eastern part of Germany and Austria did not report a single exceedance. The most extended area with exceedances in summer 1999 was situated over the United Kingdom, Benelux and the northern part of France between 29 July and 4 August. In southern Europe, exceedances were recorded frequently throughout the reporting period.

6. References

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