Air Quality in Major European Cities
Part I:
Scientific Background Document to Europe's Environment

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The '*Europe's Environment*' project was co-ordinated by the European Environmental Agency Task Force.

PREFACE

At the "Environment for Europe" conference held at Dobris Castle in the Czech and Slovak Federal Republic in June 1991, environment ministers and the EC Commissioner called for preparation of a pan-European state of the environment report; subsequently all European countries joined this initiative. The Dobris Castle conference agreed that in order to prepare the report, the CEC, in co-operation with the United Nations Economic Commission for Europe (UN-ECE), would set up a Project Group of individual European countries and relevant international organisations. Within the CEC, responsibility has fallen to the Directorate-General XI, and specifically to the Task Force which is making preparations for the European Environment Agency (EEA-TF).

The declaration from the 'Environment for Europe' conference specified that, among others, the pan-European state of the environment report should:

- facilitate the development of an Environmental Programme for Europe, which will "...identify priorities for the repair and restoration of existing environmental damage and the prevention of future problems.";
- be "...a basis for the effective implementation of environmental policies and strategies.";
- act as "...a useful tool to inform the public and raise awareness about environmental problems.".

The Dutch National Institute of Public Health and the Environment (RIVM) and the Norwegian Institute for Air Research (NILU) were requested by the EEA-TF to provide information for the report work package 'Air'. The Main Geophysical Observatory (MGO) of St. Petersburg provided data for cities in the former Soviet Union.

This document summarises the research carried out for Section 4.1 on urban and local air pollution of the report *'Europe's environment'* (Stanners & Bordeau, (eds.), *in press*).

We would like to thank all the city authorities who responded to our questionnaires, without their data it would have been impossible to write this report. We wish to thank the members of EEA-TF, especially Sylvain Joffre and David Stanners for their contributions and assistance. Kari Nevalainan's (UN-ECE Statistical Division, Geneva) help in obtaining population data and checking urban environmental indicators is greatly appreciated. We are especially grateful for the help we received from Irina Smironova, and Alla Schutskaya (both MGO) in collecting data for the cities in the Former Soviet Union. We thank Frank Vermoesen (Free University Brussels) and Albert Venema (State University Utrecht) for providing us with city maps.

EXECUTIVE SUMMARY

Chapter 1: Introduction

This report documents the research that RIVM, NILU and MGO have conducted into urban and local air pollution in Europe. The research was carried out in the framework of the Europe's Environment programme (to be published in *'Europe's Environment'* (Stanners & Bordeau, (eds.)), commissioned by the EU, EEA Task Force. The main goals of this research were:

- To define and make an inventory of natural and man-made environmental characteristics determining the air quality situation in European cities;
- To provide a systematic survey of the ambient air pollutant concentrations in cities compared to the World Health Organisation Air Quality Guidelines (WHO-AQGs);
- To estimate the number of citizens exposed to exceedances of WHO-AQGs;
- To estimate the damage to buildings and cultural heritage caused by air pollution;
- To indicate (industrial) areas with acute local air pollution problems ("hot-spots" outside the biggest cities).

Only cities with more than 500 000 inhabitants (105 cities in 35 countries) were described. Approximately 148 million people live in these cities (22% of the total European population).

Chapter 2: Data Acquisition

To be able to provide a review of the air quality situation in the selected cities, existing data bases and information were first reviewed and combined whenever possible. UN-ECE delivered population statistics through the International Environmental Data Service. City maps of all cities were available. From the ECMWF Observational Data Set, 10 years of 6-hourly meteorological data from a representative station near the cities were selected. For EU Member States, urban air quality data were available through their Air Pollution Information System (APIS). With the exception of some GEMS-AIR stations, hardly any air quality data for cities outside the EU were available. CORINE/EMEP Emission data were available only on a country level (NUTS 1). A literature search was conducted to find relevant urban air quality data references.

Information from (international data bases proved a good starting point for the research, however a lot of necessary data was lacking. Important data gaps existed, particularly concerning air quality and specific emission and exposure data.

To cover the data gaps, responsible authorities for air quality monitoring were first identified through a small first questionnaire. A second more extensive questionnaire was sent to the identified authorities. More than 70% of these questionnaires were returned. The questionnaire focused on the main topics: environmental characteristics, urban emissions, air quality statistics and exposure data.

Municipal authorities were requested to transmit data for the "morphological" or "physical" city rather than for the "administrative" city, since this is the area in which air pollutants are emitted. To meet this morphological concept a definition of conurbation was developed and applied in the data collection process. It proved difficult for a number of cities to generate data on the basis of the conurbation definition.

As far as population, area and meteorological data are concerned, a complete data set is now available. The availability of emission data varied between 29 and 45% of the cities, depending on the component. Not all cities, however, had emission figures available covering all source categories.

All of the cities have an operational monitoring network. Network design and procedures, however, vary widely within Europe. Air quality data were basically collected for the years 1985 and 1990. Some cities reported another recent year then 1990 (1989-1992).The availability of air quality data within this project varied between 33 and 79% of cities, depending on the component.

Apart from these data gaps, intercomparison of information between countries or even between cities in one country was difficult because of differences in inventory methods and monitoring techniques. To overcome this data inconsistency, tools (e.g. standard questionnaires, dispersion models) for collecting urban environmental data in a standard way and for assessing urban air quality on the basis of this information should be disseminated. The set-up of a complete international urban environmental data base, preferably by an international organisation such as EU-EEA is indispensible for future urban air quality assessment studies. The data base should at least contain emission estimates, air quality data and population and built-up area data.

All relevant data from the (inter)national data bases and questionnaires have been incorporated into City Report Forms (CRFs) published elsewhere (van Zantvoort, Sluyter & Larssen, 1995). In this report, the data are summarised, tabulated and presented.

An inventory of industrial hot-spots was made by sending a small ad-hoc questionnaire to the national focal points of the Task Force EEA for the compilation of the "Europe's Environment" report. This questionnaire was answered by 25 of the 37 countries.

Chapter 3: Analysis of Data[i]

A number of indices describing natural and man-made environmental characteristics have been defined to study their individual and combined influences on urban air quality (exceedances of WHO-AQGs) and to be able to find (dis)similarities between environmental characteristics of cities in different parts of Europe. Indices have been ranked in 5 classes.

Together with the topographical siting of the city, the average wind speed is used as indicator for the city's <u>average dispersion</u> conditions. An index called <u>meteorological smog potential</u> has been defined for both the winter and summer half years to describe the probability of enhanced concentrations on the basis of the meteorological situation independent of emissions.

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i Unless otherwise stated, data presented refers to 1990 or another recent year (1989-1992).

Total urban emissions are correlated with population size and population density. City size also influences advection and vertical exchange of pollution and consequently the residence time of pollutants in the urban atmosphere. Environmental pressure is defined from a combination of population size and density. Since emission data are fragmented, emission indices have been defined only for winter smog pollutants (SO_2 and/or particulate matter) and summer smog precursors (VOCs and NO_X).

The inventory of natural and man-made environmental characteristics proved to be a promising tool to study the individual and combined influences of environmental factors represented by indices on urban air quality and to be able to find (dis)similarities in environmental conditions of cities in different parts of Europe. Both emission indicators and in particular the meteorological smog potential indices show distinct regional differences. The number of exceedances of the 24-hour WHO-AQGs for winter smog pollutants correlates significantly with both the natural environmental indicators and the man-made environmental indicators.

Natural urban environmental conditions such as topographical siting and meteorology are important factors determining the urban air quality climate, especially when considering pollution episodes. In view of future international emission reduction plans, cities with unfavourable natural environmental conditions should be identified more precisely, since stricter emission regulations will be necessary to meet air quality standards.

Air quality data were basically collected for the years 1985 and 1990. Some cities reported another recent year then 1990 (1989-1992). The assessment given, is based on these data.

Maximum 24h SO_2 levels at city background locations still exceeded the short-term WHO-AQG in 43% of all cities for which data is available (N=76) on one or more days in recent years. These exceedances are not confined to Central European cities; they are also observed in the Western and Southern regions. Annual average SO_2 concentrations have fallen considerably over large parts of Europe during 1985-1990. In 1990, the long-term WHO-AQG was exceeded in 13% of the cities for which SO_2 data is available. Approximately 15% (16 million) of the total urban population in this sample (N=78 cities) are potentially affected by these exceedances. In 51% of all Central European cities (N=13), the long-term WHO-AQG was exceeded.

Average maximum 24h particulate matter city background concentrations exceeded the short-term WHO-AQG in 86% of all cities for which data is available (N=77) in 1990. These exceedances are observed in all European regions. In busy streets and especially near industrial estates observed maximum 24h levels can even be extremely high. In most cases exceedances are confined to a few days per year. Cities experiencing more structural exceedances are Belfast, Berlin, Birmingham, Dublin, Hamburg, Turin, Bratislava, Istanbul, Krakow, Katowice, Prague and Tirana. Annual average particulate matter concentrations (measured as Total Suspended Particulates (TSP) or black smoke) show a mixed trend in Western, Northern, Southern and Central European cities during recent years (1985-1990). In some cities a (slight) upward trend is visible, in others a (slight) downward trend. Cities in the former Soviet Union (FSU) report very high TSP concentrations, but concentrations follow a downward trend in most cities. Only 15 cities had black smoke data available. In 1990, the long-term WHO-AQG for black smoke is exceeded only in Tirana and Istanbul. No long-term WHO-AQG has been set for TSP.

To get a first order estimation of the city contribution to the total concentration field, average SO_2 and TSP city background concentrations have been compared to modelled regional background concentrations. The calculated city contributions for SO_2 are generally highest in Central European cities; lower values are found in Western and Northern European cities. The calculated city contribution of many FSU cities is negative, a phenomenon observed for FSU cities alone, indicating data inconsistencies. City contributions were plotted against emission parameters. No significant correlation is apparent between city contributions and urban SO_2 emission density (per square kilometre). The calculated city contribution for TSP is, in contrast to that for SO_2, very high for cities in the Former Soviet Union (FSU) (on average 145 $\mu g/m^3$). For cities situated in Southern Europe the average city contribution was 84 $\mu g/m^3$. For cities in Northern and Western Europe low contributions were calculated (16 and 18 $\mu g/m^3$ on average respectively). The city contributions for a few cities in these regions were even slightly negative. This is due to the scale on which the regional concentrations were calculated. No relation was apparent between TSP emission density and the TSP city contribution.

As a rough first assessment of population exposure to short-term winter smog episodes (SO_2 and TSP or black smoke), the number of people experiencing concentrations in ambient air above the WHO-AQGs were estimated for each city. It was found that approximately 49% of all citizens in the selected cities (72 of 148 million people) were exposed to exceedances of at least one of the WHO-AQG for winter smog pollutants in recent years.

Exceedances of the short-term WHO-AQG (24h) for NO_2 at city background locations in 1990 have been observed in Katowice, Manchester, Prague, Stuttgart, Ufa and Warsaw (6 of the 40 cities with data). No long-term WHO-AQG has been set for NO_2.
Annual average NO_2 concentrations in Western European cities (N=22) in 1990 were 46 $\mu g/m^3$ with a standard deviation of only 6 $\mu g/m^3$. Average concentrations in the FSU are the same as in Western European cities, but differ more from city to city (N=26, average 46 $\mu g/m^3$, standard deviation 22 $\mu g/m^3$). While traffic is the most important contributor in West Europe, in FSU cities space/domestic heating in (small) boiler houses is most important. Annual average concentrations in Northern European cities seem to be lower than in West and East European cities. Southern and Central European cities seem to experience slightly higher annual average concentrations. Sample sizes however are too small to make these differences statistically significant.

Lead concentrations in many European cities have dropped sharply in the period 1985-1990. This is mainly due to the introduction of lead-free fuels. Annual average concentrations at *hot-spots* (mostly busy streets) in most cities are now below the lower limit of the WHO-AQG (annual average 0.5 $\mu g/m^3$). Of the 49 cities from which recent (1989-1992) monitoring results were available, the lower limit of the WHO-AQG was exceeded in only 5 cities (Lyon, Manchester, Turin, Zagreb and Zaragoza); in Turin and Zaragoza the upper limit of 1 $\mu g/m^3$ was also exceeded). Concentrations in the FSU are still relatively low (0.11 $\mu g/m^3$ on average), but increasing traffic is likely to cause a rise in concentration levels, since lead levels in fuel are still high.

The 1h WHO-AQG for ozone was exceeded in 22 of the 27 cities for which data is available during recent years (1989-1992). Hourly concentrations of up to 400 $\mu g/m^3$ have been monitored in cities located in coastal regions subject to land-sea wind systems. Insufficient data were available to allow an estimation of human exposure to ozone (indicator for summer-type smog).

"Hot-spot" CO concentrations do not show a clear trend. The short-term WHO-AQG is exceeded in almost all cities for which data were available. Exceedances by a factor 4 have recently been observed in Athens and Milan.

Benzene and benzo[a]pyrene are considered representative for organic compounds associated with volatile organic hydrocarbons, or with soot and polycyclic hydrocarbons from combustion processes, respectively. From available data and model calculations, benzene will probably exceed the lifetime cancer risk level of 10^{-4} in most cities, and benzo[a]pyrene probably even up to a lifetime risk of 10^{-3}.

A limited ad-hoc questionnaire sent to the national focal points showed that the most severe exposures to high air pollutant concentrations near industry occur in Central and Eastern European countries. The industries which are most often responsible for very high local industrial pollution in Europe are non-ferrous metal industry (Copper, Aluminium) and coal-fired power stations. Extreme SO_2 exposure, for example, occurs in some industrial areas of Bulgaria, the Czech republic, Romania and Poland with annual average concentrations around 500 $\mu g/m^3$ and 24h averages in excess of 6000 $\mu g/m^3$ (Romania).

Air pollution in urban and industrial areas increases the rate of deterioration of many buildings and construction materials. For structural metals such as steel, zinc, copper and aluminium, quantitative dose-response relations are available describing the corrosion rate as a function of, *inter alia*, sulphur dioxide concentrations, chloride deposition rates, and climatic factors such as time of wetness. Extensive documentation exists on the effects of acid pollutants, particularly SO_2, on the deterioration of marble, and other calcareous stone used in buildings and monuments. There is a strong correlation between the weight decrease of calcareous sandstone and ambient sulphur dioxide concentrations. Various attempts have been made to estimate the costs of material degradation and maintenance due to air pollution. Extrapolation of the data from one study suggests that costs for damage by sulphur dioxide to buildings and construction materials might be in the order of ten billion ECU per year for Europe as a whole.

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1 INTRODUCTION

R.J.C.F. Sluyter

Europe is a highly urbanised continent. In 1990, more than 70% of its total population lived in cities. The concentration of human activities on a relatively small area causes enormous pressure on the urban system and has led to numerous environmental problems. Air pollution may be the problem that is best known but its effects are not well understood.

In the last decade air quality problems and associated topics such as exposure of citizens have been addressed by means of case studies. One of the first attempts to describe the air quality in a number of cities and investigate (dis)similarities between them was made within the GEMS-AIR project (WHO/UNEP). In 1992, WHO/UNEP published a report "Urban Air Pollution in Megacities of the World", summarising air quality data for the 20 most populated cities of the world (WHO/UNEP, 1992).

In the framework of the Europe's Environment programme, commissioned by the EU and co-ordinated by the EEA Task Force, RIVM[1], NILU[2] and MGO[3] have conducted a study on the air quality situation in a selection of cities, in different parts of Europe. It was impossible to assess the air quality situation in all European cities within the time available for this project. An arbitrary decision was made to describe only cities with more than 500 000 inhabitants. If no such city exists in a country, the largest city was chosen. The air quality situation has been described per city, including the natural and man-made environmental conditions acting on the atmospheric compartment. Next to this description of urban air pollution, an inventory has been made of local or 'hot spot' industrial air pollution outside the biggest cities.

Recently, WHO published their Concern for Europe's Tomorrow study (CET; WHO, *in press*). Urban air quality is also addressed in this study, however not through comparative city analysis but through statistical analysis of European air pollution concentration and population density fields.

1.1 Air Quality in Cities

In the atmosphere a large number of different anthropogenic and natural compounds disperse, mix, are transported and undergo chemical reactions. These pollutants have an impact on human beings, ecosystems and materials. Atmospheric residence times vary from less than one hour (e.g. reactive volatile organic compounds) to tens of years (e.g. CFCs). Winds can easily transport pollutants over continental scale distances even if their residence times are as short as 1-2 days. Regional air pollution levels in Europe are dominated by the contribution of European emissions.

Within cities emissions are concentrated, yielding high local pollution concentrations of primary pollutants and enhanced deposition. The actual occurrence and frequency of these

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2 Norwegian Institute for Air Research
3 Main Geophysical Observatory (Russian Federation)

increased concentrations depend on the magnitude and distribution of emission sources, on local topography and prevailing meteorological conditions in and around the city.

The concentration level of a given pollutant in the city's atmosphere is made up from up to four contributions:

- The ***natural background*** contribution;
- The ***regional background*** contribution: Longe-range transport of anthropogenic emissions leads to a regional increase in the concentration levels of many pollutants and their chemical transformation products. Emissions from cities themselves contribute to this regional background concentration; in this report 'regional background concentration' also refers to the concentration of a pollutant upwind of the city;
- The ***city background*** contribution: Concentration levels of a number of pollutants are higher in cities than in the surrounding rural areas. 'City background concentration' refers to the concentration of pollutants at places within cities, not directly influenced by sources such as industry or traffic;
- The ***traffic or industrial contribution***: In busy streets and near industrial sources the concentration field is further elevated through nearby emissions. 'Traffic' or 'industrial' concentrations refer to the concentration of pollutants at places directly influenced by traffic or industry. The contribution of each of these to the concentration levels in the city may be expressed as a fraction or, more usually and in this report, as a concentration.

Especially high concentrations, so called 'episodes' with a life-time of a few days, are observed in urban areas when the large-scale synoptic weather situation is unfavourable for dispersion and deposition and enhanced regional concentrations are present.

What is to be considered as 'high concentration' is dependent on the pollutant, the length of exposure to be expected and the health or damage effects associated with this exposure. Air Quality Guidelines (AQGs) for a number of pollutants have been set by national authorities and by international organisations. These AQGs often have a considerable safety margin with respect to the lowest observed effect level. The air of a city consists of thousands of components and for many of these the effects and their combined influence on human health and ecosystems are still unknown. Even if all air pollutants in a city are below their AQG values it is still not possible to guarantee healthy urban air quality.

Within this project, urban air pollutant concentration levels have been compared to World Health Organisation Air Quality Guidelines (WHO-AQGs) (WHO, 1987). In Table 1.1 WHO-AQGs are given for a number of pollutants, together with the effects they aim to prevent. These indicator pollutants are supposed to represent three major air pollution situations as they occur in cities: 1) winter-type smog, 2) summer-type smog, 3) long-term exposure to air pollutants.

Winter-type smog episodes occur during spells of cold winter weather when a high pressure system persists for several days. Dispersion is limited due to low wind speeds and a marked subsidence inversion. Winter-type air pollution episodes are generally characterised by high concentrations of sulphur dioxide (SO_2) and particulate matter (PM), mainly due to increased use of, and subsequent emissions from fossil fuels for space/domestic heating (RIVM, 1992; Rombout et al, 1990).

Summer-type smog episodes occur during warm and sunny weather in the summer season. Under the influence of sunlight, ozone is formed from nitrogen oxides and volatile organic compounds. At the same time the concentrations of other secondary formed compounds are increased as well as those from primarily emitted compounds such as traffic emissions (RIVM, 1992; Rombout et al, 1989).

Table 1.1: WHO-AQGs for relevant pollutants and expected effects (RIVM, 1992; WHO, 1987)

Pollution type	indicator	WHO-AQG risk level µg/m^3	Effect level	Effects
Short-term effects				
Summer smog	O_3	150 (1 hour)	200 µg/m^3 classification mild	Lung function decrements, respiratory symptoms, inflammation
Winter smog	SO_2+ TSP	250 (1 day)	400 µg/m^3 classification moderate	Decreased lung function; increased medicine use for susceptible children
Urban/traffic	NO_2	150 (1 day)		
Long-term effects				
Traffic	Benzene	2.5 (1 year)	10^{-7} yearly risk on cancer	Leukaemia; neurologic symptoms
Traffic/industry	Lead	0.5 (1 year)		Effects on blood formation, kidney damage; neurologic cognitive effects
Combustion	SO_2+BS	100 (1 year)		Respiratory symptoms, chronic respiratory illness
Combustion/industry	B(a)P	0.0001 (1 year)	10^{-7} yearly risk on cancer	Respiratory tract and lung cancer

TSP: Total Suspended Particulates

Local industrial air pollution

High concentration levels of harmful pollutants can occur near industrial areas or individual industrial plants, most often located outside the largest cities or in smaller industrial cities. Often the air pollutants are emitted from relatively low stacks or at low height as diffuse emissions from production halls/buildings. The main compounds involved are SO_2 and particles containing heavy metal oxides and organic compounds. Other important industries which cause local air pollution problems in several European countries are the power industry (e.g. coal-fired power plants; main compounds SO_2, particulates), inorganic chemicals, cement factories (SO_2, PM), and oil refineries/petrochemical industries. Local pollution from nuclear plants is not within the scope of this project.

1.2 Goals

Prime goals of this research were:

1. To define and make an inventory of natural and man-made environmental characteristics determining the air quality situation in cities;
2. To provide a systematic review of the ambient air pollutant concentrations in cities compared to their WHO-AQGs;
3. To estimate the number of citizens exposed to exceedances of WHO-AQGs;
4. To estimate the damage to buildings and cultural heritage caused by air pollution;
5. To indicate (industrial) areas with acute local air pollution problems ("hot spots").

1 The air quality climate in a city is the result of a complex interaction between natural and man-made conditions. A number of indices describing natural and man-made characteristics have been defined to those single and combined effects of these conditions on exceedances of WHO-AQGs and to be able to find (dis)similarities between environmental characteristics of cities in different parts of Europe. Climatological parameters such as temperature, wind speed, solar radiation and precipitation are important factors determining the average city air quality climate. For example high average wind speeds are favourable for the dispersion of pollutants and a dry climate can favour accumulation of air pollutants in the atmosphere. Together with the topographical siting of the city, the average wind speed is used as indicator for the city's ***average dispersion*** conditions. The topographical siting of the city can aggravate adverse meteorological conditions. For example low-level inversions can be more persistent in a valley than on a plain.
An index called ***Meteorological Smog Potential*** (MSP) has been defined for both the winter (***MSP-W***) and summer half year (***MSP-S***), to describe the probability of enhanced concentrations on the basis of the meteorological situation independently of emissions.
Total urban emissions are correlated with population size and population density. City size also influences advection and vertical exchange of pollution and thus residence time of pollutants in the urban atmosphere. To study the effects of population density and size of the city on air quality, the index ***(urban) environmental pressure*** is defined as the average of the city population density and area classes.
Emission figures per capita have been calculated for SO_2 and/or PM (***winter smog emission index***) and for nitrogen oxides (NO_X) and/or volatile organic compounds (VOCs) (***summer smog emission index***). Figures have been ranked. The urban environmental pressure index and emission indices together act as the ***man-made sensitivity*** of the urban system to enhanced air pollutant concentrations.

2 In this project special interest is paid to city background concentrations. Humans are exposed to these levels whenever they are outdoors. In busy streets and near industrial estates concentrations of a number of components can be far higher and thus the total human exposure. Indoor levels may deviate from outdoor levels.
Episodic unfavourable meteorological conditions can cause concentrations of air pollutants to increase dramatically during short periods. The term winter-type smog is used to describe the increased concentration levels of SO_2 and particulate matter caused by enhanced emissions from in particular space/domestic heating during cold winter spells in a stagnating atmosphere under low level inversions. The term summer-type smog is used to describe the increased concentrations of O_3 caused by photochemical reactions of NO_X and VOCs during warm sunny weather. Exceedances of the short-term WHO-AQGs for SO_2 and/or PM are used as an

indicator for ***winter smog episodes***, the exceedance of the short-term WHO-AQG for ozone as an indicator for ***summer smog episodes***.

3 The actual *outdoor* exposure of the urban population to air pollutants is difficult to estimate. Next to estimating the spatial distribution and time variation of the pollutant concentration, the location and physical activity level of the population should be known. Since detailed data about the activity and actual location of the population is not available, the description of exposure has been limited to estimating the number of people living in areas experiencing at least one exceedance of a WHO-AQG per year. Daily average concentrations of SO_2 and suspended particulates (PM) are used as an indicator for ***short-term exposure to winter-type smog air pollutants***. O_3 peak levels are used as an indicator for ***short-term exposure to summer-type smog pollutants***.

4 Air pollution increases the deterioration of many buildings and construction materials. Some estimates will be made of the costs of material degradation and maintenance.

5 A general review will be given of main European local industrial hot spot areas.

1.3 Outline of the report

Existing information/data bases used in this research are described in Chapter 2. New information has been collected directly through ad-hoc questionnaires sent to city authorities. Questionnaires and data-collection procedures are described in the second part of Chapter 2. Special attention is focused on the procedures followed for the cities of the former Soviet Union. Data analysis is described in Chapter 3. Special attention is given to the natural and man-made environmental characteristics. Air pollution levels are described in general terms. Specific winter and summer pollutants are evaluated against their WHO-AQGs. A method to estimate population exposure is described and results are presented for winter-type smog pollutants. Results are presented in the form of tables, graphs and maps. Conclusions and recommendations from this study are presented in Chapter 4.

The text on urban and local air pollution as published in the *Europe's Environment*-report (Stanners & Bourdeau, (eds.), *in press*) is presented as separate annex. Because of the tight time schedule kept for the production of the Europe's Environment-report, this text was written and transmitted to EEA-TF in summer 1993. Many new data became available between the deadline of the Europe's Environment-report and the deadline of this scientific background document (June 1994). These data have been used while writing this document and compiling the statistics presented. Because of this, figures given in Annex XII (Europe's Environment) can be slightly different from those given elsewhere in this document.

The air quality situation per city was summarised in a systematic way in so-called City Report Forms (CRFs). CRFs are presented in a separate report (van Zantvoort, Sluyter, and Larssen (eds.), 1995). Because information contained in the CRFs has been updated until December 1994, figures can differ from those presented in this scientific background document.

Urban environmental data collected within this project is also available at UN-ECE Statistical Division in Geneva.

2 DATA ACQUISITION

2.1 Introduction

R.J.C.F. Sluyter

A distinction must be made between the description of the air quality in cities in general terms and the description of the air quality for a *specific* city. The former can rely to a great extent on general knowledge of the behaviour of air pollutants in an urban environment, the latter requires detailed information for every city to be described. In some cases however, aspects of air quality can be extrapolated from one city to another when cities experience similar activity/emission patterns and dispersion conditions.

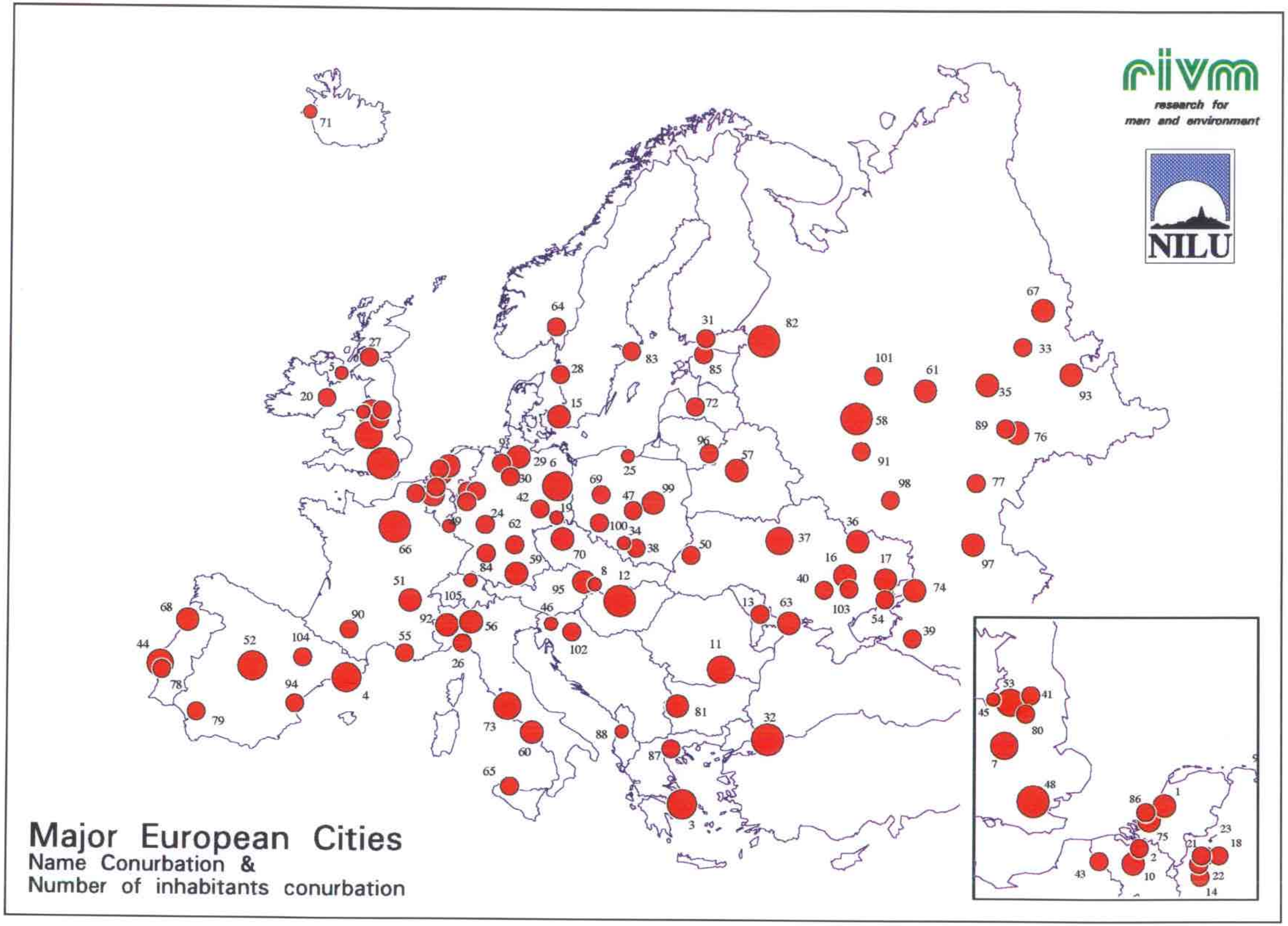
Map 1 presents the location and number of inhabitants of the selected cities[1] . Approximately 148 million people live in the 105 selected cities (22% of the total European population) (for selection procedure, see Section 1.1).

It is not trivial to define a city, especially the city boundary. This is important because existing (environmental) data is often available on the level of 'administrative units' (municipalities) rather than on the 'city' level. The administrative unit can be far greater than the city (e.g. Oslo) but often it is only a part of the conurbation (e.g. Paris, London). In other words, the conurbation or agglomeration can be made up of several municipalities.

From the literature (Buursink, 1980) no unambiguous city definitions are known. For example definitions based on functional differences between 'rural' and 'city' do not satisfy because typical urban functions are situated more and more in rural areas, moreover no agreement exists on what exactly 'urban' functions are. Definitions based on population density or building density are not useful because these indices vary from country to country. Besides, modern cities as a whole tend to decrease in building and population density because of sub-urbanisation.

Modelling urban environmental phenomena (e.g. air quality) requires a city definition on the basis of the physical boundary rather than on the administrative boundary because Europe's large cities often are vast urban areas made up of a prime city coagulated with secondary satellite towns and/or suburbs (e.g. London). The physical city is the three-dimensional space in which pollutants are emitted and the resulting concentration fields are directly influenced by the city's meteorological environment.

1 Belgrade (Serbia) was first selected, but not drawn on this map and accounted for in this project because of a UN embargo.


research for
men and environment
Major European Cities
Name Conurbation &
Number of inhabitants conurbation

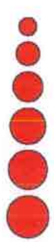
Major European Cities

Number of Inhabitants Conurbations

Nr	City	Inh.	Nr	City	Inh.	Nr	City	Inh.
1	Amsterdam	1080	36	Kharkov	1620	71	Reykjavik	110
2	Antwerp	790	37	Kiev	2500	72	Riga	900
3	Athens	3100	38	Krakow	800	73	Rome	2830
4	Barcelona	3100	39	Krasnodar	595	74	Rostov at the Don	1100
5	Belfast	295	40	Krivoj Rog	770	75	Rotterdam	1090
6	Berlin	3430	41	Leeds	710	76	Samara	1240
7	Birmingham	2310	42	Leipzig	510	77	Saratov	910
8	Bratislava	480	43	Lille	950	78	Setubal	800
9	Bremen	550	44	Lisboa	2000	79	Sevilla	780
10	Brussels	1350	45	Liverpool	470	80	Sheffield	530
11	Bucharest	2390	46	Ljubljana	273	81	Sofia	1300
12	Budapest	4434	47	Lodz	850	82	St. Petersburg	4950
13	Chisina	680	48	London	10570	83	Stockholm	670
14	Cologne	950	49	Luxembourg	80	84	Stuttgart	580
15	Copenhagen	1700	50	Lvov	800	85	Tallin	500
16	Dnepropetrovsk	1220	51	Lyon	1260	86	The Hague	650
17	Donetsk	1120	52	Madrid	3120	87	Thessaloniki	970
18	Dortmund	800	53	Manchester	2580	88	Tirana	450
19	Dresden	480	54	Mariupol	545	89	Togliatti	670
20	Dublin	550	55	Marseille	810	90	Toulouse	610
21	Duisburg	540	56	Milan	1430	91	Tula	540
22	Dusseldorf	580	57	Minsk	1600	92	Turin	1780
23	Essen	630	58	Moscow	9000	93	Ufa	1030
24	Frankfurt am Main	650	59	Munich	1210	94	Valencia	750
25	Gdansk	470	60	Naples	1210	95	Vienna	1560
26	Genoa	700	61	Niznhy Novgorod	1450	96	Vilnius	570
27	Glasgow	890	62	Nurnberg	500	97	Volgograd	1010
28	Goteburg	730	63	Odessa	1140	98	Voronezh	960
29	Hamburg	1630	64	Oslo	620	99	Warsaw	1650
30	Hannover	510	65	Palermo	710	100	Wroclaw	660
31	Helsinki	930	66	Paris	8510	101	Yaroslavl	620
32	Istanbul	6890	67	Perm	1120	102	Zagreb	950
33	Izhevsk	640	68	Porto	1315	103	Zaporozhe	900
34	Katowice	360	69	Poznan	590	104	Zaragoza	590
35	Kazan	1100	70	Prague	1220	105	Zurich	360

Key

Nr. of inh. conurbation



< 600.000
600.000 - 1.000.000
1.000.000 - 2.000.000
2.000.000 - 3.000.000
3.000.000 - 4.000.000
> 4.000.000

Number of Inhabitants Conurbation:

Core municipality (city) together with its morphologically integrated neighbouring cities/towns, or a city and its suburbs. Secondary towns or suburbs separated by more than 2.5 km from the prime city are excluded.

Population data in thousands

Source: RIVM/NILU Cartography: RIVM-LLO

To meet this morphological concept the term ***conurbation*** is used:

Conurbation: Core municipality together with its morphologically integrated neighbouring cities/towns, or a city and its suburbs, excluding secondary towns or suburbs separated by more than 2.5 km from the prime city.[2]

The choice of a separation distance of 2.5 km was guided by atmospheric transport calculations. Model runs (Jaarsveld, 1989) for an inert emission source distributed evenly over the city area showed that the contribution to the resulting annual average concentration field of that component under average meteorological conditions has decreased to 10% of its maximum at 2.5 km from the source area.

A different research approach was needed to give an review of the air quality situation in all major European cities. First available data sources had to be reviewed thoroughly and combined whenever possible. The inventory of available data should give a clear picture of data gaps. To cover these gaps responsible persons for air quality were identified in each city through ad hoc questionnaires. Responsible persons were asked to deliver missing and additional information.

2.2 Description of existing data bases and information

R.J.C.F. Sluyter, S. Larssen, W. Smeets

This chapter focuses on the data bases and information available within this project. The data bases are described in general terms. Information available is tabulated.

2.2.1 City list and population data

Two obvious problems arose when defining the project's city list. First, the register problem: some cities were not mentioned at all in some sources. Second, the consistency problem: population statistics often are not consistent between different data sources. A combination of data sources has been used to compile a city list.

The Times Atlas of the World (Times, 1990) was used to make a first list of possible cities/conurbations with more than 500 000 inhabitants. UN-ECE, through their International Environmental Data Service (UN-IEDS), checked and annotated the list and provided the number of inhabitants in the cities and sometimes conurbations. These population statistics were taken from the 1989 UN demographic yearbook (UN, 1991) and made up the preliminary city list. The list has been annotated during the project; this is described in Section 3.2.1 (Analysis of data; population and area statistics).

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2 No definition was set a priori of 'built-up area', responsible authorities in the cities were asked to draw the boundary between rural and built-up (see Section 2.3.3.3). The only precondition set is on secondary towns or suburbs near the conurbation.

2.2.2 Topographical maps

A city map is a useful tool for assessing the air quality situation and to estimate the number of citizens exposed to a certain level of air pollution. A lot of effort has been undertaken to obtain relevant topographical and thematic maps of every city.

The Faculty of Geographical Sciences (Department of Cartography), State University of Utrecht (The Netherlands) was requested to make an inventory of topographical material available for cities in the University's extensive map collection. The pre-conditions set for the usefulness of a topographic map were:

- The scale of the map should enable thematic information to be drawn on it;
- The scale of the map should enable the map to be printed on a standard A4 form;
- The map should have been published recently.

Because the size of cities varies enormously three scale categories were adopted (pre-condition 2): 1 : 100 000, 1 : 200 000 and 1 : 400 000

In some cases not all three pre-conditions could be met. In these cases various maps, differing in age and scale have been used to provide a more complete picture. With the exception of a number of cities in the **F**ormer **S**oviet **U**nion (**FSU**) relevant maps were available for most cities.

Municipal authorities were requested to deliver thematic information/maps on their city in the second questionnaire (see Section 2.3.4.3). Maps showing the main roads and the location of air quality monitoring stations in cities of Ukraine, Belarus and the European part of Russia became available as additional information for those cities (see Section 2.3.5).

The Free University of Brussels (Belgium), ***Groupe d'etude pour la valorisation de l'espace rural et urbain***, delivered additional population-density maps for a number of cities.

2.2.3 Meteorological data: The ECMWF **O**bservational **D**ata **S**et (ODS)

Climatic/meteorological data is needed for characterisation of the abiotic environment of the city (e.g. dispersion conditions, smog potential) and to model the air pollutant concentrations in cities. Only a windrose for a downtown station was requested from the cities themselves. The reason why no detailed information was asked from the cities is that the data are not measured in a uniform manner and uniform information was preferred. Climatic data was taken from a data base (**ODS**: **O**bservational **D**ata **S**et) provided by the **E**uropean **C**entre for **M**edium-range **W**eather **F**orecasts (**ECMWF**) (described in Potma, 1993). The ODS data base contains 6-hourly meteorological information from 1 January 1980 - 31 December 1989 for approximately 1200 standard WMO stations in Europe (**Table 2.1**).
In order to calculate climatological indices the station located nearest to, but not in, the city was selected. Information taken from ODS and procedures followed in calculating climatological indices are described in Chapter 3.

Table 2.1: Meteorological information available from the ECMWF-ODS data base (summary)

Env.	Fields describing location of station (co-ordinates), altitude, station nr.
T	Temperature (0.1 °C)
Td	Dew point temperature (0.1 °C)
P	Pressure (0.1 hPa)
RR	Precipitation (0.1 mm)(+ indicator for time period of measurements: 6 or 12 h)
DD	Wind direction (tens of degrees)
FF	Wind velocity (m/s)
W	Past weather (0..9)(00..99 code) (hour before observation)
WW	Present weather (00..99 code) (at the time of observation)
N	Total cloud amount (octas)
Nh	Cloud amount, low clouds (octas)
Tmax	Maximum temperature (0.1 °C) (+indicator for time period measurement)
Tmin	Minimum temperature (0.1 °C) (+indicator for time period measurement)
E	State of the ground (0..9)

2.2.4 Emission inventory

The Laboratory for Waste, Materials and Emissions (RIVM - LAE) aimed to provide an approximate estimate of anthropogenic emissions of SO_2, NO_X and VOCs per country, per source category, per inhabitant for the whole of Europe for 1990. The results were used here to compute estimates of cities' emissions when these were not available from the cities themselves.

Procedures for estimating emissions included:

- collection of data on total emissions per country for 1990;
- collection of data on source category allocation of emissions per country for 1990 or, if not available, for the most recent year possible;
- collection of population data per country for 1990;
- calculation using the above data of emissions per source category, per inhabitant, per country.

Source category allocation was based on CORINAIR-1985 definitions (CORINAIR, *in preparation*). Emissions were assigned to one of three categories:

1. Industry (including public power/co-generation/district heating, oil refining, combustion in industry, production processes, industrial solvent use);
2. Transport;
3. Commercial/institutional/residential combustion, and non-industrial solvent use.

Annex I presents the calculated emission figures. A reference list on which the data is based is attached. Population totals were taken from The Economist World Statistics (Economist, 1992).

Data presented in Annex I must be interpreted with great care as they are rough estimates. The following points should be taken into consideration:

- emission source category allocation was often based on detailed but not up-to-date emission inventories, such as those from 1985 (CORINAIR-1985; Veldt, 1991) and 1980 (OECD, 1990);
- as far as non-EU countries are concerned, it is often not clear whether natural VOC emissions and CH_4 emissions have been included in their VOC emission estimates;
- it is not always known if the source category "other transport" (off-road vehicles, air, rail and water transport) was included in the collected total emission figures;
- emission totals used were based as far as possible on data provided by the countries themselves (ECE, 1992; Zierock and Zachariadis, 1991), otherwise data from various other sources were used;
- the CORINAIR-1985 source category classification does not distinguish between industrial and non-industrial solvent use; here, total emissions from solvent use were divided evenly between industrial and non-industrial categories, as expected from Netherlands data;
- EU country VOC emission totals exclude typical CH_4 sources such as mining, agriculture, gas distribution and land-fills, and natural VOC emissions; they include emissions in the category other transport, and CH_4 from other source categories.

2.2.5 Girafe

Girafe is the (French) abbreviation for ***Guide d'Information sur les Résaux de qualité de l'Air Fonctionnant en Europe*** (Information system for operational European Air Quality Monitoring networks). The inventory was made in 1990 by DGXI of EU (EU, 1994). The data base contains information on all operational air quality monitoring networks in the EU. It contains information on the location and environment of all stations, the components monitored, techniques used and on the organisations responsible for the networks. More than 3000 stations are described.
The Girafe data base is not fully operational yet. To be able to use the information the information was loaded in **AMNIS** (***Air quality Monitoring Network Information System)***. AMNIS is an Ingres data base located at RIVM in which network information and air quality data can be stored. Although this system is not fully operational yet, the Girafe data could be handled.

The monitoring network information was used to identify addresses of responsible organisations for air quality monitoring in cities. The information was also used to assess air quality data provided by the cities and air quality data from the APIS data base.

2.2.6 Air Pollution Information System (APIS)

APIS is the abbreviation for Air Pollution Information System (APIS, 1992). It is a software package (data base) designed for the exploration of air quality data. These data were transmitted by the EC Member States in the framework of the Exchange of Information on Air

Pollution (Council Decision 82/459/EEC). APIS is capable of performing statistical treatment of data and presentation of data and statistics in graphs and tables.

The data base consists of ca. 50 Mb of air quality data from air quality monitoring stations which were selected by the Member States themselves. According to Article 4.3 of EEC Directive 82/459 'the stations selected should reflect, where possible, the different types of urbanisation, topography and climatology, as well as the different pollution levels prevailing upon the territory of the Member State concerned'. Most stations selected are located in urban environments (**Table 2.2**).

Table 2.2: Contents of APIS in 1991 (EC Member States only).

APIS Data base information Population class	nr. of cities	nr. of stations
> 2 million	10	63
1 - 2 million	10	84
0.5 - 1 million	23	108
0.1 - 0.5 million	53	172
1 - 100 thousand	63	87
< 1000 ('background')	47	47

Apart from the population class, some general information on the location and siting of the station is available in most cases: co-ordinates and address of the station are given and an 'environment' indicator.

Indicator describing the environment of the station:

Group 1: type of area

•***Urb***: urban, ***Sub***: sub-urban, ***Rur***: rural;

Group 2: type of zone

•***Ind***: industrial, ***Com***: commercial, ***InC***: industrial-commercial, ***Res***: residential, ***InR***: industrial-residential, ***CoR***: commercial-residential, ***ICR***: industrial-commercial-residential;

Group 3: traffic density

•***Vel***: very light, ***Lig***: light, ***Mod***: moderate, ***Hea***: heavy.

The following components are covered in APIS:

•SO_2, BS, SPM, acidity (SO_2-equivalents): ***daily values***;

•NO, NO_2, O_3, CO: ***hourly values***;

•Pb, Cd, Cu, Zn: ***daily values***;

Time series vary, the earliest beginning in 1975 and the latest ending in 1991.

Considering the averaging time recommended in Decision 82/459/EEC the statistical module computes:

- •the arithmetic mean;
- •the maximum;
- •50, 95 and 98 percentiles;
- •the number of exceedances (3 days, 2 threshold values);
- •a shape estimator.

APIS was used to fill in missing data and to assess long-term trends in concentration levels. APIS was not used more extensively, since many stations had operated for only a few years, or data from stations were transmitted irregularly. This resulted in fragmented time series. APIS data are often difficult to compare because of differences in methods of analysis between Member States. Moreover, the method of analysis is not always known.

2.2.7 GEMS-AIR

WHO and UNEP (United Nations Environment Programme) carry out an urban air quality monitoring and assessment programme, known as GEMS-AIR, which is a component of the Global Environment Monitoring System. This programme has been operating since 1974 and its activities include collecting, handling and assessing air quality data from over 50 cities in 35 countries. For some cities, GEMS air quality and emission data have been used. Data were gathered through GEMS-AIR publications (WHO/UNEP, 1992; UN, 1992).

2.2.8 Literature search

The search for articles and reports on local and urban air pollution in European cities was done in the following manner:

- data base: Base 41 - Pollution abstracts
- key words: air and (quality or monitoring or modelling) and city name (European big cities)

The search gave as a result 38 references, which were all investigated.

The references contained information on air pollution in the following cities:

Athens	Madrid
Barcelona	Manchester
Belfast	Marseille
Budapest	Milan
Istanbul	Sheffield
Lancaster	Venice
Leeds	Vienna
Liverpool	Zagreb

One reference dealt with the cities of North Rhine-Westfalia. Another referred to suspended particle concentrations in Amsterdam, Brussels, Frankfurt, London, Madrid, Prague and Zagreb. Two further references provided data on some cities in France and Germany.

The reference list and summary tables of information are given in **Annex II**.

Most of the references are from the 1980s. A few are older. Some present data and modelling studies from 1988-90.

Athens and Milan are the cities from which most results have been presented in the literature.

A brief summary of some results is given below.

Athens

10 references have been found on Athens, covering the period 1985-91, plus one from 1977. Extensive monitoring and modelling of air pollution in Athens is reported. The most recent studies deals with SO_2, NO_2, smoke, ozone in air and lead content in blood of inhabitants. Measurement results are compared to results from dispersion modelling based on emission data. The Athens air pollution problem is caused by the city's location and topography, i.e. its location close to the Aegean Sea and surrounded by mountains. This is combined with a high emission density. High concentrations of primary pollutants are caused by strong subsidence and low wind speeds during winter episodes, while high ozone concentrations (>200 ppb) occur during land-sea-breeze conditions with strong insulation in summer.

Milan

4 references from 1981 to 1991 describe the air pollution situation in Milan. SO_2 has been studied extensively based on emission data, modelling studies and measurements. The source reductions (of SO_2 and NO_x) necessary to meet air quality guidelines (AQG) have been calculated.

UK 5-city studies, 1990-91

One reference describes the results from an SO_2 and smoke study performed in the cities Belfast, Leeds, Liverpool, Manchester, Sheffield. In Manchester and Sheffield, NO_2 and NO_x were also included in this reference. 2-7 measurement sites in each city. The measured values were compared to WHO air quality guidelines. At all sites, except one for SO_2 in Belfast, the guidelines were not exceeded. In Sheffield, the data set was not complete enough to allow comparison.

Another reference discusses the results of 363 NO_x monitoring stations all over UK. London had the highest average concentrations. The highest concentrations were measured close to busy roads. The NO_x concentrations were reported to be only moderately higher in winter than in summer.

Other studies

In Lancaster, NO_2 was measured at 9 sites near roads, in 1989-90. At road sites, annual average NO_2 up to 122 $\mu g/m^3$ was measured.

In Budapest a number of compounds were measured at up to 8 sites during summer 1991. The main problem was considered to be the extra traffic through Budapest caused by the bridges over the Danube. 2-stroke engine cars were described as giving a large contribution to TSP concentrations in Budapest.

Barcelona SO_2-concentrations in 1985 were presented in one reference. Madrid SO_2 and PM-concentrations and trends for the period 1979-85 were presented in one reference.

The North Rhine-Westfalia city reference deals with, for 1989, emissions and measurement results for CO, CO_2, SO_2, NO_2, VOC, SP, Pb and PAH. Road traffic is the main source of NO_x, CO and VOC. The reference contains an extensive report on air concentration levels.

One reference also gives a pollutant emission and ambient concentration inventory for inorganic gases, organic gases and vapours and dust for the Cologne area in 1976.

For the cities Brussels, Helsinki, Frankfurt, Athens, Dublin, Amsterdam, Warsaw, Wroclaw, Madrid, Glasgow, London and Zagreb, there was one reference giving emissions of SO_2 and NO_x and discussing the trends from 1970-1980. Decreasing trends of SO_2 concentrations in all the cities.

One reference provided a table of suspended particle concentrations in the period 1973-1985 for the cities Brussels, Prague, Copenhagen, Helsinki, Gourdan, Frankfurt, Munich, Athens, Dublin, Milan, Amsterdam, Warsaw, Wroclaw, Lisbon, Madrid, Glasgow, London and Zagreb.

2.2.9 Concluding remarks

The scope of this project calls for information from many disciplines. International environmental urban data are not yet integrated into one data base. This project has made an inventory of the existing data bases.

The information available from the data bases was a good starting point to assess the air quality in cities, but many required data were missing. Important information gaps existed, particularly as far as air quality data, specific emission data and exposure data were concerned.

Besides obvious data gaps, differences in inventory methods and monitoring techniques often make comparing information between countries (or even between cities in one country) difficult.

No time was available within the scope of this project to incorporate the existing data bases into one integrated data base.

2.3 Data Collection, handling and storage

R.J.C.F. Sluyter, E. Bezuglaya, S. Larssen, H.C. Eerens

2.3.1 Introduction

From Section 2.2 it is clear that existing data sources contain insufficient data to be able to describe the air quality situation in the selected cities. It was decided that missing data would be gathered through ad hoc questionnaires. Two questionnaires were sent. These two questionnaires are described in this chapter. Main Geophysical Observatory in St. Petersburg (Russian Federation) offered their help in collecting data for cities in the former SU. The procedures followed in collecting and calculating data for these cities are different from those applied for other cities in Europe and are described in Section 2.3.4. Besides urban air quality, data on (industrial) "hot spot" air pollution was also gathered through an ad hoc questionnaire. This questionnaire is described in Section 2.3.5.

2.3.2 The first urban air quality questionnaire

The goal of the first questionnaire was primarily to identify the persons responsible for air pollution information in the cities and to assess in general terms if sufficient data were available in the cities to be able to give a description of the air quality situation. The data themselves were collected in a later stage through a second questionnaire.

The first questionnaire was designed in such way that it could be completed in a short time and in easy to handle form which would make it easy to store the information in a data base. The first questionnaire is presented in **Annex III** (English version). The questionnaire and accompanying letter were translated into German, French and Russian to get as much response as possible.

Because of the lack of contact persons in many cities four routes were identified to send the questionnaire:

1. By sending it to the Directors of the local authorities directly (anonymous);
2. By sending it to persons responsible for air quality in the cities directly (anonymous);
3. Through the National Focal Points who have been asked to send the questionnaires on to responsible persons in the selected cities, and also to smaller cities with major air pollution problems (to be selected by the national focal points).
4. By sending it to known contact persons. They have been asked to fill in the questionnaire and send it to other persons they know who are responsible for air quality in other cities.

Questionnaires were sent out in July 1992 and had to be returned to RIVM or NILU before 1 September 1992.

More than 75% of the cities responded to the first questionnaire. It may not be concluded that the cities who did not return the first questionnaire were unwilling to co-operate in the project. Problems encountered with identifying contact persons in some cities may have contributed to this. In some cases, two or even three questionnaires were returned from a city, filled in by different people, since the questionnaire was sent using four routes. It gave us the opportunity to check whether information provided was consistent between the various sources. The information returned with the first questionnaire was stored in a data base (dBase III) and used for a first evaluation of data available at cities necessary for this project.

2.3.3 The second urban air quality questionnaire

Evaluation of the material sent by the cities through the first questionnaire showed that in most cities enough data is available for a more or less detailed description of the air quality situation. Several possible routes could be followed to obtain data:

1. To organise a workshop in which city delegates could present their data;
2. To visit the cities in order to collect the data;
3. To collect the data through a second questionnaire.

It was decided to collect the data through a second detailed questionnaire. In some cases cities were visited for additional information. The Main Geophysical Observatory of St. Petersburg (Russian federation) collected information on the cities in Belarus, Ukraine and the European part of Russia (see Section 2.3.4).

The second questionnaire, which was available in English and Russian versions, is presented in **Annex IV** (English version).

The questionnaire focused on the major topics outlined in the introductory chapter:

- environmental characteristics (natural and man-made);
- urban emissions
- urban air quality (air quality statistics, exceedance of WHO-AQGs);
- exposure to air pollutants in cities (humans, materials).

In the introductory chapter the problems of defining the city's boundary were stressed. A work definition was given of a **city** and a **conurbation**. As far as air quality research is concerned it was stated that data on the conurbation is more relevant than data on the city. Throughout the questionnaire, the information asked was on conurbations. In this chapter some general remarks are made on the information asked.

2.3.3.1 Population and area figures

Population figures were asked for both the city and conurbation. In Section 2.2.1 it was made clear that population figures can vary enormously from one data source to the other. One of the reasons for this is the definition of the city's boundary. The population figures given by the municipal authorities are used within this project as 'best estimate'. Using population figures and the built-up area of the city, the population density was calculated (Section 3.2).

2.3.3.2 Topographic and Meteorological information

The location of a conurbation on the macro/meso scale determines the city's major climatological characteristics. These climatic characteristics can have a significant effect on the city's air quality (see also Section 3.3.1).
The description of the conurbation's siting is important in relation to adverse meteorological conditions. For example cities sited in valleys tend to have more persistent inversions and thus a higher pollution episode risk (see also 3.3.3). Data for a down-town wind station were requested to compare the wind characteristics in the centre of the city with those observed outside the city (available from the ECMWF-ODS data base).

2.3.3.3 Thematic city maps

In addition to the topographic maps already available (see Section 2.2.2), municipal authorities were asked to deliver a thematic map. The two map sources combined are very useful when assessing the city's air quality conditions and for example to estimate the number of citizens exposed to a certain level of air pollution. The following topological information was requested in the second questionnaire:

Residential areas
It is important to know where residential areas are situated in relation to industrial zones, major point sources, harbours and motorways when estimating the exposure of citizens living in residential areas to air pollution.

Industrial areas
In these zones most industrial estates are clustered. If specific emission amounts and the prevailing wind direction are known, air pollution levels in downwind residential areas can be estimated or modelled.

City centre/commercial areas
The city centre is also the area where in general commercial and administrative activities take place in most European cities. In many cases the morphological structure of the centre leads to traffic congestion. Taken together with the fact that the building density in the city centre/commercial area is high with 'building/street canyons', this can lead to high pollutant concentrations.

Woodlands/parks green areas
Generally speaking 'green areas' will have lower pollution levels than the surrounding built-up areas. In some cases however, when the green area is sufficiently large the concentrations of photochemical components (e.g. ozone) can be higher than in the surrounding built-up areas. Information on the location and extent of green areas can also be necessary to assess the damage caused by air pollution to the city's nature.

Main roads
The number of main roads and motorways within the city's boundary and the location of these roads gives an indication of the traffic contribution to total air pollution levels.

Air quality monitoring site
The usefulness of air quality data is very restricted when no information is available on the analytical methods used, environment (site) and location of the station. Information on site and analytical methods was requested in the questionnaire. The location of the air quality monitoring sites was requested to be drawn on the thematic map.

Major point sources
Major point sources within the conurbation boundaries can have a significant effect on the air quality downwind of the stack during unfavourable meteorological conditions. Information on major point sources (components, emission amounts, stack height and thermal capacity) was asked for in the questionnaire. The locations of the major point sources was taken from the thematic map.
Meteorological (wind) station
A wind rose is asked for in the questionnaire. The location of the wind station is to be drawn on the thematic map. Ideally, the station would be located in the centre of the city but would not be influenced by buildings or other obstacles. On many occasions this will not be feasible and the station will be influenced directly by buildings. The reason why the wind rose is asked for is that the meteorological station selected from the ODS data base (Section 2.2.3) is often sited on a airport outside the city where quite different conditions prevail. Combination of the two stations gives some indication of the wind climate in and near the city. Local air flow systems caused by the morphology of the landscape and the city itself are not accounted for.

2.3.3.4 Emission and activity data

Urban emissions have been requested to be able to classify cities according to their emission environment and to estimate the contributions of the different sources to total emissions. Urban emissions are necessary input for dispersion models (which were, however not used within this project).

The following components were chosen: SO_2, NO_X, NM-VOCs, particulate matter, CO and Pb. The components requested were selected for the following reasons:

- A WHO-AQG should have been set for the component;
- (in connection with point 1):The component should cause a well-known risk to the health of humans;
- Emission amounts should be available for a broad selection of cities to make comparisons possible between cities as far as pollutant levels and exposure of citizens are concerned;
- The components chosen should reflect typical urban processes and environmental conditions (act as an indicator).

Emission data was requested on three main source categories: industry and power plants, traffic and domestic/space heating. Traffic has been split up in the contributions of road traffic, and ships and trains. This is mainly done because ships combust sulphur rich fuels and may make an important contribution to the total transport emissions in cities with a harbour.

Emissions caused by industry and power plants have been divided into 2 categories (those with stack heights below and above 50 meters). This distinction has been made because components emitted high above the ground will in many cases not contribute to the pollution level in the city itself but to the concentration field well outside and downwind from the city.

Emission data per capita and/or per square kilometre is necessary to enable comparisons between cities.

In cases when emission amounts are not available they can be calculated to some extent from activity data and/or fuel use if emission factors are known. Both urban fuel use and activity data were requested in the questionnaire.

2.3.3.5 Air Quality Data

The amount of information asked on air quality monitoring networks, necessary to assess the air quality data, was limited. The reason why not more information was asked was not to overburden the respondents with work. The information that was asked made a general assessment possible of the quality of the air quality data sent by the cities. For cities located in the European Community, additional data was available through the Girafe/APIS data bases (see 2.2.5 and 2.2.6).

- Method of analysis and quality assurance

It is a known fact that a pollutant monitored using different techniques will give different results. Comparison tests are common and are well documented so comparison between methods can be made to some extent. Information on quality assurance is needed to assess the usefulness of air quality data measured by a particular technique. Some general comments were requested to get a first impression.

- Types of stations

As discussed in Section 1.1 the concentration field of a pollutant over a city can be seen to be made up of at least 3 components: the regional background component, the city background component and the street/traffic or industrial component. To be able the assess the air quality situation in a city, information on all three components is necessary. Information can be obtained from models or measurements from representative locations.

Air quality monitoring stations can be grouped according to their location. Within this project the following station types have been defined:

- **Regional background stations**: Stations located outside the urban area and not directly influenced by anthropogenic emission sources (minimum 3 km distance and maximal distance 50 km from the conurbation built-up area); the stations are used to monitor regional background air pollution levels;
- **City background stations**: Stations located within the built-up area of conurbations, but situated away from busy streets and industrial sources (not directly influenced by traffic or industry). Citizens are exposed at least to city background levels when outdoors. City background measurements are used to estimate citizens exposure;
- **Traffic stations**: Traffic (street/kerbside) stations are located in busy streets and are used to monitor the contribution of traffic to (urban) air pollution levels. Within this project data from these types of stations is only requested for the station measuring the highest concentrations to get an indication of possible pollution levels in traffic situations;

- **Industrial stations**: Industrial stations are located near or at industrial sites/estates . In many cases these stations are part of an alarm/alert network. Within this project data from these types of stations were required only from the station measuring the highest concentrations to get an indication of possible pollution levels near industrial estates.

- Components and years

Data has been gathered for the components SO_2, NO_2, PM (TSP/PM10/Black smoke), CO, Pb and O_3. Cities were asked to send data for 1985 and 1990 or two other recent years and a maximum of 10 city background stations. To get an impression of air quality levels in traffic situations and near industrial estates, data was also requested for a traffic and industrial station measuring the highest concentrations. **Annex IV** lists the statistics requested per component.

2.3.3.6 Exposure estimates

Municipal authorities were asked to send in any material they had on exposure research carried out in their city. Exposure estimates from epidemiological research could be very useful in assessing the city's air quality climate.

2.3.4 Procedures applied for cities in the former Soviet Union

28 (26%) of the cities selected for this project are located in one of the republics of the FSU. Main Geophysical Observatory (MGO) of St. Petersburg was requested to deliver data on the air quality situation of cities in the former Soviet Union. In the Russian Federation the methodical guidance of the national air quality network is provided by MGO. Until 1992 MGO was a methodical centre for all stations of the FSU. At MGO urban emissions, meteorological and air quality data are analysed and summarised into (annual) reports.

Additional data was provided by the municipal authorities through the two questionnaires. The response from cities in the FSU was enthusiastic, so for the first time detailed information on these cities is available and the air quality situation can be compared to that of cities in other parts of Europe.

From first analysis of available data it became clear that former Soviet cities have typical air quality problems such as high dust levels and especially very high concentrations of organic compounds such as B(a)P and formaldehyde (Bezuglaya et. al., 1991a; Mnatsakanin, 1992). Moreover different air quality sampling methodologies are used than in other parts of Europe. This section gives a general review of the methods followed to assess the urban air quality and the procedures used to write the city reports on the cities in Ukraine, Belarus and the European part of the Russian Federation.

2.3.4.1 Emission data

Emission data in the FSU is collected on a yearly basis by the State committee on statistics. At MGO this information is analysed and summarised into annual reports (Beryland, 1986;1991). The term 'Total' emissions must be interpreted carefully. For suspended particulates, SO_2 and VOC only the contribution of industry is known. For CO and NO_X emission estimates are available for traffic and industry. From a RIVM study (RIVM, 1993) it is known that space/domestic heating can make up 21% of total SO_2 emissions in the FSU (in cities this amount will be lower due to the centralised heating systems which combust mainly natural gas). For NO_X this contribution is less than 1%. VOC emission caused by traffic and households (including the use of solvents) according to this study contribute to ca. 46% of total emissions.
A new system to estimate emissions was adopted in 1986. The new system provided dramatically lower emission estimates for all components (average SO_2 emissions for the 26 cities within this project dropped with 40% between 1985 - 1986). Because of this discrepancy only estimates for 1988 and 1990 have been used (in 1988 all enterprises followed the new system).

2.3.4.2 Sampling methodology and analytical methods

Air quality monitoring has been performed since 1965 in the cities of the FSU. In each of the countries all stations are operated by the State Service of Observations (SSO). In 1990 there were 45 monitoring stations operational in Belarus, 60 in Ukraine and 378 in the European part of the Russian Federation (Bezuglaya, 1986). There are several stations in every city.

According to Soviet recommendations, the following rules for location of monitoring sites were followed:

1 station:	Residential area in the city centre.
2 stations:	Residential area in the outskirts of the city, in opposite directions from the centre; one in a polluted, the other in a relative clean area.
1 station:	Next to a main road with high traffic density.
1 station:	In an area strongly loaded with industrial pollution.
1 station:	Close to a railway station.
1 station:	In an open area belonging to an industrial estate.
1 station:	Control point outside the city, in a relative clean area.

The division of stations into 'background' (in residential districts), 'industrial', and 'traffic' used in this project is relative since residential districts are located near industrial enterprises and motorways. This is a distinguishing feature of cities in the FSU.

Concentrations of not only 'common' pollutants (TSP, SO_2, CO, NO_2) are monitored, in many cities the concentrations of hydrogen sulphide, phenol, hydrogen fluoride, B(a)P and formaldehyde are also being measured. The monitoring programme of each station is determined taking into consideration the emissions of the pollution sources nearby.

AQ observations are made 3-4 times a day at 0100, 0700, 1300 and 1900 hours local time. The duration of sampling is 20-30 min, depending on the component measured. This programme is explained by the absence of automatic analysers and by AQGs (Maximum Permissible Concentrations (MPCs) based on a 20-30 min. averaging interval), set in the FSU.

In a recent study (Curran et. al., 1991), FSU (USSR) discrete sampling methodology was compared to the continuous methodology followed in the USA. To compare the two different sampling patterns, the FSU approach was simulated by using US data and taking only the 4 hourly averages that correspond to the hours when the FSU samples. The data used were obtained for the site monitoring the highest concentrations in each of the 80 largest US cities for the period 1984-1989 for the pollutants SO_2, CO and NO_2.

FSU discrete sampling is on average likely to miss the daily peak values, especially for CO. The daily peak to annual mean ratios show that the FSU intermittent sampling schedule has a similar yet slightly higher ratio than the US for all three components. The average daily peak to mean ratios for the simulated FSU schedule were 10% higher for CO, 2% higher for NO_2, and 8% higher for SO_2.

For CO, annual mean concentrations in the FSU are higher than the US means. The median of ratios was 1.07, 87% of the site years were above the one to one ratio. For NO_2, the median of ratios was 1.02 and 78% of the site years were above the one to one ratio. For SO_2, the median was 1.01 and 57% of the site years were above the one to one ratio.

Sampling air for assessing gaseous pollutants is made in sorption tubes with film chemisorbent. Samples are transported to laboratories for chemical analysis. Photometric methods are used to determine the pollutant concentrations. Concentrations of metals are assessed by analysing aerosol filters by X-ray fluorescent or atomic-absorption methods (monthly samples).

Checks on the measurement accuracy are performed each month using standard solutions. Two times per year measurement accuracy is checked using standard solutions which are sent by MGO. An assessment of the total measurement error has been made using a method based on statistical analysis of time series (Bezuglaya et. al., 1991b). The results of analysing the measurement data for 2-5 years for 51 cities have shown that the mean relative errors of measuring SO_2 and NO_2 concentrations do not exceed 25% of the population standard deviation in 57% and 67% of the cities respectively. For other pollutants the measurement error does not exceed 30% of the population standard deviation in 55-72% of the cities.

The analytical method used for monitoring NO_2 concentrations was compared to other methods at two comparative tests. The comparisons were carried out at the Institute für Meteorologic and Geophisiks in Frankfurt am Main (Germany) and at the Norwegian Institute for Air Research (EMEP Workshop on Quality and Comparability of Atmospheric Measurement) (Hanssen, ed., 1991). At the EMEP workshop 17 manual methods with 24-hour averaging of concentration data were compared. The MGO method has shown good results, constant values very close to the means. The results proved to be close to those of the instruments and methods used in Denmark, Norway and Sweden.

2.3.4.3 Calculation of air quality indices

It is well established that SO_2 concentration fluctuations in the atmosphere can be described by a log-normal distribution. Given a log-normal distribution , and the value of two percentiles, all other percentiles can be calculated.

According to Curran et al. (1991) the 98 percentile of the 20 minutes values, sampled three times a day in the FSU, can be used as an estimate for the 98 percentile of daily values.

From the yearly average concentration and the 98 percentile value, as collected from the FSU cities, the number of days above the WHO-AQG (125 $\mu g/m^3$ as 24h average) and the maximum daily concentration can be calculated:

$$\ln C_{px} = \ln C_{p50} + Z_{px} \ln S_g \qquad (1)$$

Where C_{px} is the measured concentration of the x^{th} percentile,
Z_{px} is the eccentricity for the x^{th} percentile,
S_g is the geometric standard deviation

$$\ln C_{am} = \ln C_{p50} + 0.5 \ \ln S_g \qquad (2)$$

Where C_{am} is the arithmetic mean

Combining equations 1 and 2:

$$\ln S_g = (1/Z_{px} - 0.5) \ln (C_{px}/C_{am})] \qquad (3)$$

The eccentricity for 125 $\mu g/m^3$ can be calculated, using equations 3 and 1:

$$Z_{125} = [\ln(125/C_{am})/\ln S_g] + 0.5 \qquad (4)$$

The maximum daily value ($P_{99.7}$) can also be calculated using equation and 1:

$$C_{Pa} = C_{Pb}. (S_g)^{(Zpa-Zpb)}$$
$$C_{P99.7} = C_{P98}.(S_g)^{0.70} \qquad (5)$$

For 47 cities the number of days above 125 $\mu g/m^3$ and maximum daily values were available. In Figure 2.1 and Figure 2.2 the calculated values are plotted against the measured values. Especially in the lower concentration/exceedance area (98 percentile 66-300 $\mu g/m^3$, days above 125 $\mu g/m^3$ less than 20) a good linear regression estimate was found (Y = 0.97 + 0.96X), with correlation coefficients of 0.95 and 0.87. Over the whole concentration area (98 percentile 66-500 $\mu g/m^3$, days above 125 $\mu g/m^3$ up to 60) the lineair regression estimates were Y = 2 + 0.74X, Y = -5 + 1.08X with correlation coefficients of 0.93 and 0.94, respectively. For the FSU cities, with 98 percentile concentrations ranging from 12 to 160, the above mentioned approach seems to be feasible and was adopted. The calculated figures are presented in Annex X and in the CRFs (van Zantvoort, Sluyter and Larssen (eds.), 1995). Calculated number of days with exceedances have been used in data analysis (see Chapter 3).

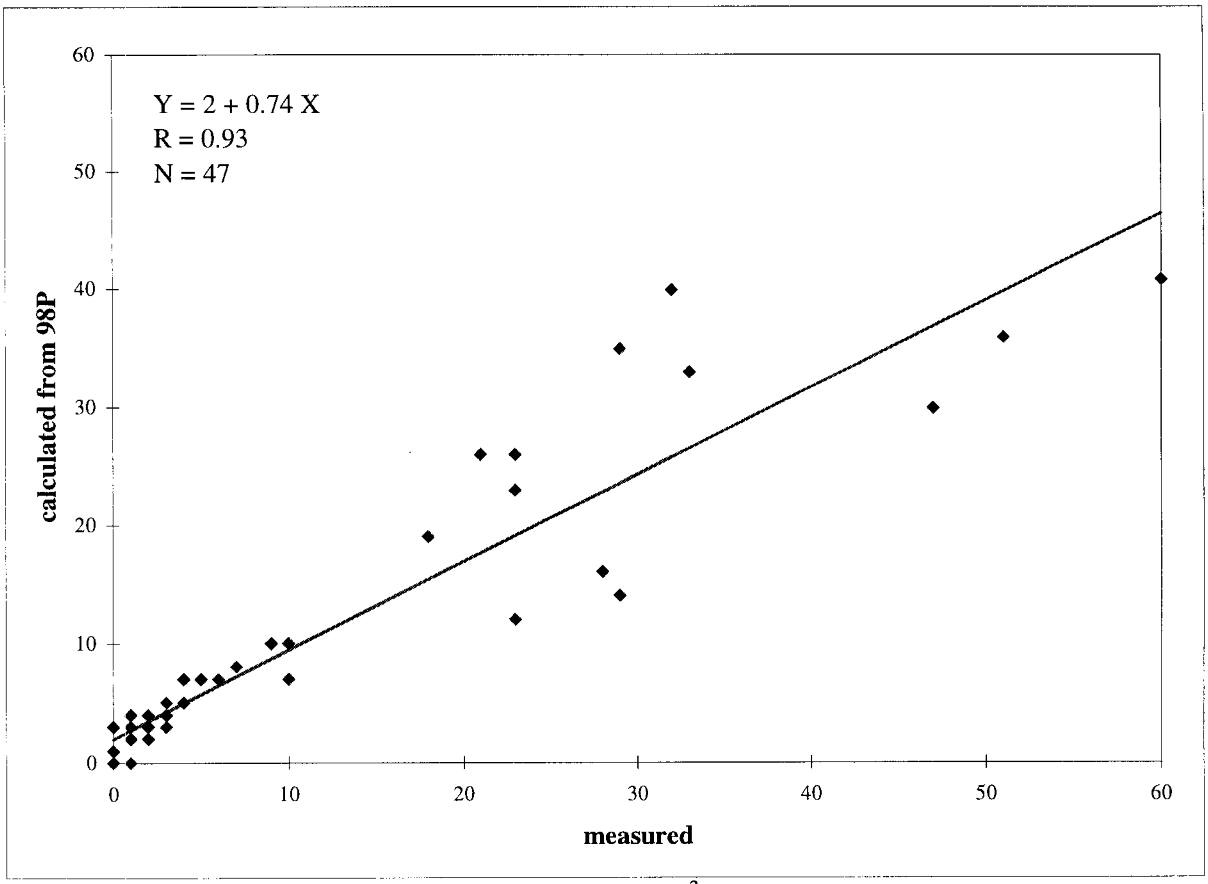


Figure 2.1: Number of days with SO_2 > 125 µg/m^3; measured against calculated.

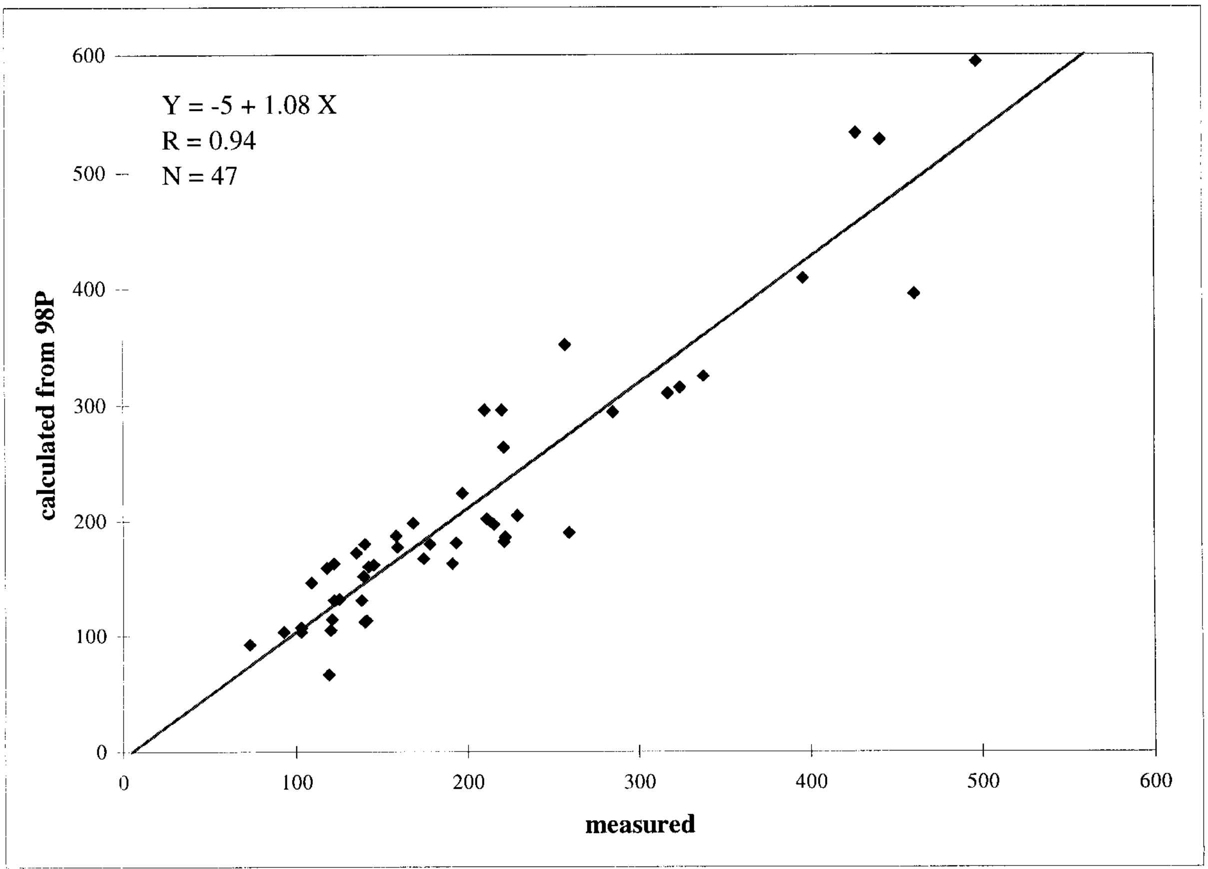


Figure 2.2: Daily maximum SO_2; measured against calculated.

2.3.5 The industrial questionnaire

Some of the most severe exposure to harmful air pollutants in Europe occurs near individual industrial plants or industrial areas. A comprehensive data base on air pollution concentrations and exposure near industrial plants and areas in Europe does not exist. However, for the EU countries, selected data on air pollution in industrial areas have been collected by the European Commission as part of the EU Decisions on the Exchange of Air Quality Information, and as part of the procedures to control the Implementation of the Council Directives on Air Quality Standards for particulate matter, sulphur dioxide and nitrogen dioxide. For countries in Central and Eastern Europe, some data were available from the Environmental Action Programme for Central and Eastern Europe.

The available data base was judged as being too incomplete to provide a basis for the description of local industrial air pollution in Europe. To collect more data, a questionnaire was developed and sent to national focal points of all (37) European countries. The focal points were asked to provide summary data on emission components, local concentrations, population and vegetation exposure, and emission controls, for up to 10 selected industrial plants causing the main local industrial air pollution problems in their country. The goal was to collect data suitable for presenting a description of the extent of local industrial air pollution problems in Europe.

The questionnaire is presented in **Annex V**.

2.3.6 Data Storage and quality assurance

Information from the first and second questionnaire and from the various international data bases has been incorporated in a City Report Form (CRF). This city report forms the backbone of the data analysis and interpretation of Chapter 4.1 of 'Europe's Environment' (Stanners & Bordeau (eds.), *in press*). City reports have been sent back to the cities for verification. Because of the time pressure, not all city reports could be verified by the city authorities in time. These reports are marked. It is possible that typing errors are present in these reports. Besides that, for some cities no contacts were established and CRFs were subsequently based on international data base information only. These CRFs have not been verified by any authority.

All relevant information has been entered in spread sheets by subject. These data have carefully been checked for errors. Outliers were identified by expert judgement, these were marked and no analysis has been performed with them. Cross validation has been performed on calculated indicators.

2.3.6.1 City Report Forms (CRFs)

The city reports are published as a separate report (van Zantvoort, Sluyter & Larssen (eds.), 1995). All cities from the city list are incorporated. However, the amount of information available in the report varies from city to city. Cities which did not respond to either the first or second questionnaire have been described using only information available in international data bases. A number of cities could not provide us with all the information requested within the given timeframe. If available, missing information was taken from international data bases, otherwise tables are left out. Only a few cities delivered all data requested. It may not be concluded that cities who did not respond to the questionnaires or delivered only limited data requested were unwilling to co-operate. In many cases the tight time schedule of the project was to blame; there was simply not time enough to calculate specific statistics which were requested.

A detailed description of the procedures followed in writing the CRFs is given in *van Zantvoort, Sluyter & Larssen (eds.), 1995.*

2.4 Data availability and quality of data

R.J.C.F. Sluyter

Map 2 presents the cities which returned either of the two questionnaires. The responses were beyond any expectations, especially since questionnaires were sent on an ad-hoc basis. Questionnaires returned in combination with data from international data bases resulted for most cities in a workable data set. Data availability and quality of data regarding the main topics of this research are addressed in this chapter.

Population data from various sources has been compared. Many of the cities provided recent population estimates. The quality of the 'city' estimates is good, 'conurbation' estimates vary more and are subject to definition problems. The same problems apply to area statistics (total and built-up) for both cities and conurbations.
Meteorological indices have been calculated for all cities using the ECMWF-ODS data base. Analysis has shown that for most cities a meteorological station was present within 25 km of the city co-ordinates. Short-term indices are in general based on at least 85% of all possible data. Long-term indices (10 year averages) are in most cases based on 9 or 10 years of data. Outlier analysis showed that precipitation amounts given for the FSU are not reliable, however in general ODS data showed good agreement with data provided by the cities.

The availability of emission data per component per city can be read from Table 2.4. As can be seen from the Table not to much emission data was available. Moreover, emission inventories often did not cover all sources. Since inventory methods vary from city to city but are largely unknown, quality of data could not be assessed. In many cases it is not clear if emission figures were provided for the city or conurbation. Emission density figures per square kilometre are least reliable because of the uncertainty in area figures.

Table 2.4: Availability of emission data within this project (N=105)

Component	Percent of cities with data available
SO_2	45
Particulates	33
NO_X	46
Pb	29
VOC	40

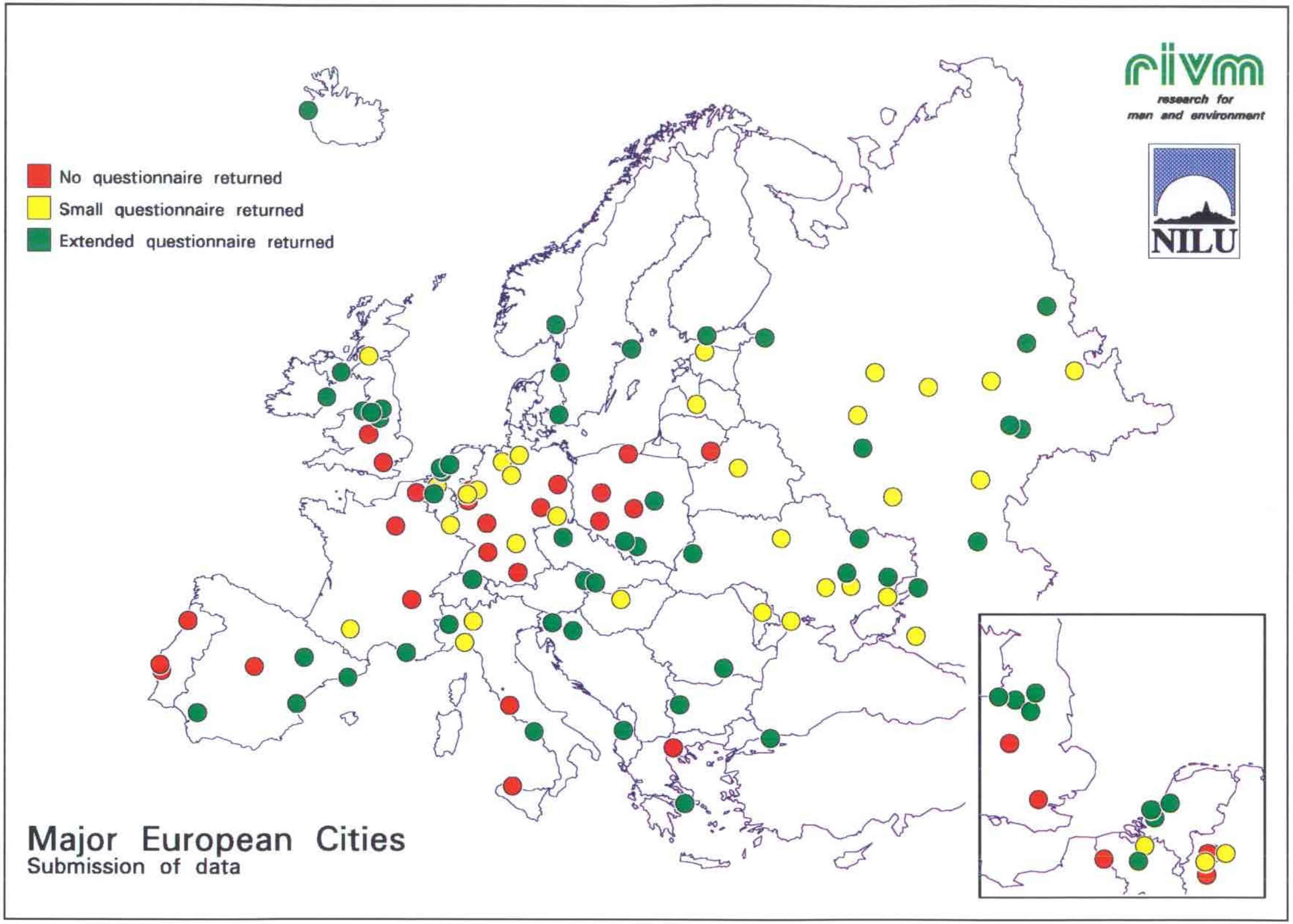
The availability of air quality data per component is given in Table 2.5. All the cities which reacted to the questionnaires have an operational air quality monitoring network. Sometimes the AQ monitoring stations are part of a national network but in most cases monitoring activities fall under the responsibility of local authorities. This is the reason why monitoring techniques used, data published etc. can vary from city to city even in one country. Although the analysis method in many cases is known, quality assurance procedures often were not. Because of this, quality of data is difficult to assess. During analysis all data has been used with the exception of obvious outliers.

Table 2.5: Availability of concentration data within this project (N=105)

Component	Percent of cities with data available
SO_2	79
TSP/Black smoke	74
NO_2	75
Pb	47
CO	56
O_3	33

The industrial "hot spot" questionnaire was returned by the following countries:

Bulgaria, Russian Federation, Norway, Belgium, Croatia, Finland, Czech Republic, Austria, Slovenia, Latvia, Italy, Estonia, Romania, Germany, Poland, Spain, Denmark, Sweden, Malta, Switzerland, Iceland, Ireland, Netherlands, Albania and Moldova.
The extent, representativeness and relevance of the information returned on the questionnaires varied very much. A few countries (Denmark, Iceland, Ireland, Sweden, Switzerland) indicated that there were no significant local industrial air pollution problems. For France, Greece, Hungary, Portugal and United Kingdom some information was extracted from other sources. From the remaining 7 countries there was no information available.



No questionnaire returned
Small questionnaire returned
Extended questionnaire returned
Major European Cities
Submission of data
riVm
research for
man and environment
NILU

3 ANALYSIS OF DATA
3.1 Introduction

R.J.C.F. Sluyter

In this Chapter research results are summarised and presented. Basic data referred to in this Chapter are summarised by topic in **Annexes VI-XI**. Information per city is published as a separate report (Van Zantvoort, Sluyter and Larssen (eds.), 1995). In section 3.2-3.3 attention will be focussed on the man-made and natural environmental indices which were defined to reflect reflect both the natural and man-made environmental conditions "determining" urban air quality. Air pollutant concentrations are described in Section 3.4-3.7. Results of the questionnaire on local industrial pollution is given in section 3.9. Some information on the exposure of materials, buildings and cultural heritage is given in section 3.10.

In the area of investigation, the pan-European territory, differing climatological regimes and meteorological conditions are found superimposed on regions with a variety of cultural and socio-economic backgrounds. Together with differences in access to natural resources, energy and technology, this combination leads to different living conditions and air pollution problems. The European regions as used in this Chapter are listed in Table 3.1.

Table 3.1: European regions

Name of Region	Coverage
Northern Europe	Finland, Iceland, Norway, Sweden
Western Europe	Austria, Belgium, Denmark, France, Ireland, Luxembourg, Switzerland, The Netherlands, United Kingdom, former West Germany
Southern Europe	Greece, Italy, Portugal, Spain
Central Europe	Albania, Bulgaria, Czech Republic, former East Germany, Hungary, Poland, Romania, Slovak Republic, former Yugoslavia
Eastern Europe	Belarus, Estonia, Latvia, Lithuania, Moldova, the Russian Federation, European part of Turkey, Ukraine

As pointed out in the introductory chapter, a number of natural and man-made environmental indices were defined to reflect both the natural and man-made environmental conditions "determining" urban air quality. They have been used to study those single and combined effects on the urban air quality climate and to be able to find (dis)similarities between characteristics of cities in different parts of Europe. The defined indices and their relations are presented graphically in Figure 3.1. Together with the topographical siting of the city, the average wind speed is used as indicator for the city's *average dispersion* conditions. An index called *Meteorological Smog Potential* (MSP) has been defined for both the winter (MSP-W) and summer (MSP-S) half year to describe the probability of enhanced concentrations on the basis of the synoptic situation independent of emissions. The meteorological smog potentials are at the moment based only on the local 6-hourly synoptic situation. Total urban emissions are correlated with population size and population density. City size also influences advection and vertical exchange of pollution and thus residence time of pollutants in the urban atmosphere. *Environmental pressure* is defined as the combination of population size and density. Since emission data are fragmented, *emission indices* have been defined only for winter smog pollutants (SO_2 and/or particulate matter) and summer smog precursors (VOCs and NO_X), both as density per square kilometer.

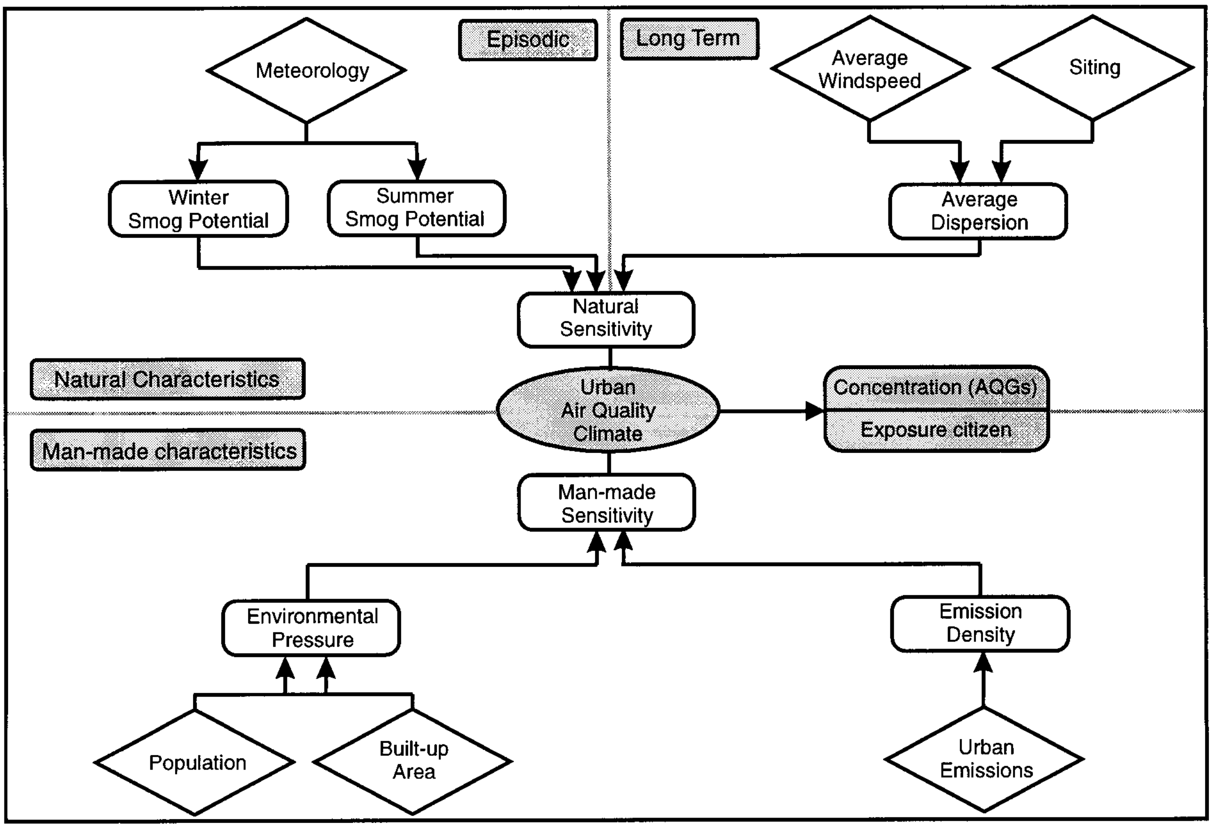


Figure 3.1: Defined indices used to study (dis)similarities in city air quality conditions

It must be stressed that far more indices can be thought of. Indices have been ranked in five (nominal) classes ranging from ***most favourable conditions*** to ***most unfavourable conditions***. Since emissions are always regarded as negative, emission classes range from ***less unfavourable*** to ***most unfavourable conditions***. Class intervals of the MSP, urban emissions, environmental pressure and average dispersion indices have been chosen on the basis of the standard deviation (σ) from the population average (***M***):

++	$< M - 1.5\,\sigma$	(most favourable)
+	$\geq M - 1.5\,\sigma$ and $< M - 0.5\,\sigma$	
o	$\geq M - 0.5\,\sigma$ and $< M + 0.5\,\sigma$	
–	$\geq M + 0.5\,\sigma$ and $< M + 1.5\,\sigma$	
– –	$\geq M + 1.5\,\sigma$	(most unfavourable)

The classification of the siting index is based on expert judgement (see also Table 3.6).

In case of an index being composed of two classed indices A en B, the following scheme has been used to calculate the combined index (Table 3.2):

Table 3.2: Composition of an index from two indices

Composition of an Index		Index A: ++	+	o	–	– –
	++	++	+	+	o	o
	+	+	+	o	o	–
Index B:	o	+	o	o	–	–
	–	o	o	–	–	– –
	– –	o	–	–	– –	– –

3.2 Man-made environmental characteristics

R.J.C.F. Sluyter, H.C. Eerens

3.2.1 Population and area statistics

Taking the 1989 Demographic yearbook of the United Nations and information from the Times Atlas of the World as a starting point, a preliminary city list was made (see Section 2.2.1). This list was continuously updated during the project with information coming from the first and second questionnaires and UN-IEDS. **Annex VI.a** presents the final city list with population figures for every city obtained through the various information sources. **Annex VI.b** presents the population and area estimates used within this project as best estimates for both city and conurbation. Figures used to calculate population density are printed bold. The following rules were applied: if the city itself gave a population figure, this figure was used. If no questionnaire was returned, information from UN-IEDS was applied if available, otherwise information from the UN demographic yearbook was used. Unfortunately the UN gives information on cities rather than on conurbations. If the number of inhabitants for the conurbation was available in the Times Atlas of the World or in the Economist statistical compendium series, this figure was used instead of UN statistics. In this way, the total number of inhabitants in the 105 selected cities was calculated at appoximately 150 million (22% of the total European population).

Figure 3.2 shows the percentage of cities in the different population classes. 10% of all cities fall in the class under 0.5 million inhabitants. These are the capitals of countries without cities with more than 500 000 inhabitants, and cities with a population of just under 500 000, which have been included because of the uncertainty in population figures (see Annex VI.a). Figure 3.3 presents the percentage of citizens within each city population class. Although 10% of all cities have populations of less than 500 000, only 2% of all citizens under investigation live in these cities. 27% live in the 5 largest cities.

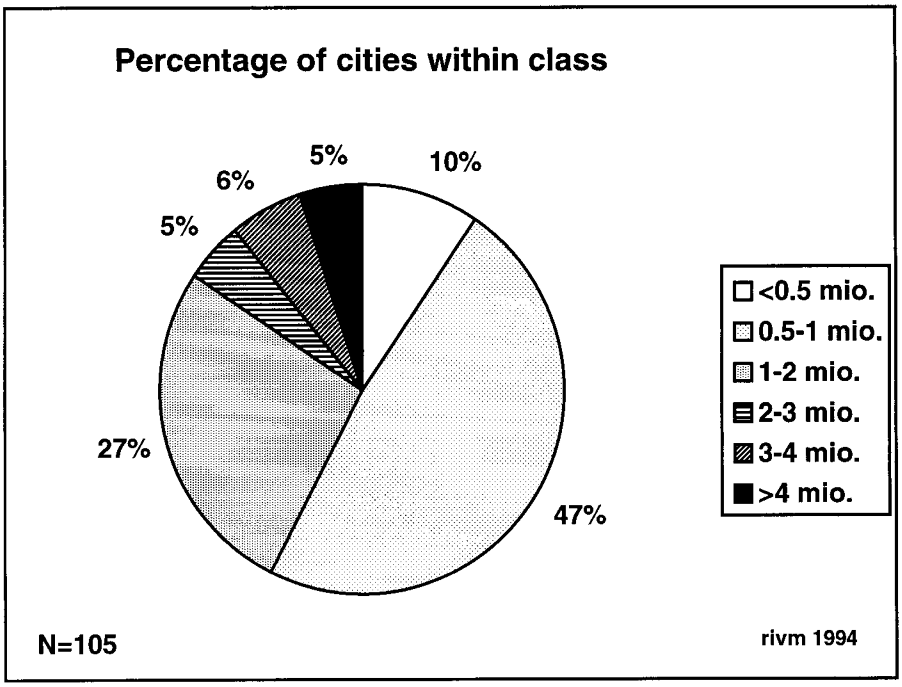


Figure 3.2: Frequency distribution of cities by population class

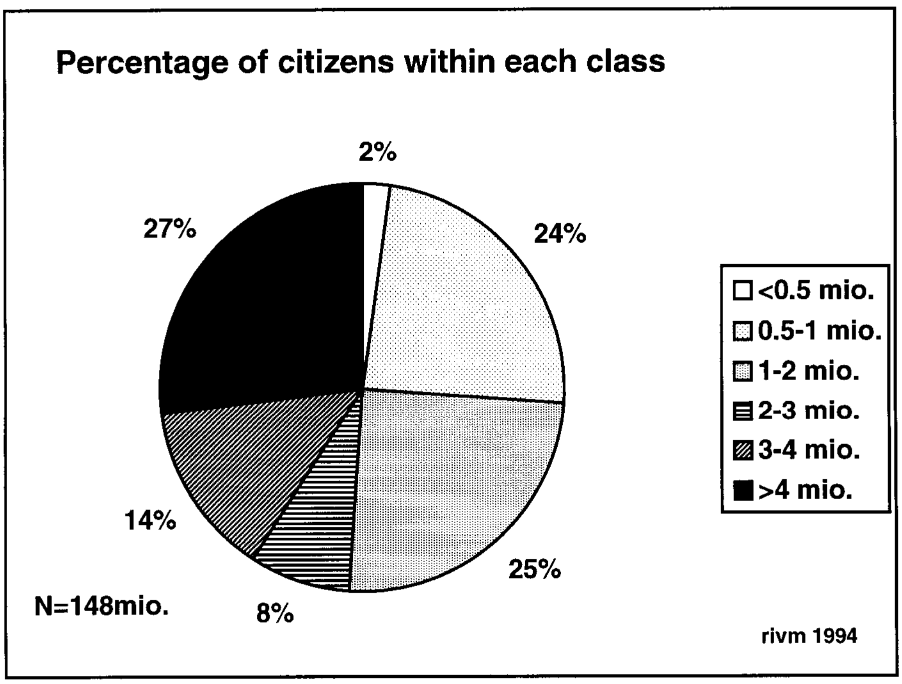


Figure 3.3: Frequency distribution of population by city class.

Population density is plotted against city area in Figure 3.4. Population density has a strong negative correlation with city size for smaller cities; for cities between 200 and 400 km^2 with typical density figures between 2 000 and 4 000 inh./km^2 , the relation is less marked; despite few European cities being larger than 400 km^2, available data suggests that population density in these increases slightly with city size.

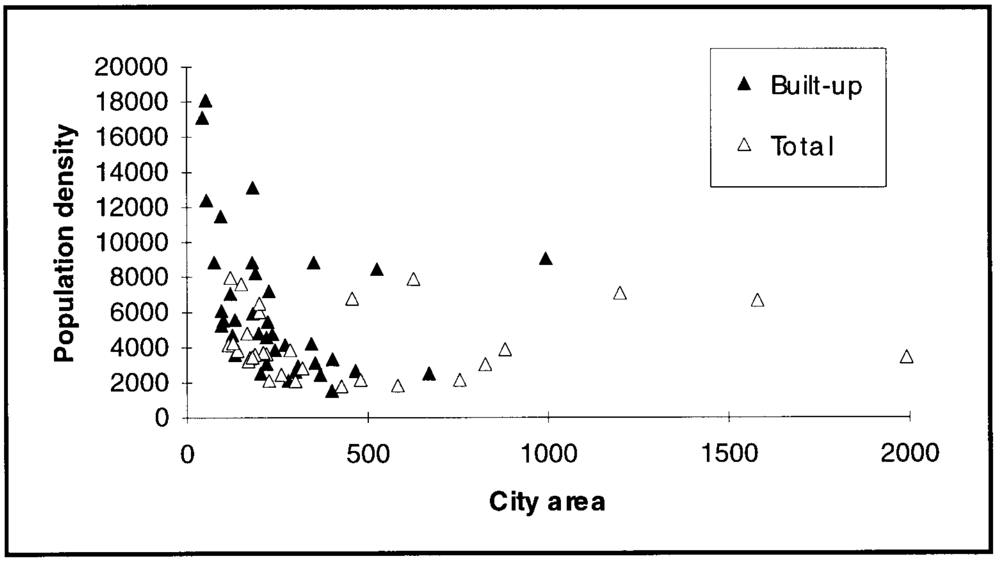


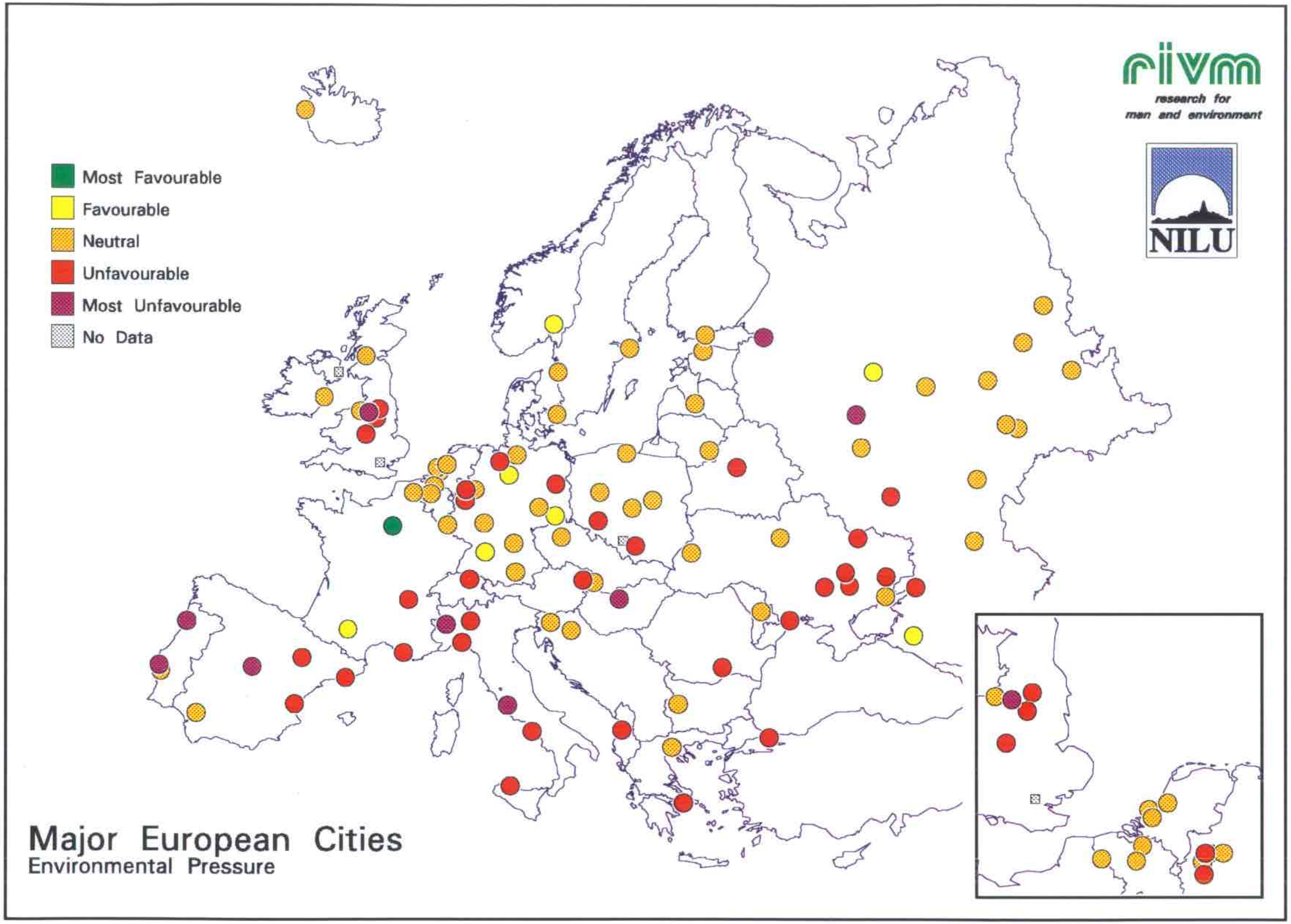
Figure 3.4: Relation between city area (either built-up area or total area) in km^2 and population density (inh./km^2).

3.2.1.1 Environmental pressure classification

Human activities result in the emission of pollutants into the atmosphere. More humans lead to more emissions, a higher population density gives rise to higher emission densities. To describe the effects of population size and density on emissions an index called '*environmental pressure*' was defined as:

Environmental pressure (class) = (nr. of inhabitants (class) + population density (class))/2

Logarithmic values were taken from raw population and population density data before classification. **Annex VII** presents the environmental pressure index for all cities. **Map 3** presents the geographical distribution of the environmental pressure. From this map it is clear that no geographic differences are apparent.


Most Favourable
Favourable
Neutral
Unfavourable
Most Unfavourable
No Data
Major European Cities
Environmental Pressure
rivm
research for
man and environment
NILU

3.2.2 Urban emissions

The most direct and important man-made environmental impact on urban air quality comes from atmospheric emissions. In Section 2.4 it was noted that emission data are available for only some of the cities; moreover, the quality of the data is in most cases unknown. Because of this, comparisons between European regions cannot be made.

Total emissions per component and emission density figures are presented in **Annex VIII.a-VIII.e.** Detailed sectoral contributions to emissions are presented in the CRFs (van Zantvoort, Sluyter and Larssen (eds.), 1995). No method was available to combine total urban emissions into one index. Attention was focused on emissions important for winter-type and summer-type smog (see 3.2.2.1). General information per component is presented in this section.

SO_2 emissions (**Annex VIII.a**) have dropped considerably in many cities during recent years (1985-1990). The largest decrease has been reported from cities in the FSU. Between 1988 and 1990 alone, both total emissions and emissions per capita decreased by 18% on average. This decrease can be attributed largely to the declining industrial output in the FSU.

Particulate matter emissions (**Annex VIII.b**) in most cities have shown a slight downward trend during recent years. Only a few cities reported that emissions were on the rise. Sharp decreases in particulate matter emissions were reported from FSU cities, between 1988 and 1990 by 18%.

Although some cities reported that NO_X emissions (**Annex VIII.c**) have dropped slightly during recent years, NO_X emissions on average show a slight upward trend. From the limited information available, it is clear that this rise is attributable mainly to increasing traffic.

Lead emissions (**Annex VIII.e**) have dropped considerably in most European cities, mainly due to the introduction of lead-free petrol in recent years. The trend in lead emissions in FSU cities is unknown, because data were available for only one year.

The SO_2:NO_X emission ratio has been calculated for those cities with data available for total emissions (contributions from traffic, industrial and space/domestic heating in a recent year). Although the number of cities for which both total SO_2 and NO_X data were available is limited (26 FSU cities and 13 cities outside the FSU), some interesting regional differences are apparent. The ratio in Western, Southern and Northern European cities is on average ~0.5, i.e. NO_X emissions are twice as high as SO_2 emissions. NO_X emissions are largely attributable to traffic. Cities in Eastern Europe on average experience a 1.11 ratio but variations between cities are larger than in other European regions (range of 0.13-2.71). Since SO_2 emissions are decreasing rapidly in the FSU, as opposed to NO_X emissions which are on the rise, the SO_2:NO_X ratio will continue to decrease. An average ratio of 3.88 (range 2.25-8.46) was calculated for the Central European cities. In these cities relatively sulphur-rich (brown) coal is still extensively used for space/domestic heating and/or in industry.

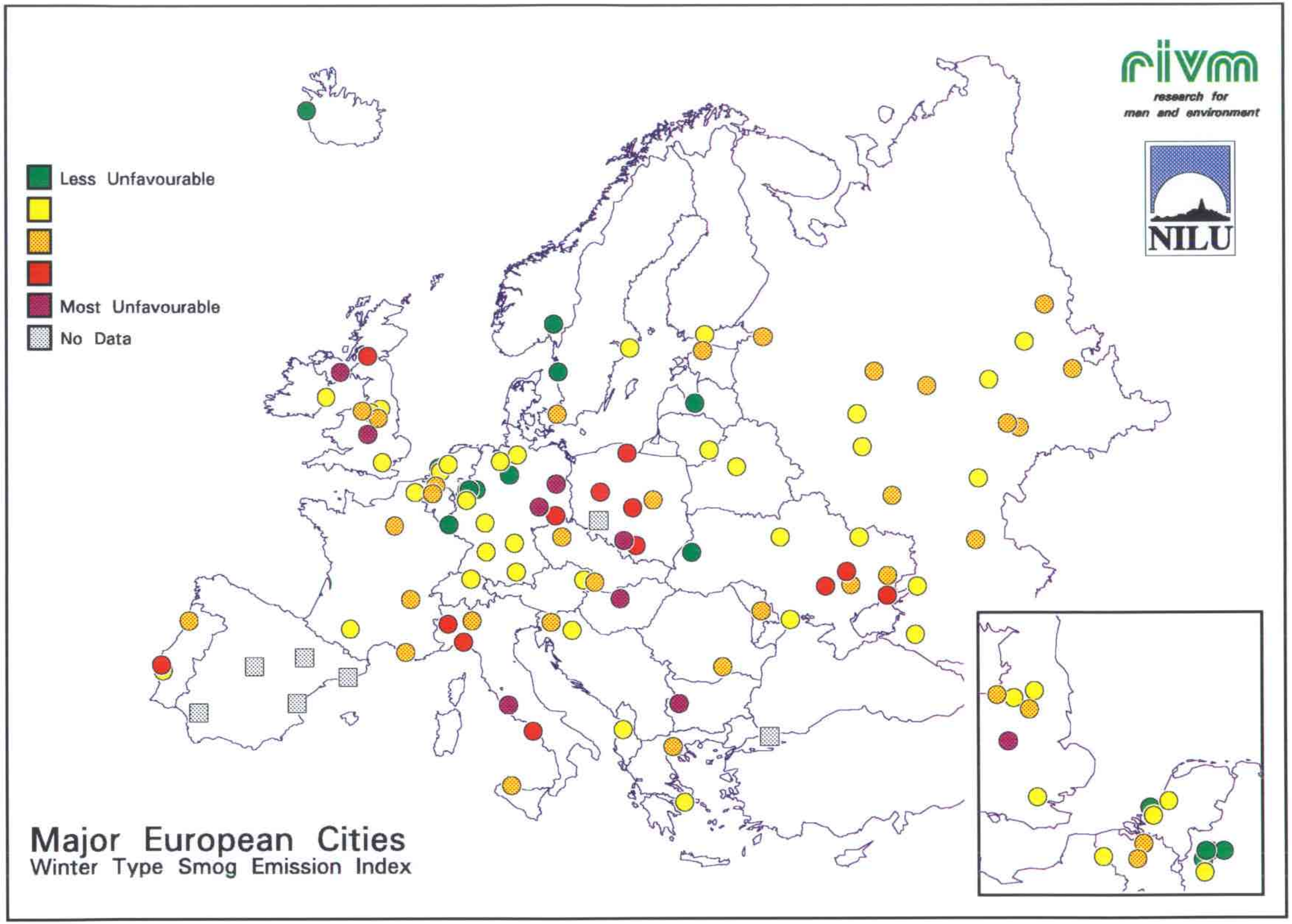
Using the combined EMEP/CORINAIR emission data base in combination with national population figures (Times, 1994), national sectoral emission densities per capita were calculated for the components SO_2, NO_X, NM-VOCs and TSP (see Section 2.2.4). The calculated emission density figures were already presented in **Annex I.** The calculated figures have been compared to emission density data provided by the cities. From these analyses it became clear that for most cities there is no significant relation between emission density figures based on national census data and emission density figures provided by the city.

3.2.2.1 Winter-type and summer-type smog emission indicators

Two emission indicators were used, one to indicate winter smog and one for summer smog emissions. SO_2 or TSP emissions were used as winter-type smog emission index, depending on which component estimates were available. If both SO_2 and TSP emissions were available, the highest of the two was used. The summer-type smog emission index is based on VOC and NO_X emissions (both precursors of summer smog), taking double values for VOC.

Recent (1990 or another recent year between 1989-1992) emission data transmitted by the municipal authorities were used in calculating the emission indicators. If these were not available, estimates calculated by RIVM-LAE (see section 2.2.4) were used. To be able to compare cities, emission density figures per square kilometre were used to classify cities according to their emission environment. The classification was made according to the procedure described in Section 3.1. Since emissions are always regarded as negative, the range of emission classes was from less unfavourable (o) to most unfavourable (----), rather than the '*most favourable (++) to most unfavourable (--)*' used above.

The winter-type smog emission index for every city is presented in **Annex VII. Map 4** presents the geographical distribution of the winter-type smog index. The index is most unfavourable in the coal-burning cities of Central Europe and some UK cities.
The same procedures were applied in calculating the summer smog emission index. The summer-type smog index for every city is presented in **Annex VII. Map 5** presents the geographical distribution of the summer-type smog indicator. No regional differences are apparent.


Less Unfavourable
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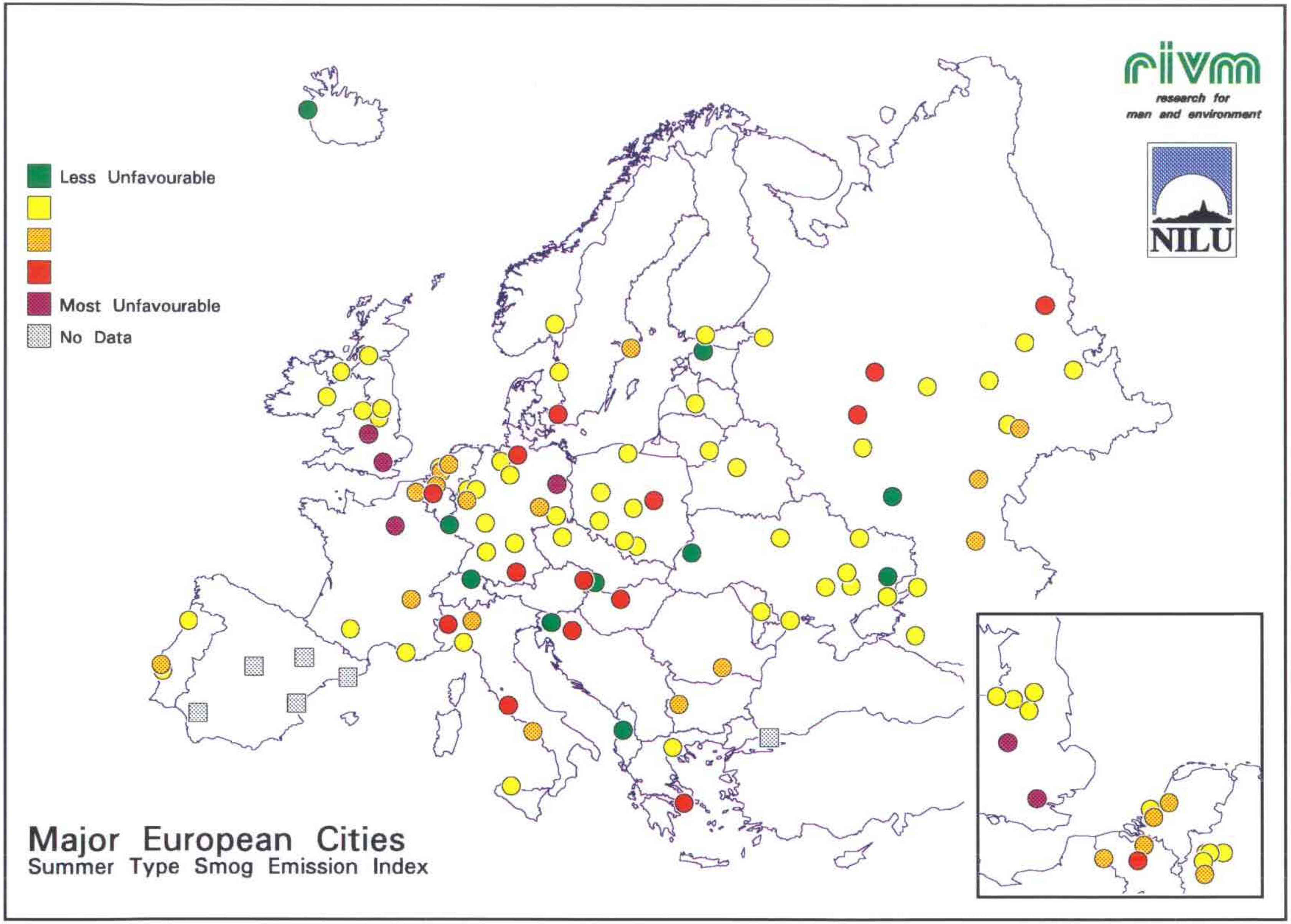
Major European Cities
Winter Type Smog Emission Index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3.3 Natural environmental characteristics

K.v. Velze, R.J.C.F. Sluyter

3.3.1 Climatological conditions

A first rough city classification can be made on the geographical location and thus the macro climatological conditions which drive activity/emission patterns to some extent. Climatic parameters such as temperature, wind speed, solar radiation and precipitation are important factors determining the city's air quality situation. Low (winter) temperature increases energy demand and thus emissions from space/domestic heating. Moreover, cold winter spells in Europe are often accompanied by low-level subsidence inversions under which air pollutants can accumulate in the stagnant layer. During hot summer spells, photochemical smog can be formed. In contrast, high average wind speeds are favourable for a city's air quality situation. Prolonged dry periods may increase air pollution, e.g. dust accumulation in the atmosphere.

Various climatological regimes are found in the pan-European territory. The well known climatic classification of Köppen-Geiger, a generic system related to plant growth and based on temperature and aridity criteria, is used to describe the climatological regions in Europe. Additionally, A. N. Strahler's genetic classification, based on atmospheric circulation and thus related to wind regimes and air masses, is used to give a more complete description of the European climatic regions. Rough agreement between the Köppen-Geiger and Strahler systems is apparent.

The climatological regions found in Europe are described in Table 3.3. In some countries, more than one climatological region is found. In these instances the country has been classified as belonging to the climatological region the selected city (cities) is/are located in. It should be noted that Central Europe is a climatic transition zone with maritime influence varying from year to year. Moreover the classification does not suffice for cities in countries on the fringe of two climatological regions defined by the Köppen-Geiger system using only temperature and precipitation. If additional climatological parameters had been used, these countries would probably have been classified differently. The city's climatological class according to Köppen is presented in **Annex IX**.

Table 3.3: Climatological regions found in Europe according to Köppen

Cfa/Cfb/Cfc			**Marine west-coast climates**
C			Coldest month > -3 °C but < 18 °C, at least one month has an average temperature above 10 °C
	f		moist, adequate precipitation in all months and no dry season
		a	hot summer, warmest month > 22 °C
		b	warm summer, warmest month < 22 °C
		c	less than four months over 10 °C
Csa/Csb			**Mediterranean climates**
C			Coldest month > -3 °C but < 18 °C, at least one month has an average temperature above 10 °C
	s		dry season in summer
		a	hot summer, warmest month > 22 °C
		b	warm summer, warmest month < 22 °C
Dfb (Dfc)			**Humid continental climate (Continental sub-arctic climate)**
D			Coldest month < -3 °C, warmest month has an average temperature above 10 °C
	f		moist, adequate precipitation in all months and no dry season
		b	warm summer, warmest month < 22 °C
		c	less than four months over 10 °C
BSk/Bsh			**Steppe climate**
BS			evaporation exceeds precipitation on the average throughout the year, boundary between steppe (BS) and dessert (BK) according to formula
	k		dry-cold, average annual temperature < 18 °C
	h		dry-hot, average annual temperature > 18 °C

Marine west-coast climates

Temperate rainy (humid mesothermal) climate with mild winter and warm summer. Exposed, mid-latitude west coasts receive frequent cyclonic storms with cool, moist maritime polar (mP) air masses. These bring much cloud and evenly-distributed precipitation. The annual temperature range is small. Cold spells are rare but often accompanied by subsidence inversions. Hot sunny spells are rare but can cause photochemical smog formation. Relatively high wind speed favours the dispersion of emitted pollutants. Type **Cfc** is found in Iceland; in the northern part of Italy (plain of the river Po), Slovenia and in the southern part of Romania type **Cfa** is found; **Cfb** in Ireland, United Kingdom, Denmark, Holland, Belgium, Luxembourg, France, Germany, Austria, Switzerland, Western part of Poland, Czech Republic, Slovak Republic, Hungary, Croatia, Serbia, Bulgaria.

Mediterranean climate.

Temperate rainy (humid mesothermal) climate. This wet-winter, dry-summer climate results from seasonal alternation of conditions. Maritime polar (mP) air masses dominate in winter with cyclonic storms and ample rainfall, maritime tropical (mT) air masses dominate in summer and (extreme) drought. Moderate annual temperature range. Prolonged hot and sunny summer spells cause favourable meteorological conditions for photochemical smog. Summer drought favours episodes of fugitive dust pollution (found in: Portugal, Spain, Italy, Greece, Albania and the European part of Turkey).

Humid continental climate.

Cold winter snowy forest (humid microthermal) climate, prolonged cold winter, moist all year, warm summers. Located in the polar front zone, the battleground of polar and tropical air masses. Seasonal contrasts are strong and weather highly variable. Ample precipitation throughout the year is increased in summer by invading maritime tropical (mT) air masses.

Cold winters are dominated by continental polar (cP) air masses invading from northern source regions. Prolonged cold winter periods, with stagnating air and inversions, favour pollutant accumulation. In the short summer, conditions can be favourable for photochemical smog formation. Type **Dcf** is found in the northern part of the former Soviet Union and Scandinavia. Perm is the only city located in this climatic region (Dfb found in: Norway, Sweden, Finland, Eastern part of Poland, Russia, Belarus, Estland, Letland, Latvia, Moldavia, Romania, Ukraine).

Cool steppe climate.

Inland regions shut off from invading maritime air masses (mP or mT) and dominated by continental tropical (cT) air masses in summer and continental polar (cP) air masses in winter. Great annual temperature range; hot summers, cold winters. Cold winter periods, with stagnating air and inversions favour pollutant accumulation. Prolonged hot and sunny summer spells are meteorologically favourable for photochemical smog formation. Semi-arid conditions favour episodes of dust pollution. In the central region of Spain type **Bsh** is found. Bsk is found in southern and eastern part of Ukraine.

3.3.1.1 Calculation of climatological statistics

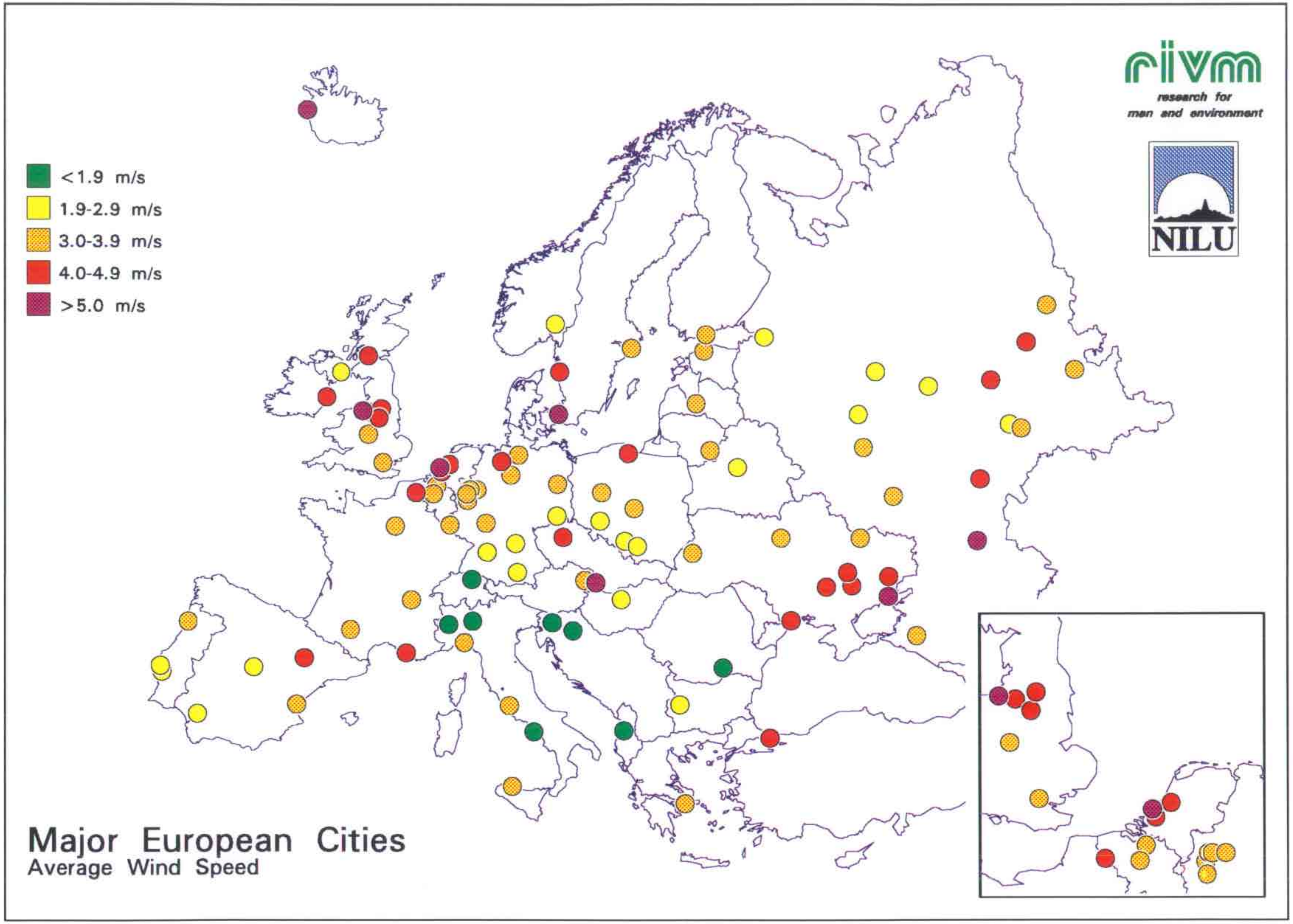
Besides the climatic region given in the city reports, climatological statistics were calculated from ECMWF data to characterise the climatological conditions important for air quality conditions in the cities. These have been published in Section II (topography and climatology) of Van Zantvoort, Sluyter & Larssen (eds.), 1995. The following statistics were calculated for 1985, 1989 and for the period 1980-1989 using meteorological stations selected from the ECMWF-ODS data base (see Section 2.2.3)

- Average temperature (indicator for energy demand space/domestic heating)
- Total precipitation (indicator for scavenging potential of atmosphere)
- Average cloud cover (indicator for photochemical reaction potential)
- Average wind speed (indicator for pollutant dispersion capacity)

The average wind speed is used to calculate the average dispersion index (3.3.3). Calculated average wind speeds for all cities are presented in **Annex IX** and in **Map 6**.

3.3.2 Meteorological conditions

Urban topography (city profile, building height) and topography of the surrounding area (mountains, large water areas, vegetation) influence turbulence and wind flows and thus the dilution of emitted pollutants. Meteorological conditions form another important environmental factor. Variations in concentrations of air pollutants in time are induced largely by meteorological factors. For instance, wind velocity, atmospheric stability and mixing depth influence dispersion of air pollutants.



rivm
research for
man and environment
NILU
<1.9 m/s
1.9-2.9 m/s
3.0-3.9 m/s
4.0-4.9 m/s
>5.0 m/s
Major European Cities
Average Wind Speed

3.3.2.1 Frequency of episodes

An episode with enhanced concentrations occurs under certain conditions. The two main causes of enhanced concentrations during smog episodes are:

- locally produced airborne pollutants combined with adverse meteorological conditions such as low wind velocities and a low inversion layer;
- long-distance transport of air with high pollutant concentration due to accumulation and low deposition during the last days of transport.

It was therefore assumed that there is a relationship between meteorological conditions and the frequency of smog episodes.

Suppose the frequency of episodes is defined as the number of days per year with concentrations of air pollutants exceeding the WHO air quality guidelines (SO_2 and PM for winter-type smog and O_3 for summer-type smog). A monitoring system is needed to ascertain the frequency of episodes. A method to estimate the frequency of episodes by use of synoptic data is presented here.

The probability of meteorological conditions favourable for high concentrations on day **n** is defined as f_n. If the meteorological conditions are favourable for high concentrations, then $f_n = 1$; if not, $f_n = 0$. For uncertain situations, f_n is between 0 and 1. The total of f_n over all days in a year indicates the frequency of episodes.

The factor f_n depends on local and large-scale conditions. In general the concentration **c** in the city is defined as the sum of the regional concentration $\mathbf{c}_{regional}$ and the contribution $\mathbf{c}_{city}$ from the city. During a smog episode the concentration $\mathbf{c}_{regional}$, or the contribution $\mathbf{c}_{city}$, or both are high. Fluctuations in $\mathbf{c}_{city}$ are caused largely by meteorological conditions.

The concentration $\mathbf{c}_{regional}$ depends on large-scale meteorological conditions and emissions. Approximation of $\mathbf{c}_{regional}$ needs a complex analysis of trajectories. Local meteorology also gives an indication of large-scale meteorology. For this reason here the calculations of f_n are based on the local meteorology alone.

Local topographical conditions are of importance for f_n too. Extra accumulation of air pollution can be expected for cities surrounded by mountains. In a valley, polluted air can be trapped under an inversion layer. For cities located near the sea, especially in the Mediterranean area, polluted air can be recirculated by land-sea breezes. Topographical conditions are not involved in the calculations of f_n, but orography influences wind velocity and thus f_n.

Different probabilities f_n are used for meteorological conditions favourable for winter-type smog ($f_{W\ n}$) and summer-type smog ($f_{S\ n}$). An index called Meteorological Smog Potential (**MSP**) has been defined for winter-type smog as the total of probabilities $f_{W\ n}$ during winter-time (MSP-W), and for summer-type smog as the total of $f_{S\ n}$ during summer-time (MSP-S). The meteorological smog potential at this moment is an arbitrary measure and is used only to classify a city.

For calculating the indices, meteorological statistics are built up for every city using data from the Observational Data Set (ODS, see 2.2.3). Data from meteorological stations located near the cities but outside the built-up area are used. For cities without a meteorological station in the surroundings, an interpolation was made by use of statistics from other stations.

3.3.2.2 Meteorological potential winter smog index

Winter-type smog episodes are generally characterised by a high pressure system above Europe which persists for several days. Wind velocities are low and a marked temperature inversion limits the vertical mixing of pollutants in the lowest atmospheric layers. Air pollutants further accumulate due to increased emissions and reduced removal rate. Due to the low temperatures, energy demand increases; space-heating-related emissions up to 70% higher than average in a winter season can be expected during episodes. The deposition of SO_2 and other pollutants is reduced when the soil is frozen and/or covered with snow. Rainfall indicates a changing large-scale weather situation.

The Meteorological Potential Winter Smog Index MSP-W is defined as the sum of probabilities $f_{w\,n}$ for all days during the winter half-year (31 March - 1 October):

$$\text{MSP-W} = \Sigma\ f_{w\,n} \qquad (0 \le f_{w\,n} \le 1)$$

The factor $f_{w\,n}$ is the product of functions of the Monin-Obukhov length (atmospheric stability) f_L, precipitation f_p, temperature f_T and wind velocity f_{wv}:

$$f_{w\,n} = f_L \cdot f_p \cdot f_T \cdot f_{wv} \qquad (0 \le f_i \le 1 \text{ with } i = L, p, T, wv)$$

The Monin-Obukhov length (L) is estimated for every period per day. The method used for calculating the Monin-Obukhov length is as described in Beljaars, *et al.*, 1990. Function f_{wv} is defined as wv^{-1} with wv the wind velocity at a height of 10 m, outside the built-up area. The other functions are equal to 0 for meteorological conditions unfavourable for smog and equal to 1 for meteorological conditions favourable for smog, as mentioned in Table 3.4. Between those margins the function is considered to be linearly related to the regarded meteorological parameter L^{-1}, p or T_{24h}. The influence of a heat island effect on atmospheric stability is not included. This phenomenon can shift the stability toward unstable conditions.
Analyses of results with other boundary values (specially for L^{-1}) have been made. It was found that the margins in Table 3.4 lead to the best distinction between cities.

Table 3.4: Meteorological conditions for winter-type smog

Function			Meteorological condition				
atmospheric stability (L^{-1} in m^{-1})	f_L	= 0	L^{-1}	≤	-0.02		
		= $(L^{-1} + 0.02) / 0.07$	-0.02	<	L^{-1}	<	0.05
		= 1	L^{-1}	≥	0.05		
precipitation (p in mm)	f_p	= 0	p	≥	2		
		= $1 - 0.5 \cdot p$	0	<	p	<	2
		= 1	p	=	0		
temperature (T_{24h} in °C)	f_T	= 0	T_{24h}	≥	10		
		= $1 - 0.1 \cdot T_{24h}$	0	<	T_{24h}	<	10
		= 1	T_{24h}	≤	0		
wind velocity (wv in m/s)	f_{wv}	= 1 / wv	wv	>	1		
		= 1	wv	≤	1		

Using the above method, it is possible to calculate the MSP-W for a city with a given geographical position and for a given period. The calculations are performed with synoptic data for the period 1980-1989 and for 1985 and 1989 separately. Figures have been ranked in 5 classes, results are presented in **Annex IX**. **Map 7** presents the geographical distribution of the calculated MSP-W values. A distinct pattern is visible, with MSP-W values increasing from West to East Europe. The calculation method has been tested by comparing results for MSP-W with the observed number of days with winter-type smog. For a number of cities SO_2 concentrations are available. The diagram in Figure 3.5 shows the number of days in the winter season 1985 with SO_2 levels exceeding the WHO-AQG for SO_2, and the MSP-W in 1985 for some major European cities. Note that cities with a high potential smog index but low local emissions will have few days with smog. On the other hand, cities with a low potential smog index can have episodes because of a long-distance supply of polluted air.

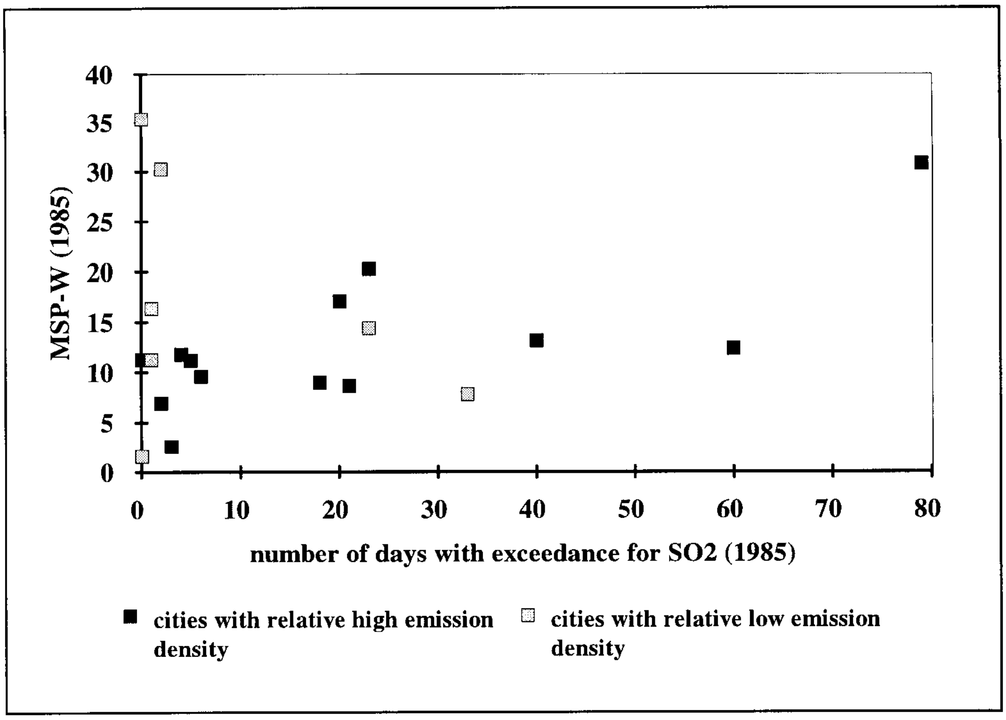


Figure 3.5: Comparison of MPS-W calculated for 1985 with number of days in 1985 with SO_2 concentrations exceeding the WHO-AQG for some European cities

3.3.2.3 Meteorological potential summer smog index

Summer-type smog episodes are generally characterised by sunny and warm weather and low wind velocities, often associated with a high pressure system. During summer-type episodes which often last for several days, high concentrations of ozone and other primary and secondary pollutants develop. Photo-chemical reactions are affected by temperature and sunshine. The time needed for the photo-chemical reactions is of the order of some hours, so the air will be transported over some distance before ozone is produced. Whether the produced ozone will elevate levels inside a city or not, depends on the residence time of the polluted air in the city.

The Potential Summer Smog Index MSP-S is the sum of probabilities $f_{s\,n}$ on all days during the summer half-year (1 April-30 September):

$$\text{MSP-S} = \Sigma f_{s\,n} \qquad (0 \leq f_{s\,n} \leq 1)$$

The factor $f_{s\,n}$ depends on photo-chemical reactions and wind velocity. The influence of photo-chemical reactions is represented by functions related to temperature f_T, cloudiness f_{Nt} and the residence time of the air in the city f_{rt}. The residence time (rt) takes into account the delay due to the reaction time needed for ozone production.
The residence time (rt, in hours) is the time needed for a parcel of air to traverse the city's canopy (with diameter D in km) at a specific wind velocity (in m s^{-1}):

$$rt = 3.6^{-1} \cdot D \cdot wv^{-1}.$$

So $f_{s\,n}$ finally is:

$$f_{s\,n} = f_T \cdot f_{Nt} \cdot f_{rt} \cdot f_{wv} \qquad (0 \leq f_i \leq 1 \text{ with } i = T, Nt, rt, wv)$$

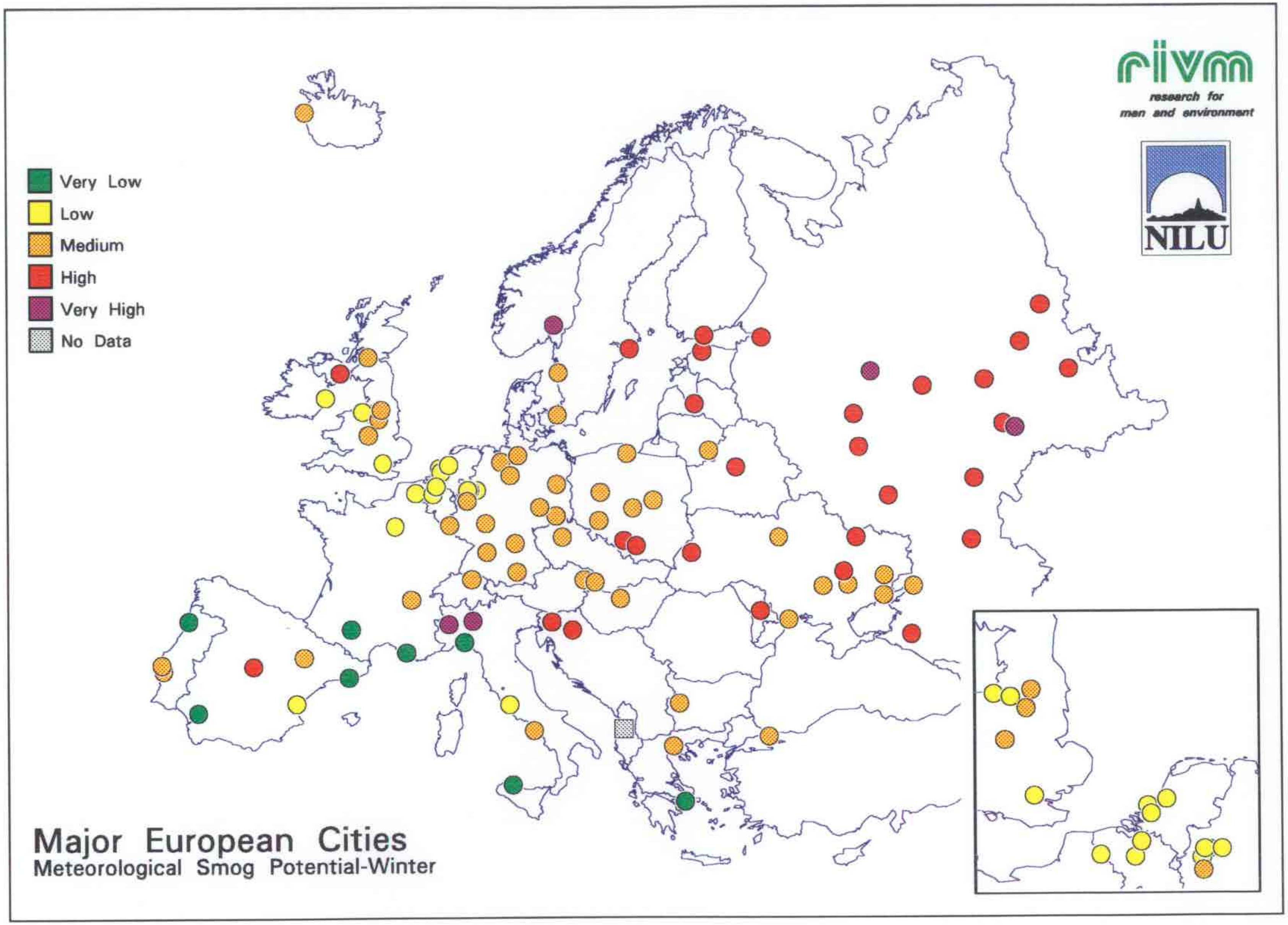
Function f_{wv} is defined as the inverse wind velocity wv^{-1} with a maximum value of 1. The other functions are equal to 0 for meteorological conditions unfavourable for smog and equal to 1 for meteorological conditions favourable for smog, as mentioned in Table 3.5. Between those margins the function is considered to be linear with the concerned meteorological parameters, except for f_{Nt}, which is assumed to be equal to $1 - Nt^{3.4}$ as described by Kasten *et. al* and slightly modified.

Table 3.5: Meteorological conditions for summer-type smog

function			meteorological condition				
temperature	f_T	= 0	T_{max}	≤	25		
(T_{max} in °C)		= $(T_{max} - 25) / 5$	25	<	T_{max}	<	30
		= 1	T_{max}	≥	30		
cloudiness	f_{Nt}	= 0	Nt	=	8/8		
(Nt in 1/8)		= $1 - Nt^{3.4}$	0/8	<	Nt	<	8/8
		= 1	Nt	=	0/8		
residence time	f_{rt}	= 0	rt	≤	2		
(rt in hours)		= 2 - rt	0	<	rt	<	3
		= 1	rt	≥	3		
wind velocity	f_{wv}	= 1 / wv	wv	>	1		
(wv in m/s)			wv	≤	1		

Using the above method, it is possible to calculate the MSP-S for a city with a given geographical position and for a given period. The calculations are performed with synoptic data for the period 1980-1989 and for 1985 and 1989 separately. Figures have been ranked in 5 classes, results are presented in **Annex IX. Map 8** presents the geographical distribution of the calculated MSP-S values. A distinct pattern is visible, the calculated MSP-S values increase from North to South Europe.

At the moment of data analasis it was not possible to compare the calculated MSP-S values against the observed number of exceedances of the short-term WHO-AQG for ozone because for only a few cities these exceedance statistics were available (see *3.5*).


Very Low
Low
Medium
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Very High
No Data
Major European Cities
Meteorological Smog Potential-Winter
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man and environment
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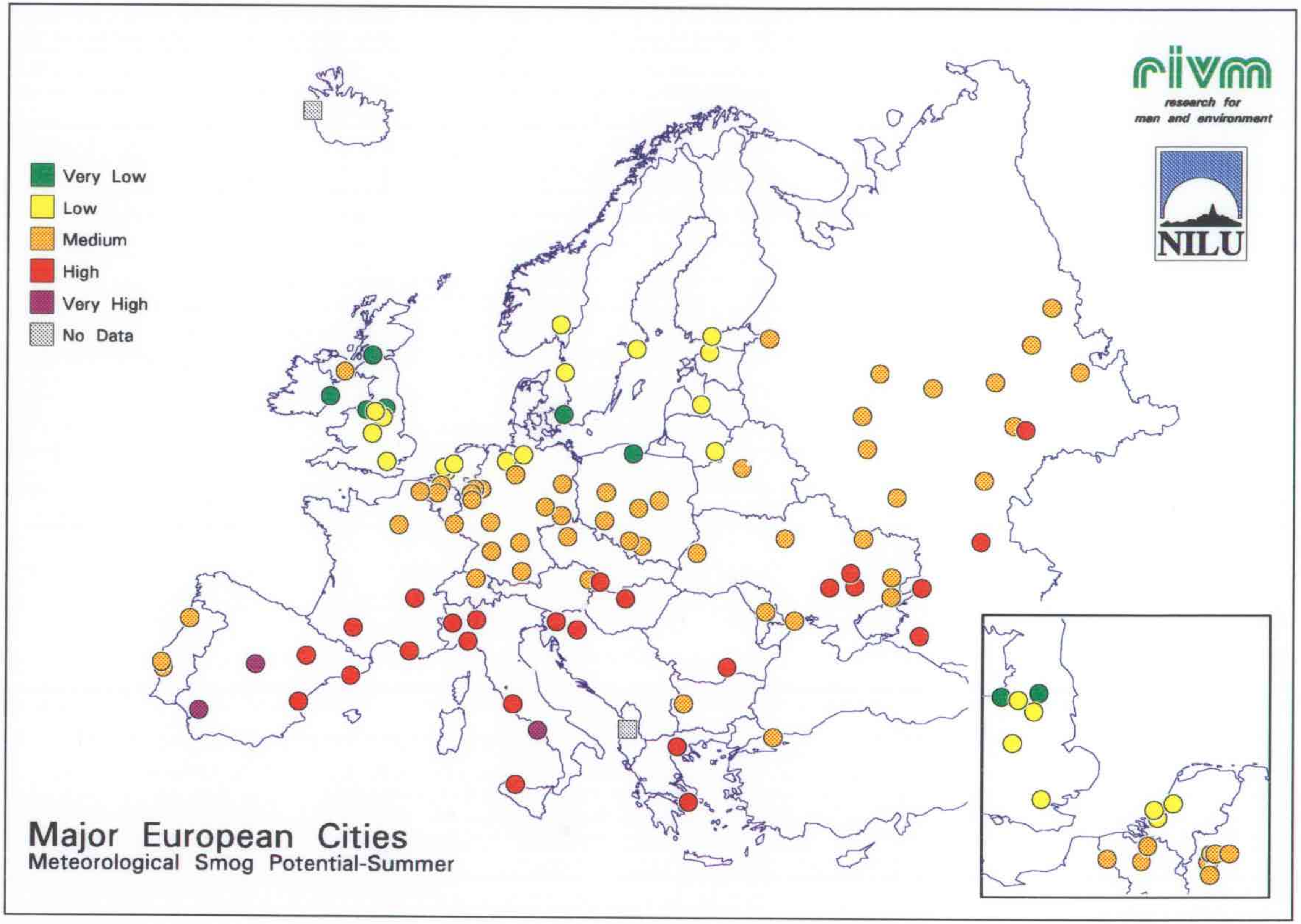
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Major European Cities
Meteorological Smog Potential-Summer

3.3.2.4 Relations between climate and meteorological smog potentials

Figure 3.6 presents the MSP-W and MSP-S for all cities grouped by their macro climatological environment. Cities located in the marine west coast temperate climatic region have relatively low meteorological winter and summer smog potentials. Meteorological conditions are tempered by the vicinity of the Atlantic Ocean and weather patterns are very changeable. Cities found in the continental climatic region with cold winters obviously have high winter smog potentials. Cities in the Mediterranean region in general have a low MSP-W but, because of the prolonged and hot summer, a high MSP-S. However a few cities in this region also experience a high MSP-W. The MSP-W and MSP-S values can vary considerably from year to year in response to the observed weather patterns.

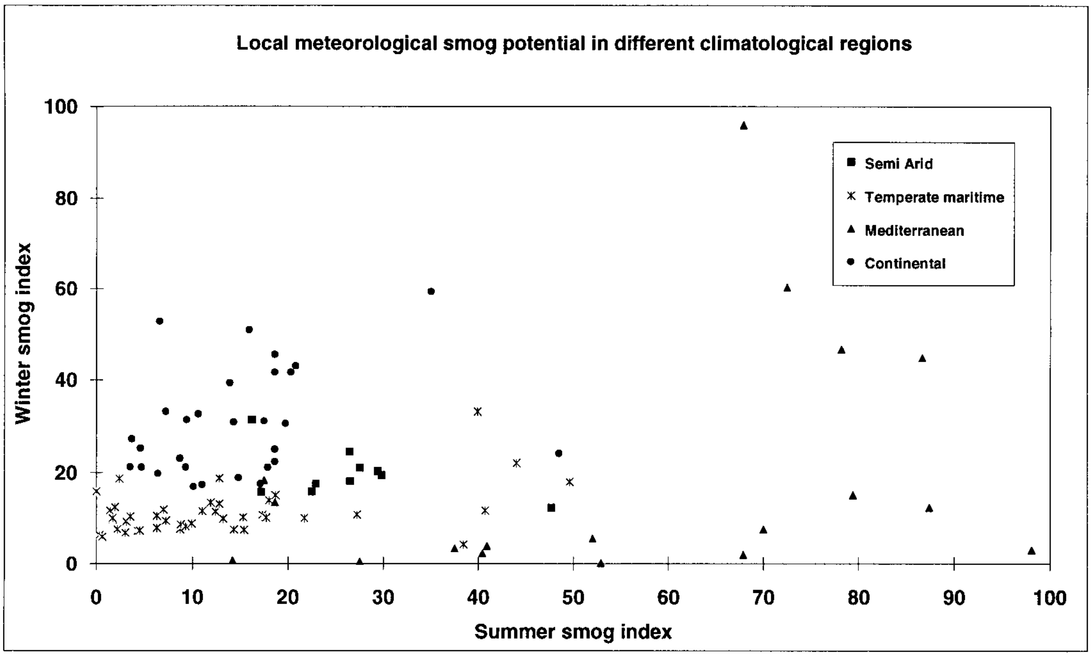


Figure 3.6: Local meteorological smog potential in different climatological regions. Each marker represents one city. Based on data from the ECMWF ODS data base (10-year averages).

3.3.3 Average dispersion classification

While the meteorological smog potentials can be seen as short-term indicators for adverse meteorological conditions, a city can also be affected by unfavourable meteorological conditions on a long-term scale through its topographical setting linked to dispersion characteristics.

Taking the topographical description and topographical maps as a reference, the siting of the city (topographical setting) has been summarised and translated into a siting class (Tabulated in **Annex IX**). Combinations of codes have been used to describe the siting, e.g. CP (coastal plain) The following classes have been attached to the siting characteristics (Table 3.6):

Table 3.6: Classification used for topographical setting

++	coastal (C), coastal-plain (C,P)
+	plain (P)
o	coastal-hills (C,H), plain-river basin (P,RB), plain-hills (P,H)
-	coastal-valley (C,V), river basin (RB)
--	valley (V), river basin-hills/valley (RB,H/V)

Table 3.7 summarises the possible effects of siting on dispersion characteristics. The geographical distribution of the topographical siting is presented in **Map 9**.

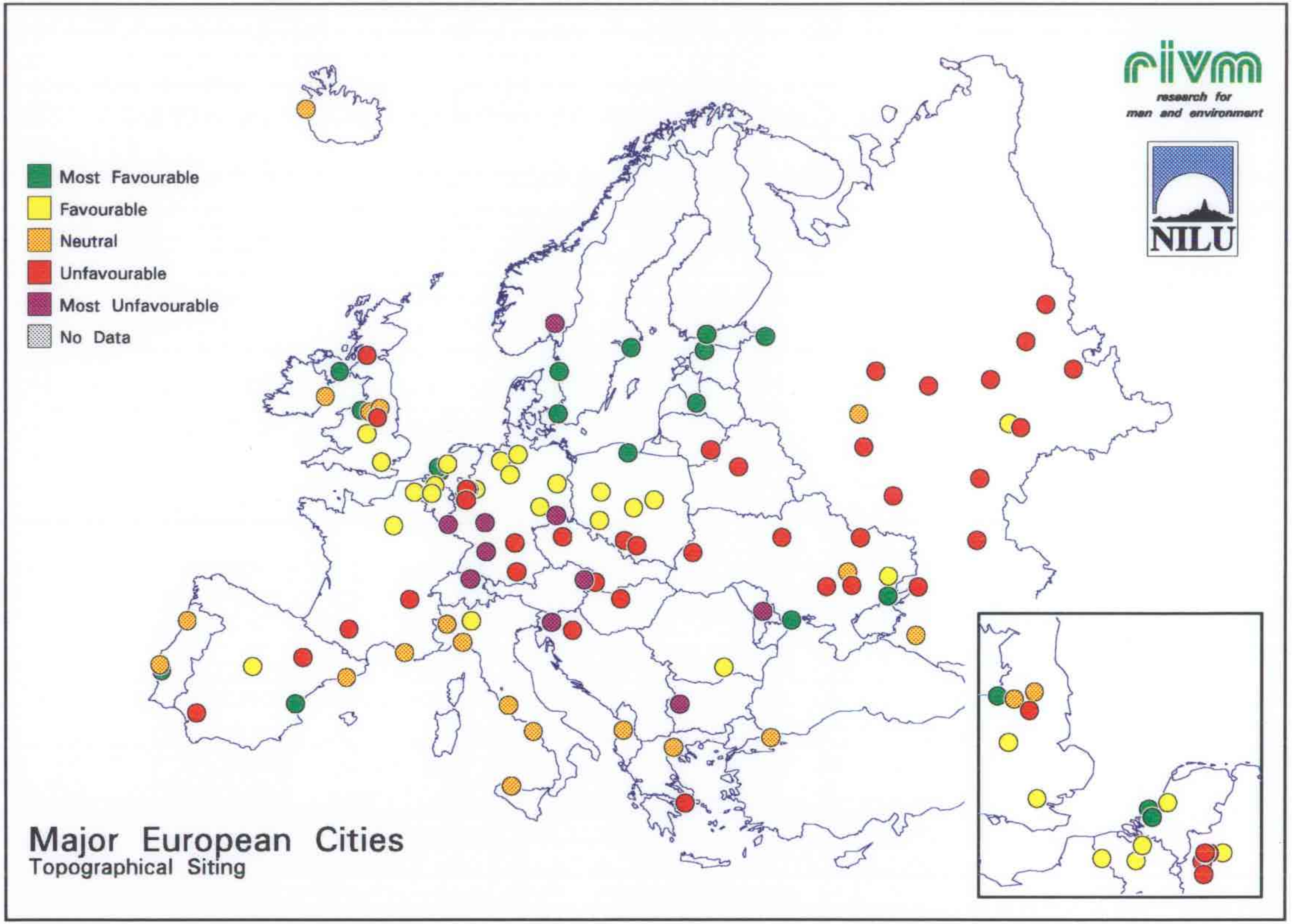
Table 3.7: Expected effects of siting on dispersion characteristics

Flat plain	(flat or undulating) No local wind effects to be expected.
Coastal	Coastal cities will be influenced by land-sea breeze systems during the summer half year in situations characterised by high pressure on the synoptic scale. Average wind speed is in general higher than for inland locations.
River basin	In the river basin diurnal local wind systems may develop. The driving forces for local-scale winds diminish in situations with cloud cover. Stagnant air and inversions may develop at night and during the winter half year.
Valley	Horizontal winds are channelled along the valley axes. Local wind systems may develop as a result of differential solar heating of mountain slopes. Persistent stagnant air and inversions may develop at night and during the winter half year.
Hills	Hills at one side, the city is located on a plain. Local wind systems may develop as a result of differential solar heating plain/hill slopes. Average wind speed can be relatively low if the hills are located upstream of the main wind direction.

The '*average dispersion*' index is defined as the average of the siting class and the average wind speed rank:

Average dispersion index = (siting class + long-term average wind speed rank)/2

The average dispersion index for each city is presented in **Annex VII**. The geographical distribution is presented in **Map 10**. No pattern in the distribution of siting characteristics is apparent in Europe. Because cities located near Europe's North and West coasts and in Ukraine experience highest average wind speeds, the average dispersion index tends to be more favourable in these regions. Lowest average wind speeds and subsequently less favourable average dispersion conditions are generally found away from large water bodies; Northern Italy and the Balkans are similar. The average dispersion indices and meteorological smog potentials are inter-related to a certain extent.


Most Favourable
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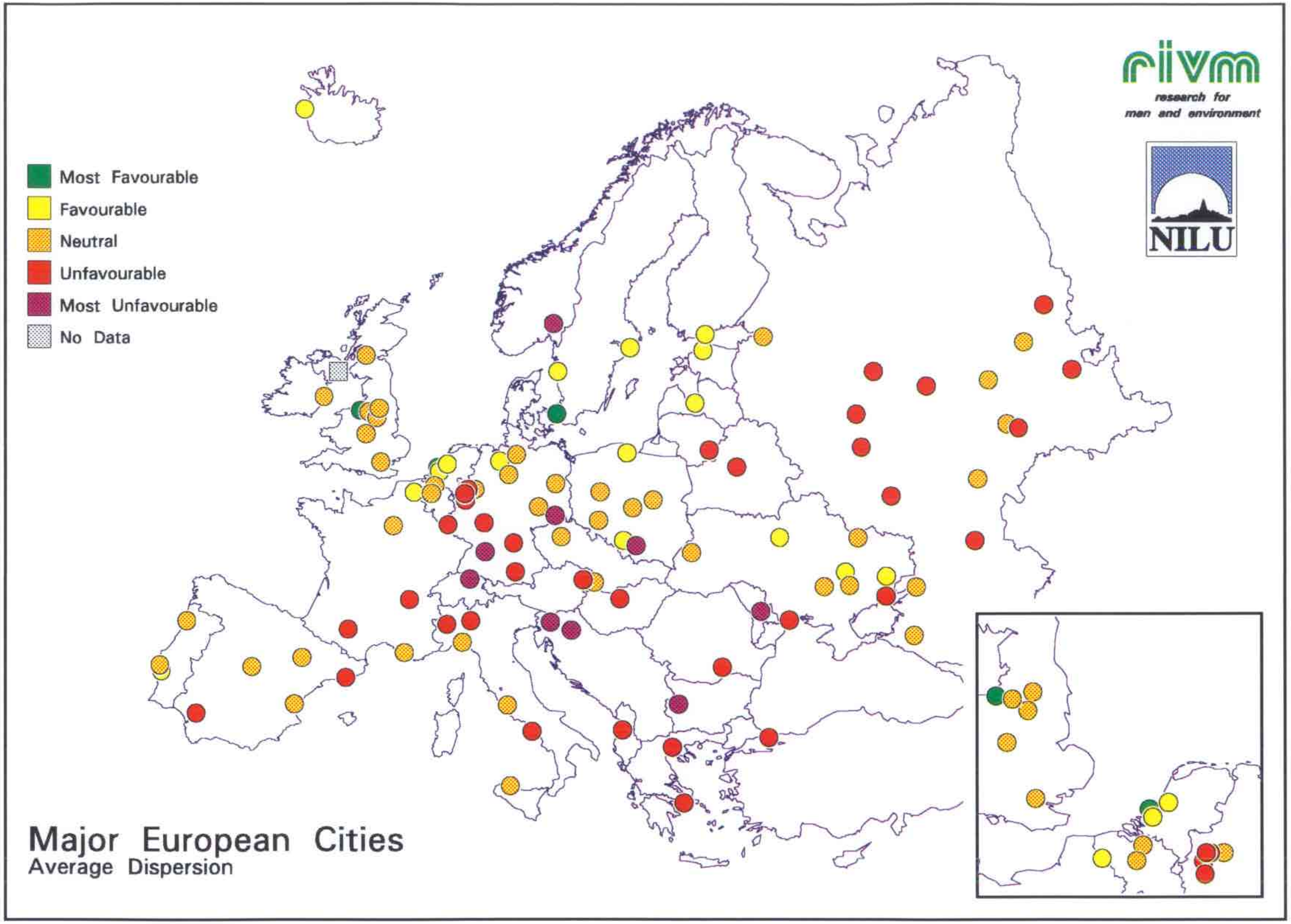


Major European Cities
Average Dispersion

3.4 Air pollutant concentrations

R.J.C.F. Sluyter

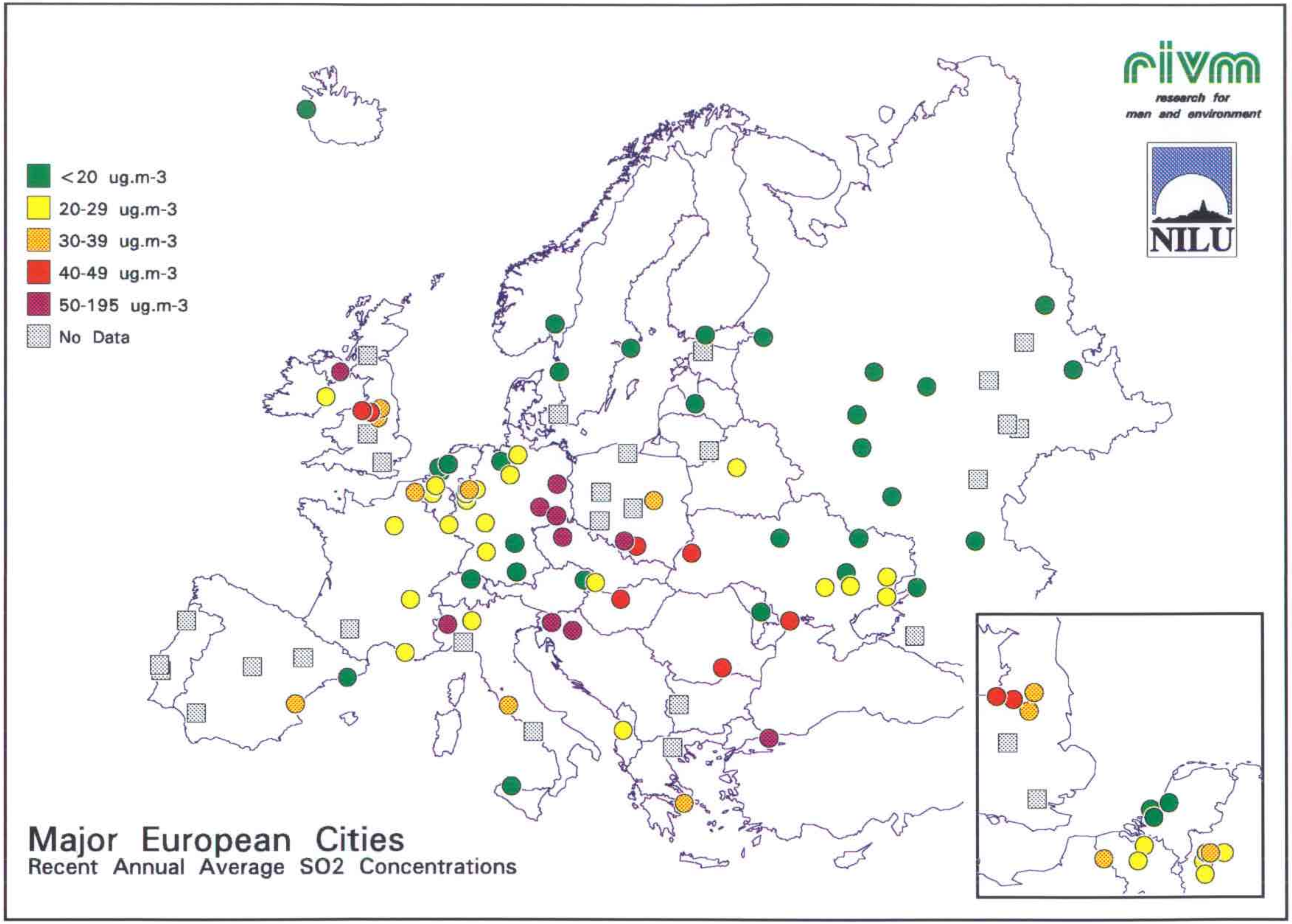
This chapter gives an survey of monitored urban pollutant concentrations. Since the amount of concentration data requested was limited to summary statistics for two years (1985 and 1990 preferred) and because of the large number of cities part of this research, the description of the air pollutant concentrations can only be limited to a general review of main characteristics. For SO_2, PM (TSP or black smoke), NO_2 and O_3, attention is primarily focused on city background concentration levels. CO and Pb concentration data are presented for `hot spots'. Summarised air quality statistics can be found in **Annex X.a-Annex X.e.** More detailed concentration data is presented in the CRFs which are published in a separate report (van Zantvoort, Sluyter & Larssen (eds.), 1995).

Except when explicitly mentioned otherwise, average concentrations refer to the average of all city background stations for which data was available.

3.4.1 Sulphur dioxide

Annual average SO_2 concentrations have dropped considerably over large parts of Europe between 1985 and 1990 (**Annex X.a**). **Map 11** presents the geographical distribution of annual average SO_2 concentrations. Lowest levels are found in Northern Europe, in general below 10 $\mu g/m^3$. Highest levels are found in some of the Central European cities. FSU cities, with a few exceptions, report very low average levels. At this point it remains unclear if these levels are realistic or if the monitor techniques and sample schemes produce unreliable results. (see also Section 2.3). Average levels in Western and Southern European cities are around 30 $\mu g/m^3$. The long-term WHO-AQG (50 $\mu g/m^3$ (annual average)) was exceeded still in recent years in 13% of the cities for which SO_2 data is available. Approximately 15% (16 million) of the total urban population in this sample (N=78) are potentially affected by these exceedances. In 51% (N=13) of all Central European cities, the long-term WHO-AQG was exceeded.

Maximum 24h levels at city background locations still exceed the short-term WHO-AQG in 43% of all cities for which data is available (N=76) on one or more days. These exceedances are not confined to central European cities, they are also observed in the Western and Southern region. No exceedances were observed in Northern European cities in recent years, data from the FSU cities (Eastern region) is unreliable. Concentrations above 375 $\mu g/m^3$ (3 times the AQG) were observed in Belfast, Berlin, Hannover, Ljubljana, Lyon, Istanbul and Prague. In busy streets and especially near industrial estates observed levels can even be far higher (**see Annex X.a**). In most cases, exceedances are confined to a few days per year. Cities experiencing more structural exceedances include Belfast, Berlin, Turin, Istanbul, Katowice, Ljubljana and Prague.
The number of people potentially affected by exceedances of short-term WHO-AQGs are described in conjunction with particulate matter concentrations in Section 3.5.1.



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Major European Cities
Recent Annual Average SO2 Concentrations

3.4.1.2 Calculation of the city contribution to the total concentration field for sulphur dioxide

To get a first order estimation of the city contribution to the total concentration field, average SO_2 city background concentrations have been compared to modelled regional background concentrations. The city contribution C_{city} is defined as the average city background concentration minus the regional background concentration.

The model used for the calculations of the regional background concentrations is the TREND model (Van Jaarsveld, 1990). The TREND model is a long-term Lagrangian model in which the transport equations are solved analytically. Dry deposition, wet deposition and chemical transformations are incorporated as first-order processes and independent of concentrations of other species. To enable calculation of an average concentration at a particular point, the occurring meteorological situations are divided into 12 wind direction classes and 6 stability/mixing height classes. Representative transport and deposition parameters are determined for each class from observations. Next a representative concentration is calculated for each meteo-class. After summation of these concentrations weighted by their relative frequencies, the period-average concentration is obtained.

The 1990 SO_2 regional concentration field was calculated for the 50 x 50 km EMEP grid using 1990 emissions with variable resolution, ranging from typically 50 x 50 in Western Europe to 150 x 150 km in Eastern Europe. The emission data base used is a combination of EMEP and CORINE data. The emissions from the cities *themselves* are part of this emission data base, but since emissions are aggregated on a 50 x 50 to 150 x 150 km grid, their contribution to the total emission in a grid cell is for most cities of limited importance and is not taken into consideration here. Calculated concentrations from the grid cells containing the cities were extracted using a computer program which projected the latitude longitude city co-ordinates to the EMEP based grid co-ordinates. This program also performed a simple inverse distance interpolation using the city's eight neighbouring cells. This interpolated value is useful for cities located in places with a strong gradient in regional SO_2 concentrations or on the boundary between two EMEP cells. Modelled regional background SO_2 concentrations (cell values) are published in the CRFs (van Zantvoort, Sluyter & Larssen (eds.), 1995). High regional concentrations are found in the English midlands, Central Europe (especially in the so-called `black triangle') and in East Ukraine.
Calculated cell values and interpolation estimates were compared to recent (1989,1990 or 1991) annual average city background SO_2 concentrations. Figure 3.7 presents the calculated city contribution C_{city} to the total concentration field of SO_2. Cities are grouped according to the defined geographical regions. The calculated city contributions are on average highest in Central European cities (30 $\mu g/m^3$, range 5-112 $\mu g/m^3$). Lower values are found in Western and Northern European cities. Many FSU cities' calculated C_{city} is a negative value. This phenomenon is observed for FSU cities only. Although the performance of the TREND model in Eastern Europe is poorer because of the uncertainties in emission estimates, the negative city contributions bring into question the reliability of SO_2 concentration data from FSU cities (see also Section 2.3.4).

City contributions are evaluated against emission parameters. No significant correlation is apparent between city contributions and total urban SO_2 emissions. In Figure 3.8 the city contributions for non FSU cities are plotted against the urban emission density per square kilometre. No significant correlation is apparent at the 95% confidence level (linear relationship presumed). Emissions describe only 23% of the variations in the city contribution.

relationship presumed). Emissions describe only 23% of the variations in the city contribution.

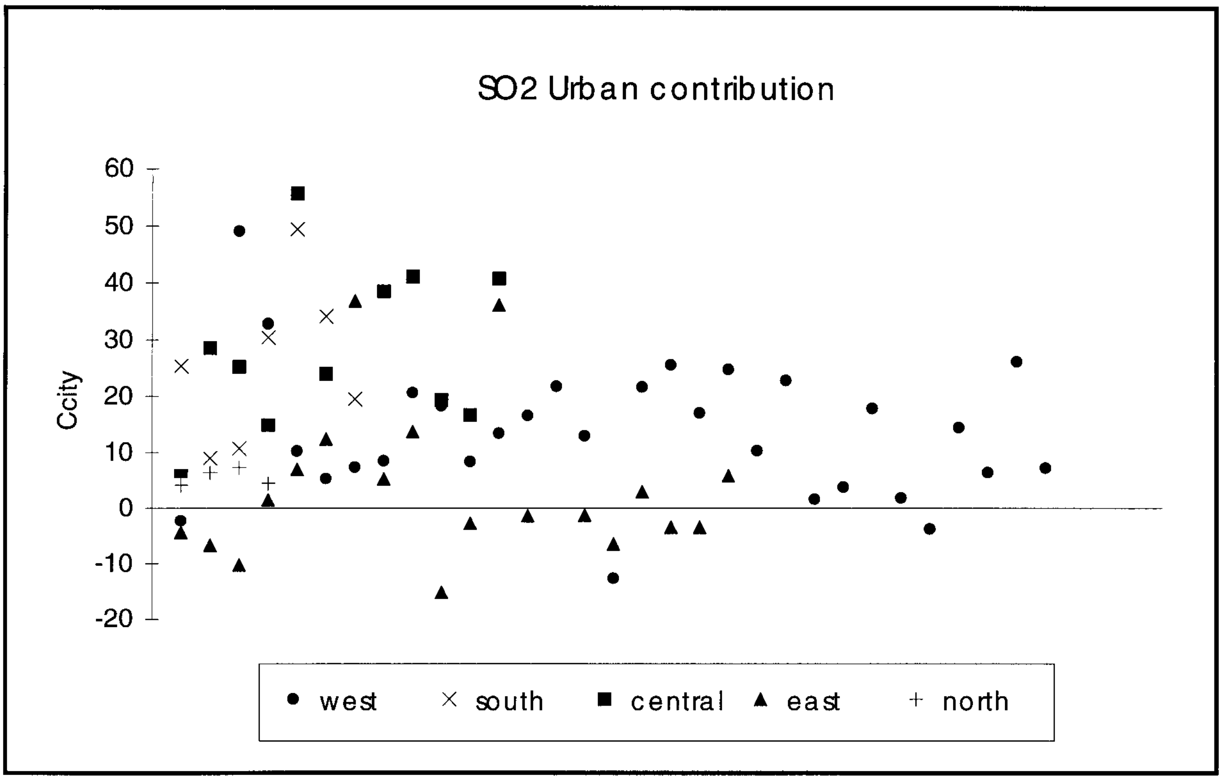
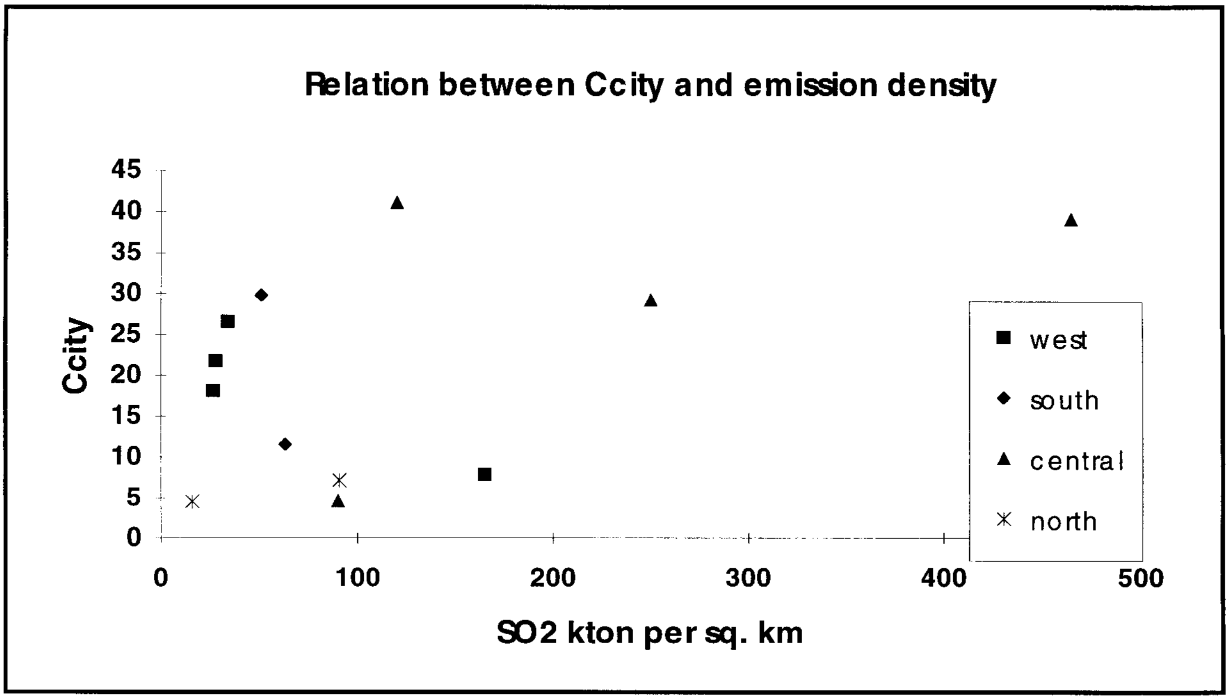


Figure 3.7: Calculated urban contributions (C_{city}) to the total regional SO_2 concentration field. Regional background concentrations based on 1990 model calculations, city background concentrations based on measurements from 1990 or another recent year (1989-92). Y-axis: Concentrations in µg/m^3. X-axis is dimensionless.



The relation between city contribution and emissions might have been disturbed by the amount and quality of the urban data available:

- The sample size is very small (N=11);
- Emission density is very sensitive to area figures used, the city area is uncertain (Section 3.2);
- Emission inventories (techniques) vary from city to city;
- For many cities it is uncertain if area and emission figures obtained are for city or conurbation;
- Important SO_2 emitters (e.g. power generating stations) are in many cases concentrated outside the cities and have high stacks, but they are counted as urban emissions in some cases;
- The number of city background stations available varied per city from only 1 to 11; besides, it is uncertain whether all stations so designated are in fact city background stations.

In future urban research, as also already pointed out in Section 2.4, standardisation of inventory methods and AQ monitoring should be seen as a priority. Apart from the above problems, the following points should also be noted:

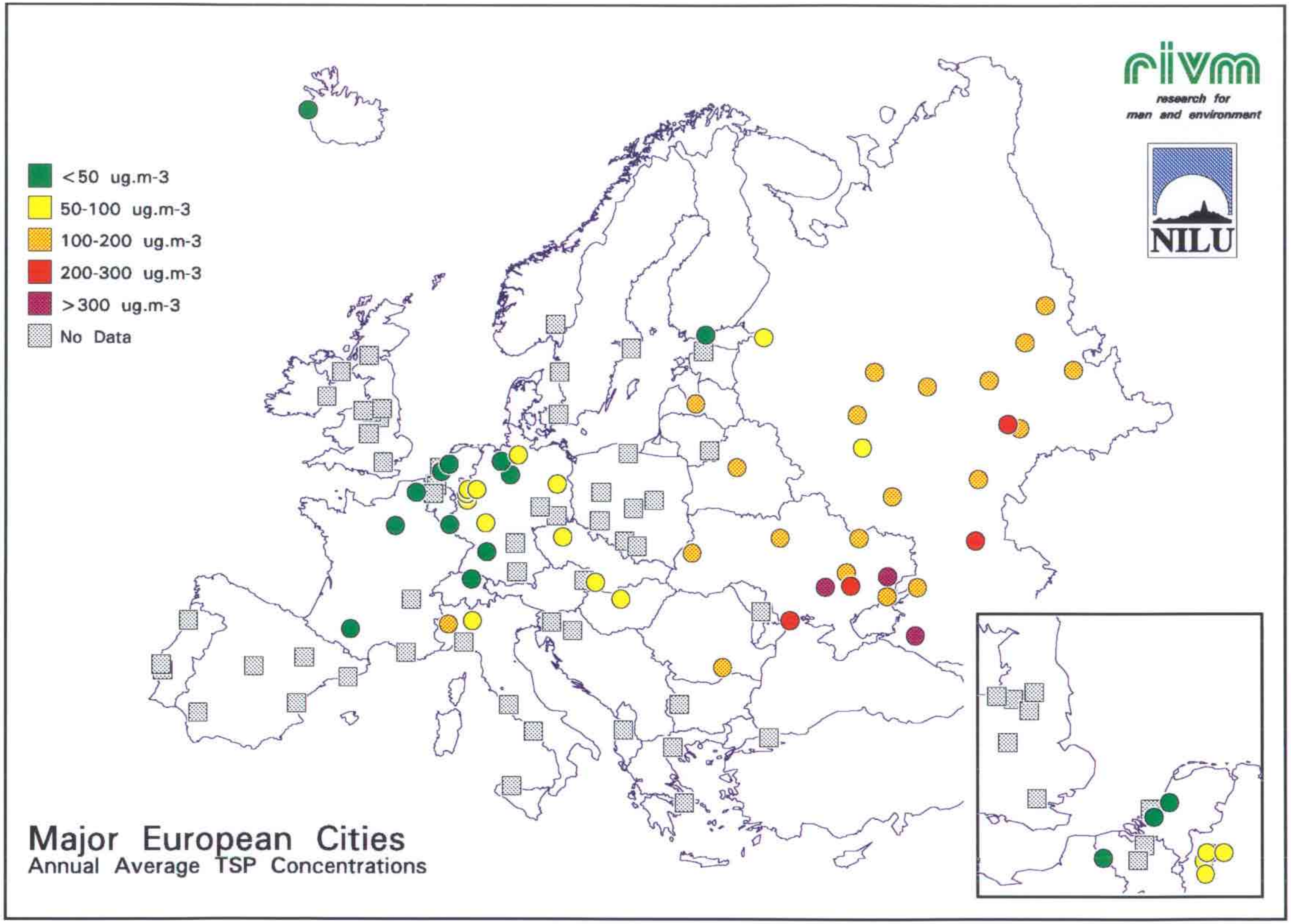
- The relation between urban emissions and city contributions depends on other environmental characteristics, such as the (urban) meteorology.
- Regional background concentrations were obtained through modelling;

The `noise' introduced through the last two points is thought to be of minor importance, but should be addressed in future research.

3.4.2 Suspended particulates

The term particulate matter represents a complex mixture of organic and inorganic substances. Because of the complexity of particulate matter and the importance of particulate size in determining exposure, multiple terms are used to describe particulate matter. Most common in Europe are TSP, black smoke and PM_{10}.
Black smoke measurements represent the darkness of the stain on a filter through which air has been passed, usually for 24 hours. Darkness of the filter is translated to a concentration. This can be a good indication of particulate pollution from combustion sources where inorganic carbon and "soot" constitutes a significant contribution (e.g. diesel vehicles and coal combustion). In other cases, the amount of pollution can be underestimated. TSP measurements represent the total amount of `dust' is collected through, in most cases, high volume samplers. Problems with TSP measurements are that not only the respiratory fraction, but all dust is collected, furthermore not only particulate matter from combustion processes is collected but also earth crustal material. To overcome this problem a 10 μm cut-off inlet is used more and more to collect only the fraction smaller than 10 μm (PM_{10}), as a better indicator of health related particulates (WHO, 1987). Within this project, TSP and black smoke concentrations are discussed together. In exceedance and exposure calculations, the appropriate AQGs have been used for both TSP and black smoke.

Annex X.b presents summarised air quality statistics for TSP, black smoke and PM10. The geographical distribution of TSP annual average concentrations is presented in **Map 12,** the distribution of Black smoke in **Map 13.**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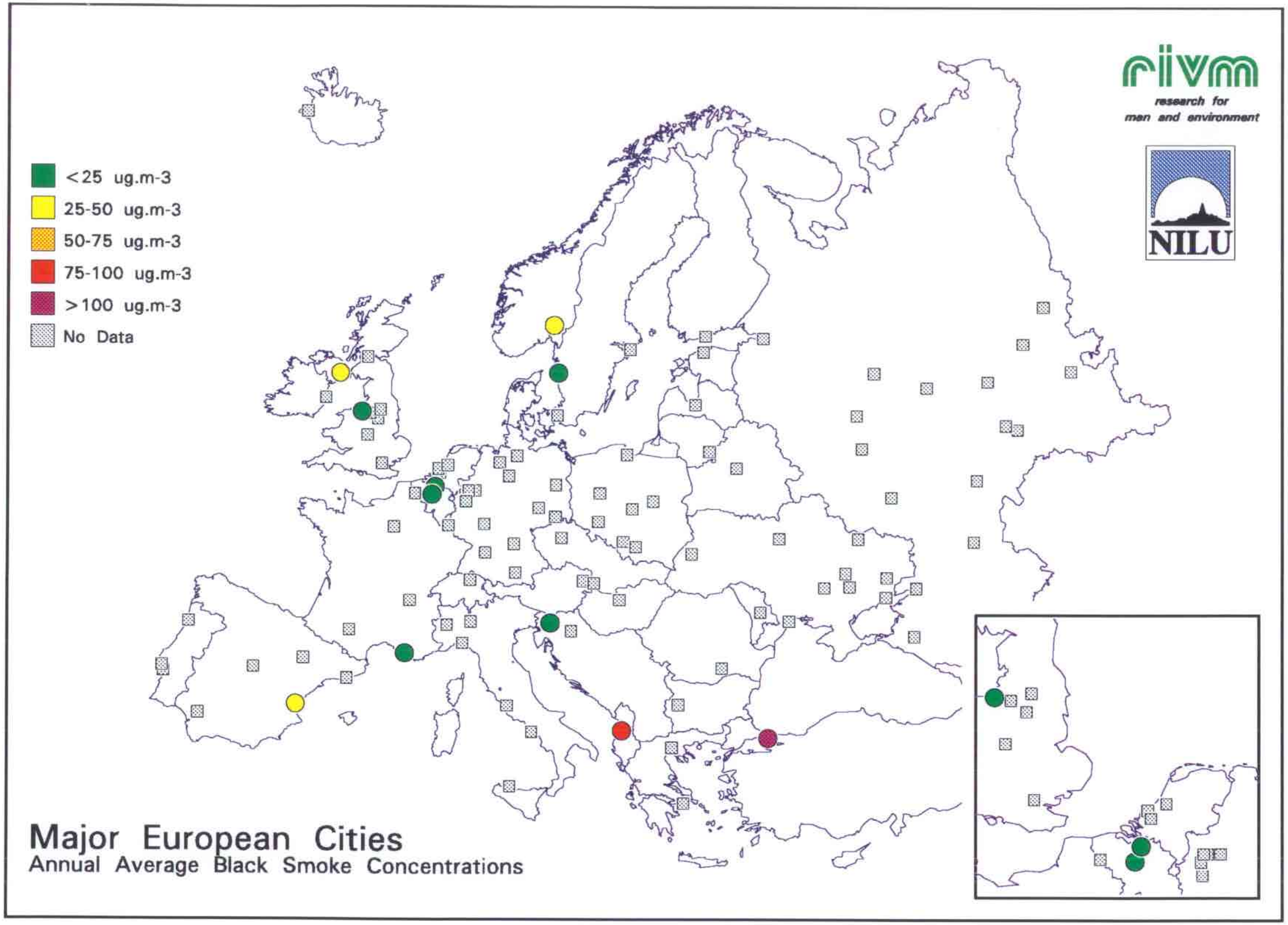
Major European Cities
Annual Average TSP Concentrations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Major European Cities
Annual Average Black Smoke Concentrations

Annual average TSP and black smoke concentrations show a mixed trend in Western, Northern, Southern and Central European cities during 1985-1990. In some cities a (slight) upward trend is visible, in others a (slight) downward trend. Cities in the FSU report very high TSP concentrations, but concentrations show a downward trend in most cities. Since no cut-off inlet is used, it is not improbable that a substantial fraction of the concentrations measured consists in fact of resuspended particles, especially in the semi-arid regions of the FSU (Ukraine).

The long-term WHO-AQG for black smoke (annual average 50 $\mu g/m^3$) was exceeded only in Tirana and Istanbul (15 cities with black smoke data available) in 1990. No long-term WHO-AQG has been set for TSP. Average maximum 24h city background concentrations exceeded the short-term WHO-AQG in 86% of all cities for which data is available (N=77) in 1990. These exceedances are observed in all European regions. Although FSU cities have no exceedance figures available, the short-term WHO-AQG will be exceeded in all FSU cities since the annual average concentrations are in many cases 100 $\mu g/m^3$ or far higher. In busy streets and especially near industrial estates observed maximum 24h levels can even be extremely high (see Annex IX). In most cases exceedances are confined to a few days per year. Cities experiencing more structural exceedances are Belfast, Berlin, Birmingham, Dublin, Hamburg, Turin, Bratislava, Istanbul, Krakow, Katowice, Prague and Tirana.

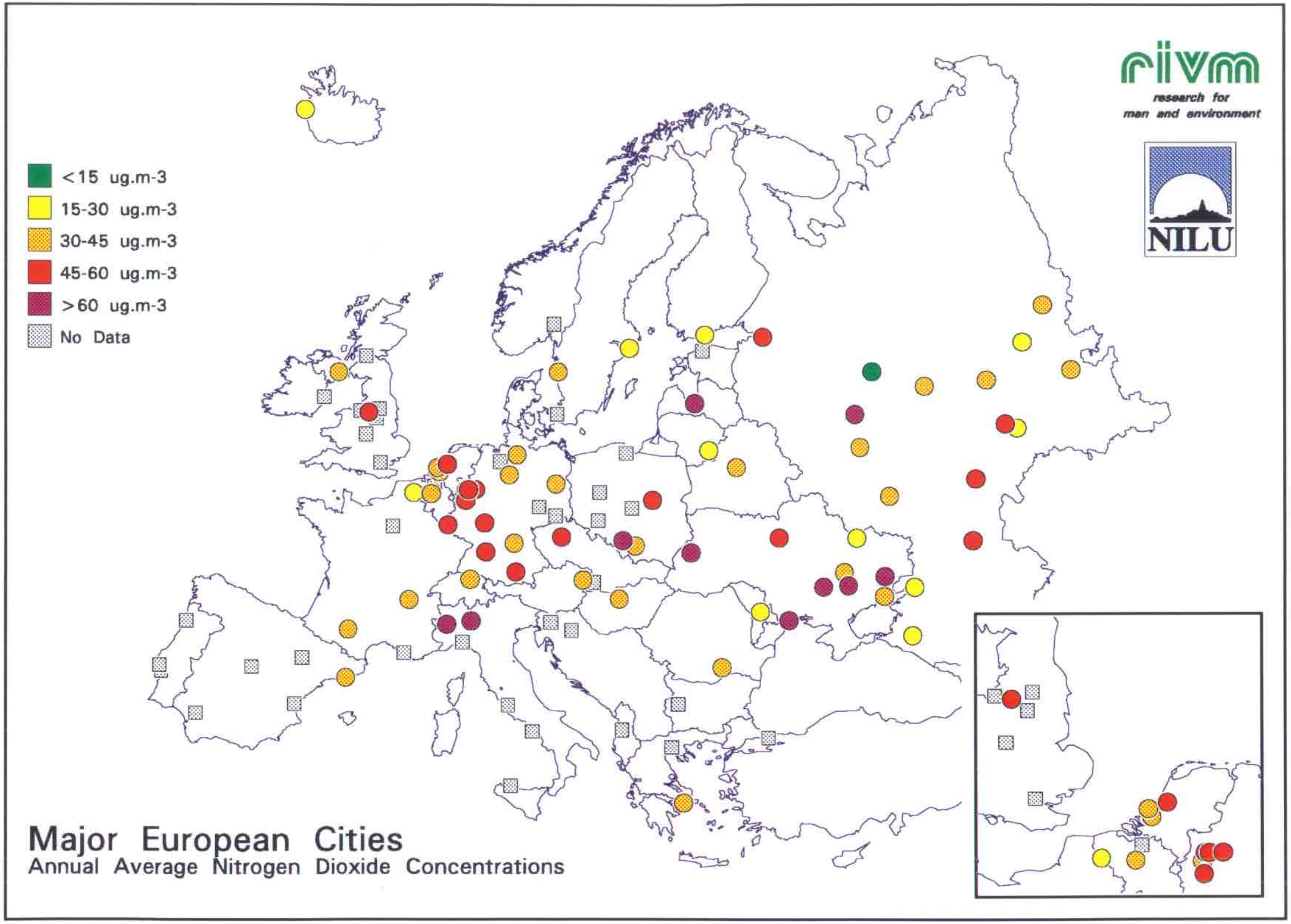
3.4.2.1 Calculation of the city contribution to the total concentration field for suspended particulates

The city contribution to the total concentration field for TSP was calculated using the procedures as described in Section 3.4.2.1. The spatial pattern in regional TSP concentrations resembles that for SO_2 (section 3.4.1.2). The calculated city contribution for TSP is, in contrast to that of SO_2, very high for cities in the FSU (on average 145 $\mu g/m^3$). FSU cities report the highest TSP concentrations in Europe by far (on average 171 $\mu g/m^3$). For cities in Southern Europe, the average city contribution was 84 $\mu g/m^3$. Prolonged dry periods can favour the accumulation of particulate matter in the atmosphere. Central European cities, with a calculated city contribution of 55 $\mu g/m^3$ take an intermediate position. For cities in Northern and Western Europe low contributions were calculated (16 and 18 $\mu g/m^3$ on average, respectively). The city contributions for a few cities in these regions were even slightly negative. This is due to the scale on which the regional concentrations were calculated.

No relation was apparent between emission density (per square kilometer) and the city contribution. The influence of complicating factors is discussed in Section 3.5.1.2.

3.4.3 Nitrogen dioxide

Summarised air quality statistics for NO_2 are presented in **Annex X.c. Map 14** presents the geographical annual average NO_2 concentrations.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Major European Cities
Annual Average Nitrogen Dioxide Concentrations

Reported annual average NO_2 concentrations (city background locations) generally do not show a clear trend. Annual average concentrations in Western European cities (N=22) in recent years (1989-1992) were 46 $\mu g/m^3$ with a standard deviation of only 6 $\mu g/m^3$. Concentrations in the FSU average the same as in Western European cities, but differ more from city to city (N=26, average 46 $\mu g/m^3$, standard deviation 22 $\mu g/m^3$). While traffic is the most important contributor in West Europe, in FSU cities it is space/domestic heating in (small) boiler houses. Annual average concentrations in Northern European cities seem to be lower then in West and East European cities. Southern and Central European cities seem to experience slightly higher annual average concentrations. Sample sizes are however too small to make these differences statistically significant. No long-term WHO-AQG has been set for NO_2.

Exceedances of the short-term WHO-AQG (24h average 150 $\mu g/m^3$) at city background locations in recent years were observed in Manchester, Stuttgart, Katowice, Prague, Warsaw and Ufa (6 of the 40 cities with data).

The short-term WHO-AQG is exceeded in busy streets in many cities, sometimes by a factor of 2.

3.4.4. Lead

Summarised Pb air quality statistics for hot spots are presented in **Annex X.d**. Lead concentrations in many European cities have dropped sharply in the period 1985-1990 (for FSU cities, only 1990 data were available). This is mainly due to the introduction of lead-free fuels. Annual average concentrations at ***hot spots*** (mostly busy streets) in most cities are below the lower limit of the WHO-AQG (0.5 $\mu g/m^3$). This lower limit of the WHO-AQG was exceeded in only 5 (Lyon, Manchester, Turin, Zaragoza and Zagreb) of the 49 cities from which recent (1989-1992) monitoring results were available (in Turin and Zaragoza the upper limit of 1 $\mu g/m^3$ was also exceeded). Concentrations in the FSU are still relatively low (0.11 $\mu g/m^3$ on average), but increasing traffic is likely to cause a rise in concentration levels, since fuels are still untreated.

3.4.5 Carbon monoxide

Only information on the station monitoring the highest CO concentrations was requested in order to get an impression of urban hot spots. Summarised CO air quality statistics are presented in **Annex X.d.** No clear Europe-wide trend in annual average CO concentrations can be seen in the available data. Data from APIS suggest that trends in concentrations vary from site to site, changes depending on trends in traffic density and on CO emission regulations.

The short-term WHO-AQG (8-hour average 10 mg/m^3) is exceeded in almost all cities for which data are available. Exceedances of the AQG by a factor 4 recently have been observed in Athens and Milan. As far cities in the FSU are concerned, 8-hourly values are not available. Statistical analysis of CO concentrations monitored in urban areas of the UK showed a fairly good relation between annual average concentrations and 8-hourly mean maximum concentrations (Harisson et.al., 1993). Analysis suggests that where annual means are ~1.25 ppm (ca. 1.56 mg/m^3) exceedances of the 8-hour WHO-AQG may occur. Extrapolating this relation to FSU cities would result in exceedances of the WHO-AQG in most FSU cities, since their annual means are often 2 mg/m^3 or higher.

3.4.6 Ozone

Summarised ozone air quality statistics are presented in **Annex X.e.** Within this project, ozone is used as an indicator for photochemical oxidants. Elevated ozone concentrations have long be regarded as primarily a regional phenomenon. Urban concentration levels are often partly suppressed due to the emission of nitrogen oxide (NO), which rapidly reacts with ozone to produce NO_2. Exceptions are cities located in coastal areas subject to land-sea wind systems and cities located in valleys where residence times can become sufficiently long for photochemical oxidisation to take place. Typical examples of such cities are Athens and Barcelona where hourly values of up to 400 µg/m^3 O_3 have been measured. It is increasingly clear that elevated ozone levels are also found in many residential districts of large urban settlements. The 1-hour WHO-AQG (150 µg/m^3) was exceeded in 22 of the 27 cities for which recent data was available.

3.4.7 Organic compounds

Hardly any benzene or benzo[a]pyrene (b[a]p, an indicator for poly aromatic hydrocarbons) measurement data were available within this project, with the exception of b[a]p for cities in the former Soviet Union. Annual average b[a]p concentrations exceed the life time cancer risk level of 10^{-4} in all cities of the former Soviet Union, in some Ukraine cities levels are up to the 10^{-3} level. From available data (RIVM, 1994) and model calculations (RIVM, 1992), benzene concentrations in most cities will probably exceed those associated with a life-time cancer risk level of 10^{-4}.

3.5 Exceedance of WHO-AQGs classification for winter- and summer-type pollutants

R.J.C.F. Sluyter

Short-term exceedances of WHO-AQGs for SO_2 and/or PM and O_3 have been taken as indicators for winter-type and summer-type smog respectively. The classification schemes applied are based on the average of all highest observed concentrations on city background stations. The number of days with exceedances observed was not taken as indicator, because in many cases it was not known how many days with monitoring results were available. From existing data bases (e.g. APIS) it is clear that many data series are up to 50% incomplete, so that a classification based on the number of days with exceedances could result in a serious underestimation.

The classification "exceedances unlikely" is applied if reported average urban concentrations were below 50% of the WHO-AQG; the classification "exceedances possible" is applied if reported average urban concentrations are between 50 and 100% of the AQG. Concentrations monitored at the most exposed sites and at individual sites can have been far higher. The classifications are given in **Annex VII.**

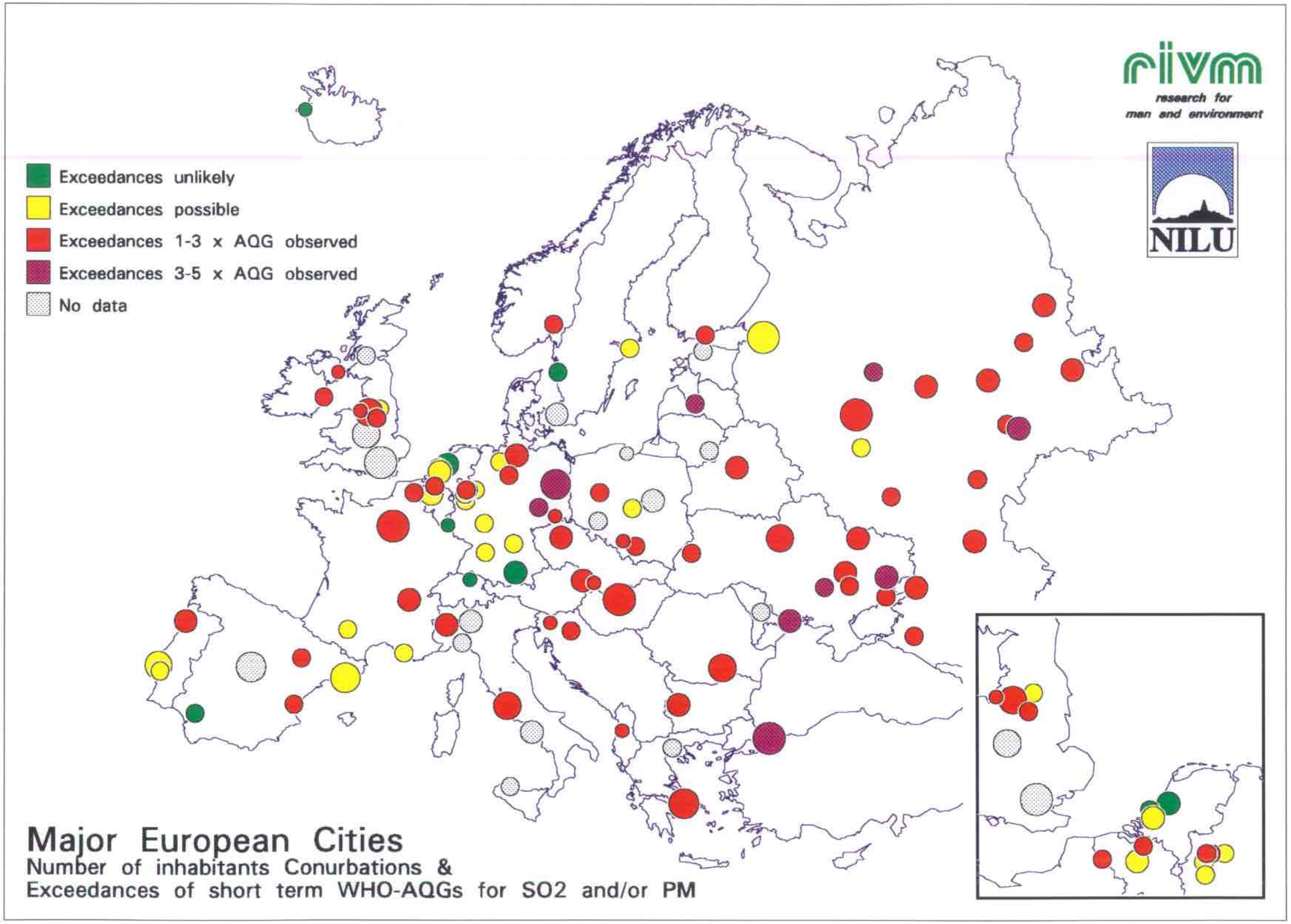
- Winter-type smog pollutants

Not all cities monitor both SO_2 and PM (TSP/black smoke). Sometimes only SO_2 or PM data are available. In these cases the classification is based on only one component, if both SO_2 and PM are monitored, the component with the highest observed values is used in the classification.

Map 15 presents recent (1989-1992) exceedances of the short-term WHO-AQG for winter-type smog pollutants. For visualisation reasons, the number of exceedance classes have been limited to 4. The map shows exceedances have been observed in all regions of Europe. Particularly high concentrations were reported from cities in Central Europe (both SO_2 and PM) and Eastern Europe (TSP).

- Summer-type smog pollutants.

Photochemical or summer-type smog is indicated by ozone concentrations. O_3 data were available from only 27 cities. For visualisation reasons, the number of exceedance classes have been limited to 4. **Map 16** presents the recent exceedances of the 1 hour WHO-AQG for ozone. In 22 of the 27 cities with data the AQG was exceeded.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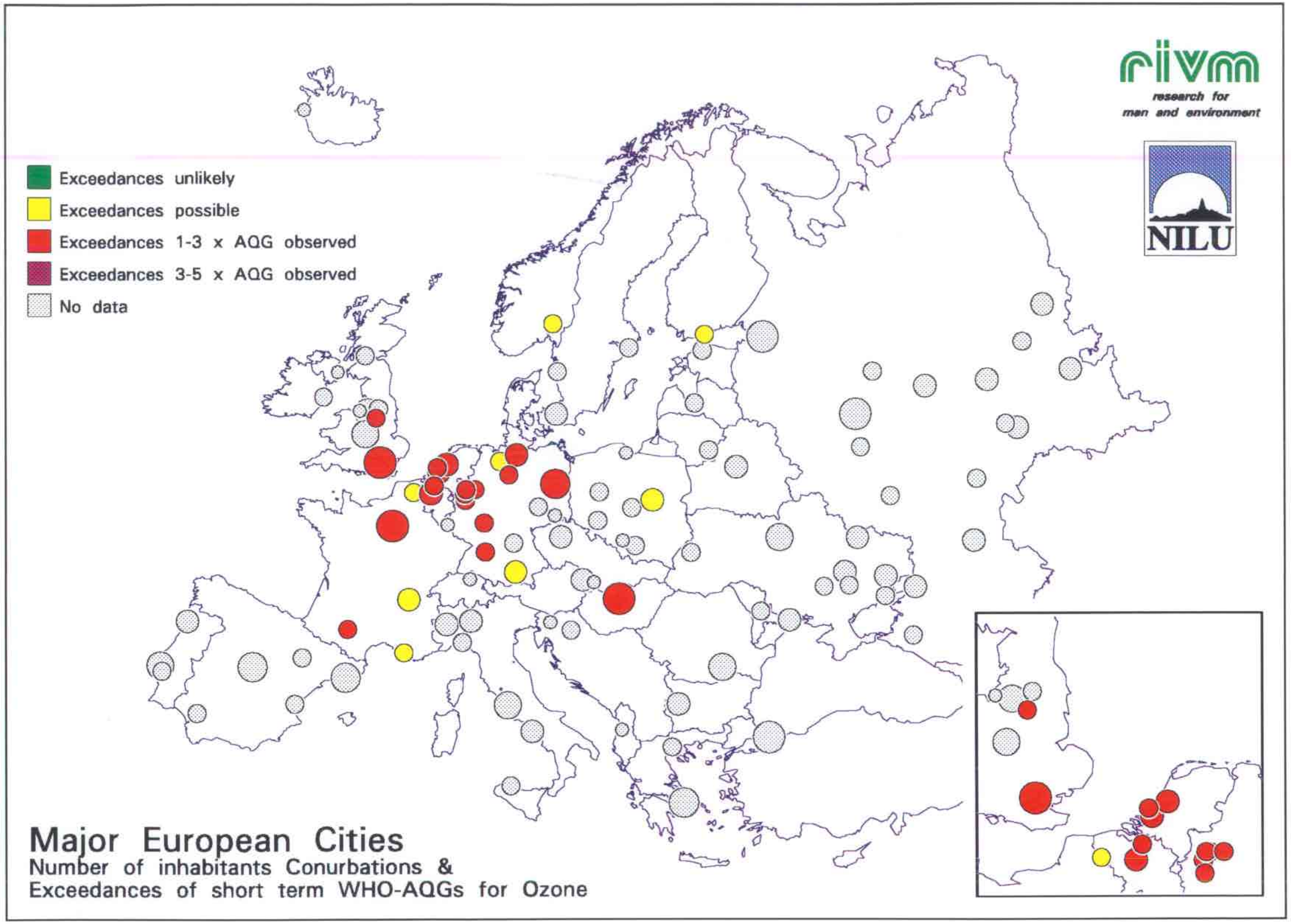
research for
man and environment
NILU
Exceedances unlikely
Exceedances possible
Exceedances 1-3 x AQG observed
Exceedances 3-5 x AQG observed
No data
Major European Cities
Number of inhabitants Conurbations &
Exceedances of short term WHO-AQGs for SO2 and/or PM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Exceedances unlikely
Exceedances possible
Exceedances 1-3 x AQG observed
Exceedances 3-5 x AQG observed
No data
Major European Cities
Number of inhabitants Conurbations &
Exceedances of short term WHO-AQGs for Ozone

3.6 Population exposure estimates and classification

S. Larssen, H.C. Eerens, K. v. Velze

The term "population exposure" is here defined as follows:

- The number (or fraction) of the inhabitants experiencing concentrations of air pollution compounds within given concentration ranges.

  The cumulative population exposure distribution gives the percentage of the total population exposed to concentrations above given values.

The second questionnaire to the cities included a section on the exposure of the population to air pollution concentrations above air quality guidelines. No cities provided such information.

People are exposed to air pollutants at home, during commuting on roads, at work and other places. The correct mapping of pollution exposure requires data on:

- Spatial concentration distribution, and its variation with time
  - city background
  - along main road network
  - near other hot spots, such as near industrial areas.

- Population distribution (residences and workplace), and the number of commuters, and time-dependent travel habits.

The data base for population exposure calculations are most often not complete. A methodology has to be developed for each specific study, dependent upon its scope.

It was decided in this study to put the main emphasis on residential population exposure. The basis for estimating this was made up by the measurement data from city background measurement sites. For quite a few cities, measurements from "hot spot" sites (traffic-exposed sites, industrial area sites) were also available. However, such sites do not as a rule provide a representative picture of the "hot spot" concentration levels in the city, and it would not be possible within the scope of this study to estimate the fraction of the population exposed to "hot spot" concentrations.

Regarding the residential population exposure, a rough estimation method had to be developed, bearing in mind that an estimate had to be made for each of the 88 cities for which concentration data were available. There were no data on the spatial distribution of the population in the cities, and only sparse information of the actual location of the city background measurement sites.

The method which was developed to estimate the fraction of the population in a city exposed to concentrations above air quality guidelines, was based on the following assumptions:

- The city background sites are located in the part of the city with the generally poorest air quality, for the compound in question.

- The higher the maximum concentrations are above the guideline, the larger is the fraction of the population above the guideline.
- The larger the number of measurement sites, the better can the exposure situation be described.

The rough method which was developed is shown in **Figure 3.9**, including some examples. The example figure concerns exposure above the 24 h air quality guideline of SO_2.

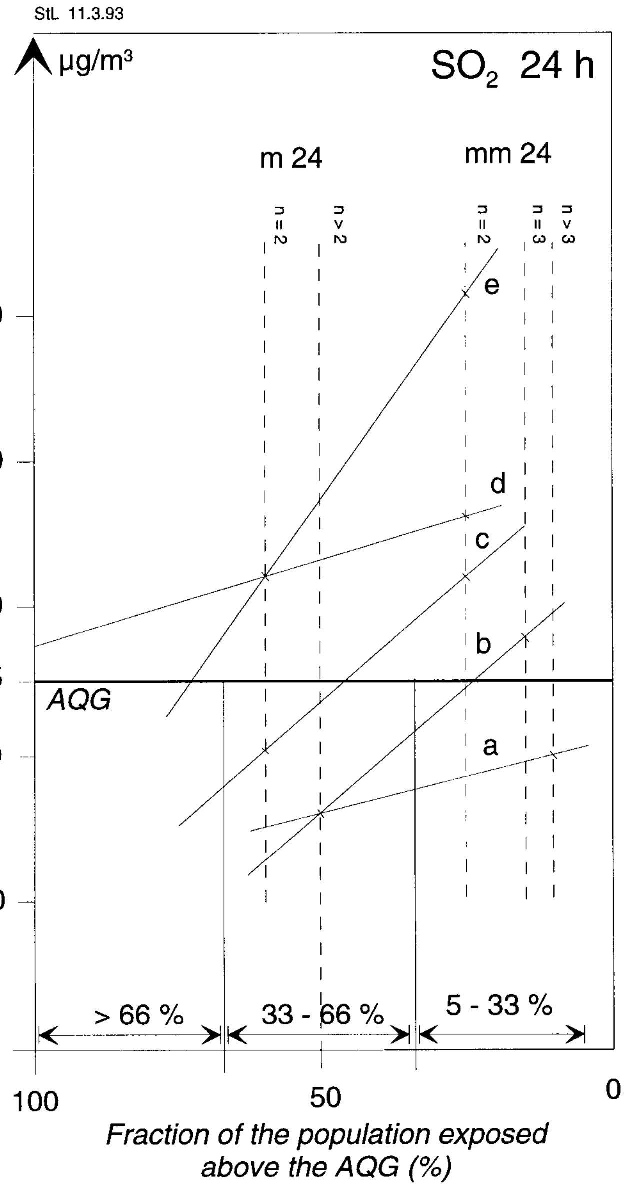


Figure 3.9 Visualisation of the method to estimate the fraction of the population exposed to air pollution concentrations above the air quality guideline (AQG). Example: 24h SO_2 concentrations. The figure includes the example calculations described in the text below.

<u>Explanation:</u>

m24 : Maximum 24 h concentration, averaged over all city background stations.
mm24: The maximum 24 h concentration measured at any of the city background stations.
n : Number of city background stations.

Description of the examples:

Line a n=4 m24 = 80 µg/m3 mm24 = 100 µg/m3	All stations are below the AQG. Exposed fraction = 0% → 0-5% → 0%
Line b n = 3 m24 = 80 µg/m3 mm24 = 140 µg/m3	The average m24 is well below the AQG, but the highest station is above AQG. Estimated exposed fraction: 23% → 5-33% → 25%.
Line c n = 2 m24 = 100 µg/m3 mm24 = 160 µg/m3	The average m24 is below the AQG, while the highest of the two stations is well above the AQG. Estimated exposed fraction: 45% → 33-66% → 50%.
Line d n = 2 m24 = 160 µg/m3 mm24 = 180 µg/m3	The average m24 is well above the AQG, and the two stations are fairly equal in concentration level. This indicates a rather flat spatial concentration distribution. Estimated exposed fraction: 100% → ≥66% → 75%.
Line e n = 2 m24 = 160 µg/m3 mm24 = 260 µg/m3	The average m24 is well above the AQG, and the highest of the two stations is more than double the AQG. This indicates a steep gradient in the spatial concentration distribution. Estimated exposed fraction: 70% → ≥66% → 75%.

3.6.1 Winter-type smog exposure classification

The exposure estimate is performed for SO_2 and suspended particulates separately (i.e. the winter smog indicators), and the city is given the exposure class which is the highest of the two calculated (i.e. the highest of the SO_2 or suspended particulates exposure). The results of the exposure estimation is given for each city in **Annex VII. Map 17** presents the geographical distribution of the winter-type smog exposure classification. Cities with a high percentage of their population potentially exposed to the exceedances of the WHO-AQGs for winter-type pollutants are primarilly found in Central and Eastern Europe.

The figure for total estimated population in these cities exposed above short-term AQGs for SO_2 and/or particles, at least once a year (actually in 1990), is about 56 mill. people. The total population in the cities so analysed is 116 million, of the 150 million inhabitants in all cities involved. The exposure is not included for the following cities, for which proper data were not available:

> Birmingham, Chisinau, Copenhagen, Gdansk, Genoa, Glasgow, Katovice, London, Madrid, Milan, Naples, Palermo, Tallin, Thessaloniki, Vilnius, Warsaw, Wroclaw, Zaragoza.

The m24 and mm24 values are plotted on the vertical lines, according to the number of stations (n). Where the line drawn between the points crosses the horizontal line of the AQG, the estimated fraction of the population exposed above the AQG can be read from the x-axis.

Considering the limited accuracy of the method, the exposed fraction is then classified within the classes 0-5%, 5-33 %, 33-66 %, >66 %. Finally, to calculate the number of people exposed, the estimated fraction ranges were translated to class values:

Exposed fraction:

0- 5 %	→	0 %	if hot-spot < AQG
0- 5 %	→	5 %	if hot-spot > AQG
5-33 %	→	25 %	
33-66 %	→	50 %	
>66 %	→	75 %	

When n=1, the fraction is estimated based on the mm24 at the one station, relative to the AQG.

The position of the vertical lines on the horizontal axis is determined based on the following considerations:

- For 3 or more stations (n>2), if m24=AQG, it is considered that 50% of the population is potentially exposed to the exceedance of the AQG, irrespectively of the value of mm24.

  For n=2, and m24=AQG, it is considered that more than 50% is potentially exposed to the exceedance of the AQG. The value of 60% has been chosen.

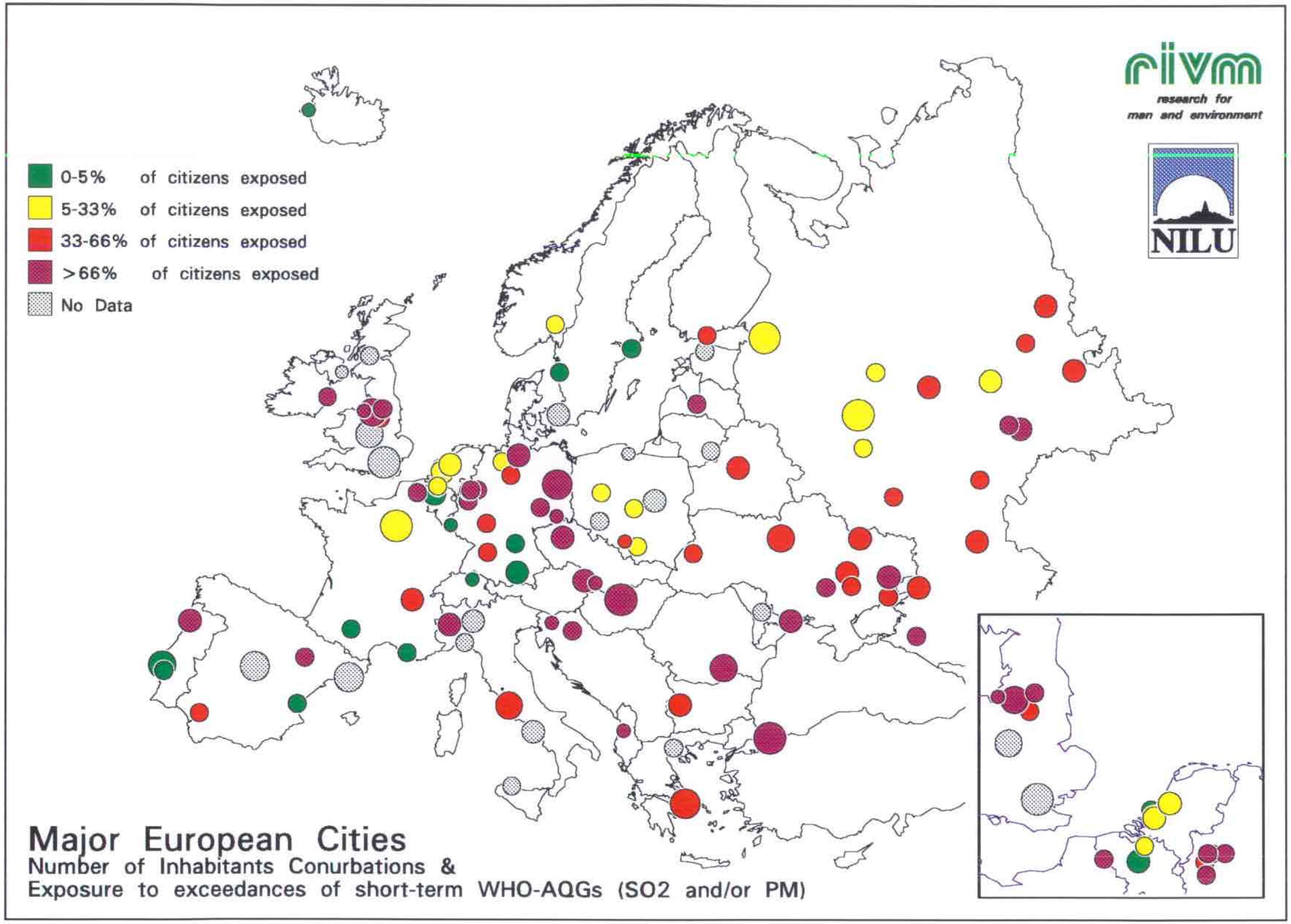
- For two stations (n=2), if mm24=AQG, it is considered that 25% of the population is potentially exposed to the exceedance of the AQG, irrespectively of the value of m24.

  For n>2 and mm24=AQG, it is considered that less than 25% of the population is potentially exposed to the exceedance of the AQG. 15% and 10% has been chosen, for n=3 and n>3 respectively.

This is a rough method suited to limited extent of monitoring data available. It is believed that the method picks up the 1. order of variation in the magnitude of population exposure between the various cities. The method should be tested for cities, where, based on extensive monitoring and modelling data, exposure estimate have been made by more accurate methods.

Exposure to suspended particles above air quality guidelines is a larger problem in European cities than exposure to SO_2.

There was not sufficient city data available to calculate the extent of exposure to high ozone concentrations (the indicator for summer smog).


0-5% of citizens exposed
5-33% of citizens exposed
33-66% of citizens exposed
>66% of citizens exposed
No Data
Major European Cities
Number of Inhabitants Conurbations &
Exposure to exceedances of short-term WHO-AQGs (SO2 and/or PM)
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research for man and environment
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3.7 Evaluation of natural and man-made environmental indices

R.J.C.F. Sluyter

The data gathered for this project currently do not permit a fully quantitative analysis of possible correlations between indices and air quality statistics. Indices are ordinal rankings and were intended and used only to describe possible differences in the air quality situation between cities. A few tests have been conducted, however, to study the correlations between natural and man-made environmental indices and urban air quality. They are described in this section.

In Figure 3.5 the calculated MSP-W was plotted against the number of days the short-term WHO-AQG for SO_2 was exceeded in 1985. Cities have been grouped according to their emission environment in those having relatively low and high SO_2 emission densities. There appears to be no correlation between MSP-W and cities with low emission densities. Cities with a high emission density show a correlation with MSP-W. In cities with a low emission density regional contributions to the concentration field can make a substantial part of the urban concentration field. MSP-W at the moment is based only on local meteorological conditions, the regional advective component will have to be added. Furthermore, the smog index will have to be tuned to observed exceedances. To be able to do so more concentration data, preferably for more years, are needed.

The relation between the size of the city and city background concentrations has been subject to research in the Netherlands. Significant correlations have been found between urban radius and the urban contribution to the total concentration field on city background locations. In Figure 3.10 the urban radius for 5 Dutch cities is plotted against the contribution of the city to the 98 percentile for NO_2. This contribution was found by subtracting the regional background concentration from the urban concentration. Data gathered in the framework of this project does not allow this kind of analysis.

Figure 3.11 presents the average number of exceedances for SO_2 or TSP (average city background concentrations) in recent years (1989-92) plotted against the defined natural and man-made sensitivity. Both sensitivity indicators correlate with the measured exceedances. This implies that cities with the same emissions and size but located in different parts of Europe (different meteorological smog potential values) can experience completely different exceedance figures. Urban air pollutant abatement strategies, when set internationally, should have to take this into account.

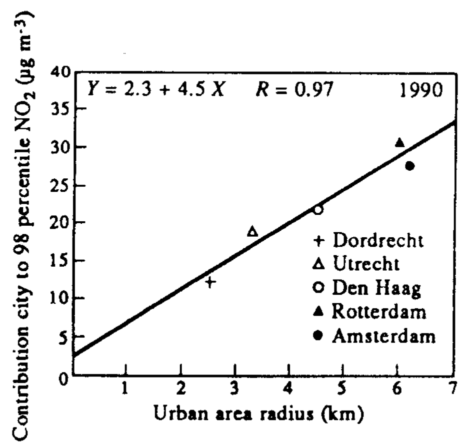

Figure 3.10 Relation between the urban radius and contribution of the city to the 98 percentile NO_2 concentrations (Eerens, *et.al*, 1993).

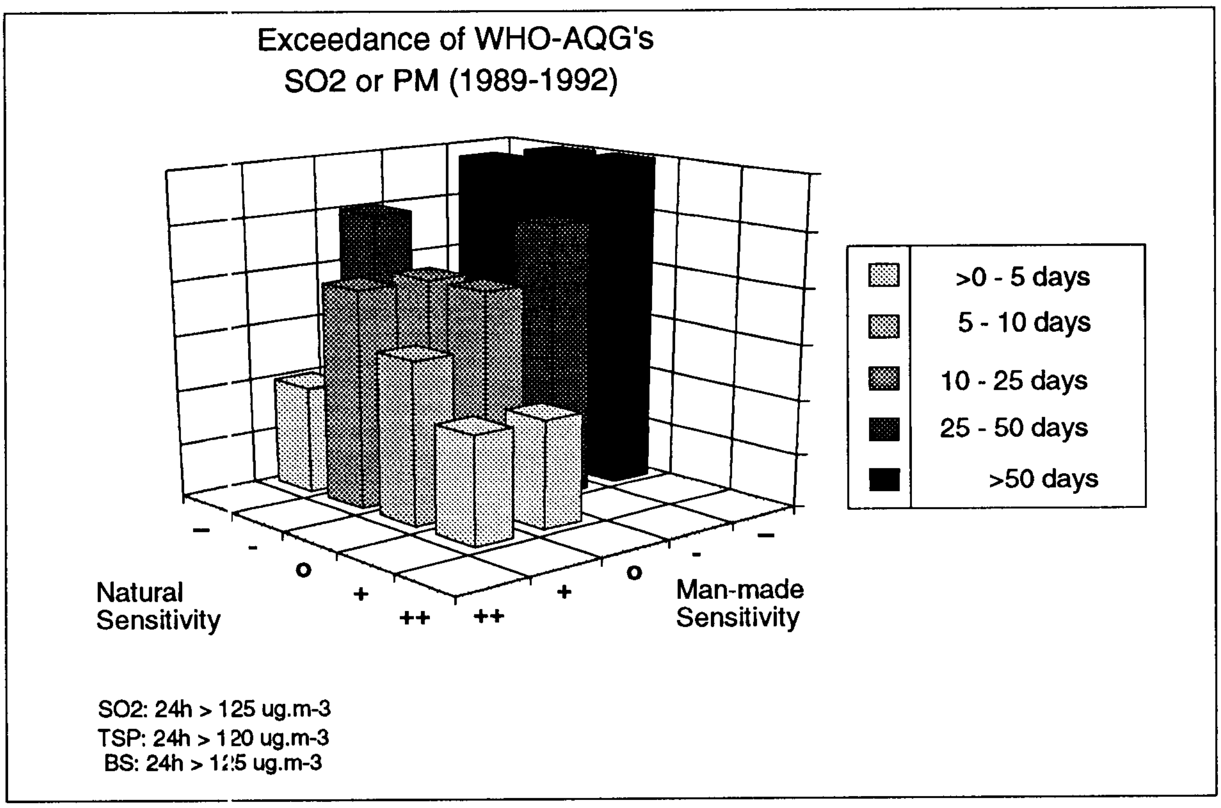

Figure 3.11: Exceedance of short-term WHO-AQGs for SO_2 or PM (winter-type smog pollutants) in recent years. Natural sensitivity: meteorological winter smog index and siting of the city, man-made sensitivity: environmental pressure and emission density (SO_2 or PM).++:most favourable --:most unfavourable

3.8 Comparison of results with CET study

S. Larssen, B. Lübkert-Alcamo

Short description of the CET-study

The WHO study 'Concern for Europe's Tomorrow" (WHO, *in press*) also provides estimates the extent of exposure of the European population to air pollution concentrations above the WHO air quality guidelines.

As part of that study, WHO developped a general concept for exposure assessment to major ambient air pollutants. A seperate estimate of air exposure was made for populations living in urban agglomerations with more than 50 000 inhabitants on the one hand, and in smaller towns and rural areas on the other hand. The WHO exposure estimates are based on outdoor ambient air pollution levels, and it was assumed that the ambient concentrations used were representative of the air pollution levels to which people are exposed during their daily activities.

The CET study includes exposure estimates for the following pollutants: SO_2, NO_2, O_3 suspended particulates (TSP and BS) and Lead. Urban exposure was estimated for the population of all large urban areas in Europe with more than 50 000 inhabitants, i.e. 314 million people out of a total European population of 700 million people west of the Ural mountains. The present study considers, as described previously, app. 150 of these 700 million people living in 105 European cities with more than 500 000 inhabitants.

Air quality data from several, mainly international networks were analysed (including the EU Exchange of Information (APIS), UN ECE EMEP, UN ECE Cooperative Program on effects on Materials) and long-term (annual) average data were collected through a WHO questionnaire sent to national focal points in all Member countries.

Based on daily or hourly data available for a part of these cities (APIS; also used in the present study), regression models were developed and applied to describe the relationships between annual average values and the amount and frequency of the exceedance of the short-term AQG levels. These regression equations were then used to estimate the exceedances of daily or hourly AQG levels for all cities which had measured annual average pollution levels available. In addition, the exceedances of the annual AQG levels were calculated directly from the yearly data. Population exposure calculations were made for those cities with annual data by matching population data with computed exceedances. These results were expressed as a fraction of the population exposed to exceedances, and were further extrapolated to the remaining cities in Europe.

For the rural population, the exposure was computed based on population densities in the 150 x 150 km^2 transport UN ECE EMEP modelling grid and ambient air concentrations in the same grid calculated with longe range models: the EMEP models for SO_2, NO_2 and O_3 (Sandness and Styve, 1992; Simpson, 1991), and the TRACE model for lead, cadmium and arsenic (Alcamo et al., 1992). These models calculate rural background concentrations in air at specified time intervals (dependent on the pollutant, as 6-hourly or annual averages). The CET study used the computed excess pollution levels and frequencies of exceedance of given annual, daily, or hourly AQG levels to compute population exposure by matching population data in the rural areas with these exceedances. Results are thus geographically-explicit for any area within Europe.

Comparison of results

Comparitive results from this study and the CET study are given in Table 3.8. TSP exposure estimated in the CET study is also shown.

Table 3.8: Study comparison

	Number of cities with data[1]		**Population in those cities (in millions)**		**% of population in these cities exposed above AQG**		**AQG** $\mu g/m^3$
	this study	**CET study**	**this study**	**CET study**	**this study**	**CET study**	
SO_2							
24h guideline	78	180	116	88	24	45	125
1 year guideline	76	180	116	88	-	20	50
Black smoke							
24h guideline	77		116	-	43	-	125
1 year guideline	-	96	-	71	-	23	50
TSP							
24h guideline			-	29	-	95	120
1 year guideline			-	29	-	61	60

1 This study, cities with population >0.5 million; CET, cities with population >50 000.

The population exposure estimates from this study and from the CET study are only partly based on the same data basis. The main source of data in this study is the data from the questionnaires filled in by each city.

The methodologies of exposure estimating are different, as described. For SO_2, CET extrapolated results to the entire European population which gives an exposure of 34% of the total population.

The selection and number of cities included in the exposure estimating procedure was different in the two studies. This study considers only cities with populations above 500 000. The CET study considered cities with populations above 50 000.

It is thus to be expected that the resulting estimates of the portion of the population living in areas with concentrations exceeding guidelines are different. Nevertheless, both studies give estimates somewhere within the range of 25-50% of the population in the cities considered are exposed to concentrations exceeding the WHO-AQGs

3.9 Local industrial pollution

S. Larssen

The extent, completeness and representativeness of the information from the industrial questionnaire varied. A summary of the information that could be extracted from the questionnaires and from the other sources referenced in Section 2.3.6 is given in **Annex XI**. For the countries not included in the Annex, there was either no information available (Belarus, Slovakia, former Yugoslavia, Lithuania, Ukraine, Lichtenstein, Luxembourg), or the answer from the national focal point indicated there was no local industrial air pollution problems (Denmark, Iceland, Ireland, Sweden, Switzerland).

Constraints in time and resources prevented us from extending the information given, through a follow-up questionnaire. It would be desirable to extend the data base, and to evaluate the representativeness and quality of the data given. We believe, however, that the information obtained, as a whole give a reasonably extensive review of local industrial air pollution problems in Europe, and the extent of the population which are potentially affected.

By far, the most severe exposures to high pollution concentrations occur in Central and Eastern European countries, where in several industrial areas, largely uncontrolled industrial emissions from old type processes result in very severe exposure of nearby population and vegetation to harmful air pollution. In most of the EC and EFTA countries, efforts to clean up industrial emissions have substantially reduced such problems, but here also industrial areas with air pollution exposure exceeding WHO-AQGs still exist.

Table 3.9, which is an extract of **Annex XI** and other sources, shows that high exposure to SO_2, TSP and other compounds associated with specific industries occur in all parts of Europe. SO_2 concentrations above 1000 $\mu g/m^3$ as 1h average are not uncommon. Extreme SO_2 exposure have occurred in recent years (and may still occur) for example in Zlatna and Baia Mare (Romania), Asenovgrad (Bulgaria), Sokolov and Teplice regions (Czech Republic) and in Torun (Poland), with annual averages around 500 $\mu g/m^3$ (Torun, Asenovgrad) and 24 h averages in excess of 6000 $\mu g/m^3$ (Baia Mare). Non-ferrous metal industries (Cu, Al) and coal-fired power plants are those industries which are most often responsible for very high local industrial pollution in Europe.
Annex XI lists the number of people affected by particular sources according to the questionnaire responses. Since it is often unclear whether this number represents the potentially affected population or those actually exposed, total numbers affected by local industrial emissions in Europe cannot be estimated.

Table 3.9: Extract of available data on local industrial pollution in Europe (maximum concentrations reported, data from recent years).

Country	Max. concentration measured (µg/m³)	Area, type of industry
Eastern/Central Europe		
Bulgaria	2 200 (SO_2, 1 hr)	Sofia. Non-ferrous metals
	485 (SO_2, year)	Asenovgrad
	530 (TSP, year)	Dimitrovgrad. Cement
	870 (SO_2, max month)	Pirdup Zlatiza. Non-ferrous metal
	Very high H_2SO_4	Pirdup Zlatiza
	248 (NH_3, max month)	Devnis. Fertilizer, PP
	290 (H_2SO_4, max month)	
	1 350 (SO_2, max 24 h)	Copsa Mica, Sibin. Non-ferrous metal
Croatia	90 (SO_2, year)	Rijeka. Petr. refinery
	381 (SO_2, 24 h)	Zagreb. PP (oil)
	608 (TSP, 24 h)	Zagreb. Cement ind.
	817 (NH_3, 24 h)	Zagreb. Fertilizer
Czech Republic	1 500 (SO_2, 24 hr)	Sokolov. Brown coal industry/power
Hungary	94 (SO_2, year)	Dorog. Chem.ind./mining
	146 (SO_2, winter)	Tata. Al.smelter
Latvia	500 (SO_2, "short term")	Daugavpils. Chem.ind.
Poland	584 (SO_2,, year)	Torun
	477 (TSP, year)	Katowice. Steel, coking, PP
	0.17 (BaP, year)	---"---
Romania	285 (TSP, year)	Bucharest. Non-ferrous metals, PP, chem.ind.
	128 (SO_2, year)	Zlatna. Al smelter
	3 020 (SO_2, year)	Zlatna. Al smelter
	6 440 (SO_2, max 24 h)	Baia Mare. Non-ferrous metall
	57 (Pb, max 24 h)	Baia Mare. Non-ferrous metall
	890 (NH_3, max 24 h)	Bacau. Fertilizer, chem., petrochem. ind., Power plants
Slovenia	1 400 (SO_2, ½ h)	Ljubljana, Thermal PP (coal), various small industries, (+ domestic coal use).

(Table 3.9 continued)

Country	Max. concentration measured (µg/m³)	Area, type of industry
Southern Europe		
Greece	377 (SO_2, 24 h-98P)	Thessaloniki
Italy	168 (SO_2,24 h-98P) 220 (TSP, 24 h-98P)	Marghera area, Veneto
Portugal	686 (SO_2, 24 h-98P) 466 (TSP, 24 h-98P)	Barreiro-Seixal Barreiro-Seixal
Spain	500 (SO_2, 24 h-98P) 499 (TSP, 24 h-98P)	Cartagena. Iron/steel, metallurgy Cartagena. PP, chem.ind.
Western Europe		
Austria	780 (SO_2, 30 min)	Lenzing. Viscose, pulp/paper.
Belgium	2 000 (SO_2, 30 min) 1.6 (Pb, year)	Antwerp. Oil refinery, PP, chem.ind. Hoboken. Lead smelter
France	955 (SO_2, 24 h-98P) 150 (TSP, 1 h-98P)	Salsigne Le Havre. H_2SO_4, petrochem, oil refinery, metallurgy
Germany	220 (SO_2, annual av.) 790 (SO_2, 24 h-98P) 2.4 (Pb, year)	Merseburg Klingental Brauback. Lead smelter
the Netherlands	6.3 (HF, 24 h)	Delfzijl. Al.industry
United Kingdom	122 (SO_2, 24 h-98P) 348 (TSP, 24 h-98P) 3.6 (Pb, year)	Newry Sunderland Walsall. Lead smelter
Northern Europe		
Finland	630 (SO_2, 1 h-99P for max. month)	Harjavalta. Copper smelter
Norway	1 000 (SO_2, 1 hr) 4 (PAH, 24 h)	Ålvik. Ferroalloy Årdal. Al.industry

3.10 Exposure of materials, buildings and cultural heritage

J.F. Henriksen

Most building materials and historic monuments are subject to deterioration caused by combined reaction of a number of meteorological and atmospheric chemical factors. Basically this deterioration occurs by natural processes, in the absence of human influences on the environment. However, both empirical experiences and systematic field and laboratory studies have shown that polluted urban and industrial atmospheres increase the deterioration processes.

For some materials such as structural metals such as steel, zinc, copper and aluminium, quantitative dose-response relations describing the corrosion rate as a function of, *inter alia,* sulphur dioxide concentrations, chloride deposition rates, and climatic factors such as time of wetness. For other materials such as coatings, rendering and calcareous stones the effect is known, but the knowledge of the pollution effect has a more preliminary character.

The greatest part of the built society and our cultural heritage are situated in areas which are characterised as urban or industrial. This shows that deterioration of materials caused by air pollution have both cultural, economic and technological implications. Both at national and international levels these thoughts have led to extensive research programmes in order to quantify the problem, to describe processes and to find solutions. At the international level political commitments have been signed by several organisations, including the Economical Commission for Europe (EEC) and the Council for Europe.

In Europe the EUREKA umbrella research programme EUROCARE aims to co-ordinate efforts for combating outdoor and indoor environmental degradation of the European cultural heritage, building stock, and other objects and material structures.

The umbrella project covered by September 1992 an activity of about 30 research projects.

An important fact in the science of materials is that materials never last for ever. To maintain the cultural heritage as well as the rest of the building stock we must be able to predict the deterioration, in order to plan the protection and maintenance. For this purpose, the international building research and material testing organisations CIB and RILEM are working on the combination of field exposure data with environmental data, to establish the practical service life and recommended maintenance or replacement intervals.

For a full appraisal of the materials damage due to air pollution, the following elements are needed:

- Quantitative dose-response relationships which describe the effects of air pollutants on materials.
- Data for the amount of materials at risk, grouped in relation to their exposure to air pollutants.
- Economic evaluation of the damage, calculated on the basis of extra maintenance or replacement costs.

These aspects are discussed in the following chapters, together with a short discussion of historical monuments.

3.10.1 Dose response characteristics

The input needed for this service life concept is collected from many sources and several international research programmes. The effect of SO_2 on metals has been described in ISO 9223 "Corrosion of metals and alloys - Corrosivity of atmosphere Classification". The classification system defines four severity classes for sulphur dioxide, four classes for chloride, and five classes for wetness impact. The environmental classes are correlated to corrosivity categories for structure materials such as steel, zinc, copper and aluminium.

In two different international exposure programmes in Europe the deterioration of different materials are studied:

- **UN-ECE international co-operative programme on effects on materials, including historic and cultural monuments;**
  aims to perform a quantitative evaluation of the effect of sulphur dioxide in combination with NO_2 and other pollutants, as well as climatic parameters.

  Several materials also calcareous stones and painted wood are exposed outdoors on 39 test sites. The programme has been run for 6 years and material results included are from 1, 2 and 4 years of exposure. The field test sites and the results from calcareous sandstone are shown in Figure 3.12

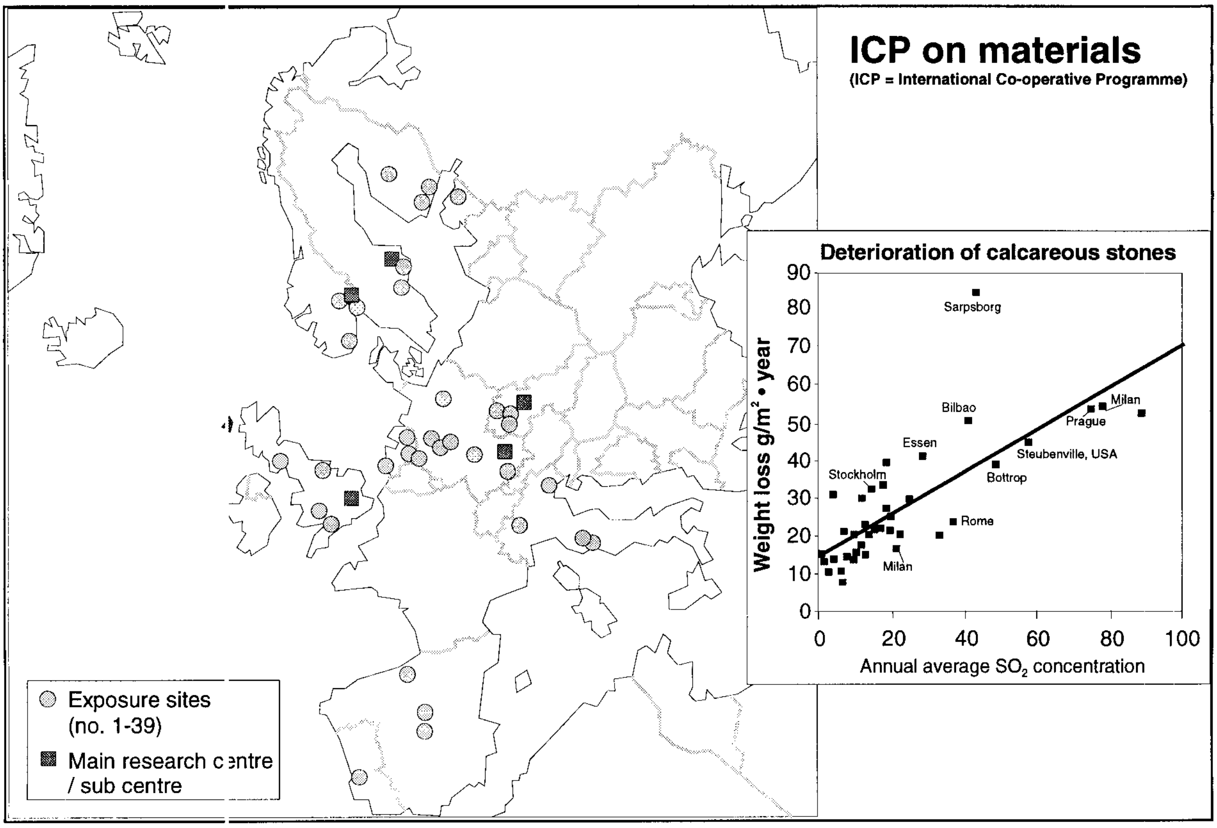

Figure 3.12 Exposure sities within the International Co-operative programme on materials and the relation between annual average SO_2 concentration and yearly weight loss of calcareous sandstone.

- **"STEP-project: conservation of historic buildings, monuments and associated cultural property".**
  The project focus on stone materials, their decay and code of practice for conservation. Both exposure studies, chamber studies and case studies are included and the project involves people from 14 different institutes and universities in Europe.

3.10.2 Inventories of materials

To assess the importance of the pollution impact on the building stock we need to know the quantity of material at risk in different areas and the cost for repair or for maintenance of the material. The first approach in this direction was made in the late 1970's (OECD 1981). The most uncertain part in this report was the calculation of the material at risk. Several groups have tried to improve that type of information later (Stakunas, 1983; Leman group, 1985; ECOTEC, 1986).

The latest study has been a "three cities study" Prague, Stockholm and Sarpsborg, where results were published at the 10th European Corrosion Congress in Barcelona 1993. In this study the amount of material was calculated from inspection and measurements for the outdoor building materials found in a statistical drawn group of houses in the cities. To have comparable costs the prices for replacement and maintenance used in Sweden was used for all cities. The types of materials found was recorded for different building categories and the total amount of materials of the different groups of materials in the cities are shown in Figure 3.13. The figure shows that there are some similarities and some differences in the use of building materials. There are more similarities between the two Scandinavian cities than with Prague. The biggest deviations are observed on wood, metal and rendering.

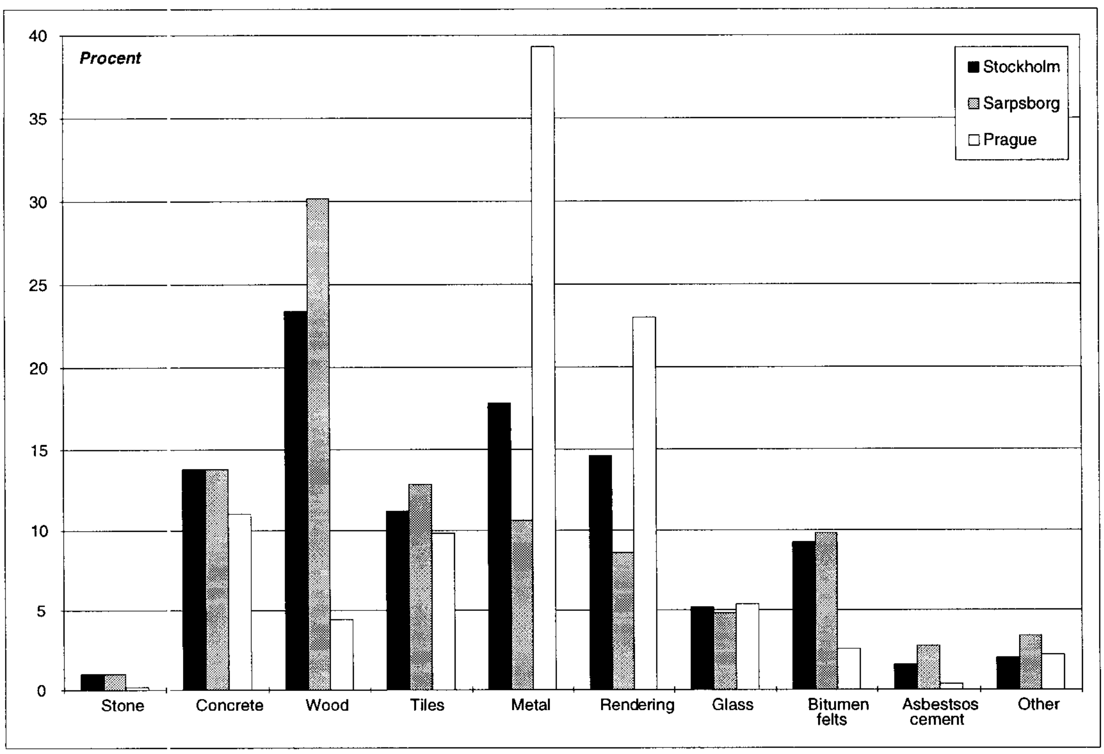

Figure 3.13: Types and percentage of materials used in buildings for three cities.

The use of sensitive materials such as metal and rendering in Prague and the higher pollutant level in the city is reflected in the calculated costs found. The cost of material losses and maintenance calculated as cost per inhabitant in the three cities gave:

For Prague	:	760 SEK/year	≈ 95 ECU/year
For Stockholm	:	140 SEK/year	≈ 23 ECU/year
For Sarpsborg	:	360 SEK/year	≈ 45 ECU/year

3.10.3 Historic buildings and materials

A main concern stated in all the international agreements signed is the increased deterioration of historic building and monuments observed the last decennaries. Many of the most prestigious cities and monuments in Europe are situated in heavily polluted areas. Examples are Acropolis in Athens, and cities such as Cracow and Venice on the UNESCO cultural heritage list.

To estimate the value of the cultural heritage is complicated and different approaches have only been done for specific monuments, such as the statue of liberty in New York. One often used way to assess the value is the "willingness to pay" concept, where people are asked how much they are willing to pay to keep the monument. For some monuments the price for a later restoration work done can be documented. However, before the society realises that all prestigious buildings and monuments need a maintenance programme as described in the service life concept, realistic costs for the cultural heritage in Europe will not be available.

The cost of repair and maintenance for a single historic building will normally be substantial. However, compared to the rest of the built society the historic buildings will only represent a small fraction of the total costs in Europe. For local areas, such as in Venice, the picture will be different and the costs of historic buildings will influence the budget in a much more drastic way.

3.10.4 Concluding remarks

As shown in the "three cities project" there are a substantial difference in the material used in the built society in Scandinavia compared to Prague. Another change in the material used is observed when moving to the west in Europe, where brick buildings without rendering are more dominating. To obtain sufficient data for a complete evaluation of the material costs for Europe is for the time being impossible.

However, as a guidance value for European cities the cost per inhabitant most probably will be on the range between the cost in Stockholm and Prague. Since roughly 1/2 of the population of Europe lives in cities, and the population in Europe including East Europe and the European part of Russia is about 730 million people, a low estimate by using the cost from Stockholm (23 ECU/year) will give material damage costs for Europe up to 8 billion ECU annually.

4 Conclusions and recommendations

Urban environmental data quality and availability

This report documents the research conducted into urban and local air pollution in Europe, carried out in the framework of the Europe's Environment programme. The study was the first European comparative urban air quality assessment carried out for a large set of cities. To be able to conduct the research, city-specific urban environmental data was needed for 105 selected major European cities. Data was collected from international data bases and through questionnaires.

The European Union has a data base containing raw air quality measurement data (APIS). Although this data base proved to be a valuable source of information, the importance of the data base in the future could be much greater if information on siting and monitors is included. Information on siting and monitors for all EU monitoring sites is available through the GIRAFE data base. The GIRAFE data base should be linked with APIS.

To date, no complete international urban environmental data base exists. Such a data base, preferably established by an international organisation such as EU-EEA, is indispensible for future urban air quality assessment studies. The data base should at least contain emission estimates, air quality data and population and area data.

As far as population, area and meteorological data are concerned, a complete data set is now available. The availability of emission data varied between 29 and 45% of cities, depending on the component. Not all cities, however, had emission figures covering all source categories.The availability of air quality data within this project varied between 33 and 79% of cities, depending on the component.

Urban environmental data collected are not consistent between countries or sometimes even between cities in one country due to differences in inventory methods. To overcome this data inconsistency, municipal authorities should be encouraged to collect urban environmental data in a standard way. Tools (e.g. standard questionnaires, dispersion models) to collect urban environmental data and to assess urban air quality on the basis of this information should be disseminated.

Basic urban environmental data is in most cases available only for the "administrative" city. To be able to assess the urban air quality situation an unconventional breakdown of statistics is needed on the basis of the "physical" city or conurbation. It proved to be difficult to generate data matching the conurbation concept. For future comparative urban assessment studies, at least a translation tool will have to be developed to aggregate data based on administrative units to data based on urban "physical" units.

All selected cities have an operational air quality monitoring network. However, measurements are often difficult to compare between cities because of the differences in monitoring strategies applied within countries and sometimes even between cities in one country. Harmonisation of monitoring activities between cities, not only as far as measurement techniques are concerned, but also regarding siting of stations, should be encouraged. This is especially the case for cities in the former Soviet Union, where air quality monitoring is carried out 3-4 times a day with out-dated equipment. In view of the extent of urban environmental problems in many cities of the former Soviet Union, new monitoring programmes or at least extensive inter-comparison programmes with (automatic) continuous monitoring sytems should be seen as a priority.

Urban environmental indices

The inventory of natural and man-made environmental characteristics proved to be a promising tool to study the individual and combined influences of environmental indices on urban air quality and to be able to find (dis)similarities in environmental conditions of cities in different parts of Europe. Further development of environmental indicators and tuning of these indicators against observed air quality statistics (indicators) should be encouraged. In addition to the environmental indicators, the relation between economic indicators and urban air quality can provide additional insight into the urban air quality problems of (European) cities.

Natural urban environmental conditions such as topographical siting and meteorology are important factors determining the urban air quality climate, especially when considering pollution episodes. In view of future international emission reduction plans, cities with unfavourable natural environmental conditions should be identified more precisely, since stricter emission regulations will be necessary to meet air quality standards against.

Air pollutant concentrations

Easy-to-calculate air quality indicators, are useful to study past, present and future trends in urban air quality, and to compare the air quality situation in a large number of cities. Air quality indicators reflecting typical urban problems and processes should be further developed, taking internationally agreed air quality guidelines such as those from WHO as a starting point.

Although considerable improvement in local air quality has been achieved in many cities in recent decades, the collected urban air quality data suggests that in almost all cities at least one WHO-AQG is exceeded in a year with average meteorological conditions. Similar exceedances may occur in smaller cities. These exceedances indicate possible human health risks to which citizens are exposed, especially in the heavily polluted cities of Central and Eastern Europe.

Air quality data was basically collected for the years 1985 and 1990. Some cities reported data for other years. The assessment made is based on these data.

Annual average SO_2 concentrations have fallen considerably over large parts of Europe during the last years (1985-1990). In 1990, the long-term WHO-AQG was exceeded in 13% of the cities for which SO_2 data is available. Approximately 15% (16 million) of the total urban population in this sample (N=78 cities) are potentially affected by these exceedances. In 51% of all Central European cities (N=13), the long-term WHO-AQG was exceeded. Maximum 24h levels at city background locations still exceeded the short-term WHO-AQG in 43% of all cities for which data is available (N=76) on one or more days. These exceedances are not confined to Central European cities; they are also observed in the Western and Southern regions.

Annual average particulate matter concentrations (measured as Total Suspended Particulates (TSP) or black smoke) show a mixed trend in Western, Northern, Southern and Central European cities during recent years (1985-1990). In some cities a (slight) upward trend is visible, in others a (slight) downward trend. Cities in the former Soviet Union (FSU) report very high TSP concentrations, but concentrations follow a downward trend in most cities. Only 15 cities had black smoke data available. The long-term WHO-AQG for black smoke is exceeded only in Tirana and Istanbul. Average maximum 24h particulate matter city background concentrations exceeded the short-term WHO-AQG in 86% of all cities for which data is available (N=77) in 1990. These exceedances are observed in all European regions. In busy streets and especially near industrial estates observed maximum 24h levels can even be extremely high.

Annual average NO_2 concentrations in Western European cities (N=22) in 1990 were 46 $\mu g/m^3$ with a standard deviation of only 6 $\mu g/m^3$. Average concentrations in the FSU are the same as in Western European cities, but differ more from city to city (N=26, average 46 $\mu g/m^3$, standard deviation 22 $\mu g/m^3$). Exceedances of the short-term WHO-AQG (24h) at city background locations have been observed in Manchester, Stuttgart, Katowice, Prague, Warsaw and Ufa (6 of the 40 cities with data) during the reported years.

Annual average Pb concentrations at ***hot-spots*** (mostly busy streets) in most cities are below the lower limit of the WHO-AQG (annual average 0.5 $\mu g/m^3$). Of the 49 cities from which recent (1989-1992) monitoring results were available, the lower limit of the WHO-AQG was exceeded in only 5 cities.

Ozone, representing photochemical smog, is at present monitored only in a limited number of (West) European cities. Available data suggest that high ozone concentrations may occur in many cities, especially in residential districts. Due to large spatial variations in urban emission density (traffic intensity), the spatial variation of ozone levels will be higher than in rural areas. Ozone monitoring in urban areas should be extended.

The short-term WHO-AQG for CO is exceeded in almost all cities for which data were available. Benzene and benzo[a]pyrene are considered representative for organic compounds associated with volatile organic hydrocarbons, or with soot and polycyclic hydrocarbons from combustion processes, respectively. From available data and model calculations, benzene will probably exceed the lifetime cancer risk level of 10^{-4} in most cities, and benzo[a]pyrene probably even up to a lifetime risk of 10^{-3}.

Population exposure

Exposure to air pollutants of the urban population is difficult to estimate. Besides estimating the spatial distribution and time variation of the pollutant concentration, the physical activity level (in relation to inhalation volume rate) of the population should be known. Data about the activity and actual location of the population were not available. A first rough estimate of possible urban population exposure levels can be made by calculating/estimating the number of citizens exposed to exceedances of (WHO)-AQGs in ambient air.

The figure for total estimated population in the cities exposed above short-term AQGs for SO_2 and/or particles, at least once a year (actually in 1990), is about 56 million people. The total population in the cities so analysed is 116 million, of the 150 million inhabitants in all cities involved. There was not sufficient city data available to calculate the extent of exposure to high ozone concentrations (the indicator for summer smog).

Exposure estimates from this study were compared to those mady by WHO (WHO, 1994). Although the selection and number of cities included in the estimation procedure was different in the two studies, the resulting exposure estimates are in the same range.

5 REFERENCES

Alcamo, J.; J. Bartnicki, K. Olendrynski, J. Pacyna (1992); Computing heavy metals in Europe's Atmosphere - I. Model Development and Testing. Atmospheric Environment 26: 3355-3369

Bary, B.G.; R.J. Chorley (1982); Atmosphere, Weather and Climate. Fourth edition, Methuen, London.

Beljaars, A.C.M.; A.A.M. Holtslag (1990); A Software library for the calculation of surface fluxes over land and sea. Environmental Software, Vol. 5, No. 2.

Berlyand M.E.(ed.) (1986); Annual report on the state of air pollution and emissions of harmful pollutants to the atmosphere of cities and industrial centers of the Soviet Union, 1985, v.1, 2. Leningrad, Main Geophysical Observatory (*in Russian*).

Berlyand M.E. (ed.) (1991); Annual report on the state of air pollution and harmful pollutant emissions to the atmosphere of cities and industrial centres of the Soviet Union. Harmful pollutant emissions. 1990, Leningrad, Main Geophysical Observatory (*in Russian*).

Bezuglaya, E. Yu. (1986); Air Pollution Quality Monitoring in Cities. Leningrad, Hidrometeoizdat (*in Russian*).

Bezuglaya, E. Yu.; G.P.Rastorgueva and I.V.Smirnova (1991a); The Breathing of an Industrial City. Leningrad, Gidrometeoizdat (*in Russian*).

Bezuglaya, E. Yu.; I.V.Smirnova, S.S.Chicherin (1991b); On the estimation of errors of assessing the concentrations of urban air pollutants. Trudy GGO, Leningrad, Gidrometeoizdat (*in Russian*).

Buursink J. (1980); City and Space. Introduction to Urban Geography. van Gorkum, Assen (*in Dutch*).

Coote, A.T.; J.T.S Yates, S. Chakrabarti, D.J. Bigland, J.P. Ridal, R.N Butlin (1991); Evaluation of decay to stone tablets: Part 1. After exposure for 1 year and 2 years. Building Research Centre, Garston, Watford, United Kingdom. (Convention on Long-Range transboundary Air Pollution. UN/ECE international co-operative programme on effects of materials, including historic and cultural monuments.)

Curran, T.C; B.A. Beard, E.Yu.Bezuglaya (1991); Application of the USSR Sampling Methodology to US Air Quality Data. Measurement of Toxic and Related Air Pollutants. Vol.1 Air and Waste Management Association. Pittsburgh, Pennsylvania.

EC (1992); Air Pollution Information System (APIS). Reference, PC database. CEC DG XI/B3.

EC (in preparation) CORINAIR-1985 inventory

Economist, the (1992); Pocket Europe. The Economist books, London.

ECOTEC Research and consulting (1986); Identification and Assessment of Materials Damage to Buildings and Historic Monuments by Air Pollution. Birmingham, United Kingdom

EEC/82/459 (1982); Council Decision establishing a reciprocal exchange of information and data from networks and individual stations measuring air pollution within the Member States.

Eerens, H.C.; C.J. Sliggers, K.D. van Hout (1993); The Car Model: The Dutch method to determine city street air quality. Atmospheric Environment, Vol.27B, No.4, pp 389-399.

EU (1994); Girafe: Air Quality Monitoring Networks in the European Community. PC database.

Hanssen, J.E.; K.Nodop (ed.) (1991); EMEP Workshop on Quality and comparability of atmospheric measurement data. Weilrod-Neuweilnau Federal Republic of Germany. 22-24 April 1991. Norwegian Institure for Air Research. Postboks 64 N-2001 Lillestrom - Norway.

Harrison, R.M.; P. Brimblescome, R.G. Derwent, G.J. Dollard, R.S. Hamilton, A.J. Hickman, C. Holman, J. Irwin, D.P.H. Laxen, M.J. Pilling, F.B. Smith (1993); First report of Urban Air Review Group

Henriksen, J.F.; A. Bartonova, M. Støre, S.E. Haagenrud (1993); External Building Materials in a Norwegian Town, Sarpsborg – Quantities, Degradation and Costs Caused by Air Pollution. In: "Progress in the Understanding and Prevention of Corrosion". Editor J.M. Costa and M.D. Mercer. London, The Insitute of Materials, pp. 39-44.

Jaarsveld, J.A. van (1990); An Operational atmospheric transport model for priority substances: specifications and instructions for use. RIVM, Bilthoven, Report No. 222501002.

Kasten, F.; G. Czeplak (1980); Solar and terrestrial radiation dependent on the amount and type of cloud. Solar Energy 24, 177-189.

Kucera, V.; J. Henriksen, D. Knotkova, Ch. Sjöström (1993); Model for Calculations of Corrosion Cost Caused by Air Pollution and its Application in Three Cities. In: "Progress in the Understanding and Prevention of Corrosion". Editor J.M. Costa and M.D. Mercer. London, The Insitute of Materials, pp. 24-32.

Leman group Inc. (1985); Acid rain impact on the urban environment. Phase 1: Methodology. National Research Council, Canada.

Mnatsakanian, R.A. (1992); Environmental legacy of the former Soviet republics as reflected by official statistics. University of Edinburgh

OECD (1981); The costs and benefits of sulphur oxide control. Organisation for Economic Co-operation and Development, Paris.

OECD (1990); Emission Inventory of major air pollutants in OECD European countries. Environment Monographs No. 21.

Potma, C.J.M (1993); Description of the ECMWF/WMO Global Observational Data Set, and associated data extraction and interpolation procedures. RIVM, Bilthoven, Report No. 722401001.

RIVM (1992); The Environment in Europe: a Global Perspective. Bilthoven, report no. 481505001.

RIVM (1993); Emissions per capita for SO_2, NO_x and VOC in European countries. LAE (Laboratory for Emissions and Wastes), *internal RIVM report.*

Rombout, P.J.A.; H.C. Eerens, F.A.A.M. de Leeuw (1989); Health risks of city populations from exposure to air pollution during summer type smog episodes and the effect of traffic limiting measures. RIVM, Bilthoven, report no. 678902 001 (*in Dutch*).

Rombout, P.J.A.; H.C. Eerens, M. Marra (1990); Health risks of city populations from exposure to air pollution during winter type smog episodes and the effect of traffic limiting measures. RIVM, Bilthoven, report no. 678902 002 (*in Dutch*).

Sandnes, H.; H. Styve (1992); Calculated budgets for Airborne Acidifying Components in Europe, 1985, 1987, 1988, 1989, 1990 and 1991. Report EMEP/MSC-W 1/92. Norwegian Meteorological Institute, Oslo, Norway.

Simpson, D. (1991); Long period Modelling of Photochemical Oxidants in Europe - Calculations for April-September 1985, April-October 1989. Report EMEP/MSC-W 2/91. The Norwegian Meteorological Institute, Oslo, Norway.

Stakunas *et al.* (1983); Air pollution damage to man-made materials, Physical and economic estimates. TRC Consultants Inc. (EPRI Research Project 1004-1).

Stanners, D.; P. Bourdeau (eds.); Europe's Environment, The Dobris assessment. European Commission DGXI, Brussels/Luxembourg (*in press*).

Times (1990); The Timea Atlas of the World, Comprehensive 8th edition, Bartholomew, London.

Tolstoy, N.; G. Andersson; Ch. Sjöström; V. Kucera (1993); External Building Materials: Inventory of Quantities and Assessment of Degradation Affected by Air Pollution. In: "Progress in the Understanding and Prevention of Corrosion". Editor J.M. Costa and M.D. Mercer. London, The Insitute of Materials, pp. 33-38.

UN (1991); Demographic yearbook. Dep. of International Economic and Social Affairs, Statistical office, New York

UN (1992); The Environment in Europe and North-America, annotated statistics 1992. United Nations Statistical Commission and Economic Commission for Europe. New York, 1992.

UN-ECE (1992); Strategies and Policies for Air Pollutant Abatement: 1992 review. UN-ECE Executive Body for the Convention on Long-Range Transboundary Air Pollution, report no. EB.AIR/R.66.

Veldt C. (1991); Emissions of So_x, No_x, VOC and CO from East European countries. Atmospheric Environment Vol. 25A, No.12, pp. 2683-2700.

Velze, K.van, C.J.M. Potma, R.J.C.F. Sluyter, W.A.J. van Pul, H.C. Eerens, S.Larssen, K.Gronskei (1993); Meteorological Potential Smog Index. Poster presented at EPH'93 conference, Antwerp 25-27 October.

WHO (1987); Air quality guidelines for Europe. World Health Organisation, European series No. 23, Copenhagen.

WHO (1991); Impact on human health of air pollution in Europe. EUR/HFA TARGET 21 report EUR/ICP/CEH 097 1499n. World Health Organisation, Regional Office for Europe, Copenhagen, Denmark.

WHO (1992); Acute effects on health of smog episodes. WHO Regional Publications, European Series No. 43. World Health Organisation,, Regional Office for Europe, Copenhagen, Denmark.

WHO; Concern for Europe's Tomorrow (CET). World Health Organisation. Wissenshaftliche Verlagsgeschellschaft mbH, Stuttgart, Germany (*in press*).

WHO/UNEP (1992); Urban Air Pollution in Megacities of the World. World Health Organisation, United Nations Environment Programme, Blackwell, Oxford.

Zantvoort, E. van; R.J.C.F. Sluyter, S. Larssen (eds.) (1995); Air Quality in Major European cities - Part II: City Report Forms., RIVM, Bilthoven, report No.722401009

Zierock, K.-H.; T.I. Zachariadis (1991); Volatile Organic Compounds: Estimated emissions of the European Communities for the eighties and the year 2000, report DGXI/605/91.

6 ABBREVIATIONS

σ	Standard deviation (statistical)
AMNIS	Air quality Monitoring Network Information System
APIS	Air Pollution Information System (EU database)
BSh/BSk	Climatological definitions according to Köppen, see Table 3.3
C_{am}	arithmetic mean (used in calculation of number of days the WHO-AQG was exceeded)
Cd	Cadmium
Cfa/Cfb/Cfc	Climatological definitions according to Köppen, see Table 3.3
C_{city}	Urban contribution to total concentration field
CEC	Commission of the European Communities
CET	Concern for Europe's Tommorow (WHO study)
CFCs	Chlorofluorocarbons
CH_4	Methane
CO	Carbon monoxide
$C_{regional}$	Regional contribution to total concentration field
Csa/Csb	Climatological definitions according to Köppen, see Table 3.3
CORINE	Coordination de l'information sur l'Environnement
CORINAIR	Coordination de l'information sur l'Environnement, section Air
C_{px}	measured concentration of the x^{th} percentile (used in calculation of number of days the WHO-AQG was exceeded)
CRF	City Report Form
Cu	Copper
D	Diameter of the city
Dfb/Dfc	Climatological definitions according to Köppen, see Table 3.3
DGM/LE	Directorate General Environment/Air and Energy (Dutch Ministry)
EC	European Community
ECMWF	European Centre for Medium range Weather Forecasts
ECU	European Currency Unit
EEA-TF	European Environmental Agency-Task Force
EEC	European Economic Community
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe
EU	European Union
$f_L/f_p/f_T/f_{wv}$	Meteorological factors used in calculating MSP-W and MSP-S (Table 3.4 and 3.5)
FSU	Former Soviet Union
f_{Nt}/f_{rt}	Meteorological factors used in calculating MSP-S (Table 3.5)
f_{wn}/f_{ws}	Probability of meteorological conditions favourable for winter (wv) and summer smog (ws)
GEMS-AIR	Global Environment Monitoring System (AIR)
GIRAFE	*French*: Guide d'Information sur les Résaux de qualité de l'Air Fonctionnant en Europe (catalogue on air quality monitoring networks in Europe)
L	Monin-Obukhov stability length
Ln	Natural logarithm
M	Population average (statistical)
m24	maximum 24 hr concentration, averaged over all city background stations

MGO	Main Geophysical Observatory (St. Petersburg, Russian federation)
mm24	Maximum 24 hr concentration measured at any of the city background stations
MPC	Maximum Permissible Concentration (AQG used in former Soviet Union)
MSP-S	Meteorological Smog Potential-Summer half year
MSP-W	Meteorological Smog Potential-Winter half year
N	Number of cases (statistical)
NILU	Norwegian Institute for Air Research
NM-VOCs	Non-methane volatile organic compounds
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NUTS	statistical spatial unit, used in EU
ODS	Observational Data Set
O_3	Ozone
p	precipitation
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PM_{10}	Fraction of particulate matter comprising particles with a median aerodynamic diamete of less than 10 µm.
ppb	parts per billion
ppm	parts per million
RIVM	National Institute of Public Health and environmental Protection
RIVM-LAE	National Institute of Public Health and environmental Protection-Laboratory for Waste and Emissions
Sg	geometric standard deviation (used in calculation of number of days the WHO-AQG was exceeded)
SO_2	Sulphur dioxide
SPM	Suspended Particulate Matter
SSO	State Service of Observations (former Soviet Union)
T	Temperature
TREND	Analytical long-term depostion model for multi-scale applications
TSP	Total Suspended Particulates
UN	United Nations
UN-ECE	United Nations-Economic Commission for Europe
UN-IEDS	United Nations-International Environmental Data Service
UNEP	United Nations Environmental Programme
US	United States
USA	United States of Amerika
VOC	Volatile Organic Compound
WHO	World Health Organisation
WHO-AQG	World Health Organisation-Air Quality Guideline
WHO-ECEH	World Health Organisation-European Centre for Environment and Health
wv	Wind velocity
Zn	Zinc
Z_{px}	Eccentricity for the x^{th} percentile (used in calculation of number of days the WHO-AQG was exceeded)

SO2 COUNTRY	Emission per capita (kg/inh) Industry	Traffic	Space h.	Total
GDR+DDR	64.4	1.6	7.7	73.6
FR	18.3	1.5	3	22.8
IT	33.2	1.4	3.3	37.9
NL	11.3	2.3	0.4	14
B	34	1.7	6.6	42.2
LU	36	1.3	5.4	42.7
UK	60.1	2.3	3.7	66.1
IR	33	1.5	13.5	48
DK	31.3	1.2	3.5	36.1
GR	49.1	0	1.4	50.5
ES	55.4	1.8	1.5	58.8
PO	18.7	0.7	0.1	19.4
NOR	10.9	0.4	1.5	12.9
SWE	16.9	0.4	2.7	19.9
FIN	51.2	0.8	0	52
AUT	9.9	0.4	2.3	12.7
SWI	6.5	0.4	2.4	9.4
AL	13.5	0.4	2.2	16.1
PL	54.6	0.6	29.4	84.7
CS	133.3	1.1	22.2	156.6
H	87	0.9	7.4	95.3
R	70.7	0.9	6	77.6
BG	119.9	0.9	19.8	140.7
YU	59.2	1	2.9	63
Belarus, Ukr., RF-EUR	34.6	0.4	9.5	44.5
RF	30.2	0.4	8.3	38.8
Estonia	76.2	0.9	20.9	98
Latvia	15.6	0.2	4.3	20
Lithuania	36.5	0.4	10	47
Belarus	46.3	0.6	12.7	59.6
Ukraine	42.4	0.5	11.6	54.5
Moldova	46.2	0.6	12.7	59.5
Former-GDR	12	1.2	2.2	15.4
Former-DDR	252.3	2.8	27.2	282

NOx COUNTRY	Emission per capita (kg/inh) Industry	Traffic	Space h.*	Total
GDR+DDR	12.1	27.8	1.5	41.4
FR	8.2	21.6	1.9	31.7
IT	12.6	16.8	1.2	30.6
NL	11.9	22.9	2.5	37.3
B	12	18.6	1.8	32.3
LU	28.4	19.8	2.5	50.7
UK	18.2	27.4	2.3	47.8
IR	19.6	16.1	2.9	38.6
DK	32.9	21.1	1.5	55.5
GR	18.8	12.1	0.2	31.1
ES	9.5	11.5	0.3	21.3
PO	4.7	6.9	0	11.6
NOR	15.2	37.3	3	55.5
SWE	17.6	25.2	4.8	47.5
FIN	29.8	28.2	0	58
AUT	7.8	18	1.3	27.1
SWI	6.1	20.4	1.3	27.9
AL	0.9	1.9	0.1	2.9
PL	23.4	8.2	2.2	33.8
CS	42.1	17.6	3.6	63.3
H	12.4	8.7	1.4	22.5
R	10.5	5.5	0.7	16.8
BG	9.9	6.8	0.6	17.3
YU	9	8.6	0.3	17.9
Belarus, Ukr., RF-EUR	11.5	11.1	0.4	22.9
RF	11.7	11.2	0.4	23.3
Estonia	12.3	11.8	0.4	24.5
Latvia	3.3	3.2	0.1	6.6
Lithuania	9.6	9.3	0.3	19.2
Belarus	13.2	12.7	0.4	26.3
Ukraine	10.8	10.4	0.4	21.5
Moldova	10.4	10	0.3	20.7
Former-GDR	9.8	31.1	1.8	42.6
Former-DDR	20.4	16.1	0.6	37.1

* Non industrial and power plants

VOC COUNTRY	Emission per capita (kg/inh) Industry	Traffic	Space h.*/solvents**	Total
GDR+DDR	10.7	26.6	10.2	47.4
FR	6.1	23	7.2	36.3
IT	6.4	17.6	4.9	28.9
NL	8.8	14.2	8.3	31.3
B	9.9	23.8	6.9	40.6
LU	9.3	21.3	4	34.7
UK	13	19.3	8.4	40.8
IR	4.7	18.3	7.6	30.6
DK	7.5	17.3	7	31.8
GR	2.6	11.9	1.4	16
ES	5.7	13	4.6	23.3
PO	5.8	6.7	3.1	15.6
NOR	14.7	17.2	17.2	49
SWE	12.6	28.2	13.2	54.1
FIN	12.9	19.8	8.9	41.6
AUT	18.9	18.6	14.9	52.3
SWI	17.9	13.3	13.9	45.2
AL	2.9	3.5	3.9	10.3
PL	4.3	8.7	13.1	26.1
CS	5.1	9.2	5.2	19.5
H	3.2	12.7	3.4	19.3
R	6.7	4.1	5.9	16.7
BG	4.9	8.6	5.2	18.7
YU	2.9	6.2	3.2	12.3
Belarus, Ukr., RF-EUR	23.1	13	6.7	42.7
RF	26.5	14.9	7.7	49
Estonia	5.8	3.2	1.7	10.7
Latvia	21.2	11.9	6.1	39.2
Lithuania	16.9	9.5	4.9	31.3
Belarus	27.6	15.5	8	51.1
Ukraine	14.5	8.1	4.2	26.8
Moldova	11.5	6.5	3.3	21.4
Former-GDR	11.1	21	9.7	41.8
Former-DDR	9.1	46.7	11.6	67.3

* space heating: non industrial and power plants
** solvets: households and non industrial

References Country totals

Country	SO_2	NO_x	NM-VOC
Former GDR	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Former DDR	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
France	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
Italy	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
The Netherlands	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
Belgium	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
Luxembourg	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
United Kingdom	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Ireland	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
Denmark	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
Greece	ECE/EB.AIR/R.66(1)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
Spain	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
Portugal	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EC, report XI/605/91(4)
Norway	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Sweden	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Finland	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Austria	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Switzerland	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR /R.66(1)
Albania	EMEP/MSC-W, report 1/92(3)	EMEP/MSC-W, report 1/92(3)	EMEP/MSC-W, report 1/92(3)
Poland	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR /R.66(1)
Czechoslovakia	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR /R.66(1)
Hungary	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR /R.66(1)
Romania	ECE/EB.AIR/R.66(1)	EMEP/MSC-W, report 1/92(3)	EMEP/MSC-W, note 4/92 (8)
Bulgaria	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EMEP/MSC-W, note 4/92 (8)
Yugoslavia	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	EMEP/MSC-W, note 4/92 (8)
Turkey	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Russia	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Estonia	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)
Latvia	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)
Lithuania	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)
Belarus	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Ukraine	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)	ECE/EB.AIR/R.66(1)
Moldova	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)	Univ. Edinburgh, report R. Mnatsakanian (6)

References source category allocation

Country	SO_2	NO_x	NM-VOC
Former GDR	UBA, pers.comm.	UBA, pers.comm.	UBA, pers.comm.
Former DDR	UBA, pers.comm.	UBA, pers.comm.	UBA, pers.comm.
France	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
Italy	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
The Netherlands	CBS, pers.comm.	CBS, pers.comm.	CBS, pers.comm.
Belgium	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)
Luxembourg	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
United Kingdom	WSL, inventory report (9)	WSL, inventory report (9)	WSL, inventory report (9)
Ireland	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
Denmark	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
Greece	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
Spain	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
Portugal	EC, CORINAIR-1985 inventory (2)	EC, CORINAIR-1985 inventory (2)	EC, report XI/605/91(4)
Norway	OECD, inventory report (10)	OECD, inventory report (10)	OECD, inventory report (10)
Sweden	OECD, inventory report (10)	OECD, inventory report (10)	OECD, inventory report (10)
Finland	OECD, inventory report (10)	OECD, inventory report (10)	OECD, inventory report (10)
Austria	OECD, inventory report (10)	OECD, inventory report (10)	OECD, inventory report (10)
Switzerland	OECD, inventory report (10)	OECD, inventory report (10)	OECD, inventory report (10)
Albania	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Poland	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Czechoslovakia	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Hungary	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Romania	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Bulgaria	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Yugoslavia	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Turkey	TNO, pers.comm.	TNO, pers.comm.	TNO, pers.comm.
Russia	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Estonia	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Latvia	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Lithuania	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Belarus	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Ukraine	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)
Moldova	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)	TNO, article C. Veldt (5)

References Annex I

1 Strategies and policies for air pollution Abatement: 1992 review, UN-ECE/Executive Body for the Convention on Long-Range Transboundary Air Pollution, report EB.AIR/R.66

2 CORINAIR-1985 inventory, EU (in preparation)

3 Sandnes H., and Styve H., 1992, Calculated budgets for airborne acidifying components in Europe 1985, 1987, 1988, 1989 1990 and 1991. Report EMEP/MSC-W/1/92.

4 Zierock, K.-H. and Zachariadis T.I., Volatile Organic Compounds: Estimated emissions of the European Communities for the eighties and the year 2000, 1991, report DGXI/605/91.

5 Veldt C., Emissions of Sox, Nox, VOC and CO from East European countries, 1991, Atmospheric Environment, Vol. 25A, No.12, pp 2683-2700.

6 Mnatsakanian, R., Environmental legacy of the Former Soviet Republics (as collected from official statistics), 1992, University of Edinburgh.

7 Annual report 1991: Structure and results of emission inventory Flemish region, Gent university (*in Dutch*).

8 Simpson D., and Styve H., 1992, The effects of the VOC protocol on ozone concentrations in Europe, note EMEP/MSC-W/4/92.

9 Gilham C. et al., 1992, UK emissions of air pollutants, report LR 887 (AP), Warren Spring Laboratory.

10 Emission inventory of major air pollutants in OECD countries, Environment Monographs No. 21, 1990 OECD.

Area	Year	Parameter	Main problem	Comments	Ref.	Publ. year
Athens	1991	Modelling SO_2 source data given by PERPA	Small industrial units	Low effective stach heights	1	1991
	1. week Sep. 1989	NO_2	Surrounded by mountains, high population	Traffic accounts to 77% of NO_2 emissions. (17 Gt/year). Level: low during monitoring period.	2	1990/1991
	1984-1987	Smoke	Warm air advection from south-west	In 90% of episode days, low wind speed, strong subsidence, mixing layer less than 500 m in 65% of the days	3	1991
	June-Sept. 1984	O_3	High concentrations accompanied by well developed sea-breezes	US Air Quality Standard of 120 ppb O_3 was exceeded 4-7 h/day. O_3 > 200 ppb recorded in smog episodes.	4	1988
	1973-1982	SO_2, Temp., rainduration, wind speed	Maximum SO_2 concentrations in December-January	Episode days (daily values of $SO_2 > 250\ \mu g/m^3$) is none existent after 1980	5	1988
	1974-1982	Smoke	When smoke conc. was high, SO_2, O_3, NO_x were also high	Decrease in mean monthly smoke values	6	1986
	February-May 1984	PAH, TSP,	Traffic causes the highest levels of BaP and mutagenicity	Mean value of Bap near traffic is 5.7 ng/m^3, and near industrial sites 2.4 ng/m^3 WHO report PAH between 1-5 ng/m^3 in urban areas	7	1985
	Sept. 1983	Pb, Zn	Mean value of Pb/Zn are 1.5 for course particles and 1.3 for fine particles	High ratios located along main traffic roads	8	1985

Area	Year	Parameter	Main problem	Comments	Ref.	Publ. year
	1974-1976	Smoke, TSP, SO_2, CO, O_3, NO_2	70% of SO_2 pollution during winter is caused by domestic heating		9	1977
	1981-1982 1984-1988	Blood lead Blood lead	14-15 µg lead/dl blood 1982 7-8 µg lead/dl blood 1988	Trend towards decreasing blood lead levels, reveals the improvement of the air quality of Athens	10	1990
Venice	1973-1977	TSP, SO_2, SO_4	Concentrations higher in the winter period	Measurements at 3 sites, in the industrial area, emissions of SO_2, TSP and SO_4 are mostly constant, while in the urban areas the emissions are seasonal related.	11	1985
		Probability model of SO_2			12	1986
Milano	1978-1979	SO_2	SO_2 air quality standards largely violated	Reduction of SO_2 emissions of 65-80% necessary to meet the air quality guidelines provided by EEC for urban areas	13	1981
	1980-1985	NO_2	Trend towards lower level of annual concentrations	Diurnal cycles of NO_2 are typical of an urban area with heavy traffic. A source reduction of 75% was estimated to meet the national standards	14	1986
	1972-1982	SO_2	Measured at 3 sites during winter periods.	Calculations of high and maximum SO_2 conc. from the arithmetic mean are used to control and plan the reductions of SO_2	15	1985

Area	Year	Parameter	Main problem	Comments	Ref.	Publ. year
	June-Sep. 1989	CO, NO_x, Meteorology	Comparing measured concentrations with the APRAC3 model	Traffic emission factors. SO_2 guidelines not maintained. NO_2 guidelines not maintained. SO_2 conc. redused. NO_x conc. increasing	16	1991
Istanbul	May 1968	SO_2, Particulates, Dust and Sootfall	No control of smoke and dust emissions. The problem are particulates	The particle conc. varid between 58-3850 $\mu m/m^3$ near and at streets in daytime Average 254 $\mu g/m^3$ residensial-sites Average 325 $\mu g/m^3$ commercial-sites Average 910 $\mu g/m^3$ industrial-sites SO_2 not very high max.0.06 ppm av. 0.03 ppm	17	1970
Belfast	1989-1991	SO_2, smoke	Measured at 7 sites with different characteristics	At 6 sites, SO_2 concentrations below WHO annual air Guideline (50 $\mu g/m^3$) Annual smoke conc. below 33 $\mu g/m^3$ at all sitcs. Annual SO_2 conc. 21 ppb	18 19 20	1992 1992
Leeds	1989-1991	SO_2, smoke	Measured at 3 sites with different characteristics	Annual SO_2 concentrations 27 $\mu g/m^3$ which is below WHO Air Quality Guideline Smoke conc. 15 $\mu g/m^3$	18 19 20	1992
Liverpool	1989-1991	SO_2, smoke	Measured at 3 sites with different characteristics	All sites below WHO Air Quality Guideline for annual conc. of SO_2. Annual smoke conc. below 18 $\mu g/m^3$	18 19 20	1992

Area	Year	Parameter	Main problem	Comments	Ref.	Publ. year
Manchester	1989-1991	SO_2, smoke, NO_2, NO_x	Measured at 3 sites with different characteristics	Annual SO_2 conc. below WHO Air Quality Guideline. Annual smoke conc. below 26 $\mu g/m^3$ NO_2 conc.25 ppb as annual average. NO_x conc.19 ppb as annual average	18 19 20	1992 1992
Sheffield	1989-1991	SO_2, smoke, NO_2, NO_x	Measured at 2 sites with different characteristics	Not complete data set to make annual average. NO_2 conc.24 ppb annual average NO_x 54 ppb	18 19 20	1992 1992
UK	1987	NO_2	Measured at 6 sites	Annual average varied from 23-39 ppb. NO_2 temporal variability was substantially lower than for NO. A marked non-proportional relationship between annual and daily average NO_2 and NO_x levels	21	1991
Lancaster	1989-1990	NO_2	Measured at 9 sites in the city of Lancaster	Annual average in the mainroad in the center 63 $\mu g/m^2$ with spatial variations 12-122 $\mu g/m^2$, near roads in suburban area 38-30 $\mu g/m^3$	22	1991
UK	1950-1990	SO_2	SO_2 concentrations dramatically decreased over the last 40 years. Current conc do not provide an adequate picture of conc. exposure	Data for Lincoln Cathedral: Current rate of exposure 2/5 of the last 40 years average. In these years urban exposure was 2 the country side. Today urban and rural exposures are similar	23	1992

Area	Year	Parameter	Main problem	Comments	Ref.	Publ. year
Marseille area	14-17 Jan. 1985	SO_2, sodar data,	The industrial emissions were not the main elements responsible for ground level pollution. Turbulence with altitude is important	The purpose was to prepare a continuous air pollution control program for Cracow (Poland)	24	1987
Budapest	May-Aug. 1991	NO, NO_2, SO_2, CO, PM_{10} at 8 sites, NMHC at 3 sites, CH_4 and O_3 at one site each TSP → Bb, Cd	Few bridges over Danube outside Budapest draws extra traffic due to travellers from one side to the other. Lots of Trabant and Wartburg cars with 2-stroke gas/oil fueled engines.	Max. contribution of vehicles to TSP is 35%. Conc. of pollutants are higher than are found in most US sites but similar to Mexico City and Athens.	25	1992
Zagreb	1977-1980	PAH	The Trend of increasing lung cancer with smoking and breathing in polluted air	The levels of PAH's are at the same level as other European cities. The concentration in suburbs are lower than in the city centre by about 30%	26	1987
Barcelona	1985	SO_2	Results of SO_2 conc. obtained by the manual Air-pollution Monitoring Network of Barcelona Metropolitan Area		27	1986
Madrid	1979-1985	SO_2, PM	Madrid is located in an area with large climatological variability from year to year. Necessary to correct for the impact of local meteorology on the System Emission-, atmosphere-conc.	Slight tendency towards decreasing emissions of both SO_2 and PM, more marked for PM	28	1988

Area	Year	Parameter	Main problem	Comments	Ref.	Publ. year
Nordrhein-Westfalen	1989	Emission data for CO, CO_2, SO_2, NO_2, HC, PAH Continuous measurements of SO_2, dust, CO and NO_x Pb in suspended particles 1975-1989 PAH 1989 HC Diesel exhaust gas 1990	Traffic is the main source to the pollution of NO, NO_x CO and voluntile hydrocarbons	For Düsseldorf the highest concentrations lies in the range 300-350 µg/m³ for SP. The Average SO_2 conc. in Essen and Düsseldorf is 40-50% higher than the rest of the area (37-40 µg/m³). Maximal conc. of CO lies in the range 30-35 mg/m³. Maximum N conc. over 1300 µg/m³ was measured while the 98% percentile lies in the range 450-650 µg/m³. Annual average of Pb in Düsseldorf 0.37 µg/m³. Annual average of BaP lies in the range 4-6 µg/m³ for the cities Bonn, Köln and Düsseldorf. The average Benzol conc. in Bonn and Düsseldorf are 2-6 times the average conc. in the Rhein-Ruhr area	29	1991
Vienna	1977/1978 1978/1979 the winter periods	SO_2	Residential heating during winter time	Verification of two regression models applied to winter daily SO_2 concentrations	30	1982

Area	Year	Parameter	Main problem	Comments	Ref.	Publ. year
Amsterdam Brussels Frankfurt London Madrid Prague Zagreb	1973-1977	SP, SO_2		For SP; the median level was increasing in commercial areas but decreasing in residentail areas. The 90 percentage de-creased progressively in all areas. SO_2 concentrations were decreasing in all areas for both the 50 and 90 per-centage with the largest reductions in industrial areas, the smallest reduction in residential areas	31	1980
France	1991	High acidity, settling dust, SO_2, black smoke, SP, F, NO_x, CO, Pb, O_3, HC, NMHC, Heavy metals, aldehydes, NH_y + NO_x, PAN aerosol Radioactis, CO_2	Measured at selected sites all over France		32	
		SO_2, NO_2, SPM, CO, Pb	Data from WHO/UNEP-GEMS Air database, Urban air quality measured at 35 cities around the world		33	
Germany	1966-1986 (1987-1989, prelimin-ary)	Annual emissions in the federal republic of Germany, 341 SO_2 monitoring stations 265 NO_x monitoring stations 212 CO monitoring stat. 278 SPM " "	Emission of SO_2 decreasing Emission of NO_x increasing Emission of CO decreasing Emission of Particulates decreasing	The article present annual concentrations of the diffe-rent pollutants. The conc. of CO, SO_2 and particulates are decreasing. It is not given any trend for the conc. of NO_x.	34	1990

Area	Year	Parameter	Mainproblem	Comments	Ref.	Publ. year
UK	1986	NO_2	363 monitoring stations. London has got the highest average conc. in the UK.	The highest conc. close to busy roads, only moderately higher in winter than summer.	35	1990
Cologne	1976	Inorganic gases, organic gases and vourpors, dust	Highly polluted area (Rhine-Ruhr-area).	Emission an immision inventory of the Cologne area.	36	1977
Brussels Helsinki Frankfurt Athens Dublin Amsterdam Warsaw Wroclaw Madrid Glasgow London Zagreb	1970-1980	SO_2, NO_x	Annual emissions of SO_2 in the specified cities. Annual emission of NO_x are given for the regions and countries.	Decreasing trends of SO_2 conc.	37	1991

Area	Year	Parameter	Mainproblem	Comments	Ref.	Publ. year
Brussels Prague Copenhagen Helsinki Gourdon Frankfurt Munich Athens Dublin Milan Amsterdam Warsaw Wroclaw Lisbon Madrid Glasgow London Zagreb	1973-1985	Suspended particles	Mean of daily values and peak levels.	Prague, Warsaw and Wroclaw showed increasing conc. Brussels, Copenhagen, Gourdon, Frankfurt, Milan, Glasgow, London showed decreasing conc. The others showed a marked increas in 1979-81 and a decrease in 1982-85, with exeption at Prague with an increase in 1982-85.	38	1988-89

Annex II: References to literature search

(1) Panagopoulos, J. and Markatos, N.C. (1991) Mathematical modelling of air pollution in the Athens basin. In: *Internat. Conf. on Environmental Pollution, Lisbon 1991.*Proceedings. Geneva, Interscience Enterprices. Vol. 1, pp. 281-290.

(2) Boucher, K. (1990/1991) The monitoring of air pollutants in Athens with particular reference to nitrogen dioxide. *Energy and Buildings, 15-16*, 637-645.

(3) Pissimanis, D.K., Karras, G.S. and Notaridou, V.A. (1991) On the meteorological conditions during some strong smoke episodes in Athens. *Atmos. Environ., 25B* 193-202.

(4) GÜsten, H., Heinrich, G., Cvitas, T., Klasinc, L., Ruscic, B., Lalas, D.P. and Petrakis, M. (1988) Photochemical formation and transport of ozone in Athens, Greece. *Atmos. Environ., 22*, 1855-1861.

(5) Kambezidis, H.D. and Papanikolaou, N.S. (1988) SO_2 concentration levels from a monitoring network in Athens, Greece. *Atmos. Environ., 22*, 2557-2568.

(6) Kambezidis, H.D. and Kassomenos, P. (1986) Smoke concentration levels in a monitoring network in Athens, Greece. *Atmos. Environ., 22*. 601-604.

(7) Athanasiou, K. (1985) Mutagenicity and polycyclic aromatic hydrocarbons analysis of ambient airborne particles collected in Athens, Greece. *Sci. Total Environ., 52*, 201-209.

(8) Rapsomanikis, S. and Donard, O. (1985) Lead and zinc in roadside dust from a suburb in Athens, Greece. *Environ. Techn. Lett., 6*, 145-148.

(9) Gilad, A. (1977) Environmental pollution control in Metropolitan Athens. *AMBIO 6*, 350-355.

(10) Environment Institute (1990) Impact of Gasoline lead on human blood. The Athens lead experiment. Luxembourg, Commission of the European Communities (EUR 12830).

(11) Bertolaccini, M.A. and Gucci, P.M.B. (1985) Atmospheric pollution in the Venice Area. I. Sulphur dioxide, suspended particles and sulphates. *Sci.Total Environ., 43*, 243-253.

(12) Buttazzoni, C., Lavagnini, I., Marani, A., Zilio Grandi, F. and Del Turco, A. (1986) Probability model for atmospheric sulphur dioxide concentrations in the area of Venice. *J. Air Poll. Contr. Ass., 36*, 1028-1030.

(13) Giugliano, M. (1981) Riduzione delle emissioni di SO_2 e standards di qualità dell' aria nell' area urbana di Milano. *Ingeniera Ambientale. 10*, 4, 393-399.

(14) Cernuschi, S. and Giugliano, M. (1986) Gli ossidi di azoto nell' atmosfera di Milano. Parte 2. Verifica del rispetto degli standards di qualità del-l'aria. *Ingeneria Ambientale, 15*, 2, 97-102.

(15) Giugliano, M. (1985) The development and application of empirical models for the high SO_2 concentrations in urban areas. *Sci. Total Environ., 44*, 89-96.

(16) Bardeschi, A., Colucci, A., Gianelle, V., Gnagnetti, M., Tamponi, M. and Tebaldi, G. (1991) Analysis of the impact on air quality of motor vehicle traffic in the Milan Urban Area. *Atmos. Environ., 25B*. 415-428.

(17) Tebbens, B.D. (1970) Investigating air quality in Istanbul. *Am. Ind. Hyg. Ass. J., 31*, 44-51.

(18) Warren Spring Laboratory (1991) UK Smoke and Sulphur Dioxide Monitoring Networks. Summary Tables for April 1989- March 1990. Prepared as part of the Department of the Environmental Air Pollution Research Programme. Stevenage (Special publ. LR 835(AP)).

(19) Warren Spring Laboratory (1992) UK smoke and sulphur dioxide, Monitoring Networks. Summary tables for April 1990- March 1991. Prepared as part of the Department of the Environmental Air Pollution Research Programme. Stevenage (special publication LR 889(AP)).

(20) Broughton, G.F.J., Bower, J.S., Stevenson, K.J., Lampert, J.E., Sweeny, B.P., Wilken, J., Clark, A.G., Willis, P.G., Stacey, B.R.W., Driver, G.S., Laight, S.E. and Waddon, C.J. (1992) Air quality in the U.K. A summary of results from instrumented air monitoring networks in 1990/1991. Stevenage, Warren Spring Laboratory (Laboratory report LR 883 (AP)).

(21) Bower, J.S., Broughton, G.F.J., Dando, M.T., Lees, A.J., Stevenson, K.J., Lampert, J.E., Sweeney, B.P., Parker, V.J., Driver, G.S., Waddon, C.J. and Wood, A.J. (1991) Urban NO_2 concentrations in the U.K. in 1987. *Atmos. Environ., 25B*, 267-283.

(22) Hewitt, C.N. (1991) Spatial variations in nitrogen dioxide concentrations in an urban area. *Atmos. Environ.*, 25B, 429-434.

(23) Eggleston, S., Hackman, M.P., Heyes, C.A., Irwin, J.G., Timmis, R.J. and Williams, M.L. (1992) Trends in urban air pollution in the United Kingdom during recent decades. *Atmos. Environ., 25B*, 227-239.

(24) Sol, B. and Geneve, C. (1987) Combined Analysis of Doppler Sodar and Weather Forecast Strategies used in the Marsceille area during air pollution incident of January 1985. *Int. Symp. on Prediction, Monitoring and Control of Urban Pollution Episodes, 14-21 January 1985*. Royal Met. Inst. Belgium.

(25) Javor, M., Wadden, R.A., Scheff, P.A., Keil, C.B. and Kelemen, B. (1992) Air Pollution Source Apportionment in Budapest. For Presentation at the *85th Annual Meeting & Exhibition, Kansas City, Missouri, 1992*. Pittsburg, PA., Air and Waste Management Association. Paper 92-164.04.

(26) Bozicevic, Z., Cvitas, T., Curic, M., Klasinc, L. and Pecina, P. (1987) Airborne polycyclic aromatic hydrocarbons in the City of Zagreb, Yugoslavia. *Sci. Total Environ.*, *66*. 127-136.

(27) Alier, S., Farrés, E., Martí, X., Massagué, G., Olivella, J.I., Salvador, J., Serena, J.M. (1986) Niveles De SO_2 en el territorio de la corporacion Metropolitana de Barcelona durante el año 1985. In *Corrosion in the ambient environment*, *2*. Universitat de Barcelona. pp. 148-152.

(28) Serrano, E., Zurita, E. and Castro, M. (1989) Analysis of the annual trend in SO_2 and particulate matter emissions in Madrid (Spain). *Atmos. Environ.*, *23*, 631-642.

(29) Pfeffer, H.-U. (1991) Immissionen im Einflußbereich des Kraftfahrzeugverkehrs. *Staub-Reinhalt der Luft*, *51*, 63-69.

(30) Bolzern, P., Fronza, G., Runca, E., Übahuber, C. (1982) Statistical analysis of winter sulphur dioxide concentration data in Vienna. *Atmos. Environ.*, *16*, 1899-1906.

(31) Akland, G., Kretzschmar, J., Fair, P. and Koning, H. de (1980) Air Quality Surveillance: Trends in selected urban areas. *WHO Chronicle*, *34*, 147-152.

(32) Delandre, J.-R. (1991) La Surveillance de la pollution de l'air en France. Historique, évolution, structures. (The Monitoring of Air Pollution in France, History, evolution structures). *Poll. Atmos.*, *131*, 376-379.

(33) Quality of Environmental Media. Urban Air Quality.

(34) Lahmann, E. (1990) Winter Smog in Germany. Berlin, WHO Collaborating Centre for Air Quality Management and Air Pollution Control. Institut für Wasser-, Boden- und Lufthygiene des Bundesgesundheitsamts (WaBoLu Report 3/98).

(35) Bower, J.S., Lampert, J.E., Stevenson, K.J., Atkins, D.H.F., and Law, D.V. (1991) A diffusion tube survey of NO_2 levels in urban areas of the UK. *Atmos. Environ.*, *25B*, 255-265.

(36) Dreyhaupt, F.J. (1977) The air conservation plan for the Cologne air quality control region as an example of the new air pollution control strategy in the Federal Republic of Germany. In: *4th international Clean air conference in Tokyo, 1977*.

(37) UNEP (1991) United Nations Environmental Programme. Environmental data report 1991/92. Oxford, Blackwell. pp. 10-37

(38) World Resources Institute (1988) World resources 1988-89. A report by The World Resources Institute and The International Institute for Environment and Development in collaboration with UNEP. New York, Basic Books. pp. 339-340.

ANNEX III: FIRST QUESTIONNAIRE ON URBAN AIR QUALITY

QUESTIONNAIRE AIR QUALITY IN EUROPEAN CITIES

'Dobříš State of the European Environment programme 1992/93'

NOTE

If not all questions fall under your responsibility, fill out your part and send a copy of the questionnaire to the person who is responsible for the remaining questions. Even if you are not able to fill out all questions for your city, please always send (part of) the questionnaire back before 1 September 1992.

Person who answered this questionnaire:

Name:	....	Country:	....
	....	City:	....
Address:	....	Human population:	....
	....	Build-up area:	...........................km^2
Tel:	....	Coordinates:	....°....' N ....°....' W/E
Telex:	....	Prevailing wind:	....
Fax:	....		

- **Please indicate the geographical siting of your city (e.g. flat plain, valley, plateau, (river) basin, coastal, or combinations of these):**

  ....

- **Are there any meteorological stations in operation in or around your city?**

  Y/N Nr........

City:... Country:...

- **Which air pollutant(s) is (are) regarded a major problem in your city (please list; e.g. SO_2, dust*, VOC*, Heavy metals*, NO_2, CO, etc.):**

  ....

- **Which emission sources cause a major air pollution problem in your city (please underline)?**

  Industry, Traffic, Power plants, Space/domestic heating, Other:..

- **Concentration data**

  Is air quality monitored in/around your city? Y/N
  If air quality is monitored, please fill in the table below:

Component	SO_2*	dust*	VOC*	Heavy metals*	NO_2	CO	Other
Number of stations							

Can the data be made available or are there any restrictions: ....

- **Emission data**

  Are there pollutant emission estimates for your city? Y/N
  For which pollutants (please list; e.g. SO_2, dust*, VOC*, Heavy metals*, NO_2, CO, etc.):

  ....

  Can the data be made available or are there any restrictions: ....

* **Dust**: soot, particles, PM10, TSP; **OCs**: toxic/carcinogenic hydro-carbons, e.g. Benzene, Benzo(a)pyrene Formaldehyde; **Heavy metals**: especially Pb, Cd, Cr.

City:.. Country:..

■ **Traffic data**

Are there statistics available about the amount of traffic in your city? Y/N

Are there statistics available about the types and amounts of fuels used by traffic in your city? Y/N

Can the data be made available or are there any restrictions: ....

■ **Space/domestic heating**

Are there any statistics available about the fuels (coal/gas/oil/otherwise) used for space/domestic heating in your city? Y/N

Can the data be made available or are there any restrictions: ....

■ **Reports**

If there are any reports or publications published about your city concerning the subjects mentioned above, or other relevant information concerning air pollution problems (e.g. exposure/effect studies, modelling activities), please give us a list of the reports, the subjects covered and the way they can be obtained.

Reports: ....
....
....
....
....
....
....
....
....
....
....

City:.. Country:..

- **Other responsible persons**

When part of the required information (air quality measurements, emission data, activity data, exposure/effect studies, etc.) fall under the resposibility of, or have been filled in by other persons than you, please give their names and addresses also:

Name: ....
Responsibility: ....
Address: ....
....
Tel: ....
Telex: ....
Fax: ....

Name: ....
Responsibility: ....
Address: ....
....
Tel: ....
Telex: ....
Fax: ....

If you are interested in more information about the Dobris project, please let us know.

Besides the final Dobris report, which will summarize the total ecological situation in Europe, a separate technical background document will be written on the air quality situations in all major European cities. Cities which fill out the questionnaire will receive a copy of this document.

End of questionnaire

ANNEX IV:SECOND QUESTIONNAIRE ON URBAN AND LOCAL AIR POLLUTION

NOTE

If not all questions fall under your responsibility, fill out your part and send a copy of the questionnaire to the person who is responsible for the remaining questions. Even if you are not able to fill in all questions for your city, please send (part of) the questionnaire back before 20 DECEMBER 1992.

2nd QUESTIONNAIRE

AIR QUALITY IN EUROPEAN CITIES

CITY REPORT:

city__________________________ country__________________________

4 February 1995

Person to whom this questionnaire was sent	
Name:	
Institute:	
Address:	
Postcode:	
City:	
Telephone:	
Fax:	

Person who filled in this questionnaire	
Name:	
Institute:	
Address:	
Postcode:	
City:	
Telephone:	
Fax:	

CITY .... COUNTRY ....

A. GENERAL INFORMATION

		City[1]	Conurbation[2]
Population[3]	(number)		
Total area[4]	(km x km)		
Built-up area[5]	(km x km)		
Coordinates[6]	(lat-/longitude)	° ' N ° '__	

Municipalities in conurbation

Major activities[7]

Development trends (1980-1990, 1990-2000)[8]

CITY .... COUNTRY ....

TOPOGRAPHY AND METEOROLOGY
Location[9] **Topography (siting)**[10] **Meteorology**[11]

LOCAL WIND DISTRIBUTION (WIND ROSE)[12]

Direction (30° sectors)		N 345-15	NNE 15-45	ENE 45-75	E 75-105	ESE 105-135	SSE 135-165	S 165-195
Average windrose	Freq. %							
1985	Wind speed m/s							
Direction (30° sectors)		SSW 195-225	WSW 225-255	W 255-285	WNW 285-325	NNW 315-345	Wind still	
	Freq. %							
	Wind speed m/s							

LOCAL WIND DISTRIBUTION (WIND ROSE)[12]

Direction (30° sectors)		N 345-15	NNE 15-45	ENE 45-75	E 75-105	ESE 105-135	SSE 135-165	S 165-195
Average windrose	Freq. %							
1990	Wind speed m/s							
Direction (30° sectors)		SSW 195-225	WSW 225-255	W 255-285	WNW 285-325	NNW 315-345	Wind still	
	Freq. %							
	Wind speed m/s							

Map of ______________________________________
Main topography, city morphology, industrial sources and monitoring network[13]

^
N

City centre /commercial area	▒		Scale 1 : ____________
Residential area	▓	╬	City coordinate (see page 2)
Industrial area	░	♦	Major point sources (+I, II, ..X)
Woodlands/parks/ 'green' areas	█	x	Air quality monitoring station (1,2,..10)
Other:	‖	▲	Meteorological (wind) station
		▌	Main road

CITY .... COUNTRY ....

B. EMISSION AND ACTIVITY DATA

Vehicle statistics and traffic activity
CONURBATION/CITY[14]

	Number of vehicles registered[15] entering from outside[16]	Total traffic activity[17]
Total[18] of which: · passenger cars · busses · freight traffic[19] >3.5 t		veh.km.a^{-1} veh.km.a^{-1} veh.km.a^{-1} veh.km.a^{-1}

Main roads

	Class[20]	Km of street/road[21]	Traffic activity[22]
Main city roads	10 - 50.000 veh/day		veh.km.a^{-1}
Motorway network	> 50.000 veh/day		veh.km.a^{-1}

TOTAL ANNUAL CONSUMPTION OF FUEL USED BY TRAFFIC
CONURBATION/CITY[23]

	Annual consumption (t.a^{-1})[24] 1985 19__[25]	Average Sulphur content (%) 1985 19__[25]
Diesel oil Petrol/Gasoline LPG		

Public transport systems[26]

CONURBATION/CITY[27]	Total public transport activity
non-electric-powered public transport (busses, diesel trains) electric-powered public transport (tramways, underground railways, trolley-busses)	passenger.km.a^{-1} passenger.km.a^{-1}

ROAD TRAFFIC[28]

▼

CITY .... COUNTRY ....

MAJOR INDUSTRY[29]

DOMESTIC/SPACE HEATING[30]

TOTAL ANNUAL CONSUMPTION OF FUEL USED BY SPACE/DOMESTIC HEATING CONURBATION/CITY[31]

	Annual consumption 1985	19__[32]	Average Sulphur content 1985	19__[32]
Fuel oil low sulphur ($t.a^{-1}$)	...	...	... %	...%
Fuel oil high sulphur ($t.a^{-1}$)	...	...	... %	...%
Coal ($t.a^{-1}$)	...	...	... %	...%
Wood ($t.a^{-1}$)	...	...		...%
Natural/city gas ($10^6\ m^3.a^{-1}$)	...	...		

▼

CITY .... COUNTRY ....

ANNUAL EMISSIONS PER SOURCE AND TOTALS IN 1985 (kton.a^{-1})
CONURBATION/CITY[33]

	SO_2	NO_x	CO	VOC	Particulate matter			Pb
					process emissions	of which percent PM_{10}	combus-tion	
Traffic								
. road traffic								
. ships and trains								
. other traffic								
Domestic/space heating								
Industry and power plants								
· stack height < 50 m								
· stack height > 50 m								
Total								
Per capita								
Per km^2								

ANNUAL EMISSIONS PER SOURCE AND TOTALS IN 1990 (OR IN THE MOST RECENT YEAR: 19__)
(kton.a^{-1})[33]
CONURBATION/CITY[34]

	SO_2	NO_x	CO	VOC	Particulate matter			Pb
					process emissions	of which percent PM_{10}	combus -tion	
Traffic								
. road traffic								
. ships and trains								
. other traffic								
Domestic/space heating								
Industry and power plants								
· stack height < 50 m								
· stack height > 50 m								
Total								
Per capita								
Per km^2								

CITY .... COUNTRY ....

LOCAL POLICIES ON AIR POLLUTION[35] (measures introduced and planned)
Traffic: **Domestic/space heating:** **Industry and power plants:**

CITY .... COUNTRY ....

C. AIR QUALITY DATA

MONITORING NETWORK[36]

AIR QUALITY MONITORING EQUIPMENT				
Component[37]	Analytical principle[38]	Manual or Automatic[39]	Integration period[40]	Quality assurance[41]
				1 2 ...

QUALITY ASSURANCE[41]	
Note	Explanation
1 2 ...	

.... Reports enclosed[42]

CITY .... COUNTRY ....

NUMBER OF MONITORING NETWORK STATIONS IN 1985 AND 1990 (OR IN THE MOST RECENT YEAR: 19__[43])								
Stations	Component							
	SO_2		NO_2		CO		O_3	
	1985	19__	1985	19__	1985	19__	1985	19__
Regional background[44] City background[45] Traffic site[46] Industrial site[47]								
Stations	Component							
	Heavy metals		TSP[48]		Black smoke		PM_{10}[49]	
	1985	19__	1985	19__	1985	19__	1985	19__
Regional background[44] City background[45] Traffic site[46] Industrial site[47]								

CITY .... COUNTRY ....

AIR QUALITY DATA[48]	SO_2 concentrations (µg/m³)									
Station identifier[49]										
Station type[50]										
Year[51]	1985	19__	1985	19__	1985	19__	1985	19__	1985	19
Annual average[52]										
Winter average[53]										
Maximum (24 h)[54]										
98 Percentile (24 h)[55]										
Number of days exceeding the WHO-AQG[56]										
Number of days exceeding 2 x WHO-AQG										
Monitoring period[57]										
First - Last year operation[58]										

CITY .... COUNTRY ....

AIR QUALITY DATA[59]	NO_2 concentrations (µg/m³)									
Station identifier[60]										
Station type[61]										
Year[62]	1985	19__	1985	19__	1985	19__	1985	19	1985	19
Annual average[63]										
Maximum (24 h)[64]										
Maximum (1 h)[65]										
Number of days exceeding the WHO-AQG[66]										
Number of days exceeding 2 x WHO-AQG										
Monitoring period[67]										
First - Last year of operation[68]										

CITY .... COUNTRY ....

AIR QUALITY DATA[69]	CO concentrations (mg/m³)									
Station identifier[70]										
Station type[71]										
Year[72]	1985	19__	1985	19__	1985	19__	1985	19__	1985	19__
Annual average[73]										
Maximum (8 h)[74]										
Number of days exceeding the WHO-AQG[75]										
Number of days exceeding 2 x WHO-AQG										
Monitoring period[76]										
First - Last year of operation[77]										

▾

CITY .... COUNTRY ....

AIR QUALITY DATA[78]	Pb concentrations ($\mu g/m^3$)									
Station identifier[79]										
Station type[80]										
Year[81]	1985	19__	1985	19__	1985	19__	1985	19__	1985	19__
Annual average[82]										
Maximum monthly average [83]										
Monitoring period[84]										
First - Last year of operation[85]										

▼

CITY .... COUNTRY ....

AIR QUALITY DATA[86]	TSP concentrations (µg/m³)									
Station identifier[87]										
Station type[88]										
Year[89]	1985	19__	1985	19__	1985	19__	1985	19__	1985	19__
Annual average[90]										
Winter average[91]										
Maximum (24 h)[92]										
98 Percentile (24 h)[93]										
Number of days exceeding the WHO-AQG[94]										
Number of days exceeding 2 x WHO-AQG										
Monitoring period[95]										
First - Last year of operation[96]										

CITY .... COUNTRY ....

AIR QUALITY DATA[97]	Black smoke concentrations (µg/m³)									
Station identifier[98]										
Station type[99]										
Year[100]	1985	19__	1985	19__	1985	19__	1985	19__	1985	19__
Annual average[101]										
Winter average[102]										
Maximum (24 h)[103]										
98 Percentile[104]										
Number of days exceeding the WHO-AQG[105]										
Number of days exceeding 2 x WHO-AQG										
Monitoring period[106]										
First - Last year of operation[107]										

CITY .... COUNTRY ....

AIR QUALITY DATA[108]	**Other components** ______________ (μg/m³)									
Station identifier[109]										
Station type[110]										
Year[111]	1985	19__	1985	19__	1985	19__	1985	19__	1985	19__
Annual average[112]										
Winter average[113]										
Maximum (__ h)[114]										
98 Percentile[115]										
Number of days exceeding the WHO-AQG[116]										
Number of days exceeding 2 x WHO-AQG										
Monitoring period[117]										
First - Last year of operation[118]										

CITY .... COUNTRY ....

D. EXPOSURE

EXPOSURE OF CITIZENS[119]

EXPOSURE OF VEGETATION[120]

CITY .... COUNTRY ....

EXPOSURE OF BUILDINGS AND MONUMENTS[121]

DOMINATING BUILDING MATERIALS[122]		
Type of building	Facade	Roof
Historic buildings Apartment buildings Small private houses Industry		

Sensitive materials used in historic monuments
Historic buildings **Historic statues and constructions**

■ *End of the questionnaire*

Annex IV: Explanatory notes to questionnaire

1 **City**: The core municipality of the named conurbation/city.
2 **Conurbation**: Core municipality together with its **morphologically** integrated neighbouring cities/towns, or a city and its suburbs. Secondary towns or suburbs separated by more than 2.5 km from the prime city are excluded.
3 **Population**: Please give the number of inhabitants.
4 **Total area**: Total administrative area.
5 **Built-up area**: Area with permanent man-made structures (e.g. houses, buildings, infrastructure)
6 **Coordinates**: The city centre coordinates have been taken from the *Times Atlas of the World* (1991 edition).
7 **Major activities**: Activities of major economic importance, e.g. harbour and port, heavy industry, business and administration, tourism, etc.
8 **Development trends**: Trends in city growth, changes in major economic activities, etc.
9 **Location**: Macro/meso scale characteristics, e.g. North, South, West or East Europe, distance to a sea, hills/mountains, plains. These characteristics determine climatic features.
10 **Topography (siting)**: Local-scale characteristics especially those leading to potentially adverse dispersion conditions, e.g. enclosed basin/valley (persistent inversions, calms, wind direction), coastal (land-sea breezes, wind direction).
11 **Meteorology**: Adverse dispersion conditions, e.g. inversions in valley systems or sea-land breezes in Mediterranean coastal cities.
12 **Local wind distribution**: For a representative wind station in or near the city centre, please give the distribution (percent of time) the wind blows from the indicated 30° sectors for annual average wind statistics for 1985 and for 1990 or, if not available the most recent year. **Indicate the position of the station on the map**. Frequence of wind still periods: the wind speed below which wind still is defined (or < 0.5 m/s).
13 **Map**: Please provide, if available, a map of your city showing at least the features mentioned above. Please use different gray shades to draw the city centre/commercial areas, residential and industrial areas. Please also indicate the borders of the constituent municipalities using broken lines.
14 **Conurbation/City**: Delete where not applicable. Conurbation data is of most interest.
15 **Registered**: Within the city or conurbation
16 **Entering from outside**: Number of cars entering the city or conurbation on weekdays.
17 **veh.km.a^{-1}**: Vehicle x kilometer per year
18 **Total/of which**: Please give totals and, if available, a breakdown into categories.
19 **Freight traffic**: Heavy-duty traffic with vehicles > 3.5 metric tons
20 **Class**: Annual average daily traffic on main streets and on the motorway network.
21 **Km of street/road**: Total number of kilometers of main streets and motorways in the city or conurbation.
22 **veh.km.a^{-1}**: Vehicle x kilometer per year
23 **Conurbation/City**: Delete where not applicable. Conurbation data is of most interest.
24 **t.a^{-1}**: (Metric) ton per year
25 Please give 1990 data or, if not available, data from the most recent year.
26 **Public transport systems**: Please give the total number of passenger kilometers per year (passenger.km.a^{-1}) divided between the two categories.
27 **Conurbation/City**: Delete where not applicable. Conurbation data is of most interest.
28 **Road traffic**: Please give other relevant information concerning road traffic (if available), e.g. the number of cars equiped with a catalyst, most evident problems (e.g. traffic jams) etc.
29 **Major industry**: Please give information on the most important emitters due to economic activity (except road traffic), for example **type of emitters** e.g. industrial estates causing specific air quality problems, power plants, incinerators and nautic activity, **stack heights** of the main emitters, **energy output** of the stacks (Mega Watt) and **emission compounds and amounts**. Please also draw the location of the main emitters on the map using roman numbers (I, II ..X).
30 **Domestic/space heating**: Please give some general remarks, e.g. on the types of space/domestic heating used.
31 **Conurbation/City**: Delete where not applicable. Conurbation data is of most interest.
32 Please give 1990 data or, if not available, data from the most recent year.
33 **Conurbation/City**: Delete where not applicable. Conurbation data is of most interest.
34 If data for 1990 is not available, please give data for the most recent year.
35 **Local policies**: Measures taken since 1980 to reduce air pollution and measures planned in the next few years. Please indicate intended/expected effects of the measures.
36 **Monitoring network**: Please provide some general information on the air quality monitoring network, e.g. the institute responsible for the network and the main objectives of the network. If (part of) the network is used as an alert network, please give some information on the alert/alarm procedures. Please also give information how information from the network is diffused to the public (e.g. reports in newspapers).
37 **Component**: The pollutant monitored. In those cases where a component is determined using different analytical principles, for example SO_2 by both UV fluorescence and flame photometry (see also *analytical principle*), list them

as $SO_2(1)$ and $SO_2(2)$.

38 **Analytical principle**: The method used to determine the ambient concentration, e.g. ultraviolet fluorescence.

39 **Manual/automatic**: M for a manually operated monitor from which samples are collected on a regular basis (e.g. black smoke monitors using filters replaced every day) and **A** for an automatic monitor with continuous output.

40 **Integration period**: For a manually operated monitor please give the sampling period (e.g. 1 week), for an automatic monitor please give the integration period of the monitoring results (e.g. 1 hour).

41 **Quality assurance**: Please indicate how quality of the measurements is assured. In this column you can give a number which responds to explanation given in the Table **Quality assurance**.

42 **Reports enclosed**: The amount of information asked on air quality monitoring stations is limited. We are aware of the fact that it will be difficult to interpret air quality data on the basis of this information alone. The reason for not requesting more detailed information is to avoid overburdening you with work. However, we remain very interested in more detailed information on air quality stations, like siting, longitude and latitude of the station, components monitored, height above sea level etc. If you have this information available, for example in the form of a technical report, we would be very interested in receiving it!

43 If data for 1990 is not available, please give data for the most recent year.

44 **Regional background stations**: stations located outside the urban area (**minimal 3 km distance and maximal distance 50 km of the conurbation built-up area**) and not directly influenced by anthropogenic emission sources: they are used to monitor regional 'background' air pollution levels.

45 **City background stations**: stations located within the built-up area of conurbations, but situated away from busy streets and industrial sources (not directly influenced by traffic or industry). For this project, city background stations are of special interest. Air quality data from these stations will be used to calculate the city background air pollution levels to which the city's inhabitants are exposed.

46 **Traffic stations**: Traffic (street/curbside) stations are located in busy streets and are used to monitor the contribution of traffic to (urban) air pollution levels.

47 **Industrial stations**: Industrial stations are located near to or at industrial sites/estates and are used to monitor air pollution levels there. In many cases these stations are part of an alarm/alert network.

48 **TSP**: Total Suspended Particulate matter.

49 **PM_{10}**: Particulate matter with a aerodynamic diameter of < 10 μm (respiratory fraction).

48 **Air quality data**: Please fill in the table. If there are many stations operational, please choose a maximum of 10 represenitive stations to describe the city background concentration, 1 station measuring the highest street (traffic-induced) concentrations and 1 station measuring the highest industry-induced concentrations. Please first list the *traffic station*, secondly the *industrial station* and then the *city background stations*. Please draw the identification number/code of the stations on the map.

49 **Station identifier**: Please give each station an identification (name or number) to show the location of the station on the map.

50 **Station type**: Please specify the station type (*regional background, city background, traffic (street) station or industrial station* (see also points 36-39)). As far as street and industrial stations are concerned, only data about the monitoring point measuring the highest concentrations should be given.

51 **Year**: Please give concentration data for two years: 1985 and 1990 or, if not available the most recent year.

52 **Annual average**: Please give the annual average. If an average is based on less than 50% of the possible values, please underline this figure.

53 **Winter average**: Please give the winter average. If an average is based on less than 50% of the possible values, please underline this figure. Winter period is defined from 1 October 1984 - 31 March 1985 and 1 October 1989 - 31 March 1990 (or most recent year).

54 **Maximum (24 h)**: Please give the maximum concentration monitored. If an maximum is based on less than 75% of the possible values, please underline this figure.

55 **98 Percentile**: Please give the 98 percentile. If a 98 percentile is based on less than 75% of the possible values, please underline this figure.

56 **Number of days above WHO-AQG**: WHO-Air Quality Guideline: **SO_2: maximum (24 hour) = 125 $\mu g/m^3$**. If the figure is based on less than 75% of the possible values, please underline this figure.

57 **Monitoring period**: Please specify the monitoring period per year, e.g. Jan-Feb.

58 **First - Last year operation**: Please give the year in which monitoring was started at the station and, if closed down, the last year of operation.

59 **Air quality data**: Please fill in the table. If there are many stations operational, please choose a maximum of 10 representive stations to describe the city background concentration, 1 station measuring the highest street (traffic induced) concentrations and 1 station measuring the highest industry-induced concentrations. Please first list the *traffic station*, secondly the *industrial station* and then the *city background stations*. Please draw the identification number/code of the stations on the map.

60 **Station identifier**: Please give each station an identification (name or number) to show the location of the station on the map.

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62 **Year**: Please give concentration data for two years: 1985 and 1990 or, if not available the most recent year.

63 **Annual average**: Please give the annual average. If an average is based on less than 50% of the possible values, please underline this figure.

64 **Maximum (24 h)**: Please give the maximum concentration monitored. If an maximum is based on less than 75% of the possible values, please underline this figure.

65 **Maximum (8 h)**: Please give the maximum concentration monitored. If an maximum is based on less than 75% of the possible values, please underline this figure.

66 **Number of days above WHO-AQG**: WHO-Air Quality Guideline: **NO_2: maximum (24 hour) = 150 µg/m^3**. If the figure is based on less than 75% of the possible values, please underline this figure.

67 **Monitoring period**: Please specify the monitoring period per year, e.g. Jan-Feb.

68 **First - Last year operation**: Please give the year in which monitoring was started at the station and, if closed down, the last year of operation.

69 **Air quality data**: Please fill in the table. If there are many stations operational, please choose a maximum of 10 representive stations to describe the city background concentration, 1 station measuring the highest street (traffic induced) concentrations and 1 station measuring the highest industry-induced concentrations. Please first list the *traffic station*, secondly the *industrial station* and then the *city background stations*. Please draw the identification number/code of the stations on the map.

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71 **Station type**: Please specify the station type (*regional background, city background, traffic (street) station or industrial station* (see also points 36-39)). As far as street and industrial stations are concerned, only data about the monitoring point measuring the highest concentrations should be given.

72 **Year**: Please give concentration data for two years: 1985 and 1990 or, if not available the most recent year.

73 **Annual average**: Please give the annual average. If an average is based on less than 50% of the possible values, please underline this figure.

74 **Maximum (8 h)**: Please give the maximum concentration monitored. If an maximum is based on less than 75% of the possible values, please underline this figure.

75 **Number of days above WHO-AQG**: WHO-Air Quality Guideline: **CO: maximum (8 hour) = 10 mg/m^3**. If the figure is based on less than 75% of the possible values, please underline this figure.

76 **Monitoring period**: Please specify the monitoring period per year, e.g. Jan-Feb.

77 **First - Last year operation**: Please give the year in which monitoring was started at the station and, if closed down, the last year of operation.

78 **Air quality data**: Please fill in the table. If there are many stations operational, please choose a maximum of 10 representive stations to describe the city background concentration, 1 station measuring the highest street (traffic induced) concentrations and 1 station measuring the highest industry-induced concentrations. Please first list the *traffic station*, secondly the *industrial station* and then the *city background stations*. Please draw the identification number/code of the stations on the map.

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80 **Station type**: Please specify the station type (*regional background, city background, traffic (street) station or industrial station* (see also points 36-39)). As far as street and industrial stations are concerned, only data about the monitoring point measuring the highest concentrations should be given.

81 **Year**: Please give concentration data for two years: 1985 and 1990 or, if not available the most recent year.

82 **Annual average**: Please give the annual average. If an average is based on less than 50% of the possible values, please underline this figure.

83 **Maximum monthly average**: Please give the highest monthly average.

84 **Monitoring period**: Please specify the monitoring period per year, e.g. Jan-Feb.

85 **First - Last year operation**: Please give the year in which monitoring was started at the station and, if closed down, the last year of operation.

86 **Air quality data**: Please fill in the table. If there are many stations operational, please choose a maximum of 10 representive stations to describe the city background concentration, 1 station measuring the highest street (traffic induced) concentrations and 1 station measuring the highest industry-induced concentrations. Please first list the *traffic station*, secondly the *industrial station* and then the *city background stations*. Please draw the identification number/code

of the stations on the map.

87 **Station identifier**: Please give each station an identification (name or number) to show the location of the station on the map.

88 **Station type**: Please specify the station type (*regional background, city background, traffic (street) station or industrial station* (see also points 36-39)). As far as street and industrial stations are concerned, only data about the monitoring point measuring the highest concentrations should be given.

89 **Year**: Please give concentration data for two years: 1985 and 1990 or, if not available the most recent year.

90 **Annual average**: Please give the annual average. If an average is based on less than 50% of the possible values, please underline this figure.

91 **Winter average**: Please give the winter average. If an average is based on less than 50% of the possible values, please underline this figure. Winter period is defined from 1 October 1984 - 31 March 1985 and 1 October 1989 - 31 March 1990 (or most recent year).

92 **Maximum (24 h)**: Please give the maximum concentration monitored. If an maximum is based on less than 75% of the possible values, please underline this figure.

93 **98 Percentile**: Please give the 98 percentile. If a 98 percentile is based on less than 75% of the possible values, please underline this figure.

94 **Number of days above WHO-AQG**: WHO-Air Quality Guideline: **TSP : maximum (24 hour) = 120 $\mu g/m^3$**. If the figure is based on less than 75% of the possible values, please underline this figure.

95 **Monitoring period**: Please specify the monitoring period per year, e.g. Jan-Feb.

96 **First - Last year operation**: Please give the year in which monitoring was started at the station and, if closed down, the last year of operation.

97 **Air quality data**: Please fill in the table. If there are many stations operational, please choose a maximum of 10 representive stations to describe the city background concentration, 1 station measuring the highest street (traffic induced) concentrations and 1 station measuring the highest industry-induced concentrations. Please first list the *traffic station*, secondly the *industrial station* and then the *city background stations*. Please draw the identification number/code of the stations on the map.

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100 **Year**: Please give concentration data for two years: 1985 and 1990 or, if not available the most recent year.

101 **Annual average**: Please give the annual average. If an average is based on less than 50% of the possible values, please underline this figure.

102 **Winter average**: Please give the winter average. If an average is based on less than 50% of the possible values, please underline this figure. Winter period is defined from 1 October 1984 - 31 March 1985 and 1 October 1989 - 31 March 1990 (or most recent year).

103 **Maximum (24 h)**: Please give the maximum concentration monitored. If an maximum is based on less than 75% of the possible values, please underline this figure.

104 **98 Percentile**: Please give the 98 percentile. If a 98 percentile is based on less than 75% of the possible values, please underline this figure.

105 **Number of days above WHO-AQG**: WHO-Air Quality Guideline: **Black smoke: maximum (24 hour) = 125 $\mu g/m^3$**. If the figure is based on less than 75% of the possible values, please underline this figure.

106 **Monitoring period**: Please specify the monitoring period per year, e.g. Jan-Feb.

107 **First - Last year operation**: Please give the year in which monitoring was started at the station and, if closed down, the last year of operation.

108 **Air quality data**: Please fill in the table. If there are many stations operational, please choose a maximum of 10 representive stations to describe the city background concentration, 1 station measuring the highest street (traffic induced) concentrations and 1 station measuring the highest industry-induced concentrations. Please first list the *traffic station*, secondly the *industrial station* and then the *city background stations*. Please draw the identification number/code of the stations on the map.

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111 **Year**: Please give concentration data for two years: 1985 and 1990 or, if not available the most recent year.

112 **Annual average**: Please give the annual average. If an average is based on less than 50% of the possible values, please

underline this figure.

113 Winter average: Please give the winter average. If an average is based on less than 50% of the possible values, please underline this figure. Winter period is defined from 1 October 1984 - 31 March 1985 and 1 October 1989 - 31 March 1990 (or most recent year).

114 Maximum (__ h): Please give the maximum concentration monitored. If an maximum is based on less than 75% of the possible values, please underline this figure.

115 98 Percentile: Please give the 98 percentile. If a 98 percentile is based on less than 75% of the possible values, please underline this figure.

116 Number of days excedding the WHO-AQG: WHO-Air Quality Guideline: ___________: **maximum (__ hour) = ___ μg/m³**. If the figure is based on less than 75% of the possible values, please underline this figure.

117 Monitoring period: Please specify the monitoring period per year, e.g. Jan-Feb.

118 First - Last year operation: Please give the year in which monitoring was started at the station and, if closed down, the last year of operation.

119 Do you have or have there been conducted any studies regarding the air pollution exposure of your city's inhabitants and its effects (e.g. epidemiological studies, health studies)? Y/N
If yes please list or send the reports. If we have already listed reports, please send us those reports.

120 Do you have or have there been conducted any studies regarding the air pollution exposure of your city vegetation and its effects (e.g. certain trees cannot be expected to survive) or on surrounding nature (e.g. downwind effects)? Y/N
If yes please list or send the reports. If we have already listed reports, please send us those reports.

121 Do you have or have there been conducted any studies regarding the air pollution exposure of materials and monuments in the city or its surroundings? Y/N
If yes please list or send the reports. If we have already listed reports, please send us those reports.

122 Please list the most dominating material for facade and roof

Questionnaire on local industrial air pollution problems in Europe

Comments

NAME	To be used for identification in texts.
LOCATION	Please indicate province, district and city/town/village.
TYPE	Industrial process/branch (excl. nuclear plants).
MAIN COMPOUNDS	Please list the main compounds causing adverse effects on health and vegetation.
MAX. CONCENTRATIONS	Please indicate, if available, the maximum concentrations occuring in the vicinity of the plant/area. NB: together with the concentration value, remember to give the associated averaging time (e.g. 1-hour, 24-hour, month, 6 months, year).
POPULATION AFFECTED	Please indicate the no. of inhabitants of the area near the plant/industrial area who are affected adversely by the emissions, i.e. living in places experiencing exceedances of air quality guidelines (WHO or national). If very little is known about the distribution of pollution levels in the area, indicate in any case the total number of inhabitants living in the vicinity of the plant.
VEGETATION AFFECTED	Please describe briefly the vegetation damage (type, extent) which may occur in the vicinity of the plant.
EMISSION CONTROLS	Please describe briefly the type of emission control equipment presently installed.

If necessary, to get enough space, please copy the questionnaire, and use more than one line per industry/area.

Questions will be answered by
Steinar Larssen or Knut Erik Grønskei at telephone no. +47 6 81 41 70.

Questionnaire: Summary information on local industrial Air Pollution Problems in Europe

Country: | Filled in by: NAME ADDRESS PHONE FAX

	NAME of plant/industrial area	LOCATION name of district, and city/town /village	TYPE of industry	MAIN COM-POUNDS causing adverse effects (health,	MAX CON-CENTRATION	POPULATION AFFECTED (thousands)	VEGETATION AFFECTED (type, area)	EMISSION CONTROLS (present controls installed)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

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ANNEX VI.a: Population estimates from various sources

Country	City (Conurbation)	Population statistics							
		UN City[1]	UN Con[2]	Times Con[3]	Economist[4]	UN-IEDS	1st City[5]	2st City[6]	2st Con[7]
Albania/Shqiperia	Tirana/Tiranë				238 000 (A)	239 000	243 000	274 000	450 000
Austria/Österreich	Vienna/Wien	1 531 346 (1986E)		1 531 000	1 500 000			1 564 000	
Belarus/**БЕЛОРУССИЯ**	Minsk/**МИНСК**	1 543 000 (1987E)		1 589 000	1 613 000	1 665 000	1 600 000		
Bulgaria/Bulgarija	Sofia/Sofiya	1 127 527 (1987E)		1 129 000	1 100 000	1 220 000			1 300 000*
Belgium/Belgique/België	Antwerp/Antwerpen	483 199 (1986E)		476 000	476 000		467 709		785 000*
	Brussels/Bruxelles/Brussel		967 443	970 000	1 268 000			970 000	1 268 000
Croatia/Hrvatska	Zagreb/Agram	649 586 (1981)		1 175 000	763 000	934 000	930 550	706 770	953 607
Czech republic	Prague/Praha	1 209 149 (1988E)		1 200 000	1 200 000	1 216 000			
Denmark/Danmark	Copenhagen/Kopenhavn	469 706 (1987E)		1 344 000	1 372 000	1 337 000			1 700 000
Estonia/Estonia	Tallin/Tallinn	478 000 (1987E)		482 000	503 000		500 000		
Finland/Suomi Finland	Helsinki/Helsingfors	488 777 (1987E)			490 800	929 000			
France/France	Lille/Lille/Rijssel	164 900 (1982)	935 000		936 000				950 000*
	Lyon/Lyon	408 860 (1982)	1 170 000		1 221 000				1 262 000
	Marseille/Marseilles	867 260 (1982)		1 080 000	1 110 000		900 000	810 000	
	Paris/Paris	2 188 960		8 510 000	8 707 000				
	Toulouse/Toulouse	345 000 (1982)	523 000				650 000		

Country	City (Conurbation)	Population statistics							
		UN City[1]	UN Con[2]	Times Con[3]	Economist[4]	UN-IEDS	1st City[5]	2st City[6]	2st Con[7]
Germany/Deutschland	Berlin Former West/Berlin	2 046 062 (1988E)							
	Berlin Former East/Berlin	1 228 715 (1982)		3 236 000	3 300 000	3 434 000			
	Bremen/Bremen	533 809 (1988E)		545 000		551 000	552 500	553 000	
	Cologne/Köln	934 375 (1988E)		928 000	934 400	954 000			
	Dortmund/Dortmund	584 595 (1988E)		2 746 000*		599 000	600 000		
	Dresden/Dresden	515 892 (1988E)				491 000	480 000		
	Duisburg/Duisburg	525 090 (1988E)		542 000		535 000			
	Düsseldorf/Düsseldorf	567 372 (1988E)		580 000		576 000	577 000	577 000	
	Essen/Essen	619 981 (1988E)		2 746 000*		627 000			
	Frankfurt/Frankfurt	623 000 (1988E)		615 000		645 000			
	Hamburg/Hamburg	1 595 255 (1988E)		1 599 000	1 624 000	1 652 000	1 670 000	1 626 000	
	Hannover/Hannover	497 184 (1988E)		524 000		513 000	514 445		
	Leipzig/Leipzig	538 860 (1988E)				511 000			
	Munich/München	1 206 394 (1988E)		1 189 000	1 200 000	1 229 000			
	Nurnberg/Nürnberg	476 000 (1988E)				494 000	500 000		800 000
	Stuttgart/Stuttgart	560 079 (1988E)		571 000		580 000			

Country	City (Conurbation)	Population statistics							
		UN City[1]	UN Con[2]	Times Con[3]	Economist[4]	UN-IEDS	1st City[5]	2st City[6]	2st Con[7]
Greece/Ellas	Athens/Athinai	885 737 (1989E)		3 027 000	3 100 000				
	Thessaloniki/				969 000				
Hungary/Magyarorszag	Budapest/Budapest	2 109 173 (1989E)		3 962 000	2 000 000	2 018 000	2 018 000		4 434 000
Ireland/Ireland	Dublin/Dublin	502 749 (1989E)		921 000	502 700	478 000		478 000	547 000
Iceland/Island (Svalbard)	Reykjavik/				143 300			112 000	150 000
Italy/Italya	Genoa/Genova	742 442 (1984E)				701 000	695 852		
	Milan/Milano	1 548 580 (1984E)		1 479 000	1 600 000 (A) 2 880 000 (B)	1 432 000			
	Naples/Napoli	1 207 750 (1984E)		1 201 000	1 200 000 (A) 2 610 000 (B)	1 206 000	1 067 365		
	Palermo/Palermo	714 246 (1984E)							
	Rome/Roma	2 828 692 (1984E)		2 817 000	2 800 000 (A) 3 000 000 (B)	2 791 000			3 710 000
	Turin/Torino	1 059 505 (1984E)		1 025 000	1 000 000 (A) 1 568 000 (B)	992 000	980 000	980 000	1 784 000
Latvia/Latvia	Riga/Riga	900 000 (1987E)		915 000	917 000	597 000	897 100		
Lithuania/Lithuania	Vilnius/Vilna	566 000 (1987E)		587 000	582 000				
Luxembourg/Luxembourg	Luxembourg/Luxembourg				76 600		78 000		

Country	City (Conurbation)	Population statistics							
		UN City[1]	UN Con[2]	Times Con[3]	Economist[4]	UN-IEDS	1st City[5]	2st City[6]	2st Con[7]
Moldova/	Chisinau/Kishinev				580 000	745 000	675 500		
Netherlands/Nederland	Amsterdam/Amsterdam	639 209 (1988E)		1 031 000	576 000 (A) 695 000 (B)		700 000	702 000	1 077 000
	Rotterdam/Rotterdam	576 226 (1988E)		1 036 000	576 000 (A) 1 025 000 (B)		1 000 000	582 000	1 089 000*
	The Hague/'s-Gravenhage			680 000	444 000 (A)		430 000	430 000	654 000
Norway/Norge	Oslo/Oslo	454 927 (1988E)		454 000	458 000 (A)			462 000	616 000
Poland/Polska	Gdansk/Danzig	469 726 (1988E)				467 000			
	Katowice/							360 000	
	Krakow/Cracow	750 842 (1988E)			734 700 (A)	751 000		800 000	
	Lodz/Lodz	857 485 (1988E)			851 000	845 000			
	Poznan/Posen	590 299 (1988E)				589 000			
	Warsaw/Warszawa	1 673 688 (1988E)		1 671 000	1 700 000	1 653 000			
	Wroclaw/Breslan	644 411 (1988E)			637 400	644 000			
Portugal/Portugal	Lisboa/Lisbon	807 167 (1981)		1 612 000	1 329 000 (A) 2 000 000 (B)				
	Porto/Oporto			1 314 794	1 700 000				
	Setubal/				799 000				
Romania/Romania	Bucharest/Bucaresti	1 807 239 (1977)		2 273 000	2 900 000	2 107 000	2 300 000		2 388 068

Country	City (Conurbation)	Population statistics							
		UN City[1]	UN Con[2]	Times Con[3]	Economist[4]	UN-IEDS	1st City[5]	2st City[6]	2st Con[7]
Russia/**РОССИЯ**	Kazan/**КАЗАНЬ**			1 099 000			1 031 000		
	Krasnodar/**КРАСНОДАР**	623 000 (1987E)					595 000		
	Moscow/**МОСКВА**	8 818 000 (1987E)		8 967 000	9 000 000		9 000 000		
	Nizhniy Novgorod/ **ГОРЬКИЙ** (former Gorkiy)	1 425 000		1 438 000	1 400 000		1 448 200	1 448 200	2 549 400
	Perm/**ПЕРМЬ**	1 075 000 (1987E)		1 091 000			1 119 400	1 119 400	
	St.Petersburg/**ПЕТЕРБУРГ** (former Leningrad)	4 948 000 (1987E)		5 020 000	5 000 000		4 948 000		
	Rostov at the Don/ **РОСТОВ-НА-ДОНУ**	1 004 000 (1987E)		1 020 000	1 000 000		1 100 000	1 100 000	
	Saratov/**САРАТОВ**	918 000 (1987E)					909 000		
	Samara/**КУЙБЫШЕВ** (former Kuibyshev)	1 280 000 (1987E)		1 257 000			1 400 000		1 244 000
	Togliatti/	627 000 (1987E)					670 000	670 000	
	Tula/**ТУЛА**	538 000 (1987E)					541 400	541 000	
	Ufa/**У Ф А**	1 092 000 (1987E)		1 093 000			1 034 000		
	Izhevsk/**ИЖЕВСК** (former Ustinov)	631 000 (1987E)					680 000	635 200	
	Volgograd/**ВОЛГОГРАД**	988 000 (1987E)		999 000	1 000 000		1 040 000	1 007 100	
	Voronezh/**ВОРОНЕЖ**	872 000 (1987E)					957 500		
	Yaroslavl/**ЯРОСЛАВЛЬ**	634 000 (1987E)					619 000		

Country	City (Conurbation)	Population statistics							
		UN City[1]	UN Con[2]	Times Con[3]	Economist[4]	UN-IEDS	1st City[5]	2st City[6]	2st Con[7]
Serbia/Serbija*	Belgrade/Beograd	1 087 915 (1981)		1 407 000	1 500 000	1 554 000	*		
Slovak Republic	Bratislava/Bratislava				435 700	444 000		445 000	475 000
Slovenia/Slovenija	Ljubljana/Laibach				500 000	322 000		273 000	
Spain/Espana	Barcelona/Barcelona	1 667 000 (1989E)		1 704 000	1 700 000 (A) 2 701 000 (B)			1 687 000	3 097 000
	Madrid/Madrid	2 991 223 (1989E)		3 101 000	3 100 000 (A) 4 120 000 (B)				3 120 000
	Sevilla/Seville	653 000 (1989E)			663 000				780 000
	Valencia/Valencia	718 750 (1989E)			774 000				753 000
	Zaragoza/Saragossa	573 994 (1919E)							
Sweden/Sverige	Gothenburg/Göteborg				725 990	734 000			
	Stockholm/Stockholm			1 617 000	1 500 000	1 503 000		667 000	
Switzerland/Helvetia	Zurich/Zürich				343 000		362 000		356 000
Turkey/	Istanbul/			5 494 916		7 944 000		6 620 000	6 886 000

Country	City (Conurbation)	Population statistics							
		UN City[1]	UN Con[2]	Times Con[3]	Economist[4]	UN-IEDS	1st City[5]	2st City[6]	2st Con[7]
Ukraine/**УКРАИНА**	Dnepropetrovsk/**ДНЕПРО-ПЕТРОВСК**	1 182 000 (1987E)		1 179 000			1 300 000	1 215 000	
	Donetsk/**ДОНЕТСК**	1 090 000 (1987E)		1 110 000	1 100 000		1 121 400	1 121 400	
	Kharkov/**ХАРКОВ**	1 587 000 (1987E)		1 611 000	1 600 000		1 621 600	1 621 600	
	Kiev/**КИЕВ**	2 544 000 (1987E)		2 587 000	2 587 000		2 500 000		
	Krivoy Rog/**КРИВОЙ РОГ**	698 000 (1987E)					786 900	769 000	
	Lvov/**ЛВОВ**	767 000 (1987E)					780 000/ 807 300	800 000	1 200 000
	Mariupol/**ЖДАНОВ** (former Zhadonov)	529 000 (1987E)					545 100		
	Odessa/**ОДЕССА**	1 414 000 (1987E)		1 115 000	1 100 000				
	Zaporozhe/**ЗАПОРОЖЕ**	875 000 (1987E)					895 000		
United Kingdom	Belfast							295 000	392 000
	Birmingham	933 695 (1987E)		2 311 000	992 000 (A)				
	Glasgow	703 186 (1988E)		894 000					
	Leeds	709 000 (1988E)			712 000				
	Liverpool	469 642 (1988E)		no data				470 000	
	London	6 735 353 (1988E)		9 022 000	6 800 000 (A) 7 678 000 (B)				10 570 000
	Manchester	445 927 (1988E)		2 578 000	2 600 000 (A) 2 339 000 (B)				
	Sheffield	528 300 (1988E)							

1: **Population of the 'city'. Information based on the 1989 Demographic Yearbook of the United Nations. E=estimate.**
2: **Population of the 'conurbation'. Information based on the 1989 Demographic Yearbook of the United Nations. E=estimate.**
3: **Population of the 'conurbation'. Information based on the Times Atlas of the World, 1991 edition ('recent information').**
4: **Population of the 'city' (A) or 'conurbation' (B). Information based on Vital World Statistics (the Economist, 1992)**
5: **Population of the 'city'. Information based on the first questionnaire 'Air Quality in European Cities'.**
6: **Population of the 'city'. Information based on the second questionnaire 'Air Quality in European Cities'.**
7: **Population of the 'conurbation'. Information based on the second questionnaire 'Air Quality in European Cities'.**
*: **University of Brussels**

Annex VI.b: Population and urban area estimates used

City	Location	City				Conurbation				Population density
	Co-ordinates	Population (*1000)		Area (km²)		Population (*1000)		Area (km²)		Inh/km²
	lat-lon	(19..)	(19..)	Total	Built-up	(19..)	(19..)	Total	Built-up	
Amsterdam	52.21/4.52	639^{88}	702^{92}	162^{92}			**1077**	**583**		1847
Antwerp	51.13/4.25	483^{86}	468^{92}				**785**	370^{92}	**299^{92}**	2625
Athens	38.00/23.44		886^{91}	427	**350**		**3100**			8857
Barcelona	41.25/2.10	1667^{89}	1687^{91}	91			**3097**	**457**		6777
Belfast	54.40/-5.50		**295**	**106**			392			2783
Berlin	52.32/13.25		3300	330			**3434**	**880**		3902
Birmingham	52.30/-1.50		934^{87}				**2311**		**150#**	15407#
Bratislava	48.10/17.10		445^{91}	368	121		**475**	400	**132**	3598
Bremen	53.05/8.48	534^{88}	**553^{92}**	327	**100**					5530
Brussels	50.50/4.21						**1349^{90}**	485^{90}	**402^{90}**	3356
Bucharest	44.28/26.07	1807^{77}	2300^{90}			1900^{80}	**2388^{90}**	228^{90}	**182^{90}**	13121
Budapest	47.25/19.13		2018^{91}	370^{89}	200^{89}		**4434^{91}**	**525^{92}**		8446
Chisinau	47.00/28.50						**675^{92}**		**220^{92}**	3068
Cologne	50.56/6.57	934^{88}	**954^{92}**	**120**						7950
Copenhagen	55.47/12.34		470^{90}	88	80		**1700^{90}**	2860	**670**	2537
Dnepropetrovsk	48.29/35.00	1182^{87}	1215^{92}	397^{92}	222^{92}		**1215^{92}**	397^{92}	**222^{92}**	5473
Donetsk	48.00/37.50	1090^{87}	1121^{92}	366^{91}	236^{92}		**1121^{92}**	366^{91}	**236^{92}**	4750
Dortmund	51.32/7.27	585^{88}	**600^{92}**		**280**					2143
Dresden	51.03/13.45	516^{88}	**480^{92}**	230	**226**					2124
Dublin	53.20/-6.05		478^{91}	115			**547**	806	**115#**	4757#
Duisburg	51.26/6.48	525^{88}	**535^{92}**	**140**						3821

City	Location	City				Conurbation				Population density
	Co-ordinates	Population (*1000)		Area (km^2)		Population (*1000)		Area (km^2)		Inh/km^2
	lat-lon	(19..)	(19..)	Total	Built-up	(19..)	(19..)	Total	Built-up	
Düsseldorf	51.13/6.47	567^{88}	**577^{92}**	220	**95**					6074
Essen	51.27/6.57	620^{88}	**627^{92}**	**300**						2090
Frankfurt	50.06/8.41		623^{88}				**645^{92}**		**50#**	12900#
Gdansk	54.22/18.41	470^{88}	**467^{92}**	**50#**						9340#
Genoa	44.24/8.56						**696^{92}**		**240**	2900
Glasgow	55.53/-4.18		703^{88}				**894**		**150#**	5960#
Gothenburg	57.45/12.00		514^{89}				**734^{92}**	654	**132**	5561
Hamburg	53.33/10.00	1595^{88}	**1626^{93}**	**755**						2154
Hannover	52.33/9.44	497^{88}	**514^{92}**		**204**					2520
Helsinki	60.08/25.00	489^{87}	491^{90}	184	105		**929^{92}**	743	**242**	3839
Istanbul	41.02/28.57		6620^{90}			5476^{85}	**6886^{90}**	**1991^{90}**		3459
Izhevsk	56.49/53.11	631^{87}	635^{92}	260^{91}			**635^{92}**	**260^{91}**		2442
Katowice	50.13/19.02		**360^{90}**	165	**46**					7826
Kazan	55.45/49.10	1068^{87}	1099^{92}	285^{90}			**1099^{92}**	**285^{90}**		3856
Kharkov	50.00/36.15	1587^{87}	1621^{91}	305^{92}	226^{92}		**1621^{91}**	305^{92}	**226^{92}**	7173
Kiev	30.25/30.30	2544^{87}	2500^{92}	825^{91}			**2500^{92}**	**825^{91}**		3030
Krakow	50.03/19.55	751^{88}	**800^{92}**	**220**						3636
Krasnodar	45.02/39.00	623^{87}	595^{92}	174^{91}			**595^{92}**	**174^{91}**		3420
Krivoy Rog	47.55/33.24	698^{87}	769^{92}	426^{92}			**769^{92}**	**426^{92}**		1805
Leeds	53.50/-1.35	709^{88}	**712^{91}**						**180#**	3956#
Leipzig	51.20/12.25	539^{88}	**511^{92}**						**140#**	3650#
Lille	50.39/3.05	165^{82}					**950^{92}**		**198**	4798
Lisboa	38.44/-9.08	807^{81}	1329^{91}				**2000^{91}**		**100#**	20000#

City	Location	City				Conurbation				Population density
	Co-ordinates	Population (*1000)		Area (km^2)		Population (*1000)		Area (km^2)		Inh/km^2
	lat-lon	(19..)	(19..)	Total	Built-up	(19..)	(19..)	Total	Built-up	
Liverpool	53.25/-2.55	484^{86}	**470^{88}**						**150$^{\#}$**	$3133^{\#}$
Ljubljana	46.03/14.30		**273^{90}**	290	**43**		322			6349
Lodz	51.49/19.28	857^{88}	**845^{92}**		**120**					7042
London	51.30/-0.10		6735^{88}		(120)		**10570^{90}**	**1580^{91}**		6690
Luxembourg	49.37/6.08						**78^{92}**	55^{89}	**22^{92}**	3545
Lvov	49.50/24.00	767^{87}	**800^{90}**	**166^{92}**			1200^{92}			4819
Lyon	45.46/4.50		409^{82}				**1262^{92}**		**150$^{\#}$**	$8413^{\#}$
Madrid	40.25/-3.43		2991^{89}				**3120**		**100$^{\#}$**	$31200^{\#}$
Manchester	53.30/-2.15	446	451^{85}				**2578**		**280$^{\#}$**	$9207^{\#}$
Mariupol	47.05/37.34	529^{87}	545^{92}	169^{91}			**545^{92}**	**169^{91}**		3225
Marseille	43.18/5.22	867^{82}					**810^{92}**		**75$^{\#}$**	$10800^{\#}$
Milan	45.28/9.12						**1432^{92}**		**160$^{\#}$**	$8950^{\#}$
Minsk	53.51/27.30	1543^{87}	1600^{92}	220^{91}	181^{92}		**1600^{92}**	220^{91}	**181^{92}**	8840
Moscow	55.45/37.42	8614^{87}	9000^{92}	1042^{91}	994^{92}		**9000^{92}**	1042^{91}	**994^{92}**	9054
Munich	48.08/11.35		**1206^{88}**	**200**			1229			6030
Naples	40.50/14.15		1067^{92}				**1206^{92}**		**93**	12968
Nizhniy Novgorod	50.16/44.00	1425^{87}	**1448^{92}**		**343^{92}**		2549^{92}			4222
Nurnberg	49.27/11.05	476^{88}	**500^{92}**	186^{93}	**95^{93}**		800^{93}			5263
Odessa	46.30/30.46		1141^{87}	150^{86}			**1141^{87}**	**150^{86}**		7607
Oslo	59.56/10.45		462^{90}	450	200		**616^{90}**	1100	**400**	1540
Palermo	38.08/13.23						**714^{84}**		**50$^{\#}$**	$14280^{\#}$
Paris	48.52/2.20		2189^{90}	105^{85}			**8510^{90}**	**1200^{90}**		7092
Perm	58.01/56.10	1075^{87}	1119^{92}	722^{91}	270^{91}		**1119^{92}**	722^{91}	**270^{91}**	4144

City	Location	City				Conurbation				Population density
	Co-ordinates	Population (*1000)		Area (km²)		Population (*1000)		Area (km²)		Inh/km²
	lat-lon	(19..)	(19..)	Total	Built-up	(19..)	(19..)	Total	Built-up	
Porto	41.09/-8.37						1315		100#	13150#
Poznan	52.25/16.53	590^{88}	589^{90}		125					4712
Prague	50.06/14.26	1212^{91}	1216^{92}	495^{91}	210^{91}					5790
Reykjavik	64.09/-21.58		112^{92}	114	4		150^{92}			28000
Riga	56.53/24.08						897^{92}		307^{92}	2922
Rome	41.53/12.30		2830^{90}		125^{90}		3710^{90}			22640
Rostov at the Don	47.15/39.45	1004^{87}	1100^{92}		354^{92}		1100^{92}		354^{92}	3107
Rotterdam	51.55/4.29		582^{91}	201			1089^{91}	307	183	5951
Samara	53.10/50.10	1280^{87}	1244^{92}		466^{92}		1244^{92}		466^{92}	2670
Saratov	51.30/45.55	918^{87}	909^{92}		386^{91}		909^{92}		386^{91}	2355
Setubal	38.31/-8.54		799							
Sevilla	37.24/-5.59		720^{90}	143			780	210		3714
Sheffield	53.23/-1.30		528^{86}						100#	5280#
Sofia	42.40/23.18		1127^{86}		200		1300^{90}			6500
St. Petersburg	59.55/30.25		4948^{87}	627^{91}			4948^{87}	627^{91}		7892
Stockholm	59.20/18.05		667^{85}	188			1503			3548
Stuttgart	48.47/9.12		560				580	200		2900
Tallin	59.22/24.48		500							
The Hague	52.50/4.16		430	65			654	151		4331
Thessaloniki	40.38/22.58		969							
Tirana	41.20/19.49		274^{92}	31^{92}	10^{92}		450^{92}	61^{92}	25^{92}	18000
Togliatti	53.22/49.24	627^{87}	670^{92}	301^{91}	54^{92}		670^{92}	301^{91}	54^{92}	12407
Toulouse	43.37/1.27						608^{92}		250^{92}	2432

City	Location	City				Conurbation				Population density
	Co-ordinates	Population (*1000)		Area (km^2)		Population (*1000)		Area (km^2)		Inh/km^2
	lat-lon	(19..)	(19..)	Total	Built-up	(19..)	(19..)	Total	Built-up	
Tula	54.11/37.38	538^{87}	541^{92}	127^{92}			**541^{92}**	**127^{92}**		4260
Turin	45.04/7.40		980^{92}	120^{92}			**1784^{92}**		**100^{92}**	17840
Ufa	54.45/55.58	1092^{87}	1034^{92}	480^{91}			**1034^{92}**	**480^{91}**		2154
Valencia	39.29/-0.29		719	51			**753**	135	**44**	17114
Vienna	48.13/16.22		**1564^{90}**	415	**190**					8232
Vilnius	54.40/25.19		566^{87}				566^{87}			
Volgograd	48.45/44.30	988^{87}	1007^{92}	440^{91}	220^{92}		**1007^{92}**	440^{91}	**220^{92}**	4577
Voronezh	51.40/39.13	872^{87}	958^{92}	430^{86}	53^{92}		**958^{92}**	430^{86}	**53^{92}**	18075
Warsaw	52.15/21.00	1665^{85}	1653^{92}							
Wroclaw	51.05/17.00		**664^{88}**		**75**					8853
Yaroslavl	57.34/39.52	634^{87}	619^{92}	180^{91}			**619^{92}**	**180^{91}**		3439
Zagreb	45.48/15.58		707^{92}				**954^{92}**	1932	**80^{92}**	11925
Zaporozhe	47.50/35.10	875^{87}	895^{92}	318^{91}			**895^{92}**	**318^{91}**		2814
Zaragoza	41.39/-0.54		**594^{90}**						**25#**	23760#
Zurich	47.23/8.33		356^{91}	92^{91}	24^{91}		**356^{91}**	92^{91}	**24^{91}**	14833

Figures printed superscript between brackets refer to year of reference
(built-up area): Area estimated from topographical maps

Annex VII: Indices describing outdoor air pollution conditions in major European cities

City name	environ-mental pressure[1]	emission[2] of smog forming pollutants		climatological impact[1]			exceedances[3]		exposure[4]
		summer smog	winter smog	average dispersion	potential conditions for smog summer	potential conditions for smog winter	city background O_3	city background SO_2 + PM	city background SO_2 + PM
Albania									
Tirana	4	1'	2'	4				2	4'
Austria									
Vienna	4	4	2'	4	3	3		2	2
Belarus									
Minsk	4	2	2'	4	3	4		2'	3
Bulgaria									
Sofia	3	3	5	5	3	3		3'	3
Belgium									
Brussels	3	4'	3'	3	3	2	2	1	1
Antwerp	3	3'	3'	3	3	2	2	1	3'
Croatia									
Zagreb	3	4	2	5	4	4		2	3'
Czech republic									
Prague	3	2	3'	3	3	3		3	4
Denmark									
Copenhagen	3	4	3	1	1	3			
Estonia									
Tallinn	3	1'	3'	2	2	4			
Finland									
Helsinki	3	2	2	2	2	4	1	2	3'

France									
Paris	5	5	3	3	3	2	2	2	2
Lille	3	3'	2'	2	3	2	1	2	4
Lyon	4	3'	3'	4	4	3	1	3'	3
Marseille	4	2'	3'	3	4	1	1	1	1
Toulouse	2	2'	2'	4	4	2	2	1	1
Germany									
Berlin	4	5	5	3	3	3	2	4'	4
Bremen	4	2'	2'	2	3	3	1	1'	3'
Cologne	4	3'	2'	4	3	3	2	1'	4
Dortmund	3	2'	1'	3	3	2	2	1	4
Dresden	2	2	4'	5	3	3		2	3
Duisburg	4	2'	1'	4	3	2	2	2	4
Dusseldorf	3	2'	1'	4	3	2	2	1'	3
Essen	3	2'	1'	4	3	2	2	1	4
Frankfurt a. Main	3	2'	2'	4	3	3	2	1'	2'
Hamburg	3	4'	2'	3	2	3	2	2'	4
Hannover	2	2'	1'	3	3	3	3	3'	3'
Leipzig	3	3'	5'	3	3	3		5	4
Munich	3	4'	2'	4	3	3	1	0.5	1
Nurnberg	3	2'	2'	4	3	3		1	1'
Stuttgart	2	2'	2'	5	3	3	2	1	3
Greece									
Athens	4	4	2'	4	4	1		2	3'
Thessaloniki	3	2'	3'	4	4	3			
Hungary									
Budapest	5	4'	5'	4	4	3	2	2'	4
Ireland									
Dublin	3	2	2	3	1	2		3	4
Iceland									
Reykjavik	3	1'	1	2	1	3		0.5	1'
Italy									
Rome	5	4'	5'	3	4	2		3	3'
Genoa	4	2'	4'	3	4	1			
Milan	4	3'	3'	4	4	5			
Naples	4	3'	4'	4	5	3			
Palermo	4	2'	3'	3	4	1			
Turin	5	4'	4'	4				2	4

Latvia									
Riga	3	2	1	2	2	4		4'	4'
Lithuania									
Vilnius	3	2'	2'	4	2	3			
Luxembourg									
Luxembourg	3	1'	1	4	3	3		0.5	1'
Moldova									
Kishinev	3	2'	3'	5	3	4			
Netherlands									
Amsterdam	3	3'	2'	2	2	2	2	0.5	2
Rotterdam	3	3'	2'	2	2	2	2	1'	2
The Hague	3	2'	1'	1	2	2	2	0.5	1'
Norway									
Oslo	2	2	1	5	2	5	1	2	2
Poland									
Warsaw	3'	4	3'	3	3	3	1		1'
Gdansk	3	2'	4	2	1	3			
Katowice		2	5'	2	3			3	4
Krakow	4	2	4'	5	3	4		2	3'
Lodz	3	2'	4'	3	3	3		1	3'
Poznan	3	2'	4'	3	3	3		2'	3'
Wroclaw	4	2'		3	3	3			
Portugal									
Lisbon	5	3'	4'	3	4	1		1	1'
Porto	5	2'	3'	3	3	1		2	4
Setubal	3'	2'	2'	2	4	1		1	1'
Romania									
Bucharest	4	3	3	4	4	5		2'	4
Russia									
Moscow	5	4	2	4	3	4		2'	2'
Izhevsk (Ustinov)	3	2	2	3	3	4		2'	3'
Kazan	3	2	2	3	3	4		2'	2'
Krasnodar	2	2	2	3	4	4		3'	4'

Nizhny Novgorod	3	2	3	4	3	4		2'	3'
Perm	3	4	3	4	3	4		2'	3'
St. Petersburg	5	2	3	3	3	4		1'	2'
Rostov-na-Donau	4	2	2	3	4	3		2'	3'
Samara	3	3	3	4	4	3		4'	4'
Saratov	3	3	2	3	3	5		2'	3'
Togliatti	3	2	3	3	3	4		3'	4'
Tula	3	2'	2	4	3	4		1'	2'
Ufa	3	2	3	4	3	4		2'	3'
Volgograd	3	3	3	4	4	4		2'	3'
Voronezh	4	1	3	4	3	4		2'	3'
Yaroslavl	2	4	3	4	3	5		4'	2'
<u>Slovak Republic</u>									
Bratislava	3	1	3	3	4	3		2	4'
<u>Slovenia</u>									
Ljubljana	3	1'	3	5	4	4		2	4
<u>Spain</u>									
Madrid	5			3	5	4			
Barcelona	4			4	4	1		1'	3'
Sevilla	3			4	5	1		0.5	1'
Valencia	4			3	4	2		2	1
Zaragoza	4			3	4	3		1	4
<u>Sweden</u>									
Stockholm	3	3	2	2	2	4		1	1'
Gotenborg	3	2	1	2	2	3		0.5	1'
<u>Switzerland</u>									
Zürich	4	1	2	5	3	3		0.5	1'
<u>Turkey/</u>									
Istanbul	4			4	3	3		5'	4

<u>**Ukraine**</u>									
Kiev	3	2	2	2	3	3		2'	3'
Dnepropetrovsk	4	2	4	2	3	4		2'	3'
Donetsk	4	1	3	2	3	3		4'	4'
Kharkov	4	2	2	3	3	4		2'	3'
Krivoy Rog	4	2	4	3	3	3		4'	4'
Lvov	3	1	1	3	3	4		3'	3'
Mariupol	3	2	4	4	3	3		2'	3'
Odessa	4	2	2	4	3	3		4'	4'
Zaporozhye	4	2	3	3	3	3		2'	3'
<u>**United Kingdom**</u>									
London		5'	2	3	2	2	2		
Belfast		2'	5		3	4		3	4
Birmingham	4	5'	5'	3	2	3			
Glasgow	3	2'	4'	3	1	3			
Leeds	4	2'	2'	3	1	3		1	4
Liverpool	3	2'	3'	1	1	2		3	4
Manchester	5	2'	2'	3	2	2		2	4
Sheffield	4	2'	3'	3	2	3	2	1	3'

' : uncertain data

1 : Indices have been ranked in five classes ranging from lowest '1' to highest '5' relative 'environmental pressure' or 'climatological impact'. The number '1' corresponds to least pressure or most favourable climatological conditions, and '5' corresponds to most pressure or most unfavourable climatological conditions. For 'environmental pressure', class intervals have been chosen on the basis of the standard deviations from the population, and population density averages for the 105 selected cities. For 'climatological impact', class intervals have been chosen on the basis of the standard deviations from the average dispersion (measured as wind speed) and smog forming potential conditions (measured as the frequency of adverse dispersion conditions for summer and winter smogs separately) for the 105 selected cities. In each case the class intervals used are defined as follows, where a = the average and sigma = the standard deviation: 1= < (a - 1.5 sigma); 2 = (a - 1.5 sigma) to (a - 0.5 sigma); 3 = (a - 0.5 sigma) to (a + 0.5 sigma); 4 = (a + 0.5 sigma) to (a + 1.5 sigma); 5 = > (a + 1.5 sigma). The class values given for each city and category in these columns are calculated as the mean of the classes obtained from the two indicators used in each case separately (ie: each of the two pairs of indicators are assumed to be equally significant as measures of environmental pressure and climatological impact respectively). **See also section 3.1**)

2 : The emission indices have been ranked in five classes from 'least unfavourable conditions' ('1'), to 'most unfavourable conditions' ('5'), relative to the average emission conditions in the 105 selected cities for compounds with summer (VOCs and NO_X) and winter (SO_2 and PM) smog forming potential. Class intervals have been chosen on the basis of the standard deviations from the averages in the ranges described in footnote '1' above **(See also section 3.1).**

3 :
- 0.5: < 0.5 AQG
- 1: 0.5-1 AQG
- 2: 1-2 AQG
- 3: 2-3 AQG
- 4: 3-4 AQG
- 5: 4-5 AQG

4 :
- 1: 0-5% population exposed
- 2: 5-33% population exposed
- 3: 33-66% population exposed
- 4: >66% population exposed

Annex VIII.a : Summary of urban emission statistics: sulphur dioxide

Conurbation; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Bratislava	1985	44.8			di	1990	34.0	76	90	di
Bucharest						1990	45.4	19	250	tdi
Dnepropetrovsk	1988	110.8	93.7	499.1	i	1990	89.2	71.9	401.8	i
Donetsk	1988	31.6	29.0	133.9	i	1990	30.9	28.0	118.6	i
Gothenburg						1992	2.1	2.86	3.2	tdi
Helsinki	1985	37.7	48	51	tdi	1990	21.9	27		tdi
Kharkov	1988	3.9	2.5	17.3	i	1990	2.0	1.2	8.9	i
Luxembourg						1989	0.58	7.5	26.5	tdi
Milan	1985	23.0	16.0	143.6	tdi	1988	10.1	7.1	63.1	tdi
Minsk	1988	29.9	19.4	165.2	i	1990	18.7	11.9	103.3	i
Moscow	1988	70.6	8.2	71.0	i	1990	51.9	5.9	52.2	i
Naples						1992	0.2			t
Oslo	1985	5.3	12	11.8	tdi					
Perm	1988	39.0	36.3	144.4	i	1990	32.4	29.5	120.0	i
Riga						1990	6.9	7.7	22.5	ti
Rostov a.t.Don	1988	14.9	14.8	42.1	i	1990	10.9	10.4	30.8	i
Rotterdam	1985	91	83.6	497.3	i	1990	67	61.5	366.1	i
Samara	1988	39.2	30.6	84.1	i	1990	31.8	25.2	68.2	i
Saratov	1988	19.9	21.7	51.6	i	1990	16.0	17.5	41.5	i
Togliatti	1988	15.8	25.2	292.6	i	1990	10.4	16.0	192.6	i
Valencia	1986	1.7			tdi					
Volgograd	1988	37.6	38.1	170.9	i	1990	29.5	29.6	134.1	i
Voronezh	1988	9.5	10.9	179.3	i	1990	8.7	9.5	164.2	i
Zagreb						1990	9.6	10.1	120	tdi
Zurich	1983	4.1	11	174	tdi	1989	3.8	11	165	tdi

City; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Athens	1985	5.1			td	1990	17.8	6.0		tdi
Ljubljana	1985	33.6			tdi	1990	20.0	73.4		tdi
N.Novgorod	1988	57.1	40.1	166.5	i	1990	59.6	41.5	173.8	i
Nurnberg						1990		8.2		tdi
Prague	1985	66.1	56	132.2	di	1990	45.8	38	91.6	tdi
Reykjavik	1985	2.0	20	18	t	1990	2.0	20	18	t
Sofia						1990	124.4			tdi
Vienna	1985	3.6			i	1990	13.9	9.1	34	tdi

Comment: t = traffic , d = domestic space / heating, i = industry

Conurbation; Total area known

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Barcelona	1985	2.7			tdi					
Budapest						1991	37.6	18.6	71.6	tdi
Izhevsk	1988	4.7	7.5	18.1	i	1990	5.5	8.4	21.2	i
Kazan	1988	16.0	15.0	56.1	i	1990	13.5	12.5	47.4	i
Kiev	1988	19.2	7.6	23.3	i	1990	13.7	5.4	16.6	i
Krasnodar	1988	28.4	45.6	163.2	i	1990	16.6	26.7	95.4	i
Krivoy Rog	1988	98.1	140.5	230.3	i	1990	82.0	111.8	192.5	i
Mariupol	1988	54.1	102.3	320.1	i	1990	54.7	101.9	323.7	i
Odessa	1988	15.3	13.4	102.0	i	1990	12.7	11.1	84.7	i
Paris	1985	122	14	100	tdi	1990	100	12	83	tdi
St.Petersburg	1988	73.6	14.9	117.4	i	1990	62.7	12.7	100.0	i
Tula	1988	9.6	17.8	75.6	i	1990	11.0	20.4	86.6	i
Ufa	1988	72.3	66.2	150.6	i	1990	48.5	44.4	101.0	i
Yaroslavl	1988	37.9	59.8	210.6	i	1990	35.3	55.7	196.1	i
Zaporozhe	1988	25.2	28.8	79.3	i	1990	24.9	28.1	78.5	i

City; Total area known

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Belfast						1990	261.6			tdi
Hamburg						1990		12.9		tdi
Krakow						1991	59			i
London	1983	50	7.5	32	tdi					
Lvov	1988	3.5	4.6	21.1	i	1990	0.9	1.1	5.4	i
Stockholm	1985	18.0	27.4	96.0	tdi	1992	2.4	3.5	12.8	tdi

Conurbation; Built-up area estimated

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Milan	1985	23.0	16.0	143.6	tdi	1988	10.1	7.1	63.1	tdi
Zaragoza						1990	4.8			tdi

Area unknown

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Tallin						1990	19.5			i
Warsaw						1990	59.3			power pl

Comment: t = traffic , d = domestic space / heating, i = industry

Annex VIII.b: Summary of urban emission statistics:Total Particulate Matter

Conurbation; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Bratislava	1985	4.9			di	1990	5.6	13	15	di
Dnepropetrovsk	1988	72.6	61.4	327.0	i	1990	62.7	50.5	282.4	i
Donetsk	1988	21.7	19.9	91.9	i	1990	23.8	21.5	100.8	i
Helsinki						1990	3.6	4.3	4.8	tdi
Kharkov	1988	16.2	10.2	71.7	i	1990	13.7	8.5	60.6	i
Minsk	1988	10.1	6.6	55.8	i	1990	9.3	5.9	51.4	i
Moscow	1988	29.8	3.5	30.0	i	1990	23.4	2.7	23.5	i
Oslo	1985	2.1	4	4.5	tdi					
Perm	1988	12.9	12.0	47.8	i	1990	10.4	9.5	38.5	i
Riga						1990	3.5	3.9	11.5	ti
Rostov a.t.Don	1988	6.5	6.5	18.4	i	1990	9.2	8.8	26.0	i
Samara	1988	16.5	12.9	35.4	i	1990	11.3	9	24.3	i
Saratov	1988	5.0	5.5	13.0	i	1990	7.3	8.0	18.9	i
Togliatti	1988	24.3	38.8	450.0	i	1990	18.8	29.0	348.2	i
Valencia	1986	2.1			tdi					
Volgograd	1988	41.8	42.3	190.0	i	1990	34.4	34.5	156.4	i
Voronezh	1988	12.2	14.0	230.2	i	1990	10.8	11.8	203.8	i
Zagreb						1990	1.6	1.7	20	tdi
Zurich	1983	0.2	1	9	tdi	1989	0.1	0.4	6	tdi

City; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Athens	1985	5.6			tdi	1990	26.4	9.0		tdi
N.Novgorod	1988	25.7	18.0	74.9	i	1990	20.0	13.9	58.3	i
Prague	1985	25.1	21	50.2	di	1990	21.0	17	42.0	di
Vienna						1990	2.2	1.5	5	tdi

Conurbation; Total area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Budapest						1991	9.4	4.6	17.8	tdi
Izhevsk	1988	20	31.7	76.9	i	1990	17.1	26.1	65.8	i
Kazan	1988	11.3	10.6	39.7	i	1990	10.1	9.3	35.4	i
Kiev	1988	12.3	4.8	14.9	i	1990	7.1	2.8	8.6	i
Krasnodar	1988	6.5	10.4	37.4	i	1990	4.9	7.9	28.2	i
Krivoy Rog	1988	207.9	297.9	488.1	i	1990	166.9	227.4	391.8	i
Mariupol	1988	112.9	213.4	668.1	i	1990	91.7	170.8	542.6	i
Odessa	1988	19.1	16.7	127.3	i	1990	14.1	12.4	94.0	i
Paris	1985	58	6.8	48	tdi	1990	36	4.2	30	tdi
St.Petersburg	1988	46.1	9.3	73.5	i	1990	34.6	7.0	55.2	i
Tula	1988	10.1	18.8	79.5	i	1990	11.8	21.9	92.9	i
Ufa	1988	9.2	8.4	19.2	i	1990	7.1	6.0	14.8	i
Yaroslavl	1988	22.0	34.7	122.2	i	1990	21.5	33.9	119.4	i
Zaporozhe	1988	69.7	79.7	219.2	i	1990	58.6	66.2	184.9	i

Comment: t = traffic , d = domestic space / heating, i = industry

City; Total area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Belfast						1990	107.3			tdi
Krakow						1991	44			i
London	1983	11	1.6	7.0	tdi					
Lvov	1988	5.7	7.4	34.3	i	1990	2.7	3.4	16.3	i
Stockholm						1992	0.4			t

Conurbation; Built-up area estimated										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Zaragoza						1990	0.9			tdi

Area unknown										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Tallin						1990	5.2			i
Warsaw						1990	34.9			combust

Comment: t = traffic , d = domestic space / heating, i = industry

Annex VIII.c: Summary of urban emission statistics: nitrogen dioxide

Conurbation; Built-up area known

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Bratislava	1985	9.4			di	1990	12.2	27	30	tdi
Bucharest						1990	21.5	9	118	tdi
Dnepropetrovsk	1988	46.5	39.3	209.5	ti	1990	46.9	37.8	211.3	ti
Donetsk	1988	14.0	12.8	50.3	ti	1990	11.4	10.3	48.3	ti
Gothenburg						1992	17.5	23.84	26.8	tdi
Helsinki	1985	27.7	35	37	ti	1990	35.7	44		ti
Kharkov	1988	13.9	8.8	61.5	ti	1990	12.6	7.8	55.7	ti
Luxembourg						1989	2.1	26.3	93.2	tdi
Milan	1985	18.5	12.9	115.5	tdi	1988	18.4	12.9	115.2	tdi
Minsk	1988	26.3	17.1	145.3	ti	1990	28.8	18.3	159.1	ti
Moscow	1988	140.3	16.3	141.2	ti	1990	156.8	17.8	157.8	ti
Naples						1992	4.5			t
Oslo	1985	13.3	28	29.5	tdi					
Perm	1988	31.2	29.0	115.6	ti	1990	26.6	24.3	98.5	ti
Riga						1990	9.1	10.1	29.5	ti
Rostov a.t.Don	1988	8.9	8.9	25.1	ti	1990	9.0	8.6	25.4	ti
Rotterdam	1985	45	41.3	245.9	ti	1990	54	49.6	295.1	ti
Samara	1988	23.3	18.2	50.0	ti	1990	21.7	17.2	46.6	ti
Saratov	1988	20.1	21.9	52.1	ti	1990	19.2	21.0	49.7	ti
Togliatti	1988	43.5	69.4	805.6	ti	1990	41.8	64.4	774.1	ti
Valencia	1986	2.4			tdi					
Volgograd	1988	24.8	25.1	112.7	ti	1990	24.3	24.4	110.5	ti
Voronezh	1988	14.6	16.7	275.5	ti	1990	12.4	13.6	234.0	ti
Zagreb						1990	7.5	7.9	94	tdi
Zurich	1983	4.7	13	200	tdi	1989	5.9	16	251	tdi

City; Built-up area known

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Athens	1985	19.9			td	1990	36.2	12.0		tdi
Ljubljana	1985	8.6			tdi	1990	8.9	32.4		tdi
N.Novgorod	1988	23.1	16.2	67.4	ti	1990	34.2	24.0	99.7	ti
Nurnberg						1990		23.3		tdi
Prague	1985	19.3	16	38.6	di	1990	22.9	19	45.8	tdi
Reykjavik	1985	1.3	13	11	t	1990	1.5	15	13	t
Sofia						1990	14.7			tdi
Vienna	1985	5.8				1990	32.0	20.9	77	tdi

Comment: t = traffic , d = domestic/space heating, i = industry

Conurbation; Total area known

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Amsterdam	1986	15.9	14.8	27.3	t	1990	9	8.4	15.4	t
Barcelona	1985	4.5			tdi					
Budapest						1991	27.5	13.6	52.3	tdi
Izhevsk	1988	17.0	26.9	65.4	ti	1990	17.8	27.1	68.5	ti
Kazan	1988	19.8	18.5	69.5	ti	1990	19.7	18.2	69.1	ti
Kiev	1988	33.8	13.3	41.0	ti	1990	30.6	12.0	37.1	ti
Krasnodar	1988	13.0	20.8	74.7	ti	1990	17.8	28.6	102.3	ti
Krivoy Rog	1988	41.2	59.0	96.7	ti	1990	34.4	46.9	80.8	ti
Mariupol	1988	32.4	61.3	191.7	ti	1990	48.3	89.9	285.8	ti
Odessa	1988	12.4	10.9	82.7	ti	1990	10.8	9.5	72.0	ti
Paris	1985	157	18	130	tdi	1990	100	12	83	tdi
St.Petersburg	1988	67.8	13.7	108.1	ti	1990	57.5	11.6	91.7	ti
Tula	1988	6.8	12.6	53.5	ti	1990	9.6	17.8	75.6	ti
Ufa	1988	30.6	28.0	63.8	ti	1990	35.4	32.4	73.7	ti
Yaroslavl	1988	18.3	28.9	101.7	ti	1990	18.6	29.3	103.3	ti
Zaporozhe	1988	19.6	22.4	61.6	ti	1990	20.0	22.6	63.1	ti

City; Total area known

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Hamburg						1990		22.0		tdi
Krakow						1991	32			i
London	1983	79	11	50	tdi					
Lvov	1988	14.4	18.8	86.8	ti	1990	7.2	9.0	43.4	ti
Stockholm	1985	19.2	29.1	101.9	tdi	1992	13.8	20.1	73.4	tdi

Conurbation; Built-up area estimated

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Milan	1985	18.5	12.9	115.5	tdi	1988	18.4	12.9	115.2	tdi
Zaragoza						1990	3.0			tdi

Area unknown

City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Tallin						1990	12.8			ti
Warsaw						1990	18.9			power pl

Comment: t = traffic , d = domestic/space heating, i = industry

Annex VIII.d: Summary of urban emission statistics: Volatile Organic Compounds

Conurbation; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Bratislava	1985	28.2			di	1990	29.4	66	80	tdi
Bucharest						1990	46.8			d
Dnepropetrovsk						1990	8.4	6.5	37.8	i
Donetsk						1990	1.7	1.5	7.2	i
Gothenburg						1992	19.9	27.11	30.4	tdi
Helsinki	1985	5.5			t	1990	11.0	13	15	ti
Kharkov						1990	7.0	4.3	31.0	i
Minsk						1990	13.0	8.3	71.8	i
Moscow						1990	25.6	2.9	25.8	i
Naples						1992	37.0			t
Perm						1990	68.7	62.6	254.4	i
Riga						1990	16.9	18.9	55.2	ti
Rostov a.t.Don						1990	8.6	8.2	24.3	i
Rotterdam	1985	36	33.1	196.7	ti	1990	32	29.4	174.9	ti
Samara						1990	35.4	28.1	76.0	i
Saratov						1990	49.7	54.4	128.8	i
Togliatti						1990	9.8	15.1	181.5	i
Volgograd						1990	46.8	46.9	212.7	i
Voronezh						1990	5.3	5.8	100.0	i
Zagreb						1990	4.3	4.5	59	tdi
Zurich	1983	4.3	12	183	tdi	1989	3.0	8	128	tdi

City; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Athens	1985	54.9			td	1990	103.1	33.0		tdi
N.Novgorod						1990	8.1	5.6	23.6	i
Nurnberg						1990		26		tdi
Prague						1990	12.3	10	24.2	tdi
Reykjavik	1985	3.3	33	28	t	1990	3.8	38	33	t
Sofia						1990	56.2			tdi
Vienna						1990	65.2	42.6	157	tdi

Comment: t = traffic , d = domestic/space heating, i = industry

Conurbation; Total area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Amsterdam	1986	8	7.4	13.7	t	1990	4	3.7	6.9	t
Izhevsk						1990	5.4	8.2	20.7	i
Kazan						1990	29.4	27.1	103.2	i
Kiev						1990	6.2	2.4	7.5	i
Krasnodar						1990	7.3	11.7	41.9	i
Krivoy Rog						1990	3.7	5.0	8.7	i
Mariupol						1990	2.4	4.5	14.2	i
Odessa						1990	10.8	9.5	72.0	i
Paris	1985	460	54	380	tdi	1990	540	64	450	tdi
St.Petersburg						1990	5.6	1.1	8.9	i
Ufa						1990	12.7	11.6	26.5	i
Yaroslavl						1990	78.4	123.7	435.6	i
Zaporozhe						1990	3.5	4.0	11.0	i

City; Total area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Hamburg						1990		18.6		tdi
Krakow						1991	18			i
Lvov						1990	2.6	3.3	15.7	i
Stockholm	1985	20.4	31.0	108.5	tdi	1992	18.3	26.7	973.0	tdi

Conurbation; Built-up area estimated										
City	Year	Total kton	Kg/inh	Ton/km2	Comment	Year	Total kton	Kg/inh	Ton/km2	Comment
Zaragoza						1990	1.6			tdi

Comment: t = traffic , d = domestic/space heating, i = industry

Annex VIII.e: Summary of urban emission statistics: Lead

Conurbation; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Bucharest						1990	0.09			i
Dnepropetrovsk						1990	0.0017			i
Donetsk						1990	0.001			
Helsinki	1985	0.087	0.1	0.12	t	1990	0.024	0.029	0.032	t
Kharkov						1990	0.006			i
Minsk						1990	0.0071			i
Moscow						1990	0.0084			i
Perm						1990	0.0001			i
Rostov a.t.Don						1990	0.0044			i
Samara						1990	0.0011			i
Saratov						1990	0.023			i
Togliatti						1990	0.0006			i
Valencia	1986	0.068			t					
Volgograd						1990	0.002			i
Voronezh						1990	0.001			i
Zagreb						1990	0.5			t
Zurich	1983	0.024	0.1	1.04	tdi	1989	0.016	0.05	0.69	tdi

City; Built-up area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Ljubljana	1985	0.06			t	1990	0.08			t
N.Novgorod						1990	0.008			i
Prague						1990	0.025			t
Reykjavik	1985	0.037	0.37	0.33	t	1990	0.014	0.14	0.12	t

Conurbation; Total area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Budapest						1991	0.09			t
Izhevsk						1990	0.0002			i
Kazan						1990	0.0001			i
Kiev						1990	0.0044			i
Krasnodar						1990	0.0003			i
Krivoy Rog						1990	0.0001			i
Mariupol						1990	0.0002			i
Odessa						1990	0.001			i
St.Petersburg						1990	0.0132			i
Ufa						1990	0.199			i
Yaroslavl						1990	0.0026			i
Zaporozhe						1990	0.0005			i

City; Total area known										
City	Year	Total kton	Kg/inh	Ton/km^2	Comment	Year	Total kton	Kg/inh	Ton/km^2	Comment
Lvov						1990	0.0004			i
Stockholm	1985	0.06			t	1992	0.8			tdi

Comment: t = traffic , d = domestic/space heating, i = industry

Annex IX: Summary of climatological and meteorological indices.

City	Climate (Köppen)	Siting	Average wind speed 1980-1989 m/s	Winter smog 1980-1989	Summer smog 1980-1989
Amsterdam	Cfb	P (+)	4.8 (+)	7.2 (+)	4.3 (+)
Antwerp	Cfb	P (+)	3.5 (o)	8.2 (+)	9.3 (o)
Athens	Csa	C/V (-)	3.4 (o)	2.0 (++)	67.9 (-)
Barcelona	Csa	C/H (o)	2.9 (-)	3.9 (++)	40.9 (-)
Belfast	Cfb	C (++)			
Berlin	Cfb	P (+)	3.8 (o)	11.4 (o)	12.4 (o)
Birmingham	Cfb	P (+)	3.7 (o)	10.3 (o)	3.5 (+)
Bratislava	Cfb	RB (-)	5.3 (++)	18.0 (o)	49.6 (-)
Bremen	Cfb	P (+)	4.1 (+)	10.5 (o)	6.3 (+)
Brussels	Cfb	P (+)	3.3 (o)	8.8 (+)	9.9 (o)
Bucharest	Csa	P (+)	1.5 (--)	46.8 (--)	78.2 (-)
Budapest	Cfb	RB (-)	2.4 (-)	11.7 (o)	40.7 (-)
Chisinau	Bsk	V (--)	2.9 (-)	31.4 (-)	16.2 (o)
Cologne	Cfb	RB/V (-)	3.0 (-)	10.2 (o)	15.3 (o)
Copenhagen	Cfb	C (++)	5.1 (++)	10.0 (o)	1.7 (++)
Dnepropetrovsk	Bsk	RB/P (o)	4.5 (+)	21.1 (-)	27.5 (-)
Donetsk	Bsk	P (+)	4.4 (+)	17.6 (o)	22.9 (o)
Dortmund	Cfb	P (+)	3.5 (o)	7.6 (+)	8.7 (o)
Dresden	Cfb	V (--)	2.8 (-)	13.9 (o)	18.0 (o)
Dublin	Cfb	C/H (o)	4.7 (+)	6.3 (+)	0.3 (++)
Duisburg	Cfb	RB (-)	3.5 (o)	7.6 (+)	8.7 (o)
Dusseldorf	Cfb	RB (-)	3.7 (o)	7.5 (+)	14.3 (o)
Essen	Cfb	RB (-)	3.5 (o)	7.6 (+)	8.7 (o)
Frankfurt	Cfb	RB/H (--)	3.2 (o)	10.1 (o)	17.7 (o)
Gdansk	Cfb	C (++)	4.2 (+)	12.4 (o)	1.9 (++)
Genoa	Csa	C/H (o)	3.4 (o)	2.3 (++)	40.4 (-)
Glasgow	Cfb	C/V (-)	4.2 (+)	11.7 (o)	1.4 (++)
Gothenburg	Cfb	C (++)	4.0 (+)	18.7 (o)	2.4 (+)
Hamburg	Cfb	P (+)	3.7 (o)	11.9 (o)	7.0 (+)
Hannover	Cfb	P (+)	3.4 (o)	11.6 (o)	11.0 (o)
Helsinki	Dfb	C/P (++)	3.5 (o)	27.2 (-)	3.7 (+)
Istanbul	Csa	C/H (o)	4.1 (+)	18.3 (o)	17.5 (o)
Izhevsk	Dfb	RB (-)	4.0 (+)	39.3 (-)	13.9 (o)
Katowice	Dfb	RB (-)	2.5 (-)	24.9 (-)	18.6 (0)
Kazan	Dfb	RB (-)	4.8 (+)	30.9 (-)	14.3 (o)
Kharkov	Dfb	RB (-)	3.8 (o)	22.3 (-)	18.6 (o)
Kiev	Dfb	RB (-)	3.7 (o)	18.9 (o)	14.8 (o)
Krakow	Dfb	RB (-)	2.3 (-)	30.5 (-)	19.7 (o)
Krasnodar	Dfb	P (o)	3.6 (o)	24.1 (-)	48.5 (-)
Krivoy Rog	Bsk	RB (-)	4.1 (+)	18.2 (o)	26.5 (-)
Leeds	Cfb	P/H (o)	4.2 (+)	9.7 (o)	1.7 (++)
Leipzig	Cfb	P (+)	3.9 (o)	13.1 (o)	12.8 (o)
Lille	Cfb	P (+)	4.0 (+)	8.6 (+)	8.8 (o)
Lisboa	Csa	C/H (o)			

City	Climate (Köppen)	Siting	Average wind speed 1980-1989 m/s	Winter smog 1980-1989	Summer smog 1980-1989
Liverpool	Cfb	C (++)	5.3 (++)	5.9 (+)	0.6 (++)
Ljubljana	Cfa	V (--)	0.9 (--)	33.2 (-)	39.9 (-)
Lodz	Dfb	P (+)	3.6 (o)	17.3 (o)	11.0 (o)
London	Cfb	P (+)	3.6 (o)	7.8 (+)	6.3 (+)
Luxembourg	Cfb	V (--)	3.5 (o)	9.4 (o)	7.2 (o)
Lvov	Dfb	RB (-)	3.7 (o)	21.1 (-)	9.3 (o)
Lyon	Cfb	RB (-)	3.0 (-)	10.8 (o)	27.2 (-)
Madrid	Csa	P (+)	2.1 (--)	44.9 (-)	86.7 (--)
Manchester	Cfb	P/H (o)	4.0 (+)	7.6 (+)	2.2 (+)
Mariupol	Bsk	C (++)	5.4 (++)	15.8 (o)	17.2 (o)
Marseille	Csa	C/H (o)	4.7 (+)	3.3 (++)	37.5 (-)
Milan	Csa	P (+)	0.9 (--)	60.3 (--)	72.5 (-)
Minsk	Dfb	RB (-)	2.5 (-)	23.0 (-)	8.7 (o)
Moscow	Dfb	P/RB (o)	2.3 (-)	41.7 (-)	18.6 (o)
Munich	Cfb	RB (-)	2.8 (-)	9.9 (o)	13.2 (o)
Naples	Csa	C/H (o)	1.8 (--)	12.3 (o)	87.4 (--)
Nizhniy Novgorod	Dfb	RB (-)			
Nurnberg	Cfb	RB (-)	2.5 (-)	15.0 (o)	18.7 (o)
Odessa	Bsk	C/P (++)	4.4 (+)	15.9 (o)	22.5 (o)
Oslo	Dfb	V (--)	2.2 (-)	52.8 (--)	6.6 (+)
Palermo	Csa	C/H (o)	3.6 (o)	0.1 (++)	52.9 (-)
Paris	Cfb	P (+)	3.6 (o)	7.4 (+)	15.4 (o)
Perm	Dfc	RB (-)	3.8 (o)	32.6 (-)	10.6 (o)
Porto	Csb	C/H (o)	3.7 (o)	0.7 (++)	14.2 (o)
Poznan	Cfb	P (+)	3.3 (o)	18.8 (o)	12.8 (o)
Prague	Cfb	RB (-)	4.1 (+)	13.4 (o)	11.9 (o)
Reykjavik	Cc	C/H (o)	5.3 (++)	15.9 (o)	0.0 (++)
Riga	Dfb	C/P (++)	3.8 (o)	21.1 (-)	4.7 (+)
Rome	Csa	P/RB (o)	3.2 (o)	5.6 (+)	52.0 (-)
Rostov at the Don	Bsk	RB (-)	4.9 (++)	19.5 (o)	29.8 (-)
Rotterdam	Cfb	P/C (++)	4.8 (+)	7.3 (+)	4.5 (+)
Samara	Dfb	RB (-)	3.0 (-)	59.3 (--)	35.0 (-)
Saratov	Dfb	RB (-)	4.7 (+)	21.1 (-)	17.9 (o)
Setubal	Csa	C (++)			
Sevilla	Csa	RB (-)	2.6 (-)	3.0 (++)	98.1 (--)
Sheffield	Cfb	RB (-)	4.1 (+)	9.3 (o)	3.1 (+)
Sofia	Cfb	V (--)			
St. Petersburg	Dfb	C/P (++)	2.6 (-)	33.1 (-)	7.2 (o)
Stockholm	Dfb	C/P (++)	3.3 (o)	25.2 (-)	4.6 (+)
Stuttgart	Cfb	RB/V (--)	2.4 (-)	10.7 (o)	17.3 (o)
Tallin	Dfb	C/P (++)	3.5 (o)	21.2 (-)	3.5 (+)
The Hague	Cfb	C/P (++)	5.2 (++)	6.8 (+)	3.0 (+)
Thessaloniki	Csa	C/H (o)	2.9 (-)	15.1 (o)	79.4 (-)
Tirana	Csa	C/H (o)	1.5 (--)		
Togliatti	Dfb	P (+)	2.6 (-)	41.7 (-)	20.3 (o)

City	Climate (Köppen)	Siting	Average wind speed 1980-1989 m/s	Winter smog 1980-1989	Summer smog 1980-1989
Toulouse	Cfb	RB (-)	3.0 (-)	4.2 (+)	38.4 (-)
Tula	Dfb	RB (-)	3.2 (o)	31.3 (-)	9.4 (o)
Turin	Cfb	P (o)	1.0 (--)	96.0 (--)	67.9 (-)
Ufa	Dfb	RB (-)	3.5 (o)	43.1 (-)	20.8 (o)
Valencia	Csa	C (++)	3.0 (-)	7.6 (+)	70.0 (-)
Vienna	Cfb	V/RB (--)	3.2 (o)	10.0 (o)	21.7 (o)
Vilnius	Dfb	RB (-)	3.5 (o)	19.8 (o)	6.4 (+)
Volgograd	Bsk	RB (-)	5.6 (++)	24.5 (-)	26.4 (-)
Voronezh	Dfb	RB (-)	3.8 (o)	31.1 (-)	17.5 (o)
Warsaw	Dfb	P (+)	3.9 (o)	16.9 (o)	10.1 (o)
Wroclaw	Dfb	P (+)	2.8 (-)	17.5 (o)	17.1 (o)
Yaroslavl	Dfb	RB (-)	2.3 (-)	50.9 (--)	15.9 (o)
Zagreb	Cfb	RB/H (-)	1.8 (--)	22.1 (-)	44.0 (-)
Zaporozhe	Bsk	RB (-)	4.0 (+)	20.3 (o)	29.4 (-)
Zaragoza	Bsh	RB (-)	4.8 (+)	12.3 (o)	47.7 (-)
Zurich	Cfb	V (--)	1.9 (--)	10.2 (o)	17.6 (o)

Symbols between brackets:

++ very favourable
\+ favourable
o neutral
\- unfavourable
-- very unfavourable

Annex X.a: Summary of urban air quality statistics: measured and calculated sulphur dioxide concentrations

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Amsterdam	1990	8	9		43	0	63	84		
Antwerp acid	1985	2	61	72	338	23	324	332	629	1
	1990	2	47	50	138	2	145	149	482	1
Antwerp fl/ph	89/90	3	25	29	196		276	317	334	2
Athens	1985	1	20	10	43	0	43	172		
	1991	1	36	18	264	7	264	359		
Barcelona	1991	3	12							
Belfast	1985	5	65	72	234	20	297			
	1990	6	58	79	427	26	780			
Berlin	1989	3	68		437	53	453			
Bratislava	1985	2	37	63	210	23	220	310	300	
	1990	2	20	32	135	2	140	160	180	
Bremen	1990	4	18		85		94			3
Brussels	1985	3	42	58	427	21	497	611	525	
	1990	3	27	28	73	0	109	94	106	
Bucharest	1990	14	40	10	123					4
Budapest	1992	6	44		124		175	127	196	
Chisinau	1990	4	2		40					5, 6
Cologne	1989	4	23		100	0	99			
Copenhagen	1985							188		
	1990							130		
Dnepropetrovsk	1990	3	9	12	70	0(0)	89	124	124	7
Donetsk	1990	3	28	26	230	1(6)	230	526	560	7, 8
Dortmund	1985	1	68		526		526			
	1989	3	25		93		102			
Dresden	1985		120							
	1990		76							
Dublin	1985	12	48	58	230	7	230	177	108	
	1990	12	26	27	133	1	175	197	144	

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Duisburg	1985	1	81		699	53				
	1989	4	36		133	2	135			
Dusseldorf	1989	3	26		81	0	85	98		
Essen	1989	3	31		114	1	151		185	
Frankfurt	1989	1	27		115	0	115			
Gothenburg	1985	1	11	19	88	0	88		92	
	1992	2	7	9	34	0	34	26	25	
Hamburg	1989	3	29		279	8	302			
Hannover	1989	1	26		379	6	379			
Helsinki	1985	1	18	22	87	0	87		246	
	1990	2	12	15	62	0	72	62	104	
Istanbul	1990	7-16	195	349	912	185				
Katowice	1985	2	84	121	285	60	304			
	1990	2	90	121	326	78	361			
Kharkov	1990	3	7	9	58	0(0)	68	92	106	7
Kiev	1990	3	13	17	150	0(2)	200	150	150	7
Krakow	1992	1	47			13				
Krivoy Rog	1990	2	28	36	260	2(8)	290	219	338	7, 8
Leeds	1985	5	41	47	215	6	229			
	1990	5	33	34	178	2	211			
Leipzig	1985		336							
	1990		170							
Lille	1985	2	39	47	396	18	461		391	
	1989	2	33	41	191	3	221		240	
Liverpool	1985	11	39	46	142	2	168			
	1990	5	41	44	174	3	259			
Ljubljana	1985	4	83	135	410	79	440	500	480	
	91/92	5	50	74	335	34	450	480	350	
Luxembourg	1985	1	28		78	0	78	105		
	1990	1	28		105	0	105	137		
Lvov	1990	1	45	43	85	0(0)	71	101	97	7

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Lyon	1985								315	
	1990	10	29		702				261	5, 9
Manchester	1985	3	51	56	166	5	216			
	1990	3	41	41	127	1	135			
Mariupol	1990	2	21	23	74	0(0)	72	91	91	7
Marseille	1985	9	39	40	172	3	259			
	1991	10	26	28	93	0	125			
Milan	85/86	10	75		277					5, 10, 11
	1990	6	24	76	164					5, 10, 11
Minsk	1985	3	30		140	0(2)				7
	1990	3	20	26	89	0(0)	76	224	125	7
Moscow	1990	3	1	3		0				
Munich	1989	2	9		42	0	49	47		
Nizhniy Novgorod	1990	2	3	4	37	0(0)	48	88	232	7
Nurnberg	1989	1	17		106	0	106			
Odessa	1990	3	44	47	140	0(2)	150	174	193	7
Oslo	84/85	3	17	26	105	0	118			
	89/90	3	8	11	40	0	49	86		
Palermo	1985	3	15		87		104			5, 10, 11
Paris	1984	5	56	78	224		269			
	1991	13	25				222			
Perm	1990	3	14	15	150	0(2)	190	198	99	7
Prague	1985	6	122	164	744	60	935			
	1991	10	75	98	429	35	631			
Reykjavik	1991	1	3	3	16	0	16	12		
Riga	1986		20		110	0				5, 12
	1990		4		140	0				5, 12
Rome	1985	1	34		260	3	260			
Rostov at the Don	1990	3	6	6	74	0(0)	160	194	83	7
Rotterdam	1985	10	36		283		322	351	432	
	1990	7	17		93	0	136	114	155	

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Sevilla	1992							42		
Sheffield	1985	1	50	49	158	4		113	157	
	1991	1	39	28	76	0		282	85	
Sofia	1985								25	
	1992						240		400	
St. Petersburg	1990	3	5	6	61	0(0)	100	86	101	7
Stockholm	1985	1	19	25	140	2	140		114	
	1990	1	7	9	54	0	54		26	
Stuttgart	1985	2	49		338	23	384			
	1989	2	22		75	0	76			
The Hague	1990	1	16	20	93	0	93			
Tirana	1985	1	24	26	112	0	112			
	1990	1	23	33	88	0	88			
Tula	1990	2	2	6	27	0(0)	18	27	30	7
Turin	1985	1		115	343	63	343	293		
	1991	1	55	76	212	32	212	189		
Ufa	1990	2	15	16	170	0(3)	210	135	169	7
Valencia	1986	5	46	51	197	9	234		637	
	1992	5	37	43	120	0	170		161	
Vienna	1985	7	40	62	235		460		260	
	1990	10	17	35	95		140	80	70	
Volgograd	1990	3	12	25	160	1(1)	270	67	325	7, 8
Voronezh	1990	3	5	9	46	0(0)	56	49	82	7
Warsaw	1992		30	43	122	0				
Yaroslavl	1990	1	2	3	34	0(0)	24	51	84	7
Zagreb	1985	2	97	146	334	93	460		321	
	1990	2	54	63	180	8	260		207	
Zaporozhe	1990	3	22	27	140	(2)	140	135	152	7
Zaragoza	1992							165	12	
Zurich	1985	1	50			≤100				
	1990	2	15			0				

1	Measuring method: acidimetric
2	Measuring method: fluorescence/photometric
3	Max (24h) = 98 percentile (1/2h)
4	Less than 75% data available
5	Not sure if city background station is really 'city background located'
6	Max (24h) = max (20 min)
7	Nr. of exceedances (figure between brackets) and 24h values are calculated by RIVM (see section 2.3.4.3)
8	Nr. of exceedances: less than 75% data available
9	Industry: 1989
10	Annual average = median
11	Max (24h) = 98 percentile
12	Max (24h) = max (20-30 min)

Annex X.b: Summary of urban air quality statistics: TSP/black smoke/PM10

City	Year	City background (average)					Highest observed max. 24h			TSP/BS/PM10	Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³		
Amsterdam	1985	3	62		203					TSP	
	1990	5	37		103	0	129			TSP	
Antwerp	1985	2	19	26	108	0	94	133	126	BS	
	1990	2	17	22	87	0	87	117	79	BS	
Athens	1985							367	388	TSP	
	1991							338	587	TSP	
Barcelona	1991	1	117		300		300	290		TSP	1
Belfast	1985	5	31	44	257	9	531			BS	
	1990	5	32	48	450	16	650			BS	
Berlin	1989	3	96		545	80	619			TSP	
Bratislava	1985	2	60	73	260	41	310	250	350	TSP	
	1990	2	58	87	310	30	380	580	610	TSP	
Bremen	1990	4	32		102		107			TSP	2
Brussels	1985	3	23	30	166	3	190			BS	
	1990	3	24	31	95	0	114			BS	
Bucharest	1990	14	130	65	273	>1				TSP	3
Budapest	1992	6	62		199		219	283	287	TSP	
Cologne	1989	4	56		194	3	418			TSP	
Copenhagen	1985							335		TSP	
	1990							508		TSP	
Dnepropetrovsk	1985	2	250	250	680		890	1860	780	TSP	4
	1990	2	100	110	390		450	1410	790	TSP	4
Donetsk	1985	2	900	485						TSP	4
	1990	2	415	415	1470		1580	1730	1960	TSP	4
Dortmund	1985	1	74		598		598			TSP	
	1989	3	72		222		279			TSP	
Dublin	1985	12	69	110	884	107	884	601	304	BS	
	1990	12	46	72	1098	42	1098	926	759	BS	
Duisburg	1985	1	97		448	27				TSP	
	1989	4	70		221	14	266			TSP	

City	Year	City background (average)					Highest observed max. 24h			TSP/BS/PM10	Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³		
Dusseldorf	1989	3	58		149	4	157	231		TSP	
Essen	1989	3	57		175	5	247		319	TSP	
Frankfurt	1989	1	60		147	13	147			TSP	
Gothenburg	1985	1	8	34	49	0	49		42	BS	
	1992	1	5	9	35	0	35		32	BS	
Hamburg	1989	2	55		316	20	321			TSP	
Hannover	1989	1	41		301	10	301			TSP	
Helsinki	1985	2	53		187	4	221	383	256	TSP	5
	1990	2	42	36	309	4	331	462	493	TSP	
Istanbul	1990	6-16	101	162	437	114				BS	
Izhevsk	1985	1	200	200	780		780	390	390	TSP	4
	1990	1	100	100	390		390	390	390	TSP	4
Katowice	1985	2	258	323	673	344	748			PM10	
	1990	2	147	171	376	243	389			PM10	
Kazan	1985	3	100	80	390		390	390	390	TSP	4
	1990	3	100	50	390		390	390	390	TSP	4
Kharkov	1985	3	133	167	415		390	470	470	TSP	4, 6
	1990	3	137	133	530		610	1120	500	TSP	4
Kiev	1985	2	100	116	390		390		390	TSP	4
	1990	3	100	100	280		270	330	700	TSP	4
Krakow	1992	1	54			15				PM10	
Krasnodar	1985	1	300	167						TSP	4, 6
	1990	1	300	254	860		860	860	780	TSP	4
Krivoy Rog	1985	2	400	415	940		940	940	1330	TSP	4
	1990	2	365	360	970		1035	960	1520	TSP	4
Leeds	1985	4	18	25	154	4	234			BS	
	1990	4	28	20	85	0	92			BS	
Lille	1985								371	TSP	7, 8
	1990	2	37		141				155	TSP	7, 8, 9
Liverpool	1985	3	18	22	88	0	111			BS	
	1990	3	16	23	120	0	138			BS	

City	Year	City background (average)					Highest observed max. 24h			TSP/BS/PM10	Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³		
Ljubljana	1985	4	28	43	150	3	190	300	170	BS	
	91/92	4	23	35	185	5	280	310	230	BS	
London	1986		12		119	0				BS	
Luxembourg	1985	1	58		227		227			TSP	
	1990	1	42		148		148			TSP	
Lvov	1985	1	200							TSP	4
	1990	1	180	200	330		330	340	340	TSP	4
Lyon	1990	1			180					TSP	
Manchester	1985	4	18		109	1	147			BS	
	1990	3	21		196	4	237			BS	
Mariupol	1985	2	150	150						TSP	4, 6
	1990	2	185	215	720		980	550	1090	TSP	4
Marseille	1985	4	28	31	122	2	158	188		BS	
	1991	4	21	31	101	0	97	141		BS	
Milan	85/86	3	138		291					TSP	7, 10, 11
	90/91	2	70		129					TSP	7, 10, 11
Minsk	1985	3	167	122	720		780	780	780	TSP	4
	1990	3	100	100	460		390	470	390	TSP	4, 6
Moscow	1985	5	120	140	404		470	470	470	TSP	4
	1990	5	100	100	430		600	390	390	TSP	4
Nizhniy Novgorod	1985	2	250	175	970		1160	1630	1160	TSP	4
	1990	2	150	155	740		1100	470	1020	TSP	4
Odessa	1985	3	300	206	860		1250	2020	1720	TSP	4
	1990	3	270	220	780		880	1020	890	TSP	4
Oslo	1985	3	26	36	170	6	190	319		BS	
	89/90	3	25	34	166	4	280	210		BS	
Paris	1985	1	155	133	997		997			TSP	
	1991	6	43				191			TSP	
Perm	1985	3	100							TSP	
	1990	3	130	200	440		470	470	470	TSP	4, 6

City	Year	City background (average)					Highest observed max. 24h			TSP/BS/PM10	Note
		Nr. of stations	Annual average µg/m^3	Winter average µg/m^3	Max. 24h µg/m^3	Nr. of exceed.	City backgrnd. µg/m^3	Traffic µg/m^3	Industry µg/m^3		
Prague	1985	3	113	132	417	33	429			TSP	
	1991	4	84	92	356	26	435			TSP	
Reykjavik	1991	1	19	19	134	1	134	221		TSP	
Riga	1986		100		2000					TSP	7, 12
	1990		100		1800					TSP	7, 12
Rostov at the Don	1985	3	200	170	920		1370	1940	2330	TSP	4, 6
	1990	3	167	182	650		780	1410	2020	TSP	4
Rotterdam	1990	1	45		137		137		263	TSP	
Samara	1985	3	230	217	510		580	470	580	TSP	4
	1990	3	100	127	390		390	860	470	TSP	4
Saratov	1985	2	400	350	1880		2220	1300	2040	TSP	4, 6
	1990	2	100	190	730		760	700	700	TSP	4
Sevilla	1992							151		TSP	
Sheffield	1986	1	20	25	165		165		96	BS	14
	1991	1	16	11	33	0	33	174	26	BS	14
St. Petersburg	1985	3	100	78	390		390	1940	390	TSP	4, 6
	1990	3	90	70	444		540	1730	280	TSP	4
Stockholm	1993	1	18	15	34	0	34	133		PM10	15
Stuttgart	1985	2	19		106	1	128			TSP	
	1989	2	32		132	2	152			TSP	
Tirana	1985	1	67	66	337	22	337			BS	
	1990	1	85	107	392	32	392			BS	
Togliatti	1985	2	300	300	860		1250	470	470	TSP	4
	1990	2	200	185	470			780	780	TSP	4
Toulouse	1990	1	14		126	>0				TSP	7
Tula	1985	2	100	100	390		390	390	390	TSP	4, 6
	1990	2	70	90	285		310	240	1640	TSP	4
Turin	1985	1	168		538	218	538	584	602	TSP	8
	1990	1	155		398	185	398	434	727	TSP	
Ufa	1985	2	100							TSP	
	1990	2	100	106	490		390	600	390	TSP	4

City	Year	City background (average)					Highest observed max. 24h			TSP/BS/PM10	Note
		Nr. of stations	Annual average µg/m³	Winter average µg/m³	Max. 24h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³		
Valencia	1986	9	54	60	198	21		306	331	BS	
		9	43	55	161	5		240	168	BS	
Vienna	1985	2	112	122						LK	13
	1990	3	40	55						LK	13
Volgograd	1985	3	200	334						TSP	4, 6
	1990	3	200	153	670		470	470	470	TSP	4
Voronezh	1985	2	200	209	470		470	580	940	TSP	4
	1990	2	170	176	520		550	592	1158	TSP	4
Yaroslavl	1985	1	100	100	390		390	390	390	TSP	4
	1990	1	100	100	390		390	390	780	TSP	4
Zagreb	1985								333	TSP	
Zaporozhe	1985	3	233	200	905		780	890	470	TSP	4
	1990	3	207	187	790		970	580	1410	TSP	4
Zurich	1985	1	50							TSP	
	1990	1	38							TSP	

1 Max (24h) = 98 percentile (24h)
2 Max (24h) = 98 percentile (1/2h)
3 Less than 75% data available
4 Max (24h) = 98 percentile (20 min)
5 Traffic and Industry: 1986
6 Winter average: less than 75% data available
7 Not sure if city background station is really 'city background located'
8 Industry: less than 75% data available
9 Industry: 1989
10 Annual average = median
11 Max (24h) = 95 percentile
12 Max (24h) = max (20-30 min)
13 Laskus Kopf
14 Traffic: TSP
15 Traffic: 1992

Annex X.c: Summary of urban air quality statistics: nitrogen dioxide

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average μg/m³	Max. 24h μg/m³	Max. 1h μg/m³	Nr. of exceed.	City backgrnd. μg/m³	Traffic μg/m³	Industry μg/m³	
Amsterdam	1985	1	48	105	172	0	105			
	1990	4	51	68		0	122	124		
Antwerp	1985							156		
	1990							136		
Athens	1985	1	20	88	222	0	88	294		
	1991	1	38	96	264	0	96			
Barcelona	1991	1	43	106	200	0	106	145		
Berlin	1989	3	39	98	188	0	120			
Bremen	1990	4	38		88		96			1
Brussels	1985	2	47	151	248	1	151	180		
	1990	2	44	96	194	0	96	132		
Bucharest	1990	14	36	158	423	>1				2
Budapest	1992	6	44	110	310	0	144	184	150	
Chisinau	1990	4	20		238					3, 4
Cologne	1989	4	52	132	229	1	153			
Copenhagen	1985							146		
	1990							140		
Dnepropetrovsk	1985	2	45		150	0	150	150	200	4
	1990	2	35		210	0	210	340	650	4
Donetsk	1985	2	70		835	31	1310	1310	460	4, 5
	1990	2	70		350	0	310	670	760	4
Dortmund	1985	1	58		296		296			6
	1989	3	46		216		234			6
Duisburg	1989	3	48	130	273	0	146			
Dusseldorf	1989	3	43	111	180	0	122	131		
Essen	1989	3	45	115	268	0	130	185		
Frankfurt	1989	1	54	134	215	0	134			
Gothenburg	1985	1	36	117	288	0	117			
	1992	2	30	104	212	0	104	88		
Hamburg	1989	3	42	87	178	0	94			

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Max. 24h µg/m³	Max. 1h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Hannover	1989	1	44	110	168	0	110			
Helsinki	1990	2	27	103	197	0	110	146	105	
Izhevsk	1985	1	50		580	3	580	1170	480	4, 5
	1990	1	20		420	1	420	420	390	4, 5
Katowice	1985	2	97	215		20	230			
	1990	2	79	194		17	233			
Kazan	1985	3	40		177	0	190	160	160	4
	1990	3	40		307	1	330	490	410	4
Kharkov	1985	3	30		287	0	220	400	190	4
	1990	3	27		317	1	110	370	410	4, 5
Kiev	1985	3	40		347	1	360	310	260	4, 5
	1990	3	50		350	4	410	350	500	4, 5
Krakow	1992	1	31			0				
Krasnodar	1985	1	40		240	0	240	240	190	4
	1990	1	20		150	0	150	680	1020	4
Krivoy Rog	1985	2	125		430	1	460	430	420	4, 5
	1990	2	75		375	1	400	440	520	4, 5
Lille	1990	1	28	81	141					3
Ljubljana	91/92							186		
London	1984							150		
	1989							162		
Luxembourg	1985							166		6
	1990	1	51		168		168	320		6
Lvov	1985	1	50		110	0	110	130		4
	1990	1	70		90	0	90	170	180	4
Lyon	1990	1	41	110						3
Manchester	1990		57	222	365	1				
Mariupol	1985	2	60		245	1	270	260	230	4, 5
	1990	2	40		300	1	360	360	460	4, 5
Marseille	1985							218		
	1991							202		

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Max. 24h µg/m³	Max. 1h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Milan	85/86	3	50		212					3, 7, 8
	1990	9	114		298					3, 7, 8
Minsk	1985	3	20		260	0	220	320	180	4
	1990	3	37		400	7	480	230	220	4, 5
Moscow	1985	7	53		368	1	220	410	780	4, 5
	1990	7	76		490	13	690	520	720	4, 5
Munich	1989	1	49	130	263	0	130	140		
Nizhniy Novgorod	1985	2	70		995	18	1260	610	530	4, 5
	1990	2	30		255	6	420	350	940	4, 5
Nurnberg	1989	1	39	104	254	0	104			
Odessa	1985	3	60		140	0	150	170	140	4
	1990	3	97		317	11	360	360	420	4, 5
Oslo	89/90	2		76	98	0	90	119		
Paris	1985	3	50	200	448		166	538		
	1991							235		
Perm	1985	2	25		275	1	160	140	100	4, 5
	1990	2	40		345	0	470	220	210	4
Prague	1985	3	66	300		41	330			
	1991	7	56	327		31	616			
Reykjavik	1991	2	15	54		0	57	149		
Riga	1986		40		260					3, 9
	1990		60		740					3, 9
Rostov at the Don	1985	3	53		423	1	370	420	590	4, 5
	1990	3	27		290	0	350	640	420	4, 5
Rotterdam	1985	2	40	225	437	≥1	388	128		
	1990	3	43	122	280	0	145			
Samara	1985	3	33		363	1	440	760	200	4, 5
	1990	3	27		207	0	280	350	210	4, 5
Saratov	1985	2	35		680	1	750	530	740	4, 5
	1990	2	55		730	6	400	580	410	4, 5
Sevilla	1992							186		

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Max. 24h µg/m³	Max. 1h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Sheffield	1991							219		
St. Petersburg	1985	4	30		700	2	280	920	570	4, 5
	1990	4	58		350	7	500	940	1240	4, 5
Stockholm	1985	2	33	103	207	0	103	119	81	
	1990	1	29	79	171	0	79	105	54	
Stuttgart	1985	2	49	177	250	2	183			
	1989	2	58	183	280	1	218			
The Hague	1985	1	45	136	220	0	136			
	1990	1	42	114	233	0	114			
Togliatti	1985	2	40		345	3	540	690	630	4, 5
	1990	2	45		560	3	750	480	390	4, 5
Toulouse	1990	4	44	129	463					3
Tula	1985	2	35		200	0	210	240	800	4
	1990	2	30		305	0	280	510	1690	4
Turin	1986	1	78	180	532	7	180	277		
	1991	1	83	142	507	0	142	229		10
Ufa	1985	2	45		400	1	400	360	590	4, 5
	1990	2	40		350	6	450	340	370	4, 5
Valencia	1986							297		
Vienna	1990	2	38	130				150	120	
Vilnius	1990	3	27		220					3, 4
Volgograd	1985	3	33		430	2	740	770	420	4, 5
	1990	3	47		250	0	340	490	210	4
Voronezh	1985	2	45		290	0	360	350	300	4
	1990	2	40		255	0	290	320	220	4
Warsaw	1992		54	175		3				
Yaroslavl	1985	1	40		190	1	190	180	220	4, 5
	1990	1	10		120	0	120	110	120	4
Zaporozhe	1985	3	80		643		800	730	780	4
	1990	3	83		427		430	530	490	4
Zaragoza	1992							206	48	

City	Year	City background (average)					Highest observed max. 24h			Note
		Nr. of stations	Annual average µg/m³	Max. 24h µg/m³	Max. 1h µg/m³	Nr. of exceed.	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Zurich	1985	1	60			0				
	1990	2	44	98		0	109	141		

1 Max (1h) = 98 percentile (1/2h) and max (24h) = 98 percentile (1/2h)
2 Less than 75% data available
3 Not sure if city background station is really 'city background located'
4 Max (1h) = max (20 min) and max (24h) = max (20 min)
5 Nr. of exceedances: less than 75% data available
6 Max (1h) = max (1/2h) and max (24h) = max (1/2h)
7 Annual average = median
8 Max (24h) = 98 percentile
9 Max (1h) = max (20-30 min)
10 Traffic: less than 75% data available

Annex X.d: Summary of urban air quality statistics: Lead and CO at hot spots

City	*Lead*	Highest observed				*CO*	Highest observed			
	Year	Annual average µg/m³	Max.monthly average µg/m³	Environment	Note	Year	Annual average mg/m³	Max. 8h mg/m³	Environment	Note
Amsterdam	1985	0.3		traffic						
	1990	0.10	0.45	traffic		1990	1.35	8.42	traffic	
Antwerp	1985	0.97		traffic						
	1990	0.26		traffic						
Athens						1985	7.7	25.0	traffic	
	1991	0.45	0.65	traffic		1991	6.8	35.0	traffic	
Barcelona	1991	0.44		traffic		1991	2.5	13.2	traffic	
Bratislava	1985	0.23	0.51	traffic						
	1990	0.11	0.16	traffic						
Bremen						1990	1.2	1.3	city backgr.	1
Brussels	1985	1.29	1.53	traffic						
	1990	0.38	0.44	traffic						
Budapest						1992	2.9	6.8	city	2
						1992	5.1	10.6	traffic	2
						1992	4.0	7.1	industrial	2
Chisinau	1990	0.08	0.27		3	1990	2	19		4
Copenhagen	1985	0.62	0.82	traffic						
	1990	0.25	0.36	traffic		1990	2.2	9.4	traffic	
Dnepropetrovsk						1985	3		traffic	
	1990	0.08	0.16	industrial		1990	3		traffic	
Donetsk						1985	2		traffic .	
	1990	0.17	0.34	industrial		1990	2		traffic	
Dublin	1985	1.32	2.06	traffic						
	1990	0.27	0.45	traffic						
Gothenburg						1992	0.9	5.8	traffic	
Helsinki	1986	0.12	0.23	traffic						
	1990	0.06	0.08	traffic		1990	1.6	12	traffic	
Izhevsk						1990	1		traffic	
Katowice	1985	0.52	0.87	traffic						
	1990	0.29	0.43	traffic		1990	7.4		traffic	

City	*Lead*	Highest observed			Note	*CO*	Highest observed			Note
	Year	Annual average µg/m³	Max.monthly average µg/m³	Environment		Year	Annual average mg/m³	Max. 8h mg/m³	Environment	
Kazan						1985	3		traffic	
	1990	0.03	0.08	traffic		1990	1		traffic	
Kharkov						1985	3		traffic	
	1990	0.13	0.29	traffic		1990	3		traffic	
Kiev						1985	1		traffic	
	1990	0.48	1.09	industrial		1990	2		traffic	
Krakow						1992	4.0		traffic	
Krasnodar						1985	3		traffic	
	1990	0.02	0.07	industrial		1990	4		traffic	
Krivoy Rog										
Leeds	1985	0.31		city backgr.						
	1990	0.12		city backgr.						
Lille	1990		0.37		5					
Ljubljana						1991	2.5	6.9	traffic	
Lodz										
London	1985	1.45								
Luxembourg						1990	1.5	16.1	traffic	6
Lvov						1985	2		traffic	
	1990	0.06	0.19	industrial		1990	4		traffic	
Lyon	1990	0.78				1990	9	70		7
Manchester	1985	2.04		city backgr.						
	1990	0.51		city backgr.		91/92	1.2	8.8	traffic	
Mariupol						1985	1		traffic	
	1990	0.06	0.13	industrial		1990	2		traffic	
Marseille	1985	2.17	3.30	traffic		1985	5	18	traffic	
	1991	0.36	0.67	traffic		1991	3	6	traffic	
Milan						90/91	5.2	37		8
Minsk	1985	0.06	0.24	traffic		1985	1		traffic	
	1990	0.11	0.38	traffic		1990	2		traffic	
Moscow						1985	6		traffic	
	1990	0.03	0.12	traffic		1990	3		traffic	

City	*Lead*	Highest observed				*CO*	Highest observed			
	Year	Annual average µg/m³	Max.monthly average µg/m³	Environment	Note	Year	Annual average mg/m³	Max. 8h mg/m³	Environment	Note
Munich						1989	4.1		traffic	
Nizhniy Novgorod						1985	1		traffic	
	1990	0.21	0.55	industrial		1990	1		traffic	
Odessa						1985	3		traffic	
	1990	0.17	0.61	traffic		1990	2		traffic	
Oslo	1989		0.71	traffic		1992		17.3	traffic	
Paris						1985	4.7		traffic	
	1991	0.70		traffic		1991	8.0	22.4	traffic	
Perm						1985	1		traffic	
	1990	0.03	0.06	city backgr.		1990	1		traffic	
Prague	1991	0.39	0.61	traffic						
Reykjavik	1986	0.46	0.99	traffic						
	1990	0.04	0.09	traffic		1991	0.75	2.7	traffic	
Riga						1986	1	15		9
						1990	1	21		9
Rostov at the Don						1985	7		traffic	
	1990	0.25		traffic		1990	5		traffic	
Rotterdam	1985	0.40	0.61	traffic						
	1990	0.08	0.13	traffic		1990	0.74	8.38	traffic	
Samara						1985	2		traffic	
	1990	0.04	0.09	traffic		1990	2		traffic	
Saratov						1985	1		traffic	
	1990	0.14	0.28	city backgr.		1990	2		traffic	
Sevilla						1992	4.6	14.2	traffic	
Sheffield	1985	1.09	1.57	traffic						
	1992	0.18	0.28	traffic		1992	0.9	9	traffic	
St. Petersburg						1985	0.6		traffic	
	1990	0.04	0.1	traffic		1990	4		traffic	
Stockholm						1985	3.2		traffic	
	1990		0.45	traffic		1990	2.6	15	traffic	

City	*Lead* Year	Highest observed: Annual average µg/m³	Max.monthly average µg/m³	Environment	Note	*CO* Year	Highest observed: Annual average mg/m³	Max. 8h mg/m³	Environment	Note
Togliatti						1985	1		traffic	
	1990	0.24	0.40	industrial		1990	1		traffic	
Toulouse	1986	1.5		city centre						
	1990	0.9		city centre		1990	3	78		7
Tula						1985	1		traffic	
	1990	0.02	0.04	traffic		1990	<1		traffic	
Turin	1985	1.5	2.4	background		1985	9.4	38.2	traffic	
	1988	1.05	1.75	background		1991	6	19.5	traffic	
Ufa						1985	2		traffic	
	1990	0.06	0.12	traffic		1990	2		traffic	
Valencia	1985	1.7	2.4	traffic						
Vienna						1990	2.9		traffic	
Vilnius	1990	0.03	0.08							
Volgograd						1985	2		traffic	
	1990	0.03	0.10	city backgr.		1990	1		traffic	
Voronezh						1985	1		traffic	
	1990	0.06	0.17	traffic		1990	1		traffic	
Warsaw						1992	1.75	3.69	traffic	10
Yaroslavl						1985	1		traffic	
						1990	1		traffic	
Zagreb	1985	0.8	1.3	suburb						
	1990	0.96	1.46	city centre						
Zaporozhe						1985	1		traffic	
	1990	0.10	0.20	industrial		1990	1		traffic	
Zaragoza	1992	1.72	2.21	traffic		1992	4		traffic	
Zurich						1990		4.6		10

1 Max (8h) = 98 percentile (1/2h)
2 Max (8h) = 98 percentile (24h)
3 Max monthly average = max (20 min)
4 Max (8h) = max (20 min)
5 Max monthly average = max annual
6 Max (8h) = max (1/2h)
7 Max (8h) = max (1h)
8 Annual average = median
9 Max (8h) = max (20-30 min)
10 Max (8h) = max (24h)

Annex X.e: Summary of urban air quality statistics: Ozone

City	Year	City background (average)							Highest observed max. 1h			Note
		Nr. of stations	Annual average µg/m³	Summer average µg/m³	Max. 1h µg/m³	Max. 8h. µg/m³	Nr. of exceed.	Exceed. class	City backgrnd. µg/m³	Traffic µg/m³	Industry µg/m³	
Amsterdam	1990	3	29					2	243			
Antwerp	1990	1	31	49	197			2	197			1
Berlin	1989	3	39		235			2	254			
Bremen	1990	4	33		107			1	115			2
Brussels	1988	1	30	42	150		1		150			
	1990	1	38	52	238		>12	2	238			
Budapest	1992				250	126		2			158	3
Cologne	1989	2	27		227			2	215			
Copenhagen	1990									62		
Dortmund	1989	1	31		236			2	236			1
Duisburg	1989	1	32		211			2	211			
Dusseldorf	1989	1	29		208			2	208			
Essen	1989	1	27		210			2	210			
Frankfurt	1989	1	29		277			2	277			
Gothenburg	1985	1	41	56	155				155			
	1992	2	44	56	91		0		95	78		
Hamburg	1989	2	37		212			2	213			
Hannover	1989	1	42		260		25	3	347			
Helsinki	1990	1	33	22	125		0	1	125	108		
Lille	1990	1	20		119		0	1				4
London	1985		33		298							
	1989		20		216			2				
Luxembourg	1990									111		1
Lyon	1990	1	10		152		1	1				4
Marseille	1985	1	52		183	94	2		183			5
	1991	1	31		73	70	0	1	73			
Milan	1985	1	16									4
	1990	1	34									4
Munich	1989	1	13		164			1	164			
Oslo	1992	3		31	88	83		1				

City	Year	City background (average)							Highest observed max. 1h			Note
		Nr. of stations	Annual average $\mu g/m^3$	Summer average $\mu g/m^3$	Max. 1h $\mu g/m^3$	Max. 8h. $\mu g/m^3$	Nr. of exceed.	Exceed. class	City backgrnd. $\mu g/m^3$	Traffic $\mu g/m^3$	Industry $\mu g/m^3$	
Paris	1985	2	25		175				223			
	1991	4	16		154	128		2	263			
Rotterdam	1985	2	33		232				240	149		
	1990	3	34		288			2	307			
Sheffield	1992	1	41			208	0	2		121		
St. Petersburg	1991	13		61	200							
Stockholm	1985	1	47	68	213				213			
	1990	1	47	55	168				168			
Stuttgart	1985	1	28		258				258			
	1989	2	30		204			2	236			
The Hague	1990	1	48	63	314	156		2	314			
Toulouse	1990	1	39		275			2				4
Warsaw	1992		48	30		117	0	1				3
Zurich	1990	1	28	74	186		≥1		186	175		

1 Max (1h) = max (1/2h)
2 Max (1h) = 98 percentile (1/2h)
3 Max (8h)= max (24h)
4 Not sure if city background station is really 'city background located'
5 Annual average: less than 75% data available

Annex XI: Local air pollution in industrial areas of Europe.

Country	Main air polluting industries	No. of people potentially effected (in thousands)	Max. conc. (µg/m³) (Compound, average time, period)
Northern European countries			
Finland	Harjavalta, Turun ja Pori Copper smelter, sulphuric acid plant	1-2	630 (SO_2, max. monthly, 99%ile of 1 hr. values) 1992 No exceededances expec-ted after 1994.
	Pulp and paper industries		Odour H_2S
Norway	Al. smelters Ferroalloy	16 (PAH) 19 (SO_2)	4 (PAH, 24 hr) 1000 (SO_2, 1hr)
Eastern European countries			
Albania	Elbasan Fe-Ni	80	99 (soot, average time?) 250 (dust, " " ?)
	Korce Power Plant	40	
	Kruja/Lac Cu	20	190 (SO_2, averaging time?) Vegetation affected: Pine
	Mirdite/Rubik Cu	5	194 (SO_2, averaging time?)
	Kukes/Gjegjan Cu	10	73 (SO_2, averaging time?)
	Vlare Cement	5	409 (Dust, averaging time?)

Annex XI: Contd.

Country	Main air polluting industries	No. of people potentially effected (in thousands)	Max. conc. (μg/m³) (Compound, average time, period)
Bulgaria	Sofia Steel, non-ferrous metals (e.g. Pb, Cu), chemical (fertilizer) (12 industrial areas)	550 (SO_2 + TSP)	2 200 (SO_2, 1 hr) 30-485 (SO_2, yr,1989-90) 160-530 (TSP, yr, 1989-90
	Pirdop/Zlatitza Non-ferrous	50	SO_2: 870/month Dust: 1560 " H_2SO_4: 1827 !?!?
	Plovdiv Non-ferrous	400	SO_2: 460/month Dust: 580 " NO_2: 153 "
	Bourgas Petro-chem. Power Plant	200	SO_2: 140/month Dust: 423 "
	Devnis Chem., Power Plant (fertilizer)	330	SO_2: 194/month Dust: 1155 " NH_3: 248 H_2SO_4: 290
	Vratza Chem. (fertilizer)	85	SO_2: 110/month Dust: 420 " NO_2: 184 "
	Kardjali Non-ferrous	57	SO_2: 410/month Dust: 450 " Pb: 3.5 " H_2SO_4: 155 "
	Plahova Petrochem.	259	1120 (NH_3, max. 24 hr)
	Pitesti, Arges Petrochem.	175	1800 (NH_3, max. 24 hr)
	Copsa Mica, Sibin Non-ferrous	80	1350 (SO_2, max 24 hr) 510 (TSP " " ")
	Slatina, Olt Non-ferrous	88	50 (SO_2, max 24 hr) 146 (TSP, " " ") 29 (F, " " ")
	Vilcea Chem.ind.	110	1100 (HCl, max. 30 min.) 1580 (NH_3, " " ")

Annex XI: Contd.

Country	Main air polluting industries	No. of people effected (in thousands)	Max. conc. (μg/m³) (Compound, average time, period)
Croatia	Rijeka Petr.refinery	20	90 (SO_2, yr) 330 (SO_2, 24 hr) 16 (H_2S, 24 hr)
	Urinj-Bakar, Rijeka Petr.refinery, coke plant, PP (coal), port (bulk handling of iron ore, coal, phosphate)	200	70-80 (SO_2, yr) 620 (H_2S, 24 hr) Particles (Pb, Cd)
	Kastela Bay, Split Cement ind. PVC, Steel Works	100	70 (SO_2, 24 hr) 40 (SO_2, yr) 120 (smoke, 24 hr) 40 (smoke, yr) up to 3700 (dustfall, mg/m²/day) 0.060 (Pb), 0.032 (Mn) 0.006 (Cr), 0.003 (Cd)
	Pula, Istria Cement prod. quarry, glass works	67	56 (SO_2, yr) 45 ("Smoke", yr) 1.1 (F, yr) Dustfall
	Labin, Istria PP (coal), Cement prod., quarry	13	86 (SO_2, yr) 13 ("Smokee", yr) 83 (TSP, yr) Dustfall
	Zagreb Crnomerec Pharmaceut. ind. Susedgrad. Cement ind. Pescenica. Chem.ind. Tresnjevka. PP (oil)	1000	355 (SO_2, 24 hr) 319 (Smoke, 24 hr) 212 (SO_2, 24 hr) 300 (Smoke, 24 hr) 608 (TSP, 24 hr) 422 (SO_2, 24 hr) 408 (Smoke, 24 hr) 381 (SO_2, 24 hr) 284 (Smoke, 24 hr)
	Kutina Fertilizer	15	68 (NO_2, 24 hr) 817 (NH_3, 24 hr) 35 (F, 24 hr) 17 (SO_2, 24 hr) 123 (Smoke, 24 hr).

Annex XI: Contd.

Country	Main air polluting industries	No. of people potentially effected (in thousands)	Max. conc. (µg/m³) (Compound, average time, period)
Croatia, cont.	Sisak Petr.refinery	46	174 (SO_2, 24 hr) 115 (Smoke, 24 hr)
Czech Republic	Sokolov region: Brown coal mining/ industry/PP	96 (SO_2 + TSP)	1 500 (SO_2, 24 hr, 1990)
	North Bohemia region: Brown coal mining/PP, Chemical industry	625 (SO_2 + TSP)	1 200 (SO_2, 24 hr, 1991)
	Ostrava region: Black coal mining/ coking/PP, steel	850 (SO_2 + TSP)	700 (TSP, 24 hr, 1991)
Estonia	Narva, PP	87[2]	
	Ida-Vizumaq, PP	39[2]	
	Kothla-Järve PP, chem.industry	64[2]	
	Kivioli, Chem.industry	10[2]	
	Tallinn, PP	492[2]	
Hungary	Iron/steel, non-ferrous (Al), chemical, PP (6 industrial areas)		52-94 (SO_2, yr,1987-88) 90-146 (SO_2, winter, 1987-88)
Latvia	Daugavpils, Chem.industry	128	500 (SO_2, "short term") 140 (NO_2, "short term") 60 (caprolactam, "short term")
	Liepaja, Steel industry	115	180 (NO_2, "short term") 500 (TSP, "short term")
	Ventspils, Chem.industry	50	2000 (Methyl alcohol, "short term")
	Olaine, Riga, Chem.industry	14.5	1200 (isopropanol, "short term")
	Jurmala, Riga, pulp/paper	66	270 (NO_2, "short term")

Annex XI: Contd.

Country	Main air polluting industries	No. of people potentially effected (in thousands)	Max. conc. (µg/m³) (Compound, average time, period)
Moldova	Ribnita, cement	70	2 300 (PM, short term)
	Ribnita, steel works		2 300 (PM, short term)
	Dnestrovsk, PP Slobozia district	500-600	790 (PM, short term) 700 (SO_2, short term) 850 (NO_2, short term)
	City Balti, PP	180	2 400 (PM, short term)
Poland	PP, coking/steel, non-ferrous (Cu), chemical (fertilizer, viscose) (17 industrial areas)		29-584 (SO_2, yr,1988) 105-477 (TSP, yr, 1988)
	Katowice, Upper Silesia Steel, coke		Max. Dobrova Gornicza (annual) (max.24 hr) SO_2 54 146 Dust 130 218 BaP 58 265 (ng/m³) " 62-90 (other villages) .." 172 Katowice Vegetation affected: crop yield, Heavy metals. Pine forests
Romania	Zlatna, Alba Non-ferrous metal	9	326 (SO_2, max. 24 hr) 1993
	Bacau Fertilizer PP, Chem., Petrochem.	 197 113	 890 (NH_3, max. 24 hr) 1993 160 (NO_2 " ") 1993
	Baia Mare Non-ferrous	152	57 (Pb, max. 24 hr) 1993 0.46 (Cd, " " ") 1993 6440 (SO_2, " " ") 1993
	Tirgu Mures Fertilizer	172	4000 ((NH_3, max. 24 hr)

Annex XI: Contd.

Country	Main air polluting industries	No. of people effected (in thousands)	Max. conc. (µg/m³) (Compound, average time, period)
Russian Federation	Balakovo Chem.ind		25 (CS_2, yr) 702 (CS_2, 20 min)
	Barezniki Fertilizer		55 (CS_2, yr) 770 (CS_2, 20 min)
	Kandalaksha Al.smelter		219 (HF, 20 min) 0.0076 (BaP, month)
	Lipetsk Metallurgy		62 (H_2S, 20 min) 33 (Formaldehyde, yr) 98 (Formaldehyde, 20 min) 0.0092 (BaP, month)
	Novgorod Fertilizer		60 (NH_3, yr) 1800 (NH_3, 20 min) 0.0092 (BaP, month)
	Perm Petrochem.ind.		100 (NO_2, yr) 1000 (NH_3, 20 min) 0.0036 (BaP, month)
	Togliatti Fertilizer		18 (Formaldehyde, yr) 112 (Formaldehyde, 20 min) 150 (NH_3, yr) 760 NH_3, 20 min) 390 (NO_2, 20 min)
	Ryazan Chem.ind.		29 (CS_2, yr) 289 (CS_2, 20 min)

Annex XI: Contd.

Country	Main air polluting industries	No. of people effected (in thousands)	Max. conc. (μg/m³) (Compound, average time, period)
Slovenia	Celje, Chem.industry	42	580 (SO_2, 24 h, 91/92) 1260 (SO_2, ½ h, 91/92)
	Hrastnik, Chem.industry	7	820 (SO_2, 24 h, 91/92) 1080 (SO_2, ½ h, 91/92)
	Ljubljana, TPP	280	460 (SO_2, 24 h, 91/92) 1400 (SO_2, ½ h, 91/92) 310 (BS, 24 h, 91/92)
	Maribor, Car industry	126	315 (SO_2, 24 h, 91/92) 685 (SO_2, ½ h, 91/92)
Southern European countries			
Greece	Thessaloniki		377 (SO_2, 24 hr, 98% ile)
Italy	Siracusa, Sicily: Chemical, PP	414	
	Cagliari, Sarodegna: Chemical, PP	775	
	Veneto: Chemical, PP	830	
	Taranto, Puglia: Chemical, PP	600	
	Napoli: Chemical, PP	3 190	
Portugal	Barreiro-Seixal		686 (SO_2, 24 hr, 98% ile) 466 (TSP, 24 hr, 98% ile)
Spain	Bilbao: PP, iron/steel, metalurgy, chemical (.......)		184 (SO_2, 24 hr, 98% ile) 397 TSP, 24 hr, 98 %ile)
	Cartagena: PP, metal, chemical (fertilizer, petro)		500 (SO_2, 24 hr, 98% ile) 499 (TSP, 24 hr, 98% ile)

Annex XI: Contd.

Country	Main air polluting industries	No. of people effected (in thousands)	Max. conc. (µg/m³) (Compound, average time, period)
Spain (contd.)	Puertollano: PP, petrochem./ refinery		328 (SO_2, 24 hr, 98% ile) 206 (TSP. 24 hr, 98% ile)
	Serch:		364 (SO_2, 24 hr, 98% ile)
	Langreo:		455 (TSP, 24 hr, 98% ile)
Western European countries			
Austria	Linz Steel works, fertilizer, chem.industry	200	190 (SO_2, ½ hr, 1991) 23 (H_2S, ½ hr, 1991)
	Lenzing Viscose, pulp/paper	5	780 (SO_2, ½ hr, 1991) 64 (H_2S, ½ hr, 1991)
	Schwechat Refinery	1 500	130 (SO_2, ½ hr, 1991)
	Brixlegg, Tyrol Copper smelter	3	590 (SO_2, ½ hr, 1991) heavy metals, dioxine
	Donawitz, Styria Steel works	30	50 (SO_2, ½ hr, 1991) 70 (NO_2, ½ hr, 1991)
	Gratkorn, Styria Pulp/paper	10	359 (SO_2, ½ hr, 1991) 185 (NO_2, ½ hr, 1991)
	St. Gertraud, Carinthia Pulp/paper	28	480 (SO_2, ½ hr, 1992)
	Pöls, Styria Pulp/paper	3	210 (SO_2, ½ hr, 1991) 80 (NO_2, ½ hr, 1991)
	Hallein, Salzburg Pulp/paper	50	230 (SO_2, ½ hr, 1991)

Annex XI: Contd.

Country	Main air polluting industries	No. of people effected (in thousands)	Max. conc. (µg/m³) (Compound, average time, period)
Belgium	Hoboken: Non-ferro-industry		1.6 (Pb, yr) 0.06 (Cd, yr)
	Beerse: Pb smelter		0.8 (Pb, yr) 0.03 (Cd, yr)
	Antwerp: Oil refinery, Chem.industry, PP		2000 (SO_2, 30 min, 1991)
	Engis PP, Chem.industry		1500 (SO_2, 30 min, 1991)
	Eve Roem Wondelgem PP, Chem.industry		1000 (SO_2, 30 min, 1991)
	Vilvoorde PP, Chem.industry		1500 (SO_2, 30 min, 1991)
	Tessenderlo Chem.industry		500 (SO_2, 30 min, 1991)
France	Le Havre: PP, metallurgy, chemical (H_2SO_4, petro)		355 (SO_2, 24 hr, 98% ile) 150 (TSP, 24 hr, 98% ile)
	Lyon:		275 (SO_2, 24 hr, 98% ile)
	Notre Dame de Gravenchou: Refinery		408 (SO_2, 24 hr, 98% ile)
	Noyelles-Godeault:		335 (SO_2, 24 hr, 98% ile)
	Petit Couronne: Pulp/paper, refinery		480 (SO_2, 24 hr, 98% ile)
	Salsigne:		955 (SO_2, 24 hr, 98% ile)

Annex XI: Contd.

Country	Main air polluting industries	No. of people effected (in thousands)	Max. conc. (µg/m³) (Compound, average time, period)
Germany	Braubach: Pb smelter		2.4 (Pb, yr, max. 1987-89)
	19 areas in new "Länder"		364-780 (SO_2, 24 hr, 98% ile)
	Merseburg Chem. paper Al. processing	119	220 (SO_2, year, 1991) 600-800 (SO_2, 97.5 % ile) 200-300 (Dust, 97.5 % ile) Org. S.
	Untermain-Frankfurt Chem., metal processing	1000	300 (O_3, ½ hour) 0.24 (Pb, max. month in Ffm) Cl_2, HCl Org. C PAH etc.
UK	Walsall: Pb smelter		3.6 (Pb, yr, max. 1987-89)
	Newry:		122 (SO_2, 24 hr, 98% ile) 418 (TSP, 24 hr, 98% ile)
	Sunderland:		117 (SO_2, 24 hr, 98% ile) 348 (TSP, 24 hr, 98% ile)

ANNEX XII: EUROPE'S ENVIRONMENT: URBAN AND LOCAL AIR POLLUTION[i]

1 Introduction

Europe today is a highly urbanised continent with more than 70 per cent of Europeans living in urban areas. Many urban activities (eg, traffic, combustion processes, industrial production) are accompanied by emissions into air yielding elevated concentrations of pollutants. This is especially significant when a large number of activities are concentrated together, as in an urbanised area.

Air pollution on the urban scale is the source of a range of problems: health risks mostly associated with inhalation of gases and particles, accelerated deterioration of building materials, damage to historical monuments and buildings, and damage to vegetation within and near the cities. In order to tackle these problems it is necessary to understand: what characterises urban air quality; what are the sources of urban air pollutants; and, which exposures are associated with the high concentrations of air pollutants occurring in cities.

The actual occurrence and frequency of increased air pollution concentrations depends primarily on the magnitude and the distribution of emission sources, on local topography (eg, flat terrain or basin or valley) and local meteorology (eg, average wind speed, frequency of calm weather conditions, occurrence of inversion layers). The significance of any air pollution depends ultimately on the type of pollutants, the resulting exposure and the health and other effects associated with this exposure. In this section, the World Health Organization Air Quality Guidelines (WHO-AQGs) have been taken as reference values to assess where ambient concentrations may possibly cause effects on human health and where further study may be necessary (WHO 1987). The AQGs are given in Table 1, together with the effects they aim to prevent. As a precaution, some national limit values are even lower than WHO-AQG values.

A considerable safety margin is often built into AQGs with respect to the lowest observed effect level, to help protect the sensitive part of the population. However, AQGs have only been specified for a limited number of the thousands of possible constituents of urban air and for a limited number of averaging times. The number of constituents covered by AQGs and the number of averaging times specified for each, increase as evidence of possible adverse effects accumulates.

Table 2 gives the main categories of sources that contribute to the total emissions of the components mentioned in Table 1. In non-industrial cities the largest contributions come from local traffic and domestic heating when oil, coal or wood is used.

Most large cities in Europe operate monitoring networks in order to assess the air quality in their city. However, the design and the technical procedure (components measured, methods used, number and location of the stations) of the monitoring activities vary widely within Europe. The most advanced networks have incorporated air dispersion models and emission inventories in order to determine the geographical distribution of air pollution in the city and to

[i] This text is pulished in the Europe's Environment report (EE-report; Stanners & Bordeau, eds., 1995). Because of the tight time schedule kept for the EE-report, this text was written and transmitted to EEA-TF summer 1993. A lot of new data became available after the deadline of the EE-report. These data has been used while writing the Scientific Background Document. Because of this, figures given in this Annex can be slightly different from those given elsewhere in this document.

determine the contribution from the different sources. In such cities the authorities are able to use this information to decide on the measures needed to reduce air pollution to an acceptable level, and to assess the cost of these measures (cost-efficient abatement measures).

Consistent information about air quality in large European cities is not yet collected systematically except by the European Commission under Council Decision 82/459/EEC and WHO/UNEP (UN-ECE, 1992). In general, air pollution problems may occur in all the 2000 cities in Europe with more than 50 000 inhabitants (WHO, 1994). For this report, only a limited number of cities were evaluated. Questionnaires were sent out to all cities or conurbations in Europe with more than 500 000 inhabitants, as well as to the largest city in each country (105 cities in all). Approximately 22 per cent of the European population, or 148 million people, live in these cities (Figure 1 and 2). A summary of the information from these questionnaires covering emissions, air concentrations and exposure situations in these European cities is presented in this chapter.

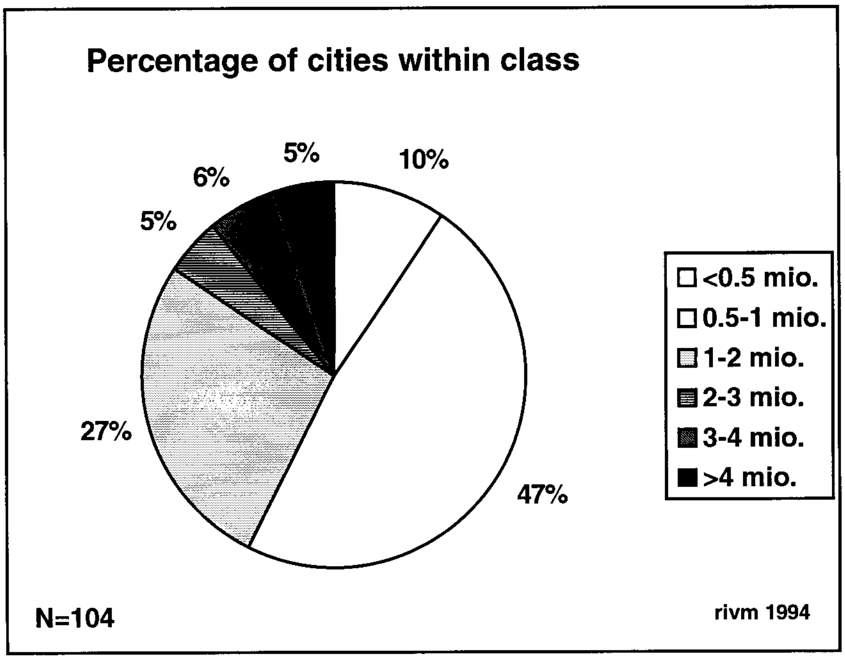

Figure 1: Frequency distribution of cities by population class

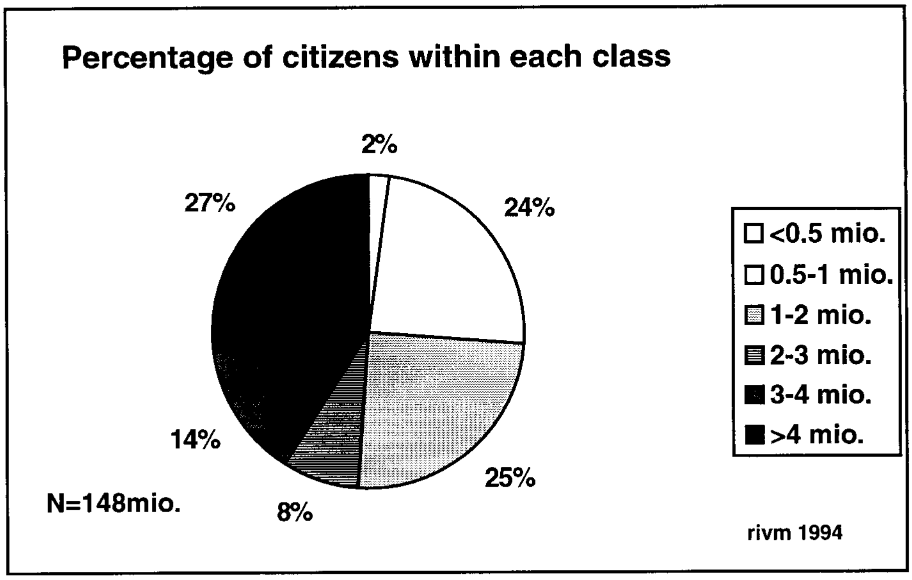

Figure 2: Frequency distribution of population by city class.

Table 1: WHO-AQGs for relevant pollutants and expected effects (RIVM, 1992; WHO, 1987)

Pollution type	indicator	WHO-AQG risk level $\mu g/m^3$	Effect level	Effects
Short term effects				
Summer smog	O_3	150 (1 hour)	200 $\mu g/m^3$ classification mild	Lung function decrements, respiratory symptoms, inflammation
Winter smog	SO_2+ TSP	250 (1 day)	400 $\mu g/m^3$ classification moderate	Decraese lung function; increased medicine use for susceptible children
Urban/traffic	NO_2	150 (1 day)		
Long term effects				
Traffic	Benzene	2.5 (1 year)	10^{-7} yearly risk on cancer	Leukaemia; neurologic symptoms
Traffic/industry	Lead	0.5 (1 year)		Effects on blood formation, kidney damage; neurologic cognitive effects
Combustion	SO_2+TSP	100 (1 year)		Respiratory symptoms, chronic respiratory illness
Combustion/industry	B(a)P	0.0001 (1 year)	10^{-7} yearly risk on cancer	Respiratory tract and lung cancer

TSP: Total Suspended Particulates