Commission of the European Communities

environment and
quality of life

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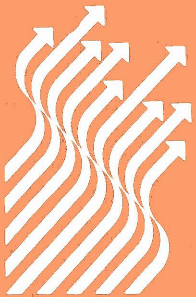

Report

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EEC Directive 80/779/EEC: A study of network design for monitoring suspended particulates and sulphur dioxide in the Member States

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1. INTRODUCTION

The EC Air Quality Directive for Sulphur Dioxide and Suspended Particulates specifies[1] air quality limit values which are to be complied with from April 1983. Reference methods of measurement are included in the Directive but it is not mandatory to use these methods for routine monitoring. However if the reference methods are not used it is necessary under Article 10(1) of the Directive "to demonstrate to the Commission at regular intervals:

- either that [the alternative method] ensures satisfactory correlation of results with those obtained using the reference method;
- or that measurements taken in parallel with the reference method at a series of representative stations chosen in accordance with the requirements laid down in Article 6 show that there is a reasonably stable relationship between the results obtained using that method and those obtained using the reference method."

Furthermore the Directive allows subject to final decision by the Commission two different sampling and analysis schemes each incorporating a different set of limit values (Annex I and Annex IV).

There is therefore a wide degree of flexibility in the strategy which can be used by the different member states to show compliance with the Directive. The Commission has initiated[2] studies to consider the reference methods, to assess the variety and number of sampling and analytical equipment used in the different member states, to consider definitions of the terms 'satisfactory correlation' and 'reasonably stable relationship' and to consider the corresponding stringency of the Annex I and Annex IV limit values.

The latter study on corresponding stringency included[3] a brief examination of network design philosophy in general and as adopted in a number of the member states but was not comprehensive. Such a study was subsequently requested by a number of member states and led to the present study being commissioned.

The aim of the present study is:

A. To collect data from all Member States on the criteria which were employed in designing national monitoring networks for SO_2, black smoke and suspended particulates. Fixed and continuously working networks as well as mobile and discontinuous ones should be studied and compared. Recent modifications and redesigns of networks as undertaken or planned by the Netherlands and the United Kingdom should be studied in order to examine whether these approaches can serve as examples for good network design. If possible, costs for different types of network should be evaluated and compared. Visits to selected networks/sites and on-the-spot checks to determine the way in which the criteria have been implemented should be undertaken by the participants of the working group at least in F.R. Germany, France, the Netherlands, Italy, Belgium and the United Kingdom. If possible network/sites should be visited, where the limit values are likely to be approached or exceeded[4]. As much information as possible should be collected from the other Member States.

B. To compare the criteria and the results of the above study with the requirements laid down in articles 2 and 6 and Annex IV of Directive 80/779/EEC.

C. To make recommendations, on the basis of the investigations A and B, of the design of monitoring networks in order to fulfil the requirements and provide the information required by the Directive.

The recommendations should aim in particular at improving the comparability of the monitoring results, e.g. by proposing:

i. means to detect the site with the greatest pollution and site(s) which is (are) representative for local conditions as required by article 6

ii. means to survey the SO_2, black smoke and SPM concentrations in the most efficient way with regard to the information gathered and the investment and running costs.

2. GENERAL PRINCIPLES OF NETWORK DESIGN

The earlier report on the corresponding stringency of Annexes I and IV presented a detailed review of the State-of-the-Art of Network Design. Hence only a brief resume will be presented here. This concentrates on the features of network design summarised by Munn[5] and relevant to the present study and the main conclusions of the earlier report.

Munn listed[5] seven principal objectives of urban air quality monitoring programmes:

1. Regulatory control (surveillance monitoring)

Information relevant to air quality standards etc is obtained from networks of stations whose locations should be widely accepted as being representative of urban conditions; sometimes the network design and station siting criteria may have been specified in the legislation.

This is the objective required by the Directive.

2. To determine present conditions and trends (exploratory monitoring)

(i) to determine whether there is need for regulatory action,

(ii) to promote public relations, and

(iii) to determine trends, for example to provide an early warning system that air quality standards may be exceeded if control measures are not taken.

These are more general objectives and most networks will be designed with one or more of these objectives specified.

3. To make short-term (1-5 day) predictions

Monitoring is required for model development, validation and operational use in alarm (or alert) systems for the control and reduction of emissions during high pollution episodes.

4. To simulate the effects of various land-use strategies on air quality

Monitoring is required for the development and validation of models which predict frequency distributions of pollutant concentrations.

5. To study dose-response relations

Dose-response investigations require various kinds of air quality data to relate to health, vegetation, or economic effects or to the soiling and corrosion of materials. In each case the quality of the air in the immediate vicinity of the receptors is important rather than the general pollution levels. There is need for studies of both episodic extremes and long-term means.

6. To provide input data on air quality for large inter-disciplinary urban models.

7. To study the effect of pollution on urban climate

The last three objectives can occasionally be the main objective of a monitoring programme but more often will be supplementary objectives of programmes designed for one or more of the first four more commonly addressed objectives.

As will be shown in the following sections most networks are established to meet at least two and often all four of the first four objectives.

Munn reviewed the methods available for network design and classified them as statistical, modelling and combination methods. In presenting the network design methods adopted in the member states consideration will be given to how closely the method used complies with one or other of the methods listed by Munn.

The following conclusions on network design were made in the earlier report[3]:

"For very good practical and theoretical reasons there are no generally accepted rules on how to design and operate monitoring networks or on how to analyse and present the data. Within Member States a great deal of emphasis is placed on prior assessments of the spatial distribution of pollution, followed by selection of monitoring station locations in such a way as to maximise the amount of relevant, representative information from the minimum number of stations. This overall approach is very much in accord with published accounts of the state-of-the-art.

Peak station densities within the networks of the Member States seldom exceed one per 2-5 km^2 and a resolution in the spatial distribution of concentrations of much better than 5 km is the exception rather than the rule, unless monitoring data is augmented by land use statistics or dispersion models."

The earlier study also considered interpretation of Article 6 concluding it was 'of crucial importance to the implementation of the Directive but open to a variety of interpretations', a view shared by the Commission. A central element of the present study has been a critical examination of member states position on Article 6 as well as a discussion of the issue.

Munn also listed several objectives for air quality monitoring in rural and remote locations:

- to study and to model regional and global climate,
- to document and to model the movements of pollutants across national and jurisdictional boundaries,
- to study dose-response relations, particularly with respect to acid rain and regional oxidant episodes,
- to complement studies of urban air quality with observations of rural air quality,
- to study and to model the regional and global biogeochemical cycling of trace substances.

The Directive, in addition to setting mandatory limit values for the protection of health, specifies guide values 'intended to serve as long-term precautions for health and the environment [and as] reference points for the establishment of specific schemes within zones determined by the Member States'. Furthermore Article 9 of the Directive requires that 'application of the measures pursuant to the Directive must not bring about a significant deterioration in the quality of the air where the levels of pollution by SO_2 and suspended particulates at the time of implementation ... is low in relation to the limit values ... '.

This report concentrates on monitoring networks relevant to the limit values of the Directive i.e. to those whose objectives include the protection of health and does not consider further non-urban networks or those linked to the guide values.

3. NETWORK DESIGN IN THE MEMBER STATES

This section presents a summary of factors which are relevant to network design as adopted in the member states.

These factors are as follows:

- Legislation and the division of responsibilities between central and local government for the monitoring and control of air pollution and the air quality standards incorporated in the legislation.
- Objectives and general strategy of the monitoring networks.
- How the design strategy addresses the requirements of the Directive.

- Sampling and analytical methods
- Station siting criteria
- Costs of monitoring

The details presented are taken from official statements and publications on pollution monitoring as well as from a questionnaire completed by the study group on network design in each of the member states.

The study group was unable to obtain any information on network design in Greece despite approaches being made to the Ministry of Physical Planning, Housing and Environment.

As far as is practicable the details on each member state under the different sub-headings of this section have been summarised in a set of tables which are presented at the start of each sub-section.

3.1 Adminfstrative Responsibilities and Relevant Legislation

Table 1 summarises the legal provisions within the different member states for the following:

- whether national air quality standards have been adopted,
- whether the limit values of the Directive have been incorporated in the national legislation,
- whether alert systems are provided for.

It has not been possible to summarise in tabular form the division of responsibilities for monitoring and control of pollution since this is highly variable from state to state and even within a given member state. Details are however presented within the text for each member state.

Belgium

The national government is responsible for air quality criteria and standards. Responsibility for the control of pollution falls within the competence of the Regional authorities while responsibility for monitoring pollution rests with the Institute for Hygiene and Epidemiology (IHE).

The air quality standards defined in the Belgian legislation are the limit and guide values given in EC Directive 80/779/EEC which was implemented by the Royal Decree of 16/3/83. Emissions from large power plant and refineries are limited by the Royal Decree of 8/8/75 which also requires continuous control of ambient SO_2 concentrations and imposes the use of fuel with low sulphur-content when the concentration level exceeds 500 $\mu g\ m^{-3}$.

In addition to the national standards the Recommendation M/78/16 of the Ministerial Committee of the Economic Union of the Benelux imposes since 1980 a mutual reporting of daily concentrations exceeding 400 $\mu g\ m^{-3}$ for SO_2 (and 150 $\mu g\ m^{-3}$ for NO_2).

Denmark

The national government is responsible for controlling and monitoring air pollution. Responsibility for the control of pollution rests with the Ministry of the Environment while the Riso National Laboratory is responsible for monitoring pollution.

The national air quality standards for SO_2 and suspended particles were defined in the governmental notice no. 119 of 24/3/83. These standards are:

POLLUTANT	ANNUAL MEAN	95-PERCENTILE
SO_2	140 $\mu g\ m^{-3}$*	400 $\mu g\ m^{-3}$**
Suspended Particles	150 $\mu g\ m^{-3}$***	300 $\mu g\ m^{-3}$***

* from daily or half-hourly averages
** from half-hourly averages
*** from daily averages

These standards are equivalent to the Annex IV limit values.

France

At the national level air pollution monitoring policy is the responsibility of the Ministry of the Environment (Direction of Pollution Prevention, Department of Atmospheric Pollution). On a local level it is mainly the interdepartmental industry and research departments under the responsibility of the 'Commissaires de la Republique' which are assigned the task of bringing policy into effect.

The Government's approach to implementation of EC Directive 80/779/EEC was set out in the Ministry of the Environment Circular of 28/7/82. The laws of 19 July 1976 and 2 August 1961 require industry to establish monitoring networks when an industrial plant emits notable quantities of pollutants and is geographically isolated or is the preponderant source of pollution in an area. When in an area pollution is both industrial and urban or predominantly urban the Ministry of the Environment and the 'Commissaires de la Republiques' can initiate a monitoring network with support from the local authority. Such networks are decentralised to the local or regional authority and finance shared between the state, local authority and major industrial plant in the area. For the management of the latter networks the Government promoted the creation of local associations (non-profit-making organisations) grouping representatives of the state and, if possible, representatives of local environmental protection associations. There are currently 18 of these local associations each operating a network and a total of 120 networks.

FR Germany

In the FR Germany air quality monitoring is based on the Federal Air Quality Protection Law (BIMSchG) issued in 1974. According to this Law, the Länder are required to monitor air quality in polluted areas (Belastungsgebiete). Two main tasks were formulated for the monitoring networks:

- measurement of the impact of pollutants at the locations of planned or existing industrial plant (plant-related measurements), and

- general monitoring of air quality in polluted regions.

National air quality standards are given in the First General Administrative Regulation on the BIMSchG, called Technical Instruction for Air Pollution Control (TA-Luft), issued in 1974 and amended in 1983. For sulphur dioxide and suspended particulates the relevant standards for continuous monitoring are as follows:

POLLUTANT	STATISTIC	LIMIT VALUE (mg m^{-3})
SO_2	Annual average of ½ hour values	0.140
SO_2	98-percentile of ½ hour values	0.400
Suspended part. (gravimetric measurement)	Annual average of 24-hour values	0.150
Suspended part. (gravimetric measurement)	95-percentile of 24-hour values	0.300

These standards are equivalent to the Annex IV limit values.

Ireland

Responsibility for pollution control and monitoring is divided between central Government and local authorities. Control of emissions from certain specified industries is administered centrally by the Chief Alkali Inspector in the Department of the Environment. Local authorities have responsibility for the control of pollution in particular of smoke emissions from other sources, except from domestic sources, and for monitoring air pollution.

The Alkali Etc. Works Regulations Act of 1906 requires 24 different types of works whose processes can give rise to noxious or offensive gases to be registered annually.

The Control of Atmospheric Pollution Regulations 1970 set limits on the length of time during which smoke of varying degrees of darkness may be emitted from premises other than private dwelling houses.

Italy

The Regional authorities are responsible for pollution control and monitoring within the requirements of national legislation.

The Decreto del Presidente del Consiglio dei Ministri of 28/3/83 (DPCM of 28/3/83) specifies national air quality standards which if necessary have to be complied with by limiting emissions from sources in the area. For suspended particulates and SO_2 these standards are as follows:

POLLUTANT	STATISTIC	STANDARD µg m^{-3}	 ppm
SO_2	Annual median of 24-hour averages	80	0.030
	Annual 98-percentile of 24-hour averages	250	0.095
Suspended Particulates	Annual average of 24-hour averages	150	-
	Annual 95-percentile of 24-hour averages	300	-

The standards for SO_2 are equivalent to the lower limit values of Annex I and those for suspended particulates are equivalent to the Annex IV limit values.

Luxembourg

The national government is responsible for controlling and monitoring air pollution. Monitoring is the responsibility of the Administration of the Environment and is carried out in conjunction with the Institute of Health and Epidemiology in Belgium.

The national legislation provides a continuous surveillance of air pollution by SO_2 and other pollutants. Concentrations of SO_2 are assessed in respect of the limit and guide values of the Directive as well as Benelux recommendation M/78/16 of 14/11/78 which specifies that the 24-hour average should not exceed 400 µg m^{-3} on more than seven days during one year.

Netherlands

The responsibility for the control and measurement of air pollution is given to the Regional authorities, the 'Provincies'. However the central government also performs quite extensive measurements in the framework of the National Air Pollution Monitoring Network to provide information on the levels of several air pollutants throughout the country. In order to control exceedances of the national standards most of the regional stations have been incorporated into the national network. This network is managed by the National Institute of Public Health and Environmental Hygiene (RIVM) at Bilthoven.

The Order in Council of June 1984 establishes national air quality standards for black smoke and SO_2 as follows (units = µg m^{-3}):

STATISTIC	BLACK SMOKE	SO_2
24-hour average:		
50-percentile	30	75
95-percentile	75	200
98-percentile	90	250

STATISTIC	BLACK SMOKE	SO_2
Maximum	150	500
Hourly average:		
Maximum	-	830

These standards are more stringent than the Annex I limit values.

United Kingdom

Central Government mainly through the Department of the Environment is responsible for exercising budgetary control, promoting the necessary legislation, advising authorities on its implementation and funding research. Local authorities (District Councils) and a number of other organisations carry out routine monitoring, the results of which are collated and assessed by Warren Spring Laboratory. Responsibility for the control of pollution from works with potentially large pollution impacts rests with the Industrial Air Pollution Inspectorate in England and Wales (and with the Industrial Pollution Inspectorate in Scotland). Local authorities have responsibility for the control of pollution from other sources including housing.

The Government's approach to implementation of EC Directive 80/779/EEC was set out in DoE Circular 11/81 of 27/3/81 and SDD Circular 40/81 of 21/12/81.

The principal statutes governing air pollution, in particular from suspended particulates and SO_2, are as follows:

(a) Alkali etc Works Regulation Act 1906, partly subsumed by the Health and Safety at Work Act 1974

These Acts cover emissions from certain chemical and industrial processes considered to be particularly dangerous or offensive or technically difficult to regulate. Over 60 processes, involving some 2200 works and 3700 operations are registrable under the Acts. Only a few processes have specific emission limits specified by the Acts, the others operate to the concept of Best Practicable Means. For some processes emission limits and operating procedures are laid down by the Inspectorates after discussions with industry and adherence to these limits is accepted by the Inspectorates as evidence that best practicable means are being observed.

(b) Clean Air Acts 1956 and 1968 and Clean Air (NI) Order 1981

These Acts extended earlier provisions relating to smoke nuisances and control certain (mainly industrial) emissions not within the scope of the above Acts. The 1956 Act also empowers local authorities to make smoke control orders prohibiting the emission of smoke from buildings including dwellings. There are now about 5800 smoke control orders in operation, covering over 800000 hectares, 9 million premises and two-thirds of urban properties.

(c) Control of Pollution Act 1974

This Act extends the powers of local authorities to carry out investigations into air pollution by enabling them to obtain information about emissions from premises other than private dwellings and gives the Secretary of State for the Environment the power to limit or reduce air pollution by making regulations to control the sulphur content of oil fuel for furnaces or engines.

3.2 Objectives and General Strategy for Monitoring Suspended Particulates and Sulphur Dioxide

Table 2 summarises the information taken into account and the tools used in the network design of the different member states:

- population density
- land use
- emission distribution
- emission inventories
- past monitoring results
- dispersion models
- statistical models

Belgium

A network of 200 stations monitoring black smoke and SO_2 - the Smoke-Sulphur Network - has been in operation since 1968. In addition, an 'automatic' network was set up in 1978 monitoring SO_2 and other pollutants at 72 stations and meteorological parameters at 18 stations. The networks were designed to provide information relevant to the protection of public health. The smoke-sulphur network sites were selected on the basis of population density and the presence of different pollution sources and are spread throughout Belgium. The automatic network is mainly centred on the 5 largest towns - Brussels, Antwerp, Liege, Gent and Charleroi - and their adjacent industrial areas but there are a number of stations in locations consistent with the Dutch grid network. These latter stations are mainly in rural areas along the border with Belgium's neighbours. Both networks are co-ordinated by the IHE in Brussels. The strategy is mainly addressed to monitoring SO_2 with emphasis on urban and industrial locations.

The distribution of stations in these two networks is shown in Fig. 1. (This figure and subsequent figures on the various networks provide little or no information on the extent of urbanisation or of industrial activity but do show the spatial distribution of the stations which is strongly linked to these two aspects.)

The locations for the monitoring stations are selected on the basis of population statistics, earlier results from the smoke-sulphur network, the structure of the Dutch national network, emission inventories and dispersion modelling studies.

In addition to the networks of fixed monitoring stations the IHE makes use of three mobile laboratories for the following purposes:

- the measurement of air quality in areas where there are no fixed stations or where the distance between stations is too large to allow extrapolation of results,

- the evaluation of the local pollution impact of a point source, for example to determine the locations where pollution can be expected to be highest under different meteorological conditions, and

- the evaluation of local complaints.

These laboratories contain the same sampling equipment as used in the fixed automatic network. A further two vans are equipped with correlation spectrometers which are used to produce pollution profiles in the vicinity of pollution sources or from the regional or international transport of pollution.

Denmark

A national network of 30 stations monitoring suspended particulates and SO_2 has been in operation since 1982. The network is designed to provide information relevant to the protection of public health, to establishing trends in air pollution and to help calibrate air quality models.

Site selection was supported by emission inventories for SO_2 and by simple dispersion calculations.

France

Most monitoring networks are located in industrial or urban areas. The objectives of the networks are:

- to provide information about pollution concentrations for those who would find it helpful (National and Local Authorities, media, environmental protection associations, industrialists, general public).
- to check conformity with air quality limit and guide values fixed by European directives, in particular EC Directive 80/779/EEC.
- to define the actions to be undertaken in order to assure permanent reduction of air pollution and determine priorities.
- to implement the actions of local and temporary reduction of air pollution in order to forecast special situations where there is a risk of acute pollution occurrence (Alarm Networks).
- to help the Government to formulate policies of human health protection and quality of human life.
- to provide data for scientific research.

In order to provide a summary of the pollution conditions within a town or to measure the spread of a pollutant from a particular factory, the following general principles for monitoring network design are applied:

- In deciding the number of sites required, account is taken of:

  the extent of the polluted area,
  the heterogeneity of the spatial distribution of pollution,
  the population density

- The sites chosen are, as far as possible, those where pollutant concentration are expected to be among the highest.

There are also some rural stations away from industry and towns to provide information on background concentrations of air pollution.

FR Germany

According to national legislation, monitoring networks are addressed to the following tasks:

- to protect human health and to ensure quality of life,
- to provide information on present conditions and trends in air pollution,
- to enable suitable action to reduce and control pollution concentrations,
- to enable action in the event of episodes (alert systems), and
- to provide data for scientific research.

The selection of fixed monitoring stations was performed on the basis of the spatial distribution of industrial and domestic emission sources as well as traffic in order to provide statistically representative results for each Belastungsgebiet. The preferred method for achieving this objective was the installation of regular grid-based networks. The locations selected on this basis form samples representative of the total risk area (Belastungsgebiet) under surveillance.

The most frequently realised interstation distance is about 4 km in accordance with the General Administrative Regulation. However networks of smaller interstation distances have also been realised, for example in Frankfurt, Kassel and Hanau.

Regular networks of 4 x 4 km mesh width have been realised in Hamburg (23 sites) and in Berlin (32 sites). In NRW, an almost regular network of 8 x 8 km mesh width was installed (42 sites) and is supplemented by random sampling of SO_2 in a 1 x 1 km grid. Random sampling is carried out as described in Annex IV of the Directive. However in contrast with the Directive, air quality statistics are calculated for areas of 1 x 1 km rather than for 4 x 4 km as required by the Directive. The strategy adopted in NRW is considered well-suited to supplement the automatic network in order to detect hot-spots on a 1 x 1 km scale.

The networks monitor SO_2 and suspended particulates with time-resolutions of ½ and 3 hours respectively. This permits the use of the networks in smog alert systems as required by the BIMSchG.

Ireland

In 1971 local authorities were advised by the Department of the Environment to install one sampling station for black smoke and SO_2 per 15000 inhabitants within urban areas. In 1982 the Minister for the Environment designated An Foras Forbartha as the National Air Pollution Data Base Centre.

40 monitoring stations are in operation within the seven largest towns, the largest number being in the city of Dublin which has 14 stations. The strategy

therefore concentrates on urban areas and considers black smoke and SO_2 together.

Warren Spring Laboratory has recently been engaged on an assessment of the network in Dublin and has made recommendations - based on the results of the existing network, an emission inventory and the results of a predictive air pollution modelling exercise - on the reorganisation of the network to provide a long-term baseline network and to provide information consistent with the requirements of the Directive.

Italy

Following enactment of the DPCM of 28/3/83 a study group has produced recommendations on general criteria for the control of air quality[6]. The pollutants to be monitored should be determined on the basis of emission inventories and dispersion models, the areas to be covered should also consider population density, and the number of stations to be used should consider spatial gradients in air pollution concentrations and topographic features. It is further recommended that the minimum number of stations for SO_2 or suspended particles should be 1 for a population between 100 and 500 thousand, 2 for less than 1 million and 5 for 1 to 4 million and that these numbers should be increased in highly industrialised areas and areas with high fuel consumption or marked irregularities in the land.

Apart from the Milan network which was visited as part of this study no further information was made available on the number of stations and their distribution within Italy.

Luxembourg

There are 12 stations monitoring black smoke and SO_2 and forming part of the smoke-sulphur network operated by the IHE in Brussels (see Fig. 1). The network is designed to provide information relevant to the protection of public health. In addition there are plans to install 5 continuous monitoring stations linked to the Belgian 'automatic' network and designed to provide information on pollution concentrations originating from domestic heating and local industry in the cities of Luxembourg and Esch-sur-Alzette and on pollution transport from sources in the surrounding countries.

Population density statistics and estimates of emissions were used in the selection of sites for the smoke-sulphur network.

Sites for the new 'automatic' network were determined as a function of the above statistics, results from the existing network (including a study by the IHE[7]) and modelling.

The locations of the smoke-sulphur network stations are changed when changes in pollution patterns emerge.

Netherlands

The strategy adopted requires that a fixed station network be designed such that 50- and 98-percentiles of daily average SO_2 concentration could be derived from the measurements for every 1 x 1 km^2 of the country with a standard error of 15% in the case that exceedance of limit values might be expected. (This strategy is presented in more detail in Section 4.)

There are 85 stations monitoring SO_2 and 20 monitoring black smoke in the reorganised national as well as 35 stations making meteorological measurements network (see Fig. 2).

Mobile laboratories are also operated by RIVM to provide measurements using similar automatic SO_2 analysers and correlation spectrometers to supplement those obtained from the fixed stations.

United Kingdom

A national network of stations monitoring both black smoke and SO_2 has been in operation since 1961. At its peak this network contained some 1200 stations in urban and non-urban locations throughout the UK. The objectives of the national network are:

- to enable central Government to carry out its administrative functions,
- to indicate where there is exposure to concentrations which might have harmful effects, and
- to provide data for further research into such effects.

These objectives provided the basis for the reorganisation of the network in 1982 into a set of networks each with distinct objectives:

- a long-term Basic Urban Network with 179 stations which provides baseline information on trends and on the range of concentrations to be found in different urban areas of the UK (see Fig. 3),
- a network of (currently) 393 stations to specifically address the requirements of the Directive (see Fig. 4).
- a rural network, and
- a network of 20 stations in support of an epidemiological study.

There are currently 572 stations involved in the new networks.

Monitoring stations for the new networks were selected on the basis of the historical data and information on land use - for example population, housing and industrial density - and degree of pollution control, in particular domestic smoke-control. Further details are presented in Section 4.

3.3 Monitoring Strategy with Respect to EC Directive 80/779/EEC

This sub-section presents a summary of how the aims and objectives of the monitoring networks in each of the member states have been modified and adapted to address the requirements of the Directive, in particular how each state has interpreted Article 6.

Belgium

An 'automatic' station was located near the centre of each large town and surrounded by a number of stations in the suburbs. These stations are considered representative of the residential and commercial areas of highest population and traffic density and hence cover those areas where pollution is likely to be greatest. In the industrial areas stations were located to measure the impact of local emission sources with winds in the prevailing wind directions (south-west and north-east). These stations are considered representative of industrial 'hot-spots'.

Denmark

The 30 fixed stations of the national network are all used to provide information relevant to the Directive. They are located in urban areas covering a range of commercial, industrial and residential positions but with emphasis on positions which are considered representative of areas of highest population density and where pollution from domestic heating and traffic are likely to be highest. Several of the stations are located at the kerbside. The Annex IV random sampling strategy for monitoring SO_2 is not used.

France

The Government's approach to the implementation of the limit values specified in the Directive is set out in the Ministry of the Environment Circular of 28 July 1982. Areas where there is a risk that the limit values could be exceeded are being identified and steps are to be taken in order to respect these values, for example:

- creation of special protection areas which impose a limitation on sulphur emissions. For instance, major combustion plant are obliged to burn low sulphur fuel.
- laying down of standards for emissions from industrial sources, and
- establishment of alarm networks.

There tends to be a high density of stations in the urban networks and there is always a station where pollution is thought to be greatest. Furthermore in industrial areas some stations are located at a critical distance and in the prevailing wind-directions from the main emission sources, based on an emission inventory.

FR Germany

Most of the approximately 250 automatic monitoring stations are installed in possible risk areas (Belastungsgebiete) as required by the BIMSchG. Air quality statistics are calculated from the measurements from these stations according to Annex I of the Directive for SO_2 and Annex IV for suspended particulates.

Black smoke is not monitored routinely in the FRG.

Since the amendment of the TA-Luft in 1983, the system of data treatment for SO_2 specified in Annex IV is no longer part of the national regulations and therefore is not generally applied. (The Annex IV scheme of random sampling and data treatment was applied in Berlin during 1984 as part of a study funded by the Commission.) According to the requirements of the BIMSchG, measures planned and applied in order to comply with the national air quality standards are presented in reports called 'Luftreinhalteplan', which are updated every 5 years if necessary.

Ireland

The requirement to install one sampling station per 15000 inhabitants in urban areas resulted in networks being established in all the major urban areas. The monitoring results are assessed annually in the DoE and the location of stations reviewed if and when changes in the pollution patterns occur. Exceedances of the limit values have been measured in the city of Dublin only. The WSL study of the Dublin network has been completed but had not been published at the time of writing. The report is known to have addressed the requirements of the Directive and to have made recommendations on the reorganisation of monitoring stations to improve definition of the area 'at risk' of exceeding the limit values of the Directive.

Italy

Monitoring is required to show compliance with the air quality standards contained in the Italian legislation (DPCM of 28/3/82). The air quality standards for SO_2 are the same as the more stringent Annex I limit values and for suspended particulates are the Annex IV limit values. It can therefore be argued that monitoring in compliance of the national standards will also show compliance with the Directive.

Luxembourg

The stations of the smoke-sulphur network are located in the areas with either the highest population densities (and hence highest non-industrial emissions) or in the vicinity of the main industrial emission sources and hence are considered to provide information relevant to the Directive.

Netherlands

The general strategy adopted is considered compatible with the requirements of the Directive. Stations are located in sufficient numbers to arrive at the local density required by the design strategy with priority to 1 x 1 km^2 squares where the highest percentiles are expected.

United Kingdom

The EC Directive Survey network initially selected as detailed in Section 4 involves 393 stations in locations within and around areas considered to be 'at risk' of approaching or exceeding the limit values as required by Article 3(1) of the Directive. Of these 393 stations, 161 have been located in the 'derogation' zones notified to the Commission under Article 3(2) of the Directive. In general terms these stations are located at sites where pollution is thought to be greatest. However more emphasis has been put on locating stations at sites considered representative of the surrounding area to within ½-1 kilometre radius i.e. representative of local conditions. Stations are visited and results reviewed regularly by WSL staff and if necessary stations are relocated to be more representative of the surrounding area. Stations will be closed from 1986 onwards in areas where there is a downward trend and recent results are well within the limit values. New stations continue to be installed in areas where there emerges the likelihood that limit values could be approached or exceeded.

3.4 Monitoring Methods

Table 3 presents a summary of the number and type of monitoring equipment operating in each of the member states and producing results relevant to the Directive. This table updates the information provided in 'Inventory of current measuring techniques for SO_2, black smoke and suspended particulates' in 1982[8].

Belgium

The 200 samplers of the smoke-sulphur network take bulk 24-hour samples which are collected weekly and analysed in the laboratory. The detection methods are:

SO_2:	Net acidity method by absorption in H_2O_2 solution and acidimetric titration of the sulphuric acid formed.
Black Smoke:	Collection on Whatman No. 1 filter and reflectometric measurement of the black stain.

The 72 SO_2 samplers in the 'automatic' network measure SO_2 continuously using flame-photometric detectors (FPD). Measurements are transmitted by telemetry from the station every minute to one of the five Regional Data Reducing Centres (located in the largest towns) where half-hour averages are calculated. These data are then sent by telemetry to the National Data Processing Centres at the IHE and the Royal Meteorological Institute in Brussels for further data-processing.

Denmark

At each of the 30 stations, bulk 24-hour samples are collected using potassium hydroxide (KOH) impregnated filters for SO_2 determination and modified LIB-samplers for the gravimetric determination of suspended particulates. In addition 4 continuous SO_2 samplers have been deployed at 4 of the bulk sampling stations, 3 samplers using flame-photometric detection (FPD) and 1 using coulometry.

France

Within the 120 networks, there are about 600 samplers measuring SO_2 continuously by the strong acidity method and providing 15-minute averages, about 300 bulk 24-hour black smoke samplers, about 100 samplers measuring SO_2 continuously using FPD or UV-Fluorescence (UVF) analysers and a limited number of samplers measuring suspended particulates using beta-absorption.

FR Germany

Continuous monitoring of SO_2 is performed at about 250 stations. The methods used are as follows:

- conductivity,
- UV fluorescence, and
- flame-photometry.

The monitoring of suspended particulates is performed at about 180 stations by radiometric methods. Gravimetric methods are used routinely at about 60 stations. To a large extent, the same locations are used for monitoring suspended particulates and SO_2.

Ireland

Each of the 40 monitoring stations collects bulk 24-hour samples using the methods of British Standard 1747 but reporting black smoke concentrations in gravimetric units as described by the OECD as required by the Directive. The detection methods are:

SO_2:	Net acidity method by absorption in H_2O_2 solution, and acidimetric titration of the sulphuric acid formed,
Black Smoke:	Collection on Whatman No. 1 filter and reflectometric measurement of the black stain.

Italy

Details were not made available for all of the networks. In the Province of Milan network there are 48 stations monitoring SO_2 using automatic UVF or coulometric samplers and four stations monitoring suspended particulates using beta-absorption.

Luxembourg

The 12 samplers in the smoke-sulphur network take 24-hour samples for analysis in the laboratory. The detection methods are:

SO_2:	Net acidity method by absorption in H_2O_2 solution and acidimetric titration of the sulphuric acid formed.
Black Smoke:	Collection on What No. 1 filter and reflectometric measurement of the black stain.

Netherlands

The National Network since reorganisation has 85 stations measuring SO_2 continuously using the UV-Fluorescence method. Data are transferred daily by telemetry to the computer centre at RIVM Bilthoven. There are also 20 stations where bulk 24-hour samples are collected on Whatman No. 1 filters for black smoke determination by reflectometry.

United Kingdom

Each of the 572 stations collects bulk 24-hour samples for analysis in the local laboratory using the methods of British Standard 1747, viz:

SO_2:	Net acidity method by absorption in H_2O_2 solution and acidimetric titration of the sulphuric acid formed,
Black Smoke:	Collection on Whatman No. 1 filter and reflectometric measurement of the black stain.

3.5 Location of Stations

This sub-section presents the criteria considered when siting monitoring stations within the networks.

Table 4 summarises the criteria cited by each of the member states relevant to the actual location of sampling stations.

Belgium

The samplers of the smoke-sulphur network are located within existing buildings usually public buildings, for example schools, town halls, universities etc. Each sampler has a downward-facing inlet-funnel located about 1 metre from the face of the building and at a minimum height of 2 metres above the ground.

The samplers of the automatic network are located in purpose-built cabins. The sampling inlets are above the roofs of the cabins about 3 metres above ground level. The immediate surroundings of the cabins should be free from obstacles such as large buildings, trees or local emission sources.

Denmark

The sampling equipment is located in purpose-built enclosures with the sampling-inlet at a height of 2.5 metres above the ground. There should be no obstacles within 4 metres of each inlet.

France

Stations are mainly located in purpose-built enclosures or in existing buildings for example schools, town halls and universities. The immediate surroundings should be free from obstacles such as large buildings, towers, trees or local sources.

FR Germany

In most of the Lander the fixed stations use purpose-built multicomponent cabins. Berlin is an exception, using existing buildings for example schools and firestations for most of its sampling sites.

The Unified Federal Practice for the Control of Emissions and Air Quality issued in 1983 requires the following points to be observed when selecting sampling locations:

- the network should form a regular grid with the distances between neighbouring stations multiples of 1 km.
- the distance of a station from nearby obstacles influencing air streaming should be at least twice the height of the obstacle.
- the distance from nearby sources which could influence the samplers should be at least 20 metres.
- up to a distance of 10 metres around the station, air streaming should not be influenced by any obstacle for example trees or buildings.
- the inlet height should be 3-3.5 metres.

Ireland

The sampling stations are located within existing buildings for example schools, offices, local works depots where they are secure but accessible to the personnel who maintain them.

The sampling inlet funnel is required to be at least one metre from the face of the building and at least 2.5 metres above the ground.

The sampling location should not be screened by obstacles for example nearby trees, hedges or other buildings nor too close to single emission sources for example boiler chimneys.

Italy

The Italian study group recommends[6] that stations should be located at least 2 metres from any building or vegetation and further if these are potential absorbers of the pollutants. The stations should not be confined on 2 or more sides or located in other sheltered positions. The sampling inlet should be 2-4 metres above the ground and at least 2 metres from the nearest vertical or horizontal surface.

The samplers in the Milan network were located in purpose-built cabins with the sampler inlets about 4 metres above the ground.

Luxembourg

The samplers of the smoke-sulphur network are located in existing buildings usually public ones with the sampling inlet at 1.5-2.5 metres above the ground. The immediate surroundings should be free from obstacles such as large buildings, trees or emission sources.

Netherlands

Continuous samplers are located in purpose-built enclosures with the inlet 3.8 metres above the ground. The immediate surroundings should be free from obstacles and local emission sources.

United Kingdom

The samplers are located in existing buildings usually public ones for example schools, clinics, libraries, offices. The sampler inlet funnel must be at least one metre from the face of the building and at least 2.5 (and preferably not more than 10) metres above the ground. The stations should not be screened by trees, fences, nearby buildings or other structures. The locations should not be disproportionately affected by single sources of pollution, for example individual chimneys, flues, bonfires or road traffic.

3.6 Cost of Monitoring

The total cost of monitoring SO_2 and suspended particulates and showing compliance with the limit values of the Directive is made up from a number of components:

- capital cost of sampling equipment, computing facilities and telemetry system (if used),

- cost of maintaining and operating equipment,
- cost of visiting stations to collect samples,
- cost of analysing samples,
- cost of data processing, and
- cost of data analysis and presentation.
- cost of supplementary activities, for example dispersion modelling and the provision of emission inventories.

These costs are spread over the various organisations operating the stations, coordinating the results and interpreting the results and their implications. Since stations relevant to the Directive are in all cases subsets of the complete network(s) in the Member States, the cost of showing compliance with the Directive is a fraction of the total cost dependent on the extent of the areas 'at risk' of exceeding the limit values and on the type of equipment deployed. It has proved a difficult task trying to quantify all aspects of the costs involved and to agree their completeness and accuracy. However first estimates have been made by the study group for the annual cost of operating SO_2/suspended particulate monitoring networks and are discussed in Section 9.

4. REORGANISATION OF MONITORING NETWORKS IN FRANCE, NETHERLANDS AND UNITED KINGDOM

This section presents a summary of the methods used to reorganise the networks monitoring suspended particulates and SO_2 in France, Netherlands and the United Kingdom in recent years. General information on the methods used for redesigning networks as used in France and the Netherlands can be found in reference 5.

4.1 France

Introduction

There are usually two stages to improving an air pollution monitoring network:

- simplification of the initial network, and
- setting up of new stations.

Statistical analyses carried out on the data obtained from the initial network make it possible to improve the network:

- by the exploitation of redundancies among the existing stations, and
- by finding areas in which stations must be set up.

These studies can also lead to the definition of general conditions in pollution, meteorology and emissions which enable the forecast of the extent of a pollution episode sufficiently in advance for the possibility of an intervention. If such an objective is obtained the modified network can function as an alarm network (see Section 5).

Summary of the various statistical studies

A. Firstly an individual survey of each station is undertaken:

- analysis of the time series
- study of the influence of meteorological parameters.

This allows the quantification of the characteristics of every station, so as not to neglect subsequently those stations which have a particular feature in certain meteorological situations, especially those where the highest peaks in pollution are measured.

B. The study of the redundancy of the information collected from the various stations of the network is then an important stage in as much as it permits simplification of the network. Various methods can be used by the statistician:

- automatic classifying techniques for discovering groups of stations which are alike on the basis of some chosen criteria,

- multiple regression analysis of each station in relation to the others; the subgroup which appears on the whole to provide the best set of predicting elements is then retained,

- within the framework of principal component analysis, the usual method for pollution data analysis in France[9] makes it possible to clearly address this problem and to define an efficient algorithm for the selection of stations within a network[10].

The principal component analysis method can be described simply as follows:

Consider a matrix X with n rows and p columns with each row representing the measurements made at time i at the p stations and each column providing all the observations obtained during the period of the study at one station. The method is designed to extract n columns from X i.e. n stations of the network which allow construction of a matrix Y_r and a measure B_r in such a way that the statistical studies (X,I,D) and (Y_r,B_r,D) are as similar as possible as measured by the vector coefficient R introduced by Y Escoufier. (I = matrix identify, D = I/n).

In practice this means that the graphic presentations of the individual tests (rows of the matrices X and Y_r) obtained during the principal component analysis (PCA) of (X,I,D) and the PCA of (Y_r,B_r,D) are as close as possible. When the coefficient R is close to 1, the subset of stations retained in matrix Y permits a global description of a pollution phenomenon which is very close to the description obtained using all the stations of the original network but at less expense.

In most applications of this method n and p are too large to allow exhaustive calculations to be carried out. A progressive algorithm has been developed in which the variables are introduced step by step. Moreover it is possible to impose the choice of certain variables. This method has been adopted for the reorganisations of networks monitoring SO_2 in the Paris area[11,12].

C. Setting up new stations

Methods of interpolation of correlations and kriging

The acquisition of data for specific locations to produce the matrix X is not an aim in itself, rather the aim is to extend the partial knowledge of the phenomenon to the whole of the field studied. This leads to solving the following problems:

- estimation of values; knowing the values at all stations measured at time i, try and reconstruct the phenomenon at a location where no measurements were made.
- estimation of error when estimating a value; having the means to quantify the uncertainty in the estimate for the location where no measurement was made permits improvement in the information provided by the network by installing new stations in the areas where the uncertainty in the estimates are highest.

Methodology

Among the techniques of estimation the kriging method developed by G Matheson appears to be one that is well adapted to the resolution of the above problems.

In the case of data produced by a network there are several realisations of the probability function describing the level of pollution i.e. the various measurements carried out in the course of time. The correlation matrix and the vector of averages provide a good estimation of the correlation function and of the variation in the averages at the points where stations are located. Interpolation of the correlations and of the averages to a point where no measurements have been made is possible with the help of cubic spline functions, without recourse to the hypothesis of stationarity. The variance of the estimation does not depend on the estimated value but only on the variance at the point of estimation and on the covariance vector of this point with the existing stations.

It is therefore possible to establish an isovariance map showing the error produced at each point without having to calculate the values of the studied phenomenon at these points. From a practical point of view the kriging variance has been estimated at 600 points on a regular grid[12]. This technique was carried out on data from the Porcheville area within the Paris region and enabled detection of two areas where the setting up of stations appeared judicious. The further collection of data over a sufficiently long period will provide the opportunity to judge the improvement to the results brought about by the introduction of these new stations.

4.2 Netherlands

In order to address the requirements of the directive an objective and straightforward measurement strategy for SO_2 had to be developed within Dutch legislation on air pollution. For the following reasons this strategy was primarily directed to the design of a fixed station network:

- the strategy should be compatible with the Directive which prescribed fixed station monitoring,

- 70 per cent of SO_2 concentrations in the Netherlands result from foreign sources giving relatively high spatial correlations between measured concentrations and resulting percentiles,

- a dense network already existed in the Netherlands; the design procedure could therefore be applied to this network and produce an optimised, legislation-based system. The original network of about 200 stations is shown in Fig. 5 and the revised network in Fig. 2.

The fixed station network is required[13] to be designed such that 50- and 98-percentiles of daily average SO_2 concentrations could be derived from the measurement for every 1 x 1 km^2 of the country with a standard error of 15% in the case that exceedance of limit values might be expected. Since the spatial gradients in the 98-percentiles are larger than in the 50-percentiles and moreover exceedances of the national threshold level of 250 $\mu g/m^3$ occurred incidently in the past, in contrast with the 50-percentile of 75 $\mu g/m^3$ which was never exceeded over a 10 year period, network design is based on the spatial statistical structure of the 98-percentile values.

The following practical procedure for the design of the network was proposed:

1. For a chosen sub-area an average structure function $b^m(x)$ based on measured values over a few years period at 4 to 12 existing stations is computed using:

$$b^m_{ij} = \tfrac{1}{2}\,\overline{(\ln (C_{it} + H_{it}) - \ln (C_{jt} + H_{jt}))^2}$$

where C_{it} and C_{jt} are measured values of station i and j and H are corresponding errors.

2. By means of a weighted regression analysis the model function

$$b^m (x) = h^2 + (b_\infty - h^2) (1 - \exp (-x/x_s))$$

is adopted to the measurements resulting in estimates for

h , the local average relative error
b_∞, the value of $b^m(x)$ at large mutual interstation distance x, and
x_s , a spatial scale, which defines the area over which the variability of monitoring results is interelated.

For the Rijnmond industrial area, the field variance $\surd b_\infty$ was found to be about 45%; the local error about 10% and the correlation distance x_s about 12.5 km.

3. Since the interpolated value is calculated as a linear combination of distance weighted station values the relative interpolation error F can be established for different network interstation distance x_0 according to:

$$\overline{F^2} = 2 \sum_{i=1}^{N} P_{io}\, b_{io} - \sum_{i=1}^{N} \sum_{j=1}^{N} P_{io}\, P_{jo}\, b_{ij} + \overline{h^2} \sum_{i=1}^{N} P^2_{io}$$

In this expression P_{io} is the distance dependent weighting coefficient (scaled with x_s) for station i and b_{ij} is derived from the model function $b(x) = b^m(x) - h^2$.

4. From the numerical relation between F and x_0 the value of x_0 is determined for which F = 15%, the initially chosen maximum allowable interpolation error.

5. For all sub-areas (for example defined by the interspace of 4 existing stations) the required x_0-values are determined and compiled on a map, for example see Fig. 6.

The station configuration of the revised network as given in Fig. 2 is designed according to the density requirement as given in Fig. 6. It shows an interstation distance of 40 km in the northern part of the country and 28 km in the southern part. Stations are added to this regular grid, to cover hot spots, in the southern part of the province Zeeland and the northern part of the province Limburg (resulting interstation distance 16 km) as well as the Rotterdam-Rijnmond industrial area (interstation distance down to 4 km). In this last area additional measurements are performed by the Rijnmond Authority (DCMR) using 15 stations complementary to the National Network.

Isolated sources which might cause an important increase in the SO_2 concentration levels are not always detected by the network. The control of these emitters is defined in art. 19 of the Air Pollution Act where the central government is given the possibility to indicate that for certain categories of emitters a licence is obligatory. The licence is given only when the increase to the already existing SO_2 concentrations remains within the national threshold values.

This contribution is calculated with the aid of a Gaussian type dispersion model including a module for the estimation of resulting percentile values. Since the Dutch threshold values are considerably lower than the threshold values as given in the Directive exceedance of these threshold is not likely to occur. Experimental control of the calculated SO_2 concentration in the vicinity of the emitter can be prescribed (by the local authority) to the emitter in the form of emission as well as air quality measurements.

4.3 United Kingdom

The National Survey of Smoke and Sulphur Dioxide was set up in 1961 to provide comparable data of a consistent minimum quality for a wide range of urban/industrial areas found in the UK. The monitoring sites in the Survey were equipped and operated to a British Standard primarily by local authorities but also by other organisations and individual industrial companies. Warren Spring Laboratory coordinated the Survey processing the data, publishing and interpreting the results on behalf of central Government. Initially there were some 500 sites and the number increased to about 1200 by 1966 and remained relatively stable at this number for the duration of the Survey (see Fig. 7). Most of the stations were located in urban areas but up to 150 were located in rural communities and open country areas.

The Survey was able to chart very substantial reductions in urban smoke and SO_2 concentrations as demonstrated in Figs 8 and 9; average smoke concentrations fell by some 80% and SO_2 by about 60% over a 20-year period. In the light of these and other related changes - extensive reductions in domestic coal consumption, higher industrial chimneys, the advent of natural gas, it was agreed that the relevance and scope of the Survey needed to be reviewed.

Atmospheric dispersion modelling techniques were developed and improved during the 1970's making it possible to predict acceptable estimates of pollutant concentrations in areas where measurements are not made, provided adequate fuel consumption or pollutant emission data are available. This in turn means that the number of monitoring stations can be reduced without an unacceptable loss in information. With the introduction of the Directive limit values for smoke and SO_2 decisions have to be made concerning what sources to control and by how much in order to achieve the require air quality. This in turn requires data on emissions and again the means to predict the effect on air quality of any changes in emissions.

With these developments in view various options[14] were considered in order to identify the best technical yet cost-effective approach to air quality surveillance. The principal objectives of measurements of smoke and SO_2 on a national basis were defined. (These are listed in Section 3.2.) The fundamental underlying concept was that surveys or monitoring networks need to be designed with specific objectives in view, each of which may be adapted or terminated as the objectives demand. To meet the new objectives a long term network, the Basic Urban Network, was set up supplemented by ad hoc surveys, in the first instance an EC Directive Survey with a network of stations in areas 'at risk' of exceeding the limit values of the Directive and a small network of stations in support of an epidemiological study.

Monitoring stations for the new networks were selected on the basis of the historical data and information on land use - for example population, housing and industrial density - and degree of pollution control, in particular domestic smoke-control.

The Basic Urban Network (see Fig. 3) includes sites in all the conurbations, most of the larger towns and a sample of the smaller ones with emphasis on the selection of sites in commercial town centre locations (potential SO_2 problem areas) and in the denser residential areas (highest smoke concentrations and hence greatest potential health risk). When consistent with geographical coverage sites with existing reliable long-term data were preferred since continuity of data for extended periods of time is of considerable value in establishing trends, assessing the influence of changing energy-consumption patterns and in epidemiological studies.

In selecting existing stations and new sites for inclusion in the so-called EC Directive Survey (see Fig. 4) the historical data and land-use information was collated to manually produce contour maps of the UK to delineate areas 'at risk' of approaching or exceeding the Directive limit values. Warren Spring Laboratory then worked with the local authorities operating the sampling stations to ensure that stations were installed within these areas in sufficient numbers and at locations capable of being representative of the areas 'at risk'.

5. ALERT SYSTEMS

It was noted earlier that several member states have enacted legislation which requires or allows pollution alert systems to be set up. Although not required by the Directive, alert systems are often integral parts of the monitoring networks used to assess compliance with the Directive. It is therefore of interest to consider the various alert systems in operation.

Alert systems (also known as alarm networks) are introduced to enable action to be taken during pollution episodes. Episodes are periods lasting between a few hours and several days when pollution concentrations are significantly above normal and potentially a risk to health and the meteorological conditions are unfavourable for dispersion. The alert systems vary from one state to the next but all make use of the pollution monitoring networks to some extent to provide data. Some of the networks were designed with the alert system as an objective, others make use of the existing networks to provide the data required. Different systems use meteorological or pollution measurements (or both) obtained from the network of monitoring stations to produce the forecast of an episode and to chart its progress. The action taken is dependent on the severity of the episode as indicated by the pollution measurements and can range from advice of the episode's occurrence being broadcast through selective reduction in emissions to complete prohibition of fuel-burning in stationary or mobile sources (traffic). In most cases selective action targetted at reduction in the emission from a small number of large sources is the main course of action.

Since episodes can develop rapidly and action needs to be taken promptly to be effective, alert systems require continuous monitoring samplers linked to a central computer. The computer is programmed to make the calculations which are the basis of the forecast from the pollution or meteorological measurements it has collected. The alert can be based on fixed threshold values for example 24-hour average SO_2 exceeds 500 $\mu g\ m^{-3}$ or a temperature inversion of more than 2.5 degrees per 100 metres or a variable threshold for example hourly average SO_2 concentration exceeds the 95-percentile of hourly values obtained over the past five years.

The alert systems established in Belgium, France, FR Germany, Italy, the Netherlands and the United Kingdom are described in the following paragraphs.

Belgium

The possible occurrence of a pollution episode is forecast by the Royal Meteorologic Institute by means of an air pollution potential index based on wind speed, vertical stability and temperature measured or derived from measurements at meteorological stations. The pollution indices are communicated systematically to the NDPC where in the event of an unfavourable forecast surveillance is intensified and pollution measurements are carefully scrutinised.

Whenever the SO_2 concentration averaged over 24 hours exceeds the threshold value of 500 $\mu g\ m^{-3}$ and the weather situation is such that no improvement is foreseen in the subsequent 12 hours the alarm (alert) procedure is started. This consists primarily of informing regional and national authorities as well as operators of the most significant sources of emission, for example power plant and oil refineries. As required by the Royal Degree of

8/8/75 these operators are asked by the regional authorities to switch to fuel of a lower sulphur content. Possible health risks are communicated to the public. The progress of the episode is followed hour by hour and further reductions in emissions involving other plant, traffic etc could be considered. However there are no official regulations prescribing such action as a function of measured pollution concentrations.

France

There are nine urban or industrial areas provided with alarm networks (alert systems).

There are four stages to establishing an alarm network:

- setting up a monitoring network including its central computer,
- operating the network to provide information on the spatial and temporal distribution in pollution and dispersion conditions in order to detect and quantify conditions unfavourable for the dispersion of pollution,
- elaborating a procedure for calculating the risk of a pollution episode and using this procedure to forecast the risk at regular intervals, for example hourly, and
- establishing a statutory procedure which specifies the conditions in which an alert is given, the authority which will issue it, the plants (emission sources) covered by the system and the regulations these plant must comply with during the period of the alert.

The REMAPPA network in Rouen is used as an alarm network under the provisions of the prefectoral (local authority) bill of 20/12/1974.

In Rouen, the alarm is given when the following two conditions are present simultaneously:

- wind speed less than 0.5 m s^{-1} on average for 6 hours, and
- temperature inversion greater than 2.5 degrees centigrade per 100 metres.

The prefectoral bill specifies how the measurement and calculation of the parameters specified are to be carried out as well as the calculation of a meteorological index and of estimated values of pollution concentration. In 1982 18 alarms were given which lasted a total of 120 hours, the corresponding figures in 1983 were 17 and 148 hours. Figure 10 summarises the progress of the alarm episode which occurred on 18 January 1980.

FR Germany

The national legislation BIMSchG requires alert systems (smog-alarm plans) to be implemented in certain areas. The first administrative Smog Alarm Plan used in NRW was issued in 1974. In 1985 the alarm levels were reduced to the following values:

PARAMETER	ALARM LEVEL ($mg\ m^{-3}$)		
	I	II	III
SO_2 (3 hours)	0.60	1.20	1.80
NO_2 (3 hours)	0.60	1.00	1.40
CO (3 hours)	30	45	60
SO_2 (24 hour) + 2xTSP (24 hour)	1.1	1.4	1.7

If one of these levels is exceeded at a minimum of 2 stations in a Smog Region (Smoggebiet) and if weather conditions are stable i.e. atmospheric dispersion is restricted and expected to remain so for the next 24 hours, the corresponding alarm level is announced by the administration. The following actions are taken when the alarm level is announced:

ALARM LEVEL	ACTIONS (ADDITIVE)
I	Warnings over radio and TV
II	Temporary prohibition of traffic in city-centres and switch to low-sulphur fuel in power plant
III	Production reduced in selected factories

There are slight differences in the smog alarm regulations adopted in the other Lander.

Italy

Complete details of alert systems were not provided but it was indicated that pollution measurements made around the AEM power plant in Cassano could be used to declare an alarm requiring fuel switching by the power plant.

Netherlands

The legislative basis of alarm procedures and the measures to be taken are found in Chapter V articles 42-58 of the Air Pollution Act of 1970. These procedures cover accidents and pollution episodes.

Information on accidents which cause pollution concentrations with serious effects on human health are to be reported to the local mayor who informs the provincial governor. The governor is required to prescribe every appropriate measure necessary in his view to reduce the pollution concentrations, this can include closure of the works responsible.

General measures can be prescribed by the provincial governor for use during particular meteorological situations (episodes). These include a total prohibition of the emission of air pollutants and a prohibition of the use of certain fuels. The Minister is given the opportunity to define threshold values above which it is assumed that serious health effects might occur. The relevant threshold values for accidents and episodes are the maximum allowable 24- and 1-hour values, viz

for SO_2	500 $\mu g\ m^{-3}$ 24-hour average
	830 $\mu g\ m^{-3}$ 1-hour average and

for black smoke 150 $\mu g\ m^{-3}$ 24-hour average.

The following warnings are issued when SO_2 concentrations measured in the National Air Pollution Network exceed the levels quoted:

PERIOD	LIMIT VALUE ($\mu g\ m^{-3}$)	WARNING TO
24-hours	400	Ministry plus IHE Brussels
"	500	Ministry
1-hour	500	Regional Inspector and Provincial Governor
"	830	As for 500 $\mu g\ m^{-3}$
"	200 (at a power plant)	Power company head office

There is no similar system for black smoke.

A separate alarm system is in operation in the Rijnmond area based on a meteorological index of the dispersion power of the atmosphere. Four alert levels have been coded:

Level 1: the meteorological situation is such that 'nuisance' may be expected in the forthcoming morning/afternoon/evening/night.

Level 2: factories are invited to cease emissions from emission points less than 40 metres above ground.

Level 3: factories are requested to reduce all emissions.

Level 4: Emission of pollutants or use of certain fuels is prohibited.

Level 5: End of all warnings.

United Kingdom

There is an alert system in operation for the London area. The London Weather Centre (LWC) operated by the Meteorological Office notifies the Greater London Council (GLC) if adverse meteorological conditions likely to cause high concentrations of SO_2 in the London area are forecast to arise. The forecast is usually made 2 or 3 days in advance with an estimate of the expected duration of the conditions. The GLC then provides the LWC with the 24-hour average concentration obtained from the continuous monitoring sampler located at its offices and the LWC provides a revised prediction of the expected duration of the event and the likely SO_2 concentrations. The forecasts are revised daily until the event is passed.

If measured 24-hour average SO_2 concentration exceeds 500 $\mu g\ m^{-3}$ at the GLC site, the extent of the episode is checked from results from other stations, WSL is notified and intensifies monitoring at its central London laboratory and the Department of the Environment (DoE) is contacted. The DoE warns Ministers and other Government Departments as thought necessary and the GLC provides DoE with up-to-date information at least daily. In a severe or prolonged episode consideration will be given to action necessary, for example the need to inform the media and the public and any action required to reduce concentrations. The procedure terminates when 24-hour average concentrations of 250 $\mu g\ m^{-3}$ or less are recorded and the meteorological conditions are such that concentrations are not forecast to rise above 500 $\mu g\ m^{-3}$ in the immediate future.

6. VISITS TO NETWORKS BY THE STUDY GROUP

The study group visited examples of monitoring networks in six of the member states - Belgium, France, FR Germany, Italy, Netherlands and United Kingdom.

Belgium

The study group visited the Institute of Hygiene and Epidemiology in Brussels, which co-ordinates air pollution monitoring in Belgium, and the 'automatic' network in the Gent area. Gent is one of the most industrial areas of the country and experiences some of the highest SO_2 concentrations in Belgium. The limit values of the Directive have been approached and exceeded in this area in recent years. The average population density in the Gent conurbation is 1500 inhabitants/km^2 with 250-600 inhabitants/km^2 in the surrounding towns containing monitoring stations. The national networks are shown in Fig. 1 and the stations in the Gent area in Fig. 11.

The 'automatic' network around Gent is part of the national network and consists of 10 Regional (industrial/urban) and 5 National (countrywide) pollution monitoring stations as well as 4 meteorological stations. Each of the 15 pollution stations monitors SO_2 and 6 of the stations monitor a selection of the following pollutants: NO, NO_2, hydrocarbons, O_3 and dust. SO_2 is monitored using flame-photometric detection (FPD).

Each of the meteorological and pollution stations (or Remote Terminal Units, RTU's) in the Gent area is linked by telemetry to the Regional Data Reducing Centre (RDRC) located near the centre of Gent. 2-way dialogue is possible between the RDRC and an RTU for example a calibration cycle can be initiated at an RTU by command from the RDRC and the RTU transmits to the RDRC a log of all events which have occurred (calibration cycle commenced, maintenance engineer arrived, power failure on 1 instrument etc).

The joint pollution/meteorological station R711/M703 to the south of Gent, the stations R731, R742/M701, R750 and R740 in the industrial area to the north as well as the RDRC which includes met station M701 were inspected during the visit. The stations were all well located with respect to the spatial distribution of emission sources across the Gent network area. In general the stations were located at sufficient distance from large obstacles and significant emission sources although it was noted that the station R711/M703 had become slightly screened by nearby trees.

France

The visit to France included discussion of monitoring carried out by the company Elf Aquitaine and a visit to the network in Rouen.

The study group met M Camps of the Direction of the Environment of Elf Aquitaine. He indicated that Elf carry out continuous monitoring mainly for SO_2 but also for other gaseous pollutants around a number of their petrochemical complexes, being required to do so by the local authority. Elf usually locate 2-5 stations around an individual plant and up to 30 within a complex. The example of Elf's gas refinery at Lacq was cited. Originally there were 20 SO_2 samplers located around the refinery in an area of about 64 km^2 but this had been reduced to 12 on the basis of a modelling exercise which also took emission estimates and population density into account. The modelling exercise included dispersion modelling and principal component analysis. Elf are responsible for calibration and quality control of their networks, for processing data from them and for notifying the local authority of the results found.

The visit to Rouen was to M Michelier, Engineer in charge of REMAPPA (Reseau d'Etude, de Mesure et d'Alarme pour la Prevention de Pollution Atmospherique dans l'agglomeration rouennaise), the oldest of the 18 non-profit making associations charged with monitoring air pollution in France. REMAPPA operates a locally organised and designed network which was set up in 1973 and is part of the Lower Seine Network, the whole network covering 3500 km^2 and covering Le Havre and Rouen as well as the area in between these two towns. The Rouen/Le Havre area is heavily industrialised and experiences some of the highest SO_2 concentrations in France (the limit values of the Directive have been exceeded in this area in recent years) and the 2 towns have been notified as derogation zones under Article 3 of the Directive.

Rouen with a population of about 0.5 million covers an area of about 240 km^2 on a large loop in the Seine about 90 km from Le Havre. Industry flanks the banks of the river and hills tend to enclose the town on all sides. The REMAPPA network (shown in Fig. 12) contains 21 stations; SO_2 is monitored continuously using the strong acidity method at 20 of the stations and by UV-fluorescence at 2, suspended particulates are monitored every 24-hours using the black smoke method at 6 stations and gravimetrically every 3 hours by beta-absorption at 4 stations. A range of other pollutants including NO_x, CO, O_3, F and hydrocarbons are monitored at selected stations. Meteorological parameters - temperature, humidity, wind speed and direction - are monitored at 4 of the stations.

All the stations are linked by telemetry to the central computer in the REMAPPA offices. This computer logs the data received from the monitoring stations but cannot interrogate them unlike the systems in later networks. The REMAPPA computer is also linked to the computer at Le Havre.

In addition to the monitoring station at the REMAPPA offices where SO_2, strong acidity, suspended particulates, fluoride, hydrocarbons, ozone, temperature, humidity, wind speed and direction are monitored, 4 other stations located either within public buildings or consisting of weather-proof cabinets (enclosures) were visited. Each of these stations measured SO_2 using the strong acidity method while 2 of the stations also monitored black smoke. Each of the stations was well located with respect to the spatial distribution of emission sources in the area. The stations were located at sufficient distance from large obstacles and significant emission sources.

FR Germany

The study group visited the Senator fur Stadtentwicklung und Umweltschutz (SSEUS) which has responsibility for pollution monitoring in Berlin, one of the

11 Lander of the FR Germany and the one area within the Fr Germany notified to the Commission as a derogation zone under Article 3(2) of the Directive. SSEUS operates BLUME (Berliner Luftgute-Messnetz) which is a state (or Land) network of 32 fixed stations set up in 1975 (see Fig. 13). The network is based on a grid of 4 km meshwidth within the 480 km^2 of the city. SO_2 is measured at all stations using the conductimetric method (Picoflux) while suspended particulates are measured gravimetrically using beta-absorption at 10 stations. NO_x, CO and CO_2 are also measured at a number of the stations. The network includes one meteorological station measuring wind speed and direction, temperature and humidity.

West Berlin receives a significant influx of pollution from East Berlin and from further afield from industry within East Germany and experiences the highest concentrations especially of SO_2 in the neighbourhood of the boundary with East Berlin.

Most of the stations contain only one pollution sampler and are located in existing buildings for example schools, hospitals and offices. A few stations use purpose-built cabins and there is 1 recently installed so-called multi-component cabin where SO_2 (using both UVF and Picoflux), O_3, NO_x, CO_2, CO, and suspended paticulates are monitored. Each station is connected by telemetry to a central computer at the Senator laboratories. 3 minute averages are transmitted to the central computer for further data reduction, analysis and archiving.

The samplers are calibrated automatically for zero and span every 25 hours and visited every 3-4 months for calibration using calibration gas cylinders.

6 of the stations including the pollution/meteorological station in Schoneburg were visited during the course of a tour of Berlin. Each of the stations was well located in terms of coverage of the city within the grid system and lack of direct influence from nearby sources although one of the stations located in a portable cabin had become slightly screened by trees.

Italy

The study group visited the Presidio Multizoniale di Igiene e Prevensione (PMIP) in Milan which operates the pollution monitoring network of the Province (Region) of Milan. The Province of Milan has a high concentration of industry. It is located in the Region of Lombardy which is one of 2 regions notified to the Commission as derogation zones under Article 3(2) of the Directive.

The PMIP started monitoring in 1978 using bulk samplers with analysis in the laboratory. The network was gradually expanded across the Province incorporating networks operated by industry. There are now 48 stations monitoring SO_2 continuously within the Province mainly using the coulometric method although the most recently deployed samplers use the UVF method. The stations are located in purpose-built cabins. 9 of the stations are located within the city of Milan, an area of about 65 km^2, the others being located within 7 zones across the Province and centred on industrial plant within these zones. The distribution of stations in the City of Milan network is shown in Fig. 14. Suspended particulates are measured gravimetrically using beta-absorption at 4 stations (3 within the city) and NO_x, O_3 and hydrocarbons are monitored at a selection of the stations. Meteorological measurements -

temperature, wind speed and direction, rainfall, humidity and solar radiation - are measured at up to 20 stations within the network (6 of them within the city).

25 of the SO_2 stations are linked directly by telemetry to the computer at PMIP and provide measurements every minute, the remainder are linked to local computers which obtain measurements every minute then calculate half-hour averages for transmission to the PMIP computer.

The samplers are calibrated over a 40 minute period each night for zero and span using permeation devices. These checks should be within predefined limits, otherwise the sampler will be checked out and the calibration checked using calibration-gas bottles.

2 of the monitoring stations within the city and one operated by Aziende Energetica Milano (AEM - the city of Milan's own power utility company) in the town of Cassano about 20 km east of Milan were visited by the study group.

The first station (JUVARA) located at the PMIP laboratories monitored NO_x and O_3 as well as SO_2 and suspended particulates. In addition to measuring suspended particulates using beta-absorption there were a number of additional samplers being operated as part of an intercomparison exercise including a black smoke sampler and a 'Kleinfiltergerat'. The second station in Milan (MARCHE) was located within 15 m of a busy traffic-route and monitored NO_x as well as SO_2 and suspended particulates. The station operated by AEM was in the grounds of a school near the centre of Cassano and about 2 km east of the power-plant and monitored NO_x as well as SO_2 and suspended particulates. (The other stations operated by AEM monitored SO_2 only.)

Each of the stations was well located with respect to the spatial ditribution of emission sources in the vicinity of the station although the inlet to the suspended particulate sampler at the Marche station was noted to be within 2 metres of a nearby tree.

Netherlands

The study group visited the National Institute of Public Health and Environmental Hygiene (RIVM) in Bilthoven, which coordinates the National Air Pollution Monitoring Network, and the Central Environmental Service (DCMR) in Schiedam which operates the local monitoring network covering the Rijnmond area. The Rijnmond area covers about 900 km^2 and contains the conurbation and industrial complexes on the River Mass between Rotterdam and the Hook of Holland. It is one of the most industrialised areas of the Netherlands and was notified to the Commission as a derogation zone until the list of zones was withdrawn by the Netherlands in March 1985.

Monitoring was started in the area in 1969 and there are presently 31 automatic SO_2 stations and 11 semi-automatic (bulk 24-hour) smoke/SO_2 stations operated by DCMR within an area of about 300 km^2 in addition to 14 automatic stations of the national network. In addition the DCMR operate 3 multi-component stations where as the name implies a range of pollutants are monitored. The distribution of automatic monitoring stations in the Rijnmond area is shown in Fig. 15. The present networks are being reduced in size and integrated as part of the Dutch reorganisation (see Section 4.2).

Each of the 31 DCMR stations is linked by telemetry to the computer centre of the DCMR in Schiedam. The samplers are logged every second. Minute, hour and 24-hour averages are calculated from the logged data.

Four sampling locations were visited during a tour of the area:

Multi-component station 1 at the DCMR offices where there was a semi-automatic black smoke/SO_2 sampler as well as samplers for NO_x, ozone and hydrocarbons. The offices are located in a commercial area and the sampling inlet was located directly above the pavement on the edge of a relatively busy road. National network stations 416 and M8 in Vlaardingen, and 418 in central Rotterdam (where NO_x and CO were also monitored).

Each of the stations was well located with respect to the spatial distribution of emission sources in the vicinity of the station although the sampling inlet was noted to be within 1 m of a tree at one of the stations.

United Kingdom

The visit in the United Kingdom was to the Environmental Health Department of Doncaster Metropolitan Borough Council. Doncaster is one of the UK's 29 'derogation' areas and provided a typical example of the areas in the UK at risk of exceeding the limit values of the Directive; it has a number of relatively small mining communities where the heavy use of concessionary coal can produce smoke concentrations in excess of the 98-percentile limit value for suspended particulates. The borough covers a total of 580 km^2 (although only about 30% is urbanised) and contains 16 black smoke/SO_2 monitoring stations. 14 of the stations are operated by the Environmental Health Department, 1 by British Rail and 1 by Coalite and Chemical Products Ltd. Each of the 16 stations is part of the national network (now called the UK Smoke and SO_2 Monitoring Network) centrally coordinated by Warren Spring Laboratory on behalf of the Department of the Environment. The distribution of stations within Doncaster District is shown in Fig. 16.

Daily samples are analysed locally by acidimetric titration for SO_2 and by reflectometry for black smoke and the results transferred on data forms to WSL for data processing, analysis and archiving. Results therefore are not generally available until several months after the measurements are made.

Stations in the outlying mining communities of Armthorpe, Askern, Harlington, Mexborough and Moorends as well as 2 in the town of Doncaster were visited during the course of a tour around the District. The stations are mainly located in existing public buildings and were all found to be well located in terms of representivity and proximity to relevant sources.

Meteorological measurements are not made as part of the UK Monitoring Networks either by WSL or by the local organisations but are obtained from stations operated by the Meteorological Office. A station on an airfield at RAF Finningley on the eastern edge of Doncaster Borough is used by both the Environmental Health Department and WSL when required.

Separate from the national network the local Environmental Health Department operates 2 continuous SO_2 samplers which use flame-photometric detection for short-term monitoring at potential 'hot-spots'. One of the current sites for continuous SO_2 monitoring was also visited during the tour.

7. AIR QUALITY IN THE MEMBER STATES

It is relevant to a study of network design to examine the historical distribution and trends in pollution as well as the present situation. It is also important to consider the assessment made of the problem areas within each of the member states.

This section therefore presents the results available from the member states over the last few years and summarises the breaches of the Directive limit values in 1983/84, the first year the limit values were in force.

In the presentations which follow use has been made as far as possible of the statistics - annual median and 98-percentile - and the annual period - April to March i.e. legal years - available for individual stations as well as the arithmetic averages of these statistics available for a group of stations, for example those within one urban area or for the full national network. These are the statistics relevant to the Directive. However this has not always been possible; in some cases only annual (arithmetic) means or statistics for calendar years have been available.

The following paragraphs present the results available from the different member states and in particular from the networks visited in the course of this study. Results from the different networks have been drawn together in Fig. 17 which presents the annual averages (arithmetic means) of the different statistics - annual mean, median or 98-percentile - obtained at the stations of the various towns over the period 1977/78 to 1983/84 as proportions of the 1983/84 averages i.e. each network annual average concentration is plotted as its proportion of the 1983/84 network average. These graphs provide a summary of the trends in pollution within each network and between the different networks over the last seven years.

Belgium

In 1983/84 the annual medians for SO_2 from 72 stations in the automatic network ranged between 8 and 80 $\mu g\ m^{-3}$ with an average of 28 $\mu g\ m^{-3}$ while the annual 98-percentiles ranged between 51 and 354 $\mu g\ m^{-3}$ with an average of 148 $\mu g\ m^{-3}$.

The higher 98-percentile limit value for SO_2 of 350 $\mu g\ m^{-3}$ was exceeded at two stations in the industrial area to the north of Gent. (The higher limit value was considered since there was no evidence that the black smoke threshold value of 150 $\mu g\ m^{-3}$ was exceeded in this area, indeed in any part of Belgium.)

There are 15 automatic stations and 15 smoke-sulphur stations in the Gent area. Trend data are available for SO_2 from the smoke-sulphur network from 1970/71 and from the automatic network from 1978/79. Averages of the annual medians and 98-percentiles from stations in the Gent area as well as the number of stations which exceeded the limit values of the Directive are presented in Fig. 18. There has been a marked reduction in the averages over the years and the number of stations producing statistics in excess of the limit values has also decreased over the period covered.

None of the limit values were exceeded at the stations of the smoke-sulphur network, the two stations where the exceedances occurred being part of the automatic network. As indicated in Table 6 the two stations were R721 and R731 where the 98-percentiles for SO_2 were 353 and 354 $\mu g\ m^{-3}$ respectively.

Denmark

In 1982 annual averages for SO_2 and suspended particulates at monitoring stations in Copenhagen ranged between 12 and 35 $\mu g\ m^{-3}$ for SO_2 and between 50 and 90 $\mu g\ m^{-3}$ for suspended particulates; the 98th percentiles for SO_2 were between 45 and 85 $\mu g\ m^{-3}$ while those for suspended particulates were between 100 and 170 $\mu g\ m^{-3}$.

Denmark did not notify any derogation zones to the Commission and reported no breaches of the limit values in 1983/84.

France

Annual averages for SO_2 (strong acidity method) and black smoke for the network in Rouen (REMAPPA) between 1979 and 1983 are presented in Table 7. These results are also presented as indexed trends in Fig. 17 where it has been assumed the average for SO_2 and black smoke in the full year 1983 was 40 and 20 $\mu g\ m^{-3}$ respectively. There has been a substantial reduction in both SO_2 and black smoke over the five year period shown.

France notified 17 derogation zones to the Commission. Limit values were exceeded in 6 stations in 1983/84, all of which were in derogation zones. These exceedances are summarised in Table 6.

FR Germany

Trend data are available for Berlin for 1976-1983 and for NRW for 1971-1984.

Figure 19 shows the trend in the average annual median and 98-percentile values for SO_2 from 31 fixed stations in Berlin between 1976/77 and 1983/84 as well as the number of stations exceeding the Directive limit values for these statistics. It is clear that the 98-percentile is the more critical limit value. However air quality has shown some improvement over this eight year period, the number of stations exceeding the higher 98-percentile limit value of 350 $\mu g\ m^{-3}$ having reduced from 12 to 1 between 1976/77 and 1983/84. The improvement, especially in median concentrations is also seen in Fig. 17 which presents indexed trends for annual medians and 98-percentiles of SO_2 in Berlin.

For NRW, trend data for 1971-1979 have been derived from random sampling measurements at 1 x 1 km grid-points and for 1980-1984 from the automatic fixed monitoring stations of the TEMES-network. The results given in Fig. 20 show a declining trend from a mean value of 118 $\mu g\ m^{-3}$ in 1971 to 55 $\mu g\ m^{-3}$ in 1984. Within this period the average of the 98-percentile decreased from 360 to 220 $\mu g\ m^{-3}$. In Fig. 20 the total number of automatic monitoring stations exceeding the different limit values of the Directive are presented for the years 1980-1984. An alternative impression of the exceedances is found in Fig. 21 where the percentages of stations exceeding the limit values is given. In order to provide comparable results for 1971-1979, the 98-percentile of the random samples was compared to the limit value 400 $\mu g\ m^{-3}$ given in the TA-Luft.

West Berlin was notified to the Commission as a derogation zone. In 1983/84 the 98-percentile limit value of 250 $\mu g\ m^{-3}$ was exceeded at 18 of the 31 stations while the limit value of 350 μg m^{-3} was exceeded at 1 of the stations. No other exceedances of the Directive limit values were found in the FRG in 1983/84.

Ireland

Trend data are available for Dublin[15] which was notified to the Commission as a derogation zone.

The trends in average concentration for black smoke and SO_2 between 1973/74 and 1983/84 and the number of stations breaching any of the limit values between 1979/80 and 1983/84 are shown in Fig. 22. Black smoke is the more critical pollutant, showing some increase in recent years due to increased consumption of coal for domestic heating. There were no breaches of the SO_2 limit values.

7 of the stations would have exceeded the 98-percentile limit value of 250 μg m^{-3} for black smoke in 1981/82 while 5 exceeded this limit value in 1983/84 (see Table 8). The annual medians for black smoke in Dublin in 1983/84 ranged between 13 and 60 μg m^{-3} with an average of 28 μg m^{-3} while the 98-percentile ranged between 90 and 450 μg m^{-3} with an average of 190 μg m^{-3}.

Italy

Trend data are available for the Province of Milan in the Region of Lombardy which is one of the 2 regions which have been notified to the Commission as derogation zones.

17 of the 48 stations in the Province of Milan provided annual statistics between 1978 and 1983. Figure 23 shows the trends in the averages of the annual medians and 98-percentiles from these stations as well as the total number of stations where the annual median exceeded 80 μg m^{-3} and the 98-percentile exceeded 250 μg m^{-3} (these limits are the Italian air quality standards in Italy as well as the lower limit values of the EC Directive). There has been a marked improvement in the annual medians and some reduction in the average 98-percentile although a large number of the stations continue to exceed the 98-percentile limit.

12 of the 17 stations used to plot the trends in Fig. 23 and a total of 21 stations within the network of 48 stations produced 98-percentiles in excess of 250 μg m^{-3} for SO_2 in 1983[16]. A total of 14 of these stations produced 98-percentiles in excess of 350 μg m^{-3} in 1983 (statistics were not available in full for the period April 1983-March 1984 to allow direct comparison with the statistics from other Member States).

Luxembourg

The trends in average annual medians and 98-percentiles for SO_2 for the whole network for the years 1972 to 1983 are presented in Fig. 24. As in other countries there has been a substantial reduction in both of these averages over the years.

The 98-percentile limit value of 350 μg m^{-3} for SO_2 was exceeded in Colmar-Berg during 1983/84 (the 98-percentile was 642 μg m^{-3} at the station in the Rue de Luxembourg). Colmar-Berg is one of the 2 derogation zones notified to the Commission.

Netherlands

Figure 25 presents the trends in the annual averages of the medians and 98-percentiles obtained at the stations of the National Network between 1976/77 and 1983/84. There was no significant increase or reduction in either average over the 8 year period.

Figure 26 presents the trends in the annual averages of the same statistics obtained from 12 stations of the National Network located in the Rijnmond area between 1977/78 and 1983/84. There is evidence, seen more clearly in the indexed trends of Fig. 17, of some reduction in the averages over the 7 year period.

There were no exceedances of the limit values of the Directive reported for 1983/84. In the Rijnmond area during this period annual medians for SO_2 at the National Network stations ranged between 13 and 45 $\mu g\ m^{-3}$ while the 98-percentiles ranged between 59 and 167 $\mu g\ m^{-3}$. The corresponding ranges for stations operated by the DCMR were 15 and 48 $\mu g\ m^{-3}$ and 62 and 204 $\mu g\ m^{-3}$ respectively.

United Kingdom

Trend data are available for black smoke from 1960 (see Fig. 27) which indicate there has been a substantial reduction in black smoke concentrations over the years. The reduction in average black smoke concentration is mirrored in the reduction in the number of stations which would have exceeded the Directive limit values. Almost all stations would have breached in 1960, about 300 (25%) in the early seventies, less than 100 after 1977 while 13 actually exceeded the limit values in 1983/84. The stations which exceeded limit values in 1983/84 are listed in Table 6. The stations are located in 6 of the 29 derogation zones notified to the Commission.

In 1983/84 the annual median for black smoke ranged between 2 and 81 $\mu g\ m^{-3}$ with an average of 18 $\mu g\ m^{-3}$ while the 98-percentile ranged between 8 and 360 $\mu g\ m^{-3}$ with an average of 98 $\mu g\ m^{-3}$. The 98-percentile was the more critical statistic with 10 stations exceeding the limit value of 250 $\mu g\ m^{-3}$.

In Doncaster where 4 of the stations breached the Directive in 1983/84 there has been some improvement in air quality in recent years. The average concentration in the District fell over 40% between 1979/80 and 1983/84 and the 98-percentile limit value for black smoke, which would have been exceeded at 9 stations in 1981/82 and 4 stations in 1982/83, was exceeded at 3 stations in 1983/84. (In addition the lower 98-percentile limit value of 250 $\mu g\ m^{-3}$ for SO_2 - with the trigger value of 150 $\mu g\ m^{-3}$ for black smoke - would have been exceeded in 1981/82 and was exceeded in 1983/84 at 1 station).

8. DATA HANDLING

There are several aspects to data handling which can have a bearing on the statistics derived from the measurements made in the different networks:

- initial sampling or logging period
- minimum sample size required for calculation of longer-period averages

- how missing values are allowed for, and
- formulae used in the calculation of limit value statistics.

A. Initial sampling or logging period

Three of the member states - Ireland, Luxembourg and United Kingdom - produce only bulk 24-hour samples for analysis. Their initial sampling period is therefore 24-hours or 1 day which is the base period for calculation of the medians and 98-percentiles required by Annex I of the Directive.

Belgium and Denmark have a large proportion of stations providing bulk 24-hour samples but also make use of continuous monitoring (automatic) samplers for SO_2. France and the Netherlands operate bulk 24-hour samplers for black smoke but use only continuous monitoring samplers for SO_2.

France, FRG and Italy have regionally operated networks and the details of all the networks have not been studied.

Table 8 summarises the base time interval and minimum sample size for averaging over longer intervals, for example 0.5 hours, for SO_2 and suspended particulates in those networks where automatic samplers are used.

B. Minimum sample sizes and missing values for determination of limit value parameters.

Once daily values have been calculated the rules for deriving the summary statistics (medians and 98-percentiles) required by the Directive can be applied. The Directive does not specify the formulae to be used although the Commission has produced a proforma which is not mandatory to follow but which suggests the formulae to use to calculate the required statistics to check compliance with the Directive limit values. However it is clear that member states do not always use the formulae suggested by the Commission. The proformas are presented in Appendix A.

The minimum requirements and formulae used in the different Member States can be summarised as follows:

[The formulae presented plus Table 10 use the following symbols:

N = no. of results

k = rank position of percentile to be determined, i.e. after ranking results in ascending order, the required percentile is found at position k in the rank (lowest result: $k = 1$, highest result: $k = N$).

i = rank position in descending order, i.e. $i = N - k + 1$ (lowest result: $i = N$, highest result: $i = 1$).

P = P-percentile required e.g. 98th.

integer ( ) = integer part of ( )]

Belgium

No minimum sample sizes have been specified. On average more than 90% of the daily values are available for a given station. The number of missing values which can be tolerated depends on their distribution over the year; 25% missing could be acceptable as long as the missing values were spread of the year, but not acceptable if they were on consecutive days. The number of values is always quoted with the derived statistics and can be taken into account when interpreting the statistics.

Percentiles are calculated using the formula:

$$k = \text{integer}\ (PN/100) + 1 \qquad \text{Formula 1}$$

For example, if $P = 98$, $N = 348$ then $k = \text{int}(341.04) + 1 = 342$

Denmark

Calculation of 98-percentile requires more than 75% of the daily values distributed throughout the year.

Percentiles are calculated using the formula of the EC Directive for NO_2:

$k = PN/100$ (rounded off to the nearest whole number), which can be written as

$$k = \text{integer}((PN/100) + 0.5) \qquad \text{Formula 2}$$

For example, if $P = 98$, $N = 348$ then $k = \text{int}(341.04 + 0.5) = 341$.

France

Calculation of the required statistics requires at least 75% of the daily results and no gap of more than 45 days.

Percentiles are calculated using formula 1.

FR Germany

Minimum requirements vary among the Lander. Some details are given in Table 8.

Percentiles are calculated using formula 1.

Ireland

A minimum sample size has not been established. However the number of missing values seldom exceeds 30 and no measures are taken to allow for them.

The median is taken as the middle value of the daily values in rank order.

The 98-percentile is usually taken to be the 8th highest value.

Italy

The ISTISAN report recommends[6] that calculation of median concentrations requires a minimum of 330 daily values while calculation of 98-percentiles requires a full set of 365 values. Otherwise upper and lower estimates of these statistics are calculated and compared with the air quality standards. Only if the upper estimate is less than the standard is the station considered to be clear.

The median is taken as the value in the kth rank position

where $k = (N + 1)/2$ when N is odd

or $k = n/2 + 1$ where N is even.

Percentiles are determined using formula 2.

Luxembourg

The number of values used in the calculation of the required statistics is always presented with the statistics and can be taken into account when interpreting the results.

As in Belgium, formula 1 is used to calculate percentiles.

Netherlands

The minimum sample size for a valid hour is forty-five 1-minute values and for a valid 24-hour value is thirteen 1-hour values. Annual averages, 50-, 95- and 98-percentiles of 24-hour concentrations are calculated if not less than 200 24-hour values are available and the number of consecutive missing days is not higher than:

(i) 10 in the period 1 April to 30 September, or

(ii) 5 in the period 1 January to 31 March or 1 October to 31 December.

Formula 1 is used for the calculation of percentiles.

United Kingdom

Medians and 98-percentiles are calculated for a station if there are no gaps greater than 14 days and there are at least 125 values available in each of the 2 half-year periods (April-September and October-March).

After sorting the daily values from a station satisfying the minimum requirements into ascending order, the associated percentile value for each concentration value is found from

$$P_k = (k/(N + 1)) \times 100 \qquad \text{Formula 3}$$

where

P_k is the percentile for the kth concentration in the sorted set, that is P_k% of the concentration will be equal to or less than C_k.

The concentration values for the limit value statistics are obtained by linear interpolation between the concentration values for the nearest percentile values on either side. For example, in the sets

$P1, P2, \ldots P_k \ldots 97.8, 98.1, \ldots P_N$

$C1, C2, \ldots C_k \ldots 150, 159, \ldots C_N$

the 98th percentile would be 156 $\mu g\ m^{-3}$.

Furthermore, on the basis that with a complete set of 365 daily values the 98-percentile equates with the 8th highest concentration, if a limit value set for the 98-percentile is exceeded on 8 or more days the limit value is considered to have been exceeded irrespective of the number of values available i.e. the method of 8th highest value used in Ireland is also used in the United Kingdom.

9. DISCUSSION

Responsibilities for Monitoring

In Belgium, Denmark, Luxembourg, Netherlands and the United Kingdom there is a central laboratory with responsibility for coordinating the national monitoring network. In the Netherlands responsibility for monitoring is also devolved to regional authorities but the national and regional networks are being integrated. In France, FR Germany, Ireland and Italy responsibility for monitoring is devolved to regional or local authorities. This devolution has increased the range of network design strategies and (except in the case of Ireland where monitoring is done to a single standard) has caused some problems in the collation and consistency of information at the national level.

Legislation

Belgium has written the (Annex I) limit values of the Directive into its air pollution legislation. Denmark and FR Germany have passed legislation which includes air quality standards identical to the limit values of Annex IV while Italy has set air quality standards which equate with the lower Annex I limit values for SO_2 and the Annex IV limit values for suspended particulates. The Netherlands has adopted a set of air quality standards for SO_2 and black smoke which are more stringent that the Annex I limit values. The other Member States have not enacted legislation which incorporates the limit values or equivalent air quality standards.

Objectives of Monitoring

Each of the Member States has a similar range of objectives for its monitoring network; support of policy, protection of public health, surveillance monitoring, trend analysis and research are cited by most. An additional objective adopted by five of the Member States for at least part of their networks is the provision of an alert system. Belgium and the Netherlands use their national networks for the alert systems while France, FR Germany and Italy have alert systems in some of their regional networks.

Emphasis on Different Pollutants

Ireland, France, Luxembourg and the United Kingdom use only a non-specific method (the net or strong acidity method based on reaction with dilute hydrogen peroxide) for monitoring SO_2. In this report it has been assumed that the results obtained using this method are compatible with the SO_2-specific methods. Tests will be carried out under Article 10(1) of the Directive to confirm this.

Ireland, Luxembourg and the United Kingdom operate stations which monitor both black smoke and SO_2. Belgium in addition to its smoke-sulphur network where both pollutants are monitored operates a smaller network of automatic SO_2 stations. Denmark operates a network of stations monitoring both SO_2 and suspended particulates plus four automatic SO_2 stations. France operates networks of automatic and semi-automatic samplers for SO_2 as well as black smoke and suspended particulates samplers but with few stations monitoring both SO_2 and black smoke or suspended particulates. France, Italy and the Netherlands concentrate monitoring on SO_2 with fewer stations monitoring suspended particulates or black smoke while FR Germany operates slightly more SO_2 samplers than suspended particulate samplers. There is therefore a bias in favour of monitoring SO_2, partly due to the fact that this is the more critical pollutant in most Member States but also because automated methods of analysis for SO_2 are more developed and available than for suspended particulates, in particular black smoke.

Different Historical Developments

The Belgian and Luxembourg smoke-sulphur network and the Irish and United Kingdom networks were established prior to about 1970 when only bulk semi-automated methods were available. At this time the simplest and most economic methods for widespread use were reflectance for black smoke and net acidity for SO_2. The Belgian automatic network and the networks in Denmark, France, FR Germany, Italy and the Netherlands were set up after this period and had available to them, or required in order to provide an alert system, continuous monitoring equipment which could be linked directly to a central computer for data logging and processing.

Cost of Monitoring

It has proved impossible to fully quantify the costs of monitoring SO_2 and suspended particulates in the Member States since in many cases it was not possible to separate the costs for these pollutants from those for other pollutants monitored in the same network or information was not always available for each relevant item, for example computing or maintenance costs.

However the following cost ranges were obtained from the data collected by the study group:

- Bulk sampling, for example for black smoke: 2-8 ECU per 24-hour sample, or 700-2500 ECU per sampler per year.

- Automatic sampling for SO_2: 20-50 ECU per 24-hour average, or 7000-18000 ECU per sampler per year, for networks of at least 25 stations.

Unit costs were lower for larger networks and for single, centrally-operated networks. The ranges of unit costs suggest a total cost for SO_2 and suspended particulate monitoring in the Member States of the order of 20 million ECU per year.

Network Design Strategy

The above mentioned aspects all have a bearing on the network design strategy adopted in and within each of the Member States. In addition the different States have taken a more or less systematic method to determining the number of stations required and where to locate them. The Dutch method is statistical involving the use of structure functions and is based on the spatial pollution gradients in the original network and the requirement of estimating the 50- and 98-percentiles for each 1 x 1 km^2 in the country to within ±15%. In FR Germany network density is dependent on the spatial distribution of emissions and the requirement to provide statistically representative results for each heavily-polluted area as specified in legislation. This has been obtained by establishing regular (grid-based) networks. In France existing networks are reorganised systematically by statistical methods which involve principal component analysis and kriging. In the other countries stations have been located or relocated on a less systematic basis but with regard to a wider range of quantitative and semi-quantitative information, for example population density, emission distribution, land-use, modelled estimates of the spatial distribution of pollution and trends in the pollution measurements.

Interpretation of Article 6

Interpretation of Article 6 is central to implementation of the Directive and hence to the present study. Article 6 requires that "member states shall establish measuring stations designed to supply the data necessary for the application of the Directive, in particular in zones where the limit values referred to in Article 3(1) are likely to be approached or exceeded and in the zones referred to in Article 3(2); the stations must be located at sites where pollution is thought to be greatest and where the measured concentrations are representative of local conditions"[1].

The earlier study group recognised[3] that the "phraseology is open to a variety of interpretations but no further guidance is given in the Directive". The present study group has examined Member States' position on Article 6 and considered its implications.

Most countries have networks of stations which are designed to serve multiple objectives, have been developed over the years and have now provided a substantial amount of information on the spatial and temporal distribution of pollution. In addition to the monitoring networks, information has been collected on sources of emissions and on the amounts of pollutants emitted and modelling studies have been carried out to calculate air quality from a knowledge of these emissions and of the meteorology controlling the dispersion of the emissions. Estimates have therefore been compiled on the location of areas of relatively high pollution and of the contribution of the various sources to these estimates. The estimates for locations where measurements have been made can be validated against the measurements and estimates for locations where no measurements are made can to some extent be validated by installing new stations. As a consequence these member state have developed the ability to pin-point areas of relatively high pollution and concentrate their efforts in these areas. The process is not perfect (since the information available will always be incomplete and subject to some error) but permits member states some confidence in locating stations in areas within its boundaries where pollution is thought to be greatest and likely to approach or exceed the limit values of the Directive.

The authorities must then consider location of the monitoring stations within these areas in order to quantify the position 'on the ground'. Within these areas pollution will vary both spatially and temporally and in the critical areas will have frequency distributions which would produce statistics close to the limit values of the Directive. At this stage it may not be possible to pin-point the locations where pollution is greatest since due to variation in emission patterns and in weather conditions this is unlikely to stay fixed from one year to the next and certainly not fixed from one hour or day etc to the next. The area 'at risk' of exceeding the limit values may be as small as 1 km^2 or much larger up to several 100 km^2. It is unlikely that the authority responsible will have the resources to deploy a large number of samplers long-term at densities of one or more per km. As a compromise a strategy will be adopted which aims at 'representative of local conditions'. The area of spatial representivity will vary from situation to situation but as argued in the earlier report for most practical purposes will be a minimum of 1 x 1 km. The results obtained therefore are unlikely to be the highest possible within the area. However, if the spatial scale of representivity and the sampling station have been selected well it should be possible to provide results within about 25 per cent of the highest concentrations possible within the area.

Alert Systems

Alert systems are operated in Belgium, France, FR Germany, Italy, Netherlands and the United Kingdom. They require the use of continuous monitoring and computer data-logging. The alert systems are usually initiated on the basis of meteorological information forecasting adverse dispersion conditions and in most cases are used to restrict emissions from a number of major local industrial sources, the ability to restrict emissions on a voluntary or compulsory basis being defined in legislation.

Network Densities

It has already been noted that despite the different network design strategies adopted, sampling stations tend to be located in very similar locations in the different networks with a general bias to the more populated or industrialised parts of the urban areas. It is interesting to examine the network densities which have resulted.

The six towns or conurbations visited during the course of this study have been assessed and network densities are summarised in Table 9. The assessment has been made at two levels; station density across the complete network centred on the town visited and density in the central, more polluted part of the network. Table 9 presents the number of stations and the area covered, the number of stations per unit area (km^2) and the implied typical interstation distance in kilometres calculated as the square root of the number of stations per km^2 (to the nearest 0.5 km).

Detecting Trends in Pollutant Concentrations

Trends in concentration will be detected most readily in areas where network density is highest which, as indicated above, tends to occur in areas considered most 'at risk' of exceeding the limit values. In other areas where network density is lower, there will be lower confidence of detecting change, in particular increase in pollution which could bring additional areas 'at risk' of exceeding the limit values. Assessing where these additional areas are is done by a variety of methods in the member states:

- additional stations or networks in urban and non-urban areas, for example the Basic Urban Network in the United Kingdom,
- mobile measurements, as carried out in Belgium, FR Germany and the Netherlands,
- dispersion modelling, used in several member states including Luxembourg and Ireland (Dublin),
- emission inventories.

The additional activities can provide early warning of a reversal in the generally downward trends in pollution.

Application of Annex IV

Denmark and FR Germany have national air quality standards which are equivalent to the Annex IV limit values for SO_2 and suspended particulates. Italy has air quality standards for SO_2 equivalent to the lower Annex I limit values and for suspended particulates equivalent to the Annex IV limit values. It has been recognised that the Italian standards are likely to be the most stringent of standards. However, the monitoring strategies adopted in these member states are not consistent with those described in Annex IV. In Denmark and Italy fixed monitoring stations are used for both SO_2 and suspended particulates, in FR Germany random sampling is used to supplement the results from the fixed station networks but the sample areas are 1 x 1 km instead of the 16 km^2 areas required by Annex IV. Since the Annex IV random sampling strategy for SO_2 is no longer used in FR Germany the results obtained from the fixed stations are compared with the Annex I limit values.

The situation is different for suspended particulates. Denmark, FR Germany and Italy all measure suspended particulates gravimetrically and hence cannot compare their results with the Annex I limit values which apply to black smoke. The more relevant limit values are those of Annex IV which are equivalent to the national air quality standards. However it appears that the methods used in these countries are not entirely consistent with the requirements of Annex IV which specifies a range of inlet velocities (33-55 cm/sec) and that analysis of the filters is by weighing. The most widespread method used in these three member states is a radiometric method (beta-absorption) which does not involve filter-weighing. In FR Germany the radiometric method is considered fully consistent with gravimetric methods.

It appears therefore that Annex IV is no longer applied in the form specified by any of the Member States. The implications of this will be considered in the Section 11.

Air Quality

The results available indicate that in most networks and especially in the networks around the towns visited during the course of this study there have been substantial reductions in average pollution concentrations during the life of the networks or their predecessors and more importantly over the past 5 to 8 years. There has also been some reduction in peak (95- or 98-percentile) concentrations although less marked since peak concentrations are more dependent on the variation in dispersion conditions from one year to the next. The number of stations where the limit values of the Directive were exceeded has also been reducing and in 1983/84 the first year of operation of the Directive only 44 stations (excluding Italy and Greece where information is incomplete or not available) from the ~1800 in operation were reported as exceeding the limit values.

Analysis of the statistics from stations which reported exceedances of the limit values in 1983/84 is made difficult by the different methods of assessment used. In the France, FR Germany and Italy (Milan) the more stringent limit value for the SO_2 98-percentile of 250 µg m^{-3} has been used since black smoke is not monitored at the stations where exceedance of the SO_2 limit value occurred and in the case of Italy the value of 250 µg m^{-3} equates with the national air quality standard. In Belgium the upper 98-percentile limit value of 350 µg m^{-3} is considered since there is no evidence from the smoke-sulphur network that black smoke exceeds the 98-percentile trigger value of 150 µg m^{-3} although black smoke is not monitored at the two stations where exceedance of the SO_2 limit value occurred.

Exceedance of the peak (98-percentile) limit values is most common with a few exceedances of the annual median limits and no exceedances of the winter medians. The black smoke 98-percentile limit value was most commonly exceeded in Ireland and the United Kingdom while exceedances of the SO_2 98-percentile limit values occurred more frequently in Belgium, France, FR Germany and Italy.

Data Handling

There is wide variation in the methods adopted in each of the networks for handling missing values and the minimum number of data values required to produce averages over longer time intervals, for example daily averages from half-hourly averages or produce the statistics - medians and 95- or 98-percentiles - relevant to the Directive from the daily values. Four different methods of determining 95- and 98-percentiles - which tend to be the most critical limit values - are used. Recommendations are made in Section 11 for a consistent approach to data handling and the calculation of the relevant statistics.

The Commission's proforma for notification of instances in which the limit values have been exceeded does not specify minimum requirements but does request the number of measured values obtained. The equation specified for calculation of medians and percentile is that given in formula 1 above with $P = 50$ for medians and $P = 95$ or $P = 98$ for the 95th and 98th percentiles respectively.

It is interesting to compare the effects of using the different formulae especially for calculation of the 98th percentiles. Table 10 summarises the situation.

In comparison with Formula 1 which is the one recommended by the Commission, it can be seen from Table 10 that:

(i) Formula 2 is often but not always less stringent that formula 1.

This is due to the fact that rounding up or down to the nearest integer depends on the sample size N. This introduces an undesirable ambivalence which impairs the comparability of results from samples of different size and can be avoided by using the formula 1.

(ii) The Formula 3 is almost always more stringent than formula 1, and

(iii) The 8th highest result method is consistently less stringent than Formula 1 except for N close or equal to 365.

Since the higher percentiles can deviate markedly from the lognormal distribution usually used to describe the distribution of results, it is important to have an agreed definition for the determination of the higher percentiles. Otherwise the choice of formula could be used to determine whether or not a station was in breach of the Directive limit values.

10. CONCLUSIONS

1. This study has shown that despite differences in the legal basis and distribution of responsibility for monitoring and controlling air pollution and in the components of pollution monitored, a common set of design criteria have been used to establish monitoring networks for SO_2 and suspended particulates and provide information relevant to the Directive.

Firstly, the networks have been found to be centred around highly industrialised areas, for example Rouen/le Havre, Gent, Rijnmond or in densely populated cities, for example Milan and Berlin or in heavily polluted mining communities, like those in the Borough of Doncaster in the UK. When the monitoring networks were established account was taken of the spatial structure of industrial and domestic emissions as well as population density at least in qualitative terms.

Secondly, the majority of current networks were established on the basis of historical monitoring results collected over periods of up to 20 or more years.

Thirdly, effort has been concentrated in those areas most at risk of approaching or exceeding the limit values. In the areas where exceedances of the limit values have occurred and which were visited during this study - Berlin, Doncaster, Gent, Milan and Rouen - network densities as measured by interstation distance in the critical areas is about 4 km or better.

2. In order to arrange monitoring stations within the networks, different strategies were adopted. In Belgium, Denmark, France, Ireland, Italy, Luxembourg and the United Kingdom monitoring was concentrated in the more densely populated or industrialised areas where emissions were relatively high and there was the greatest risk of approaching or exceeding the limit values of the Directive. This was also the strategy adopted in the locally operated network in the Rijnmond area.

The national network of the Netherlands has been redesigned with emphasis on areas with large spatial gradients which effectively concentrates monitoring in the more industrialised areas.

Networks in FR Germany have been established to provide spatially representative data on pollution loads within the monitoring areas but do not concentrate on 'hot spots'. However due to the network density required as part of this strategy the areas relevant to the Directive are monitored and estimates of the percentage of the monitoring areas exceeding the limit values of the Directive can be made.

3. France, Ireland, Luxembourg and the United Kingdom use a non-specific method of analysis for SO_2. The other Member States use specific methods for the determination of SO_2. In this study it has been assumed that the specific and non-specific methods used produce compatible results. Belgium, France, Ireland, Luxembourg, Netherlands and United Kingdom use a black smoke method for suspended particulates and assess their results relative to the Annex I limit values. The other states - Denmark, FR Germany, and Italy - use a gravimetric method for analysis of suspended particulates. This method is incompatible with the black smoke method and these states assess their suspended particulate results relative to the Annex IV limit values, which are equivalent to the national air quality standards adopted in each of these three states.

All member states except Denmark now compare their SO_2 results with the Annex I limit values. Only Ireland, Luxembourg and the United Kingdom monitor both suspended particulates and SO_2 at all their stations. The others have adopted a range of methods for assessing compliance with the limit values for SO_2, which are dependent on an associated trigger value for black smoke. Italy consider only the lower (more stringent) limit values which for the annual median and 98-percentile are equivalent to their national air quality standards. France considers the lower limit values when there are no black smoke measurements at the station while Belgium take the black smoke results from the nearest smoke-sulphur network station.

4. The variations in minimum requirements for calculation of averages for one period from shorter-term measurements and for calculating medians and percentiles from daily results produce variability in the stringency of the limit values which is dependent on the amount of data missing. At the critical point with highest results around the limit value concentrations, one method could produce an exceedance of the limit value while another method would not. Consistent methods for data handling and the calculation of the relevant statistics are required.

5. Different approaches were adopted for reorganisation of the networks in France, Netherlands and the United Kingdom.

In France principal component analysis is used to eliminate redundant stations then a kriging technique is used to locate areas where interpolation errors are highest and hence where additional stations are required to provide more accurate information on the spatial distribution of pollution.

In the Netherlands structure functions have been used to interpolate between monitoring stations and provide estimates of pollutant concentration for each 1 x 1 km square in the country to within ±15 per cent standard error. This method appears particularly suited to the boundary conditions in the Netherlands.

In the United Kingdom a more heuristic approach was adopted taking into account past monitoring results as well as emission structures, meteorological conditions and population density at least in qualitative terms.

While the United Kingdom method cannot be described fully in quantitative terms, the more formalised methods used in France and the Netherlands do have limitations. Both methods take account of emission structure only in so far as it is reflected in the results from the existing networks. The methods do not allow for changes in emission structure and hence the networks are not so adaptable when changes in emissions occur.

6. Alert systems have been used in several member states as a means of helping reduce peak concentrations of SO_2 and thereby helping prevent exceedance of the Directive 98-percentile limit values. These systems require automatic monitoring of pollution concentration and of meteorological parameters, usually as part of the same system, in order to initiate rapid response.

11. RECOMMENDATIONS

1. Monitoring should be carried out in all areas where concentrations are likely to exceed 75 per cent of any of the limit values of the Directive. These areas being defined as 'at risk'.

2. When applying Article 6 'representative of local conditions' should be interpreted on a scale of 1 x 1 km.

3. Allow the use of regular (grid-based) networks because of their spatial representivity.

4. Define a maximum interstation distance based on population density or emission density (or both) to be applied in networks of statons located in areas 'at risk' of exceeding any of the limit values. On the basis of the network densities found in the areas considered in this report, the maximum interstation distance should be about 4 km in the 'at risk' areas.

5. Since the methods specified in Annex IV for the determination of SO_2 are not used in any Member State but limit values for suspended particulates measured gravimetrically are required if methods other than the black smoke method are to be permitted within the terms of the Directive, consideration should be given to:

   (i) whether Annex IV limit values for suspended particulates are as stringent when using gravimetric methods other than the one specified in Annex IV, and

   (ii) whether trigger values for suspended particulates by a gravimetric method can be defined for use in assessing whether the lower or upper limit values for SO_2 should be applied.

6. For consistency across the Member States, suspended particulates measured gravimetrically or by the black smoke method should be monitored at, or within 1 kilometre of, all stations 'at risk' of exceeding any of the limit values for SO_2. In the absence of suspended particulate results from a monitoring station, the SO_2 results should be compared with the lower more stringent limit values.

7. Most Member States are able to operate stations in their monitoring networks with a high percent data capture - of the order of 80 per cent (or 300 daily results) or better - without any interpolation to fill gaps in the

results. All stations 'at risk' of exceeding any of the limit values should be operated to at least this capture level.

8. Percentiles should be determined on a consistent basis using Formula 1 as suggested by the Commission in its proforma. Formula 1 is defined on page 43. If fewer than 300 results required by the 80 per cent capture recommendation are available from any stations then Formula 1 should continue to be applied with the results available.

9. Alert systems should be considered (if not already installed) in areas where there is a risk of exceedance of the limit values for SO_2.

10. Denmark should assess its SO_2 results with the Annex I limit values and confirm that no exceedances of these limit values have occurred since April 1983.

11. Although not possible or not included in the present study, information on networks in Italy, Greece, Spain and Portugal should be obtained and assessed in terms of the above findings.

12. During the present limited study, it was not possible to assess all aspects of monitoring network design in the context of the Directive. The following aspects appear worthy of further investigation:

- a common case study of the methods used for reorganising the networks in France, Netherlands and the United Kingdom, for example using monitoring data obtained in Berlin as part of another Commission sponsored study,
- statistical uncertainties in the results obtained from the various networks used to show compliance with the Directive.

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TABLE 1. - Summary of Legal Provisions for Monitoring Sulphur Dioxide and Suspended Particulates in the Member States

State	National Air Quality Standards	EC Directive Limit Values Incorporated in National Legislation	Alert Systems Provided For
Belgium	✓	✓	✓
Denmark	✓	✓*	
France			✓
FR Germany	✓	✓**	✓
Greece			
Ireland			
Italy	✓	✓***	✓
Luxembourg			
Netherlands	✓		✓
United Kingdom			✓

* Annex IV limit values

** Annex IV limit values for suspended particulates

*** Annex I lower limit values for SO_2 nd Annex IV limit values for suspended particulates

TABLE 2. - Factors Taken into Account in the Network Design

	Population Density	Land Use	Emission Distribution	Emission Inventories	Past Results	Models	
						Dispersion	Statistical
Belgium	✓			✓	✓	✓	
Denmark				✓		✓	
France	✓	✓	✓		✓		✓
FR Germany	✓	✓	✓	✓	✓		
Greece							
Ireland	✓	✓		✓	✓	✓	
Italy	✓			✓	✓		
Luxembourg	✓			✓	✓	✓	
Netherlands					✓		✓
United Kingdom	✓	✓	✓		✓	✓	

TABLE 3. - Summary of Monitoring Networks Currently in Use in Member States‡

Member State	Number of Stations					
	Sulphur Dioxide			Suspended Particulates		
	Specific	Non-Specific		Black Smoke	Gravimetric	β-absorption
		Continuous	Bulk			
Belgium	72	-	200	200	-	-
Denmark	4	-	30	-	30	-
France	~100	~600	-	~300	?	-
FR Germany	250	-	-	13	60	180
Greece*	8	-	5	20	8	-
Ireland	-	-	40	40	-	-
Italy*	>21?	-	1	-	>10?	-
Luxembourg	-	-	12	12	-	-
Netherlands	85	-	-	20	-	-
United Kingdom	-	-	572	572	-	-

* Data from reference 3

‡ This table provides an update on the summary provided in reference 8.

TABLE 4. - Station Siting Criteria and Housing Requirements

	Siting Criteria			Housing Requirements		
	Obstacles	Nearby Sources	Inlet Height	Existing Buildings	Cabins	Enclosures
Belgium	✓	✓	3 m	✓	✓	
Denmark	>4 m		2.5 m			✓
France	✓	✓		✓		✓
FR Germany	>2 x Ht of Obstacle	>20 m	3-3.5 m	✓	✓	
Ireland			>2.5 m	✓		
Italy	✓		2-4 m		✓	
Luxembourg	✓	✓	1.5-2.5 m	✓		
Netherlands	✓	✓	3.8 m			✓
United Kingdom	✓	✓	2.5-10 m	✓		

TABLE 5. - Summary of Exceedances of Directive Limit Values in 1983/84**

Member State	No. of Derogation Zones	No. of Zones in Breach		No. of Stations in Breach	Limit Values Breached (Annex 1)***								
					Black Smoke			SO_2					
		Derogation	Non-Derogation		98%ile	MED+	WMD+	98%ile‡ L	98%ile‡ U	MED L	MED U	WMD L	WMD U
Belgium	0	0	1	2					2				
Denmark	0	0	0	0									
France	17	6	0	6				5		1			
FR Germany	1	1	0	18				18	1				
Greece	0			?									
Ireland	1	1	0	5	5								
Italy	2			?	?			?					
Luxembourg	2	1	0	1					1				
Netherlands	0*	0	0	0									
United Kingdom	29	6	0	12	10	1		1		2			

NOTES ‡ L = Lower limit value
U = Upper limit value

\+ MED = Annual Median, WMD = Winter Median

* Original list of zones withdrawn in March 1985

** This Table updates the information provided in reference 2

*** Exceedances of Annex IV limit values for suspended particulates were not reported.

TABLE 6a. - Summary of Results for 1983/84 from Stations Exceeding Limit Values and Monitoring Black Smoke*

Member State	Derogation Zone	Station Name	Black Smoke			SO$_2$		
			98%ile	MED	WMD	98%ile	MED	WMD
(A) Derogation Zones								
FRANCE	-Agglomeration parisienne	-Rue du Moulin, Vitry sur Seine				326	42	-
	-Lens							
	-Dunkerque	-Clinique psychiatrique, Saint Saulve				451	17	-
	-Agglomeration de Creil							
	-Carling							
	-Agglomeration de Strasbourg	-Rue de Gerstheim, Strasbourg-Neudorf				241	99	-
	-Thann							
	-Agglomeration de Montbelliard							
	-Agglomeration Lyonnaise							
	-Agglomeration grenoblaise							
	-Region de Fos l'Etang-de-Berre							
	-Agglomeration marseillaise	-Mairie de Bouc Bel Air				315	58	-
	-Vivies							
	-Lacq							
	-Zone de Chevire-Donges							
	-Agglomeration rouennaise	-Mairie de Nitre Dame de Gravenchon				418	40	-
	-Zone du Havre	-TDF de Craucriaville				358	20	-
IRELAND	-Dublin	-Dame Street	260	47		114	54	
		-Rathmines	326	37		174	48	
		-Ballyfermot	447	60		143	49	
		-Cornmarket	296	34		153	70	
		-Cabra West	262	46		97	40	
LUXEMBOURG	-Colmar-Berg		55	17	25	642	82	131
	-Contern							
UNITED KINGDOM	-Allerdale							
	-Barnsley	-Goldthorpe 1	309	71	95	240	81	85
		-Grimethorpe 1	329	46	87	195	72	80
		-Wombwell 2	269	42	85	178	59	70
	-Bassetlaw							
	-Blyth Valley							
	-Bradford							
	-Bolsover							
	-Cannock Chase							
	-Castle Morpeth							
	-Chesterfield							
	-Copeland							
	-Crew & Nantwich							
	-Doncaster	-Askern 6	291	42	55	222	74	72
		-Doncaster 27	151	25	32	254	97	115
		-Doncaster 32	359	81	111	221	78	95
		-Moorends 1	273	76	109	188	67	82
	-Kirklees							
	-Mansfield	-M.Woodhouse 2	244	46	87	199	82	87
	-Newark							
	-Newcastle-under-Lyme							
	-Nottingham							
	-Rotherham							
	-Staffordshire Moorlands							
	-Sunderland	-Sunderland 8	321	47	88	194	52	62
	-Wakefield	-Castleford 9	286	41	65	243	60	100
	-Wansbeck	-Ashington 4	329	56	104	155	68	57
	-Cunningham							
	-Falkirk							
	-Glasgow							
	-Strathkelvin							
	-Belfast							
	-Londonderry							
	-Newry & Mourne							
(B) Non Derogation Zones								
BELGIUM	-Gent	-714/R721	102	14	24	353	28	37
		-703/R731	102	18	22	354	33	44

* Statistics which exceed the limit values are underlined.

TABLE 6b. - Summary of Results for 1983/84 from Stations Exceeding Limit Values and Monitoring Suspended Particulates**

Member State	Derogation Zone	Station Number/Name	Suspended Particulates		SO$_2$	
			98%ile	AM	98%ile	MED
FR GERMANY	-West Berlin	- 3			277	41
		5			307	64
		6			307	57
		7			259	40
		8			286	49
		9			287	52
		10			324	60
		11			428	73
		14			317	57
		15			274	61
		16			308	71
		17			307	59
		18			267	59
		19			267	59
		20			254	57
		22			264	47
		23			277	55
		24			277	54
ITALY	-Region of Venice					
	-Region of Lombardy	-MILAN*				
		-Sempione			440	77
		-Marche	250	124	540	69
		-Lattanzio			420	51
		-Juvaro	300	135	520	69
		-Zavattari			440	85
		-Niguarda			370	48
		-Brera			690	91
		-Sesto Comune			440	61
		-Sesto Asilio			440	48
		-Monza			400	64
		-Villasanta			300	43
		-Magenta			290	32
		-Pioltello			380	48
		-Cormano			450	61
		-Cassina de Pacchi			290	40
		-Villasanta CS			310	45
		-Villasanta Raffineria			300	48
		-Terrazzano			340	51
		-Baranzate			460	67
		-Pero			430	75
		-Cesano Nord			290	51

* Results for Milan only given. Results presented refer to calendar year 1983 for stations reported as exceeding the Italian air quality standards in the period 1/4/83 to 31/3/84[11].

** Statistics which exceed the limit values are underlined.

TABLE 7. - Results for Rouen (units = $\mu g\ m^{-3}$)

	1979	1980	1981	1982	1983 (10 months)	1983 (Estimate)
Strong Acidity	83	70	47	48	37	40
Black Smoke	37	25	27	27	17	20

TABLE 8. - Logging Intervals and Minimum Requirements for Calculation of Period Averages

State	Logging Intervals	Minimum Requirements (Proportions)		
		½-Hour Average	1-Hour Average	24-Hour Average
BELGIUM	1 min	0.70		0.75
FRANCE	15 min		0.75	0.75
FR GERMANY				
-Bayern	5 sec	0.66		0.66
-Berlin	3 min	0.30		0.75
-Hamburg	3 min	0.50		0.50
-NRW	1 min	0.66		0.66
ITALY				
-Milan	1 min	0.66		0.83
NETHERLANDS	1 min		0.75	0.54

TABLE 9. - Network Densities in Selected Towns

Town		No. of Stations	Area Covered km^2	Density km^2	Typical Interstation Distance* km
Berlin	(central)	31	480	15.5	4
Doncaster		14	500	36	6
"	(central)	11	240	22	4.5
Gent		26	360	14	3.5
"	(central)	19	120	6.3	2.5
Milan		48	3000	62	8
"	(central)	9	65	7.2	3
Rijnmond		45	3200	71	8.5
"	(central)	37	600	16.2	4
Rouen		20	300	15.5	4
"	(central)	17	125	7.5	3
Average of 6 Central Networks		124	1630	13.1	3.5
Average of 6 Full Networks		184	7840	42.6	6.5

* defined as square root of density, to the nearest 0.5 km.

TABLE 10. - Rank Position i for Determination of 98-Percentile

Sample Size N	Formula 1	Formula 2	Formula 3	9th Highest Result
365	8	8	7/8	8
360	8	8	7/8	8
350	7	8	6/7	8
330	7	8	6/7	8
310	7	7	6/7	8
290	6	7	5/6	8
210	5	5	4/5	8
170	4	4	3/4	8
130	3	4	2/3	8
90	2	3	1/2	8
50	1	2	1/2	8

The number given for the Formula 3 method are the lower and upper positions between which the 98-percentile is interpolated.

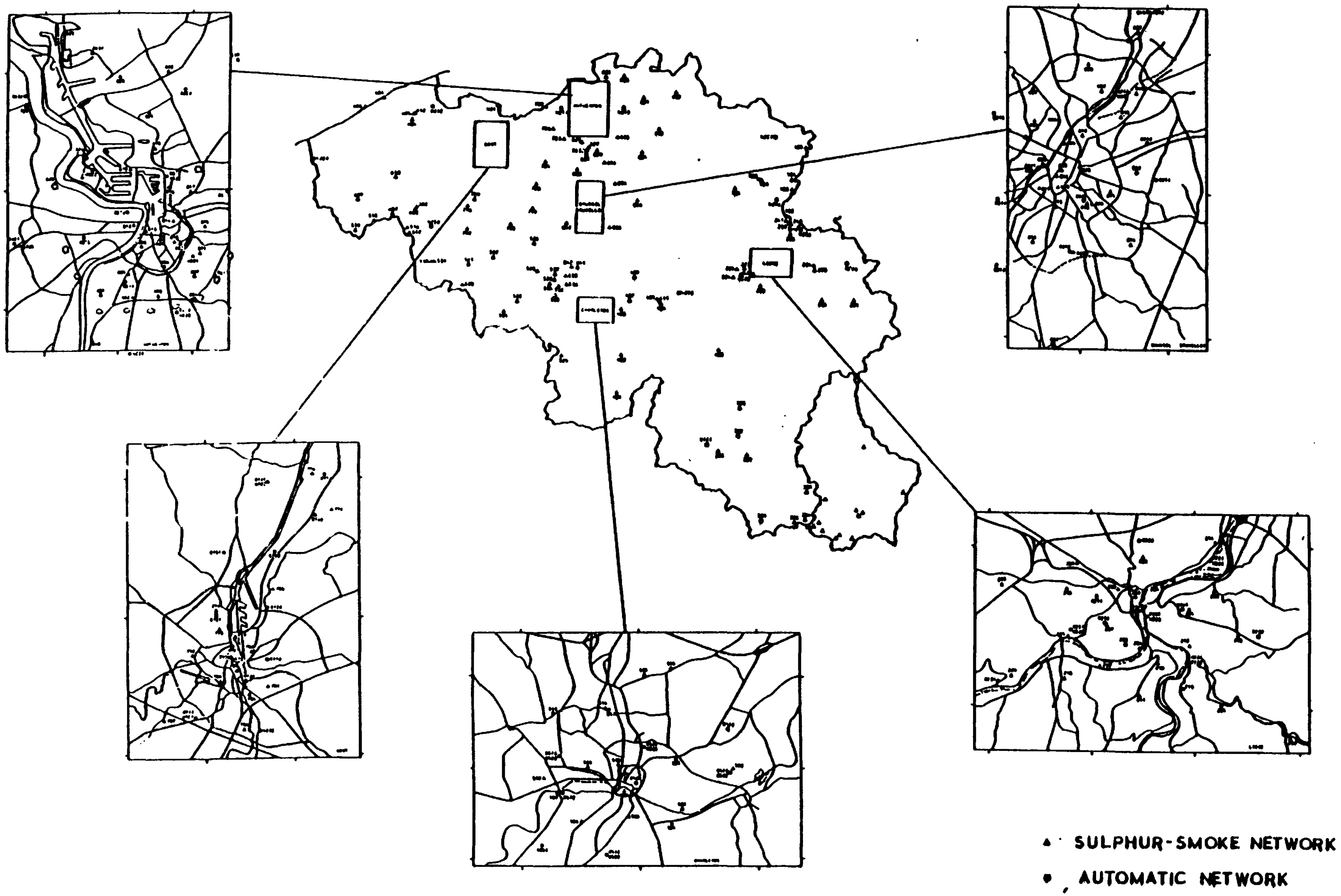

FIG. 1 MONITORING STATIONS IN BELGIUM AND LUXEMBOURG

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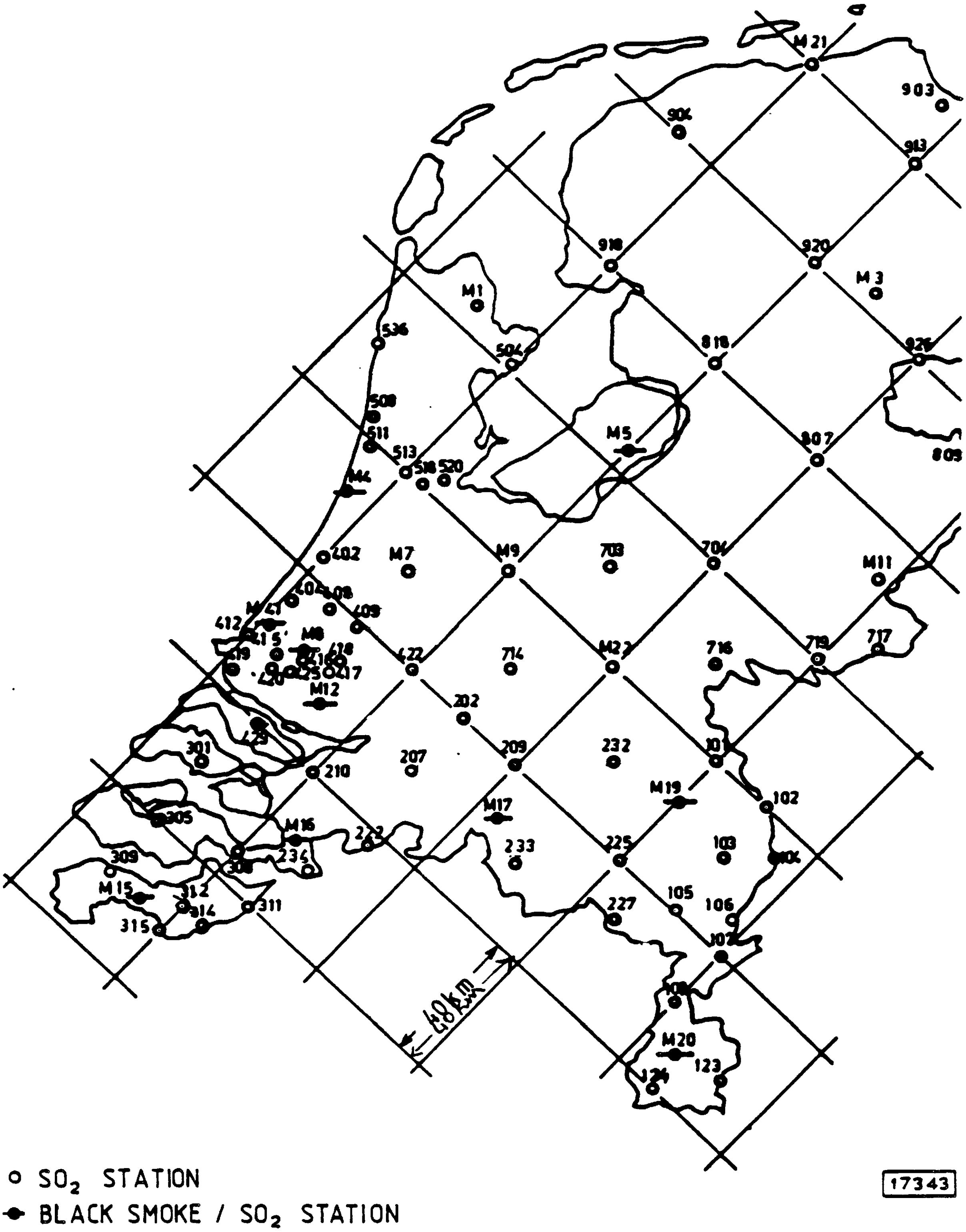

FIG. 2 NEW DUTCH NATIONAL NETWORK

17344

FIG.3 UK BASIC URBAN NETWORK

17345

FIG. 4 UK EC DIRECTIVE SURVEY

17346

FIG.5 NETHERLANDS. OLD NATIONAL NETWORK

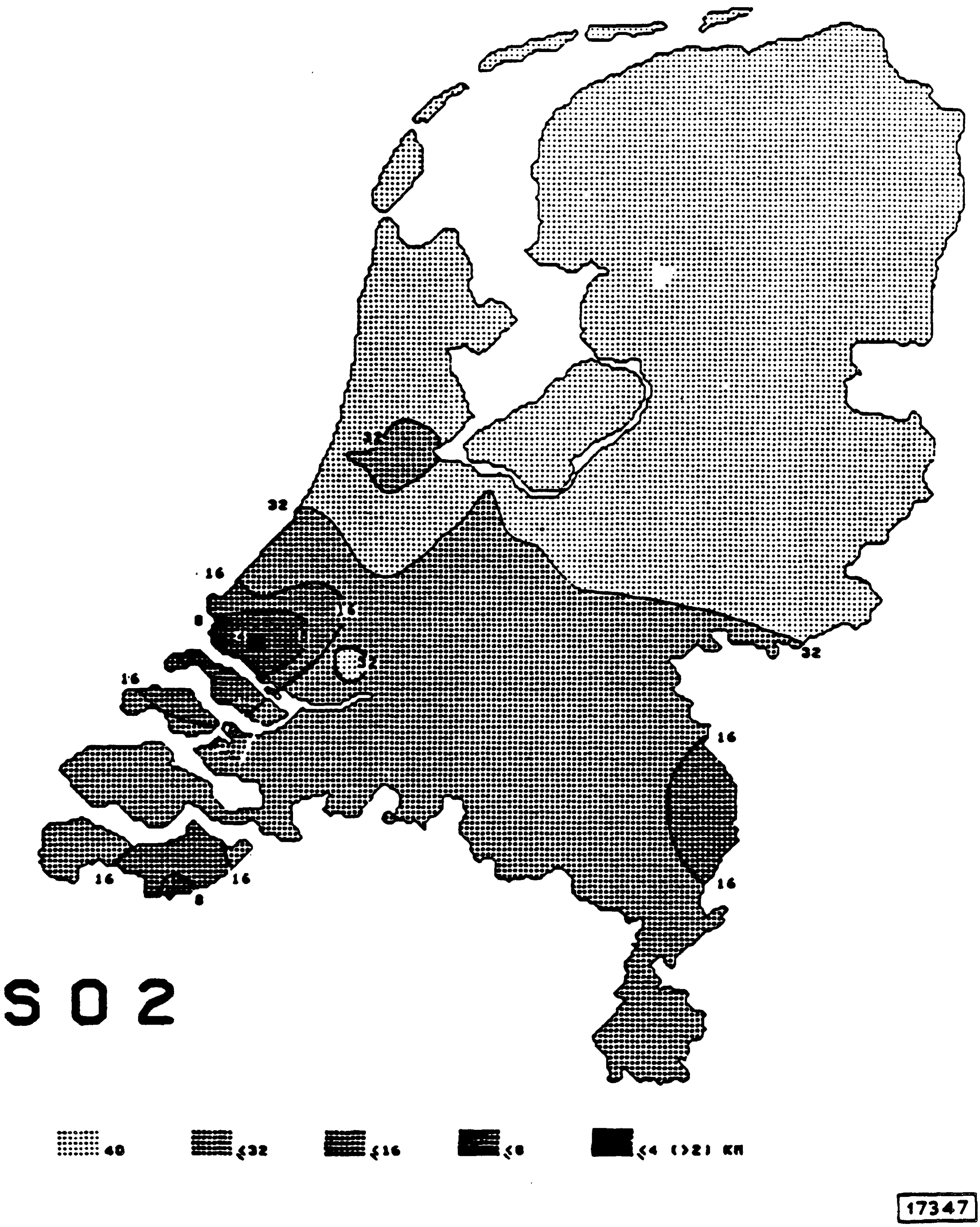

FIG. 6 NETHERLANDS. INTERSTATION DISTANCES x_0 , REQUIRED FOR A STANDARD ERROR OF 15% IN RECONSTRUCTED 98-PERCENTILE 24h SO_2 CONCENTRATIONS

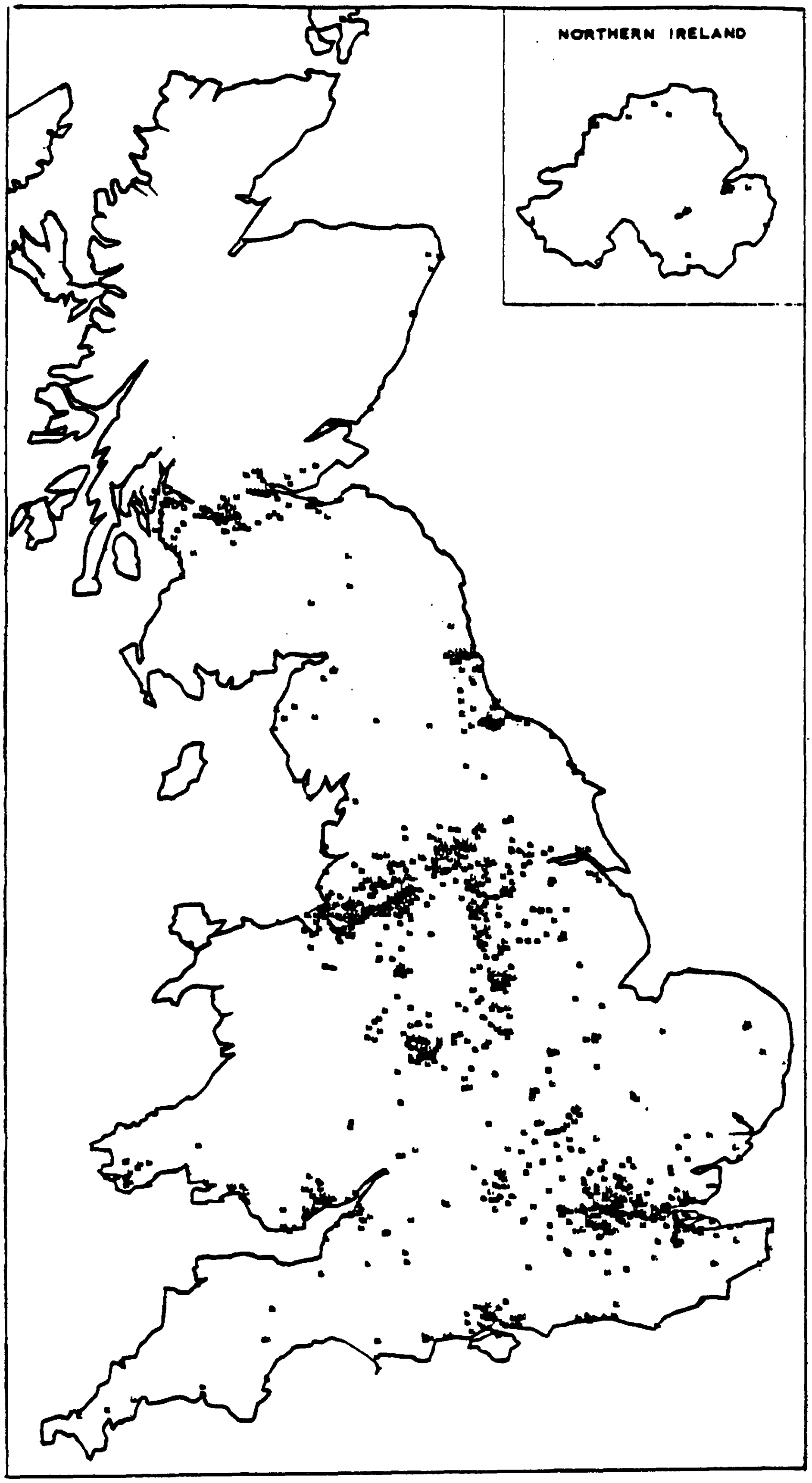

FIG.7 UK NATIONAL SURVEY, 1981/82

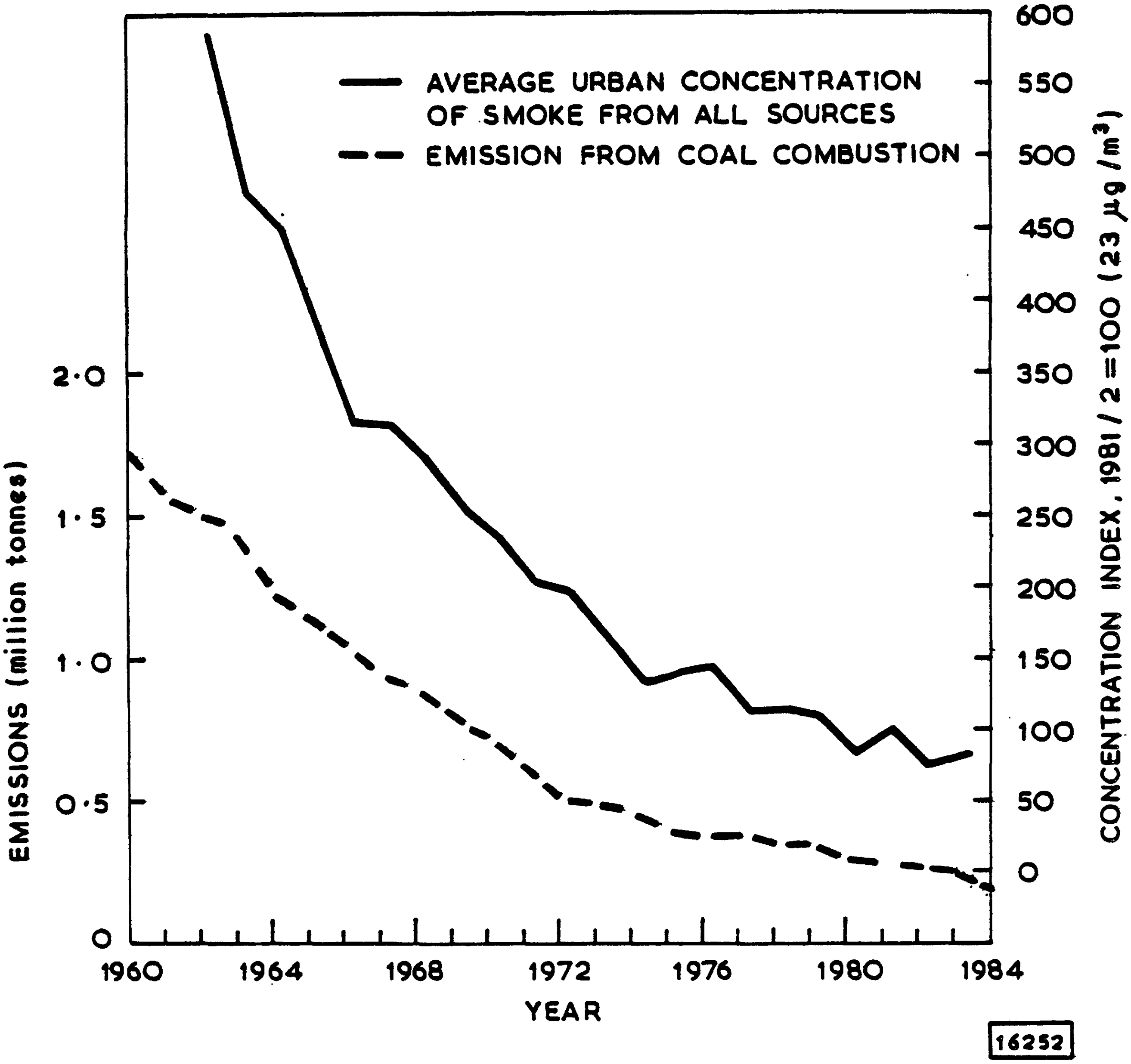

FIG.8 SMOKE: EMISSIONS FROM COAL COMBUSTION AND AVERAGE URBAN CONCENTRATIONS

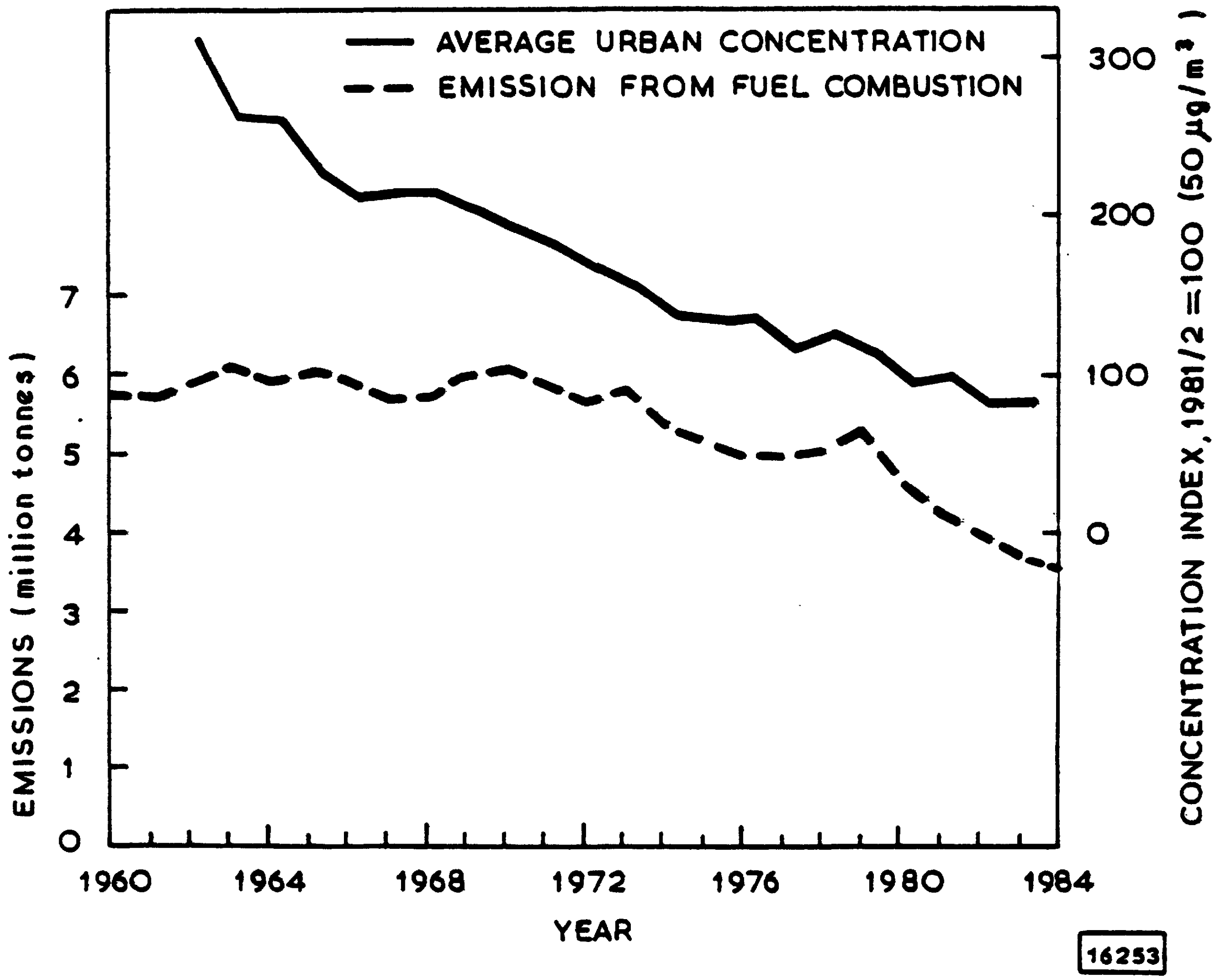

FIG. 9 SULPHUR DIOXIDE: EMISSIONS FROM FUEL COMBUSTION AND AVERAGE URBAN CONCENTRATIONS

EVOLUTION OF THE SO_2 GAS EMISSION AND THE LEVELS OF STRONG ACIDITY DURING AN ALARM

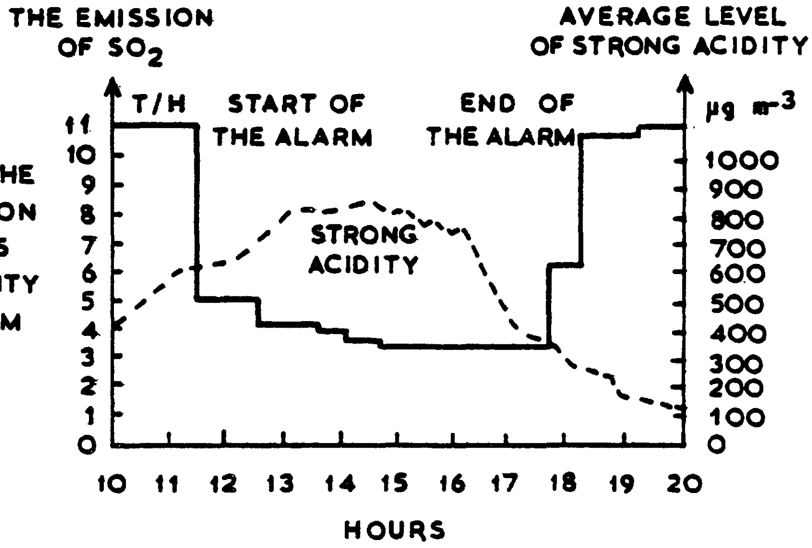

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FIG. 10 ALARM OF 18-1-1980 IN ROUEN

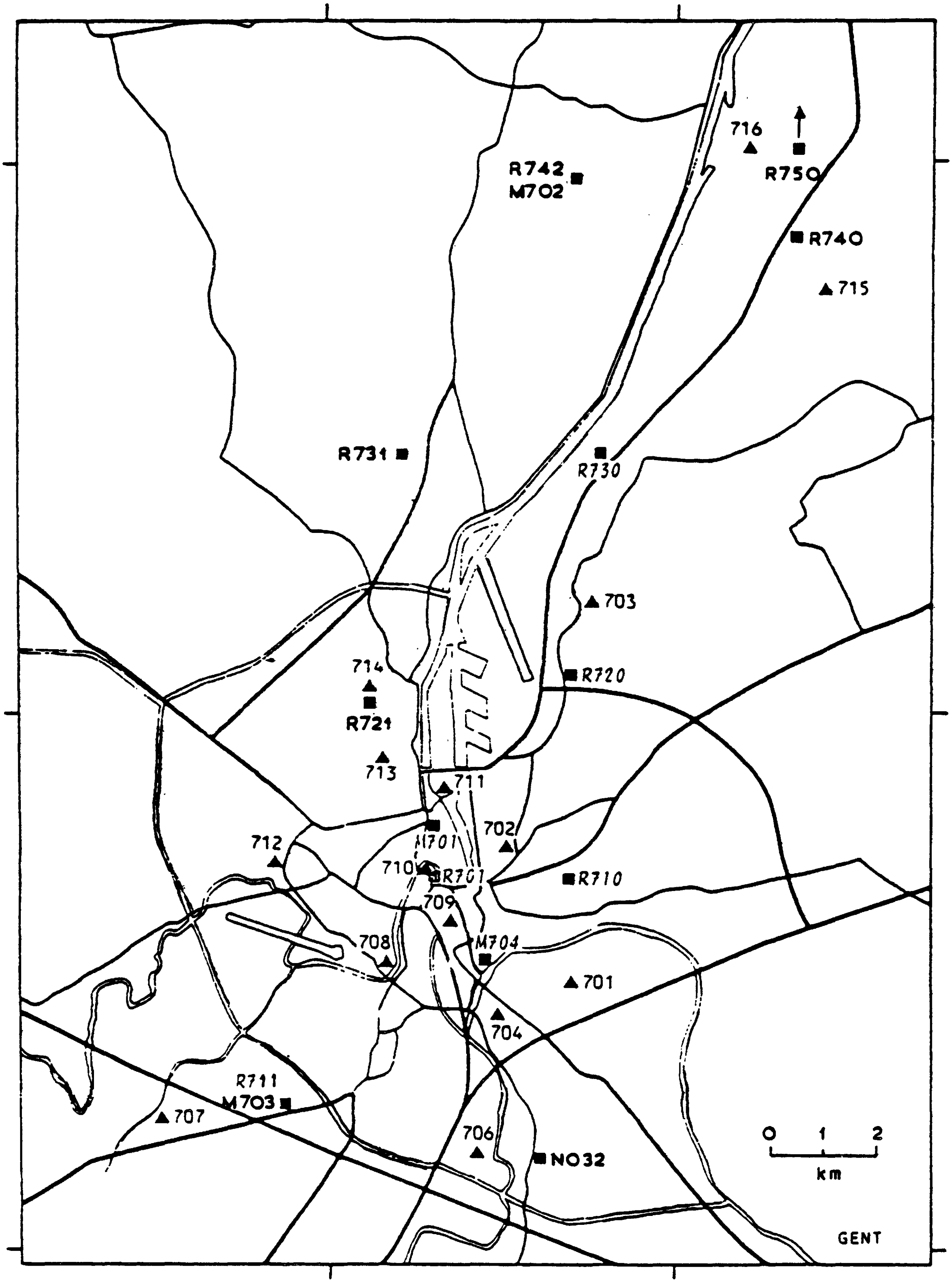

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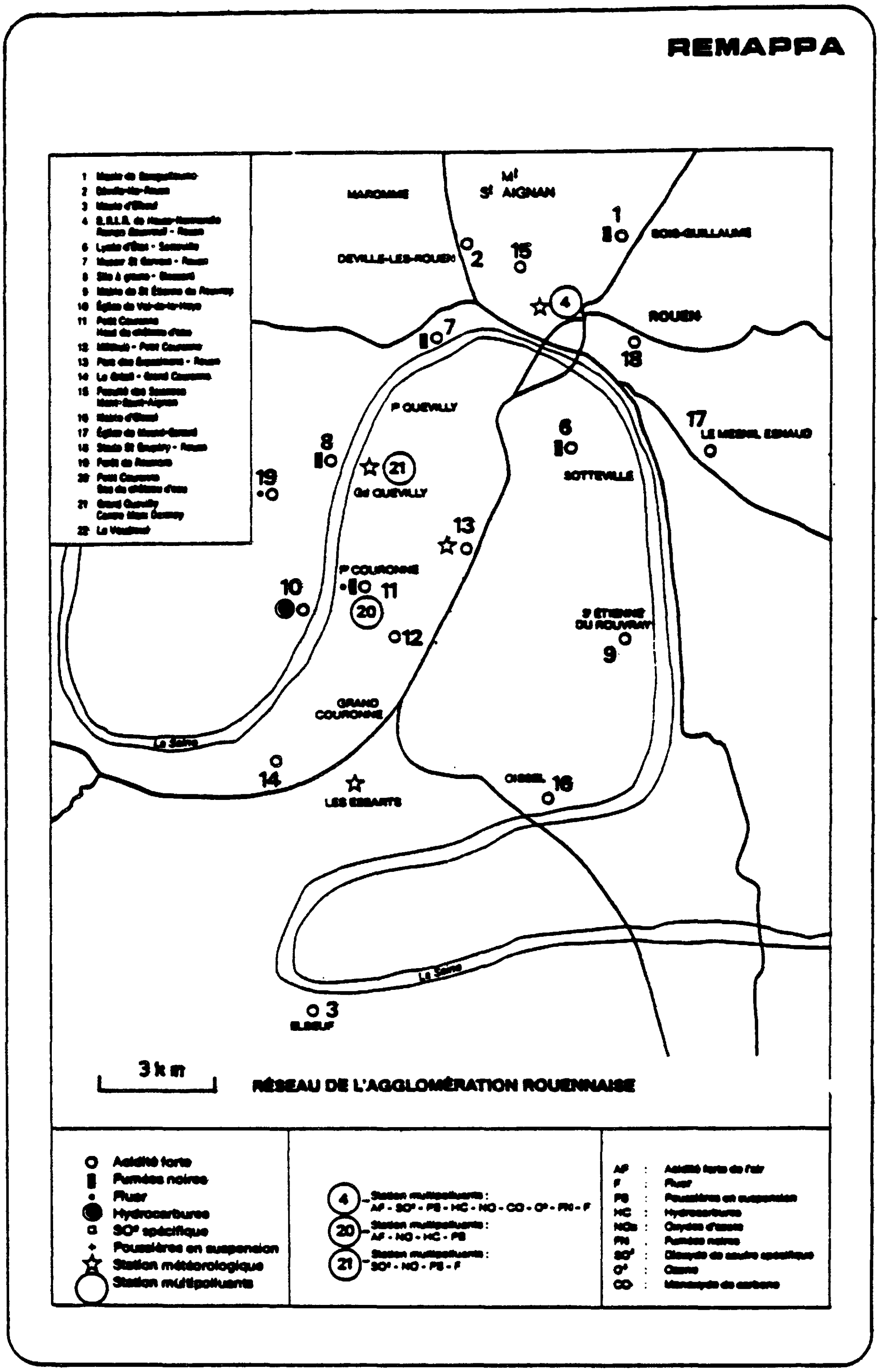
FIG.11 BELGIUM. NETWORK AROUND GENT



17351

FIG.12 FRANCE. NETWORK AROUND ROUEN

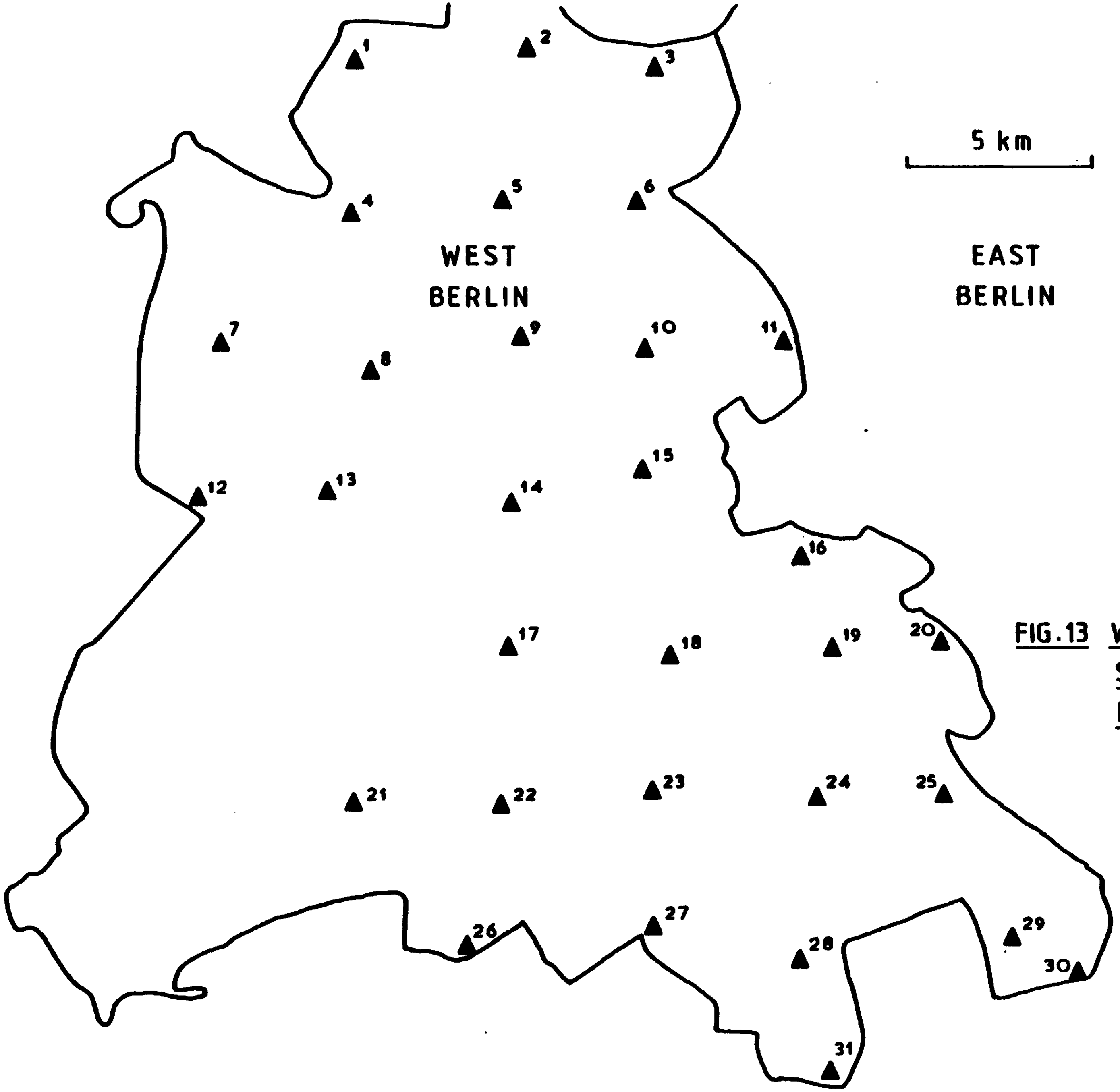


FIG.13 WEST BERLIN: SO_2 MONITORING NETWORK, 1984

17352

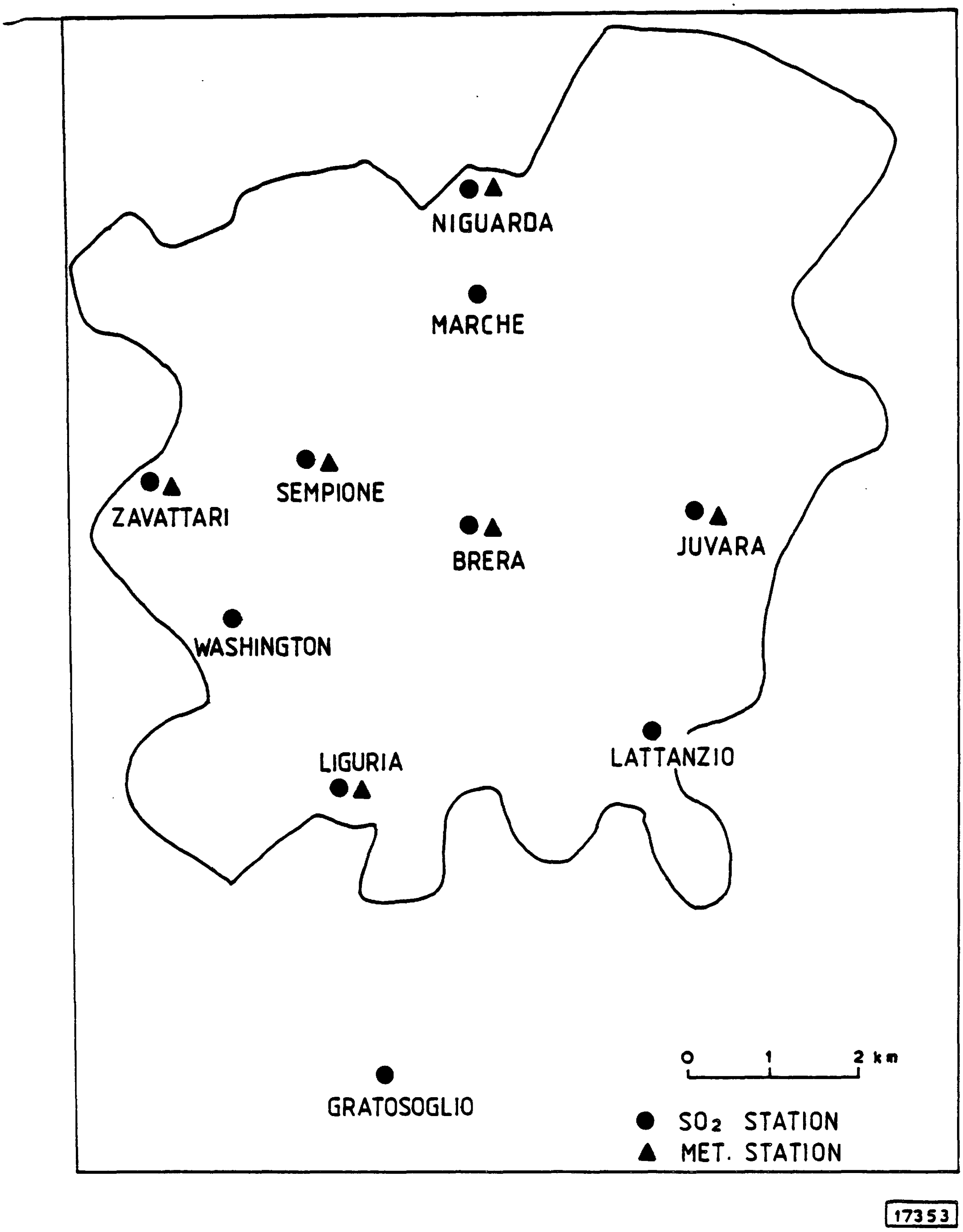


FIG. 14 ITALY. NETWORK AROUND MILAN

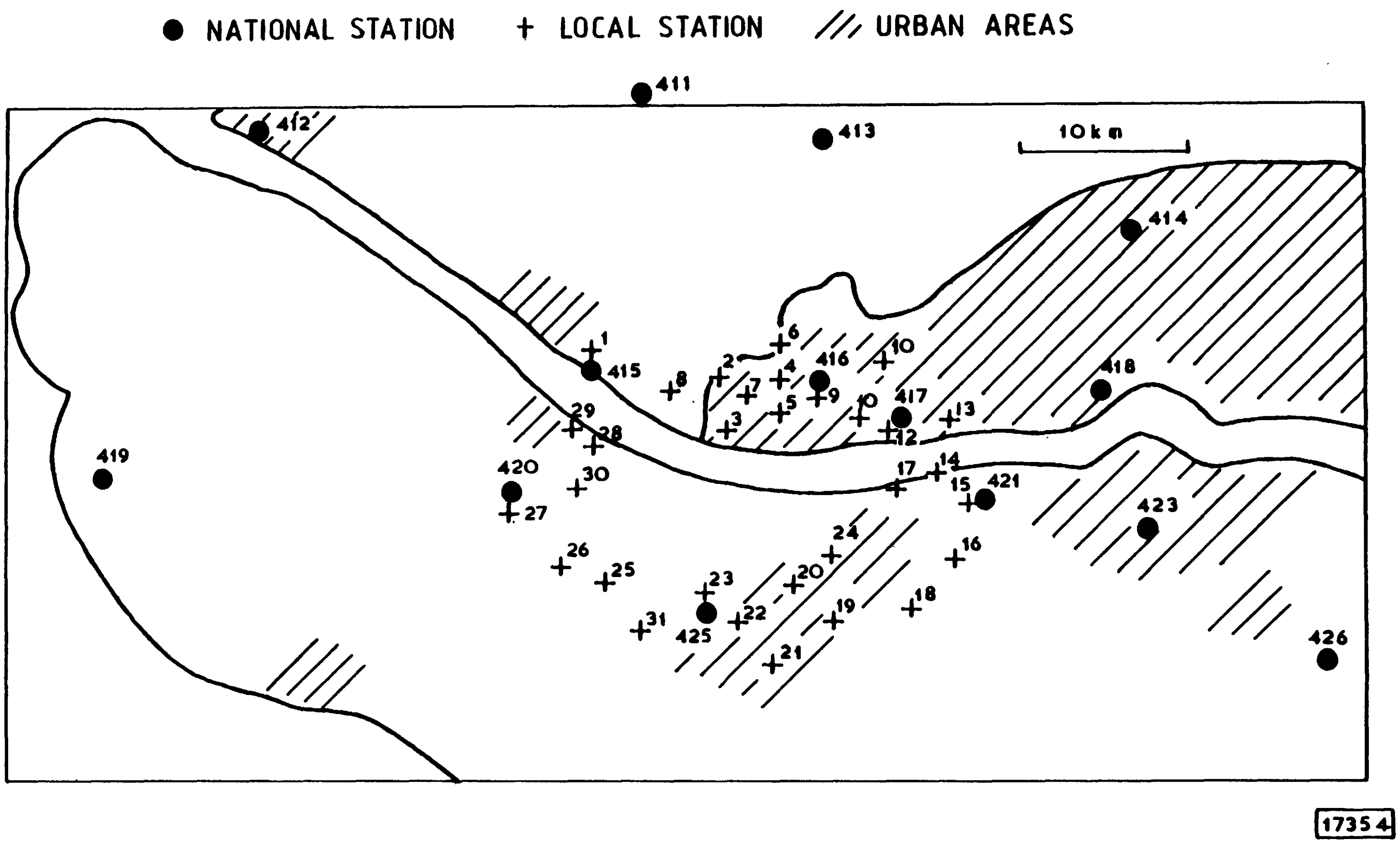


FIG. 15 NETHERLANDS. RIJNMOND AREA AUTOMATIC SO_2 MONITORING STATIONS 1984

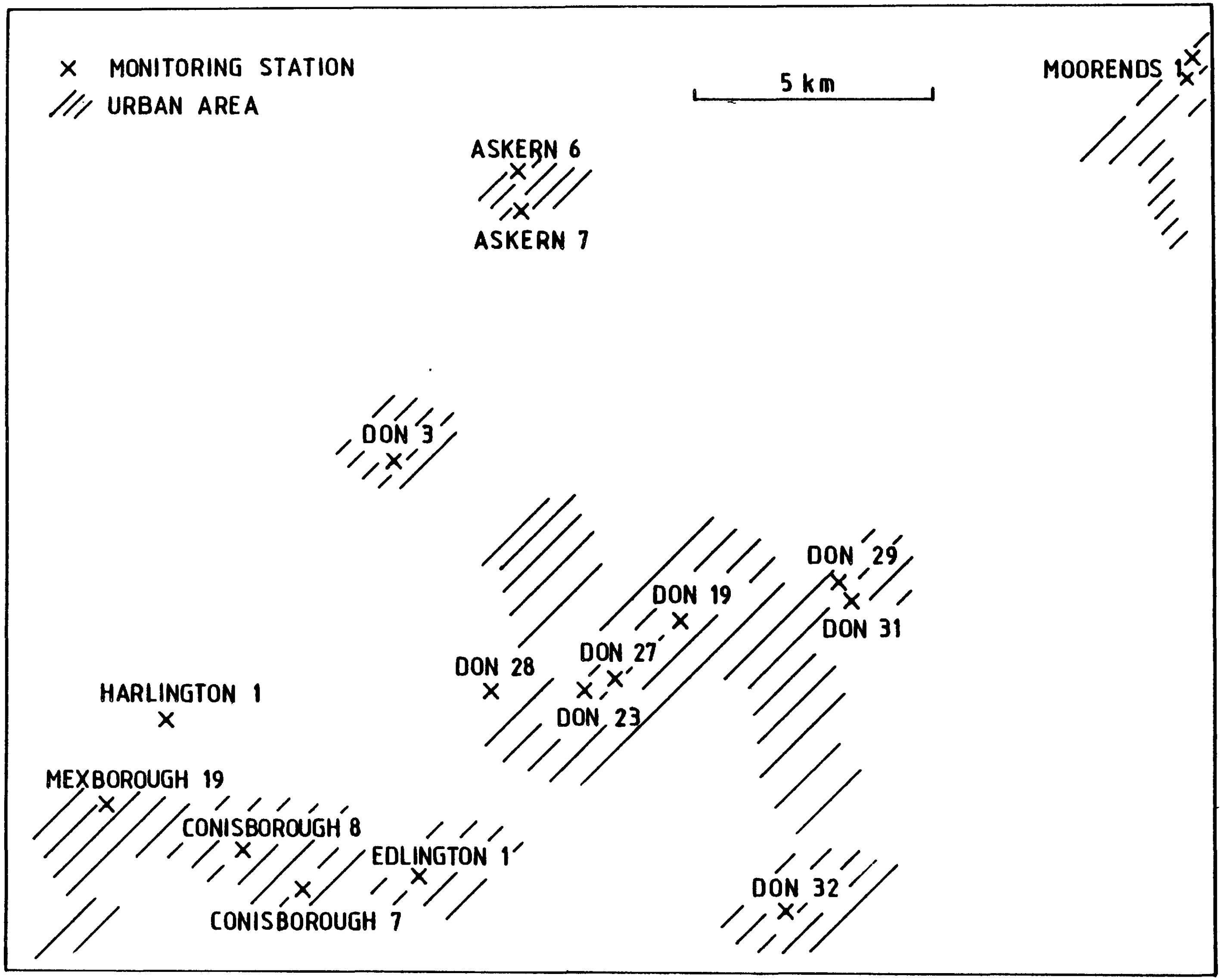


FIG. 16 UNITED KINGDOM. DONCASTER SMOKE / SO_2 STATIONS, 1984/85

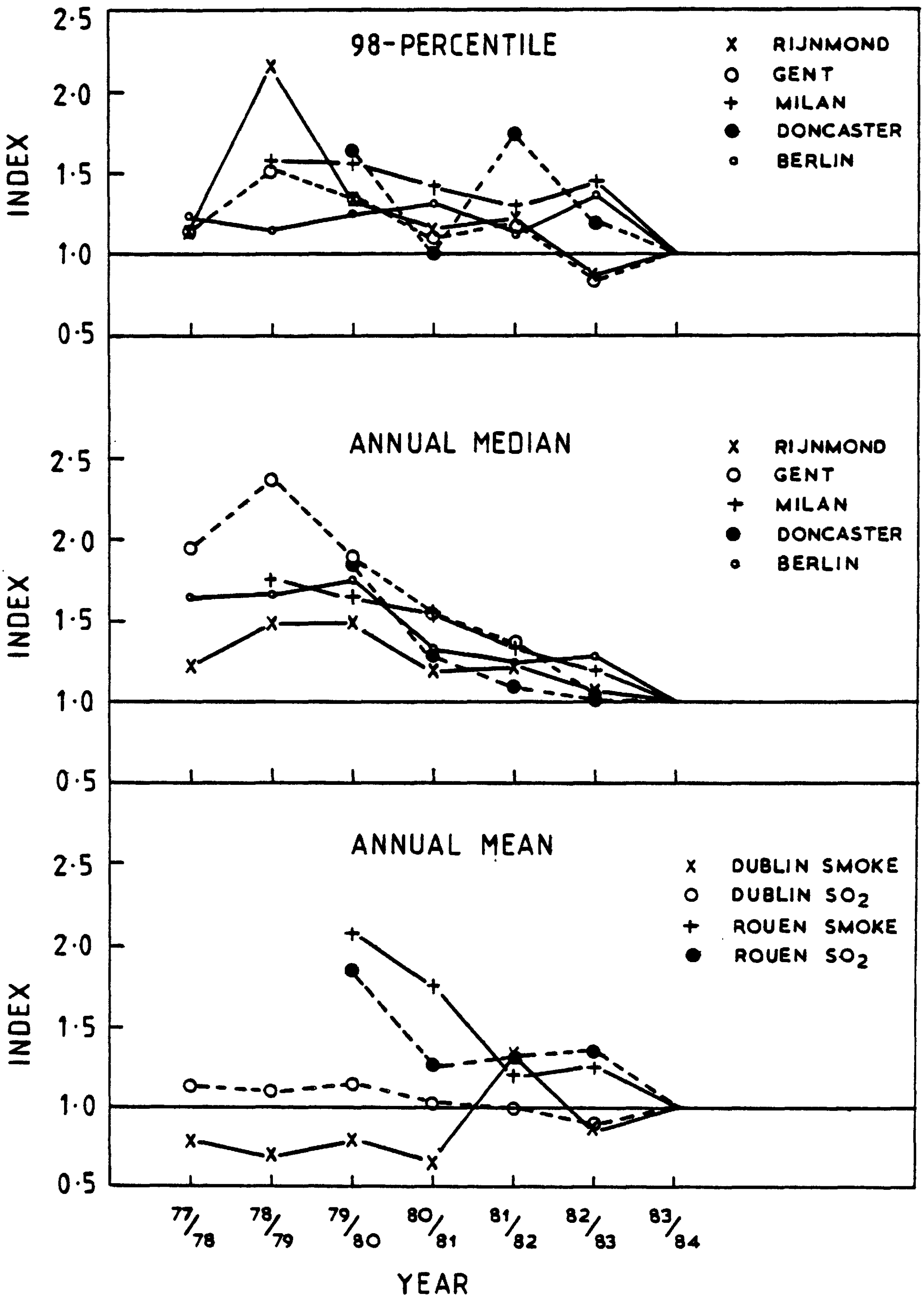


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FIG.17 INDEXED TRENDS FOR SELECTED NETWORKS

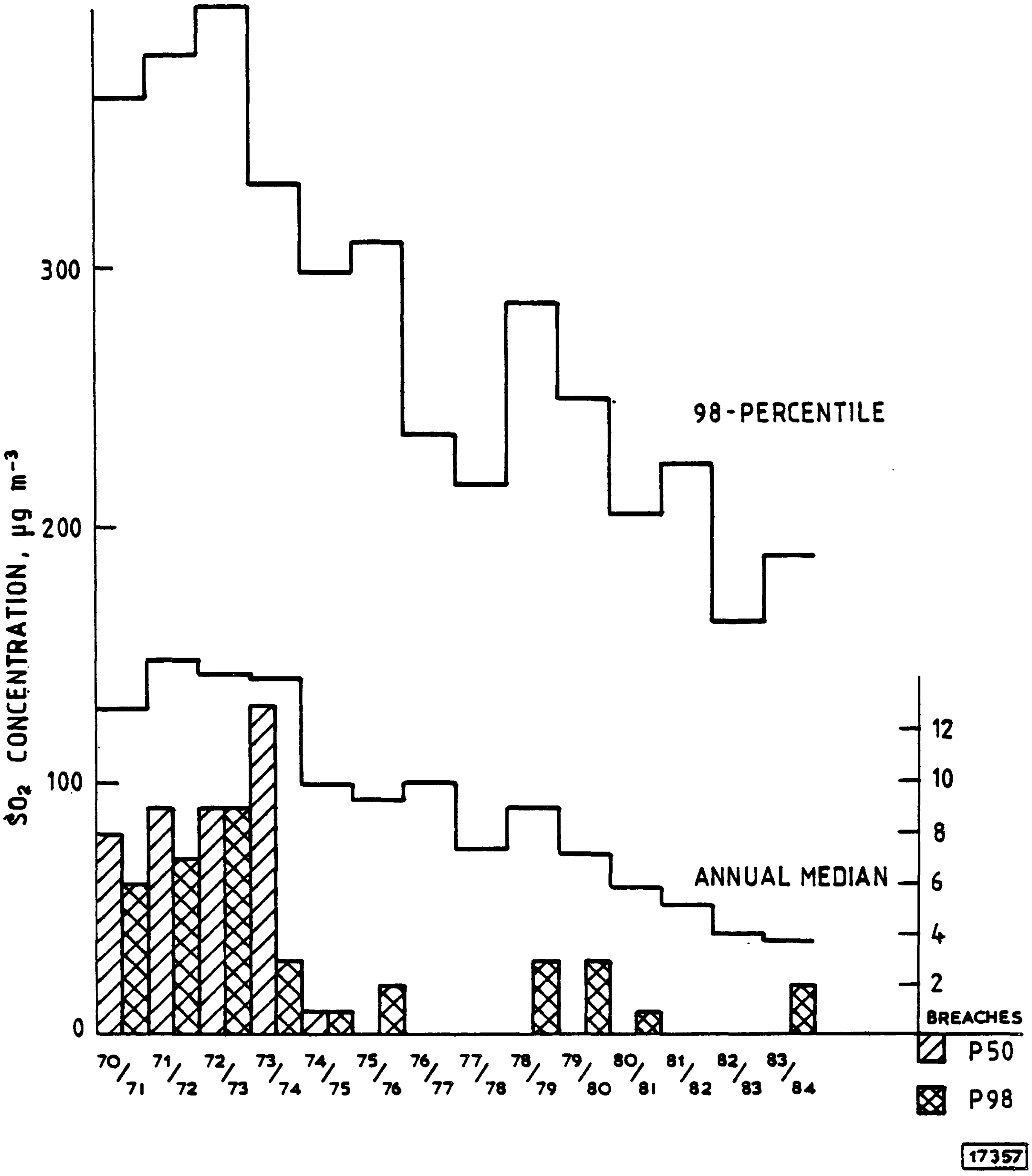

FIG. 18 GENT NETWORK. TRENDS IN MEDIANS AND 98 PERCENTILES

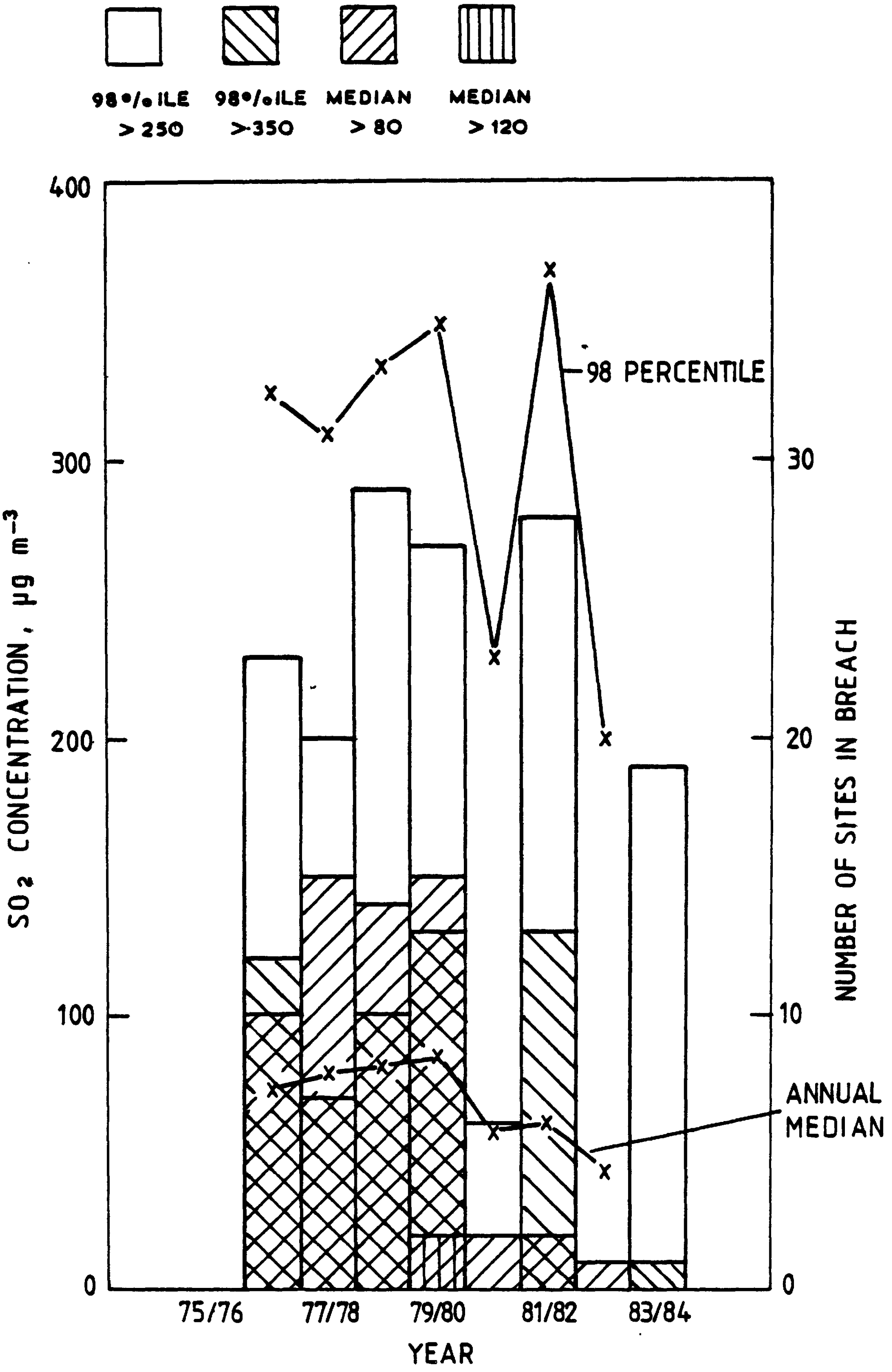

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FIG. 19 BERLIN. ANNUAL NETWORK AVERAGES FOR ANNUAL MEDIANS AND 98 PERCENTILES

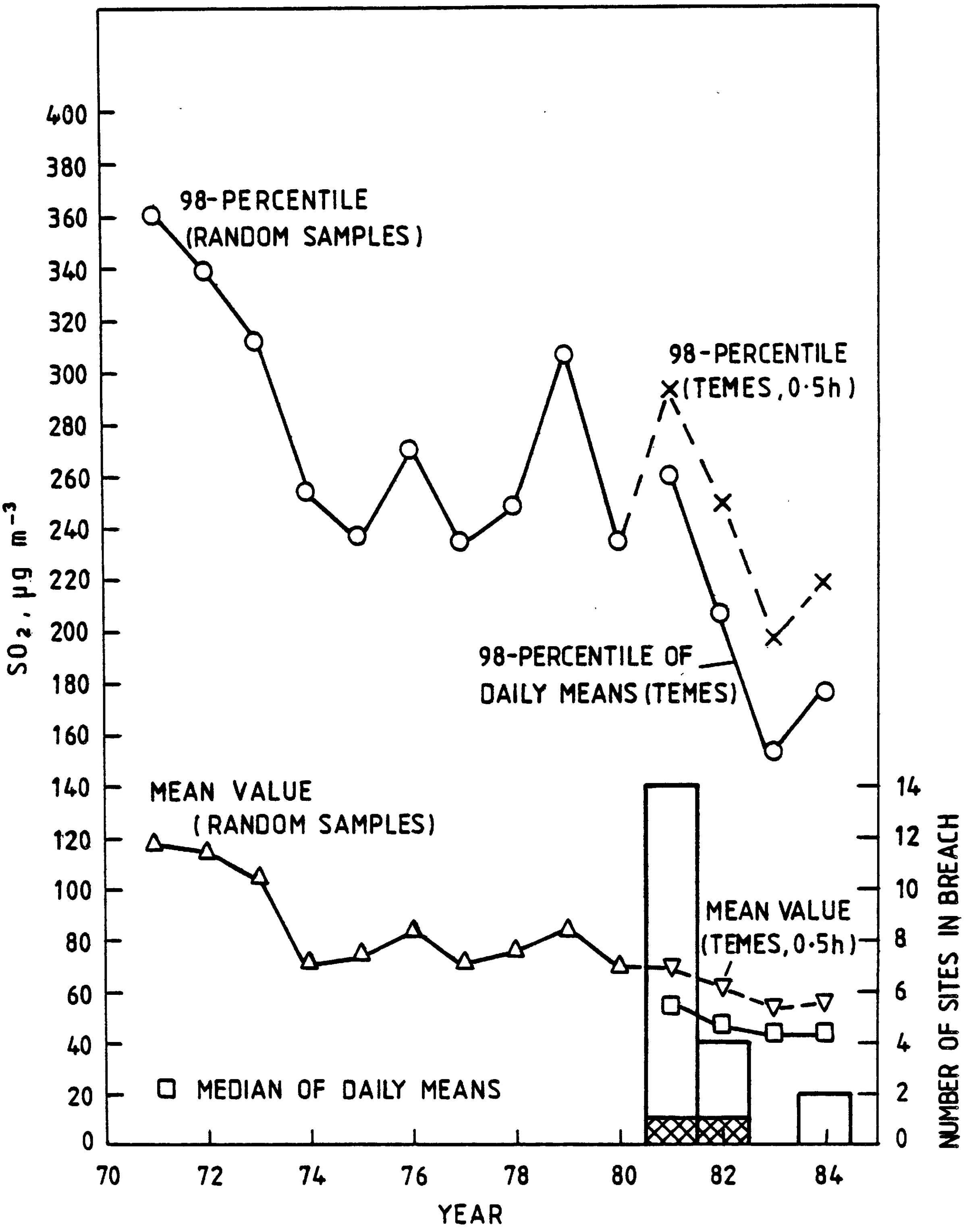

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FIG. 20 NRW - ANNUAL NETWORK AVERAGES

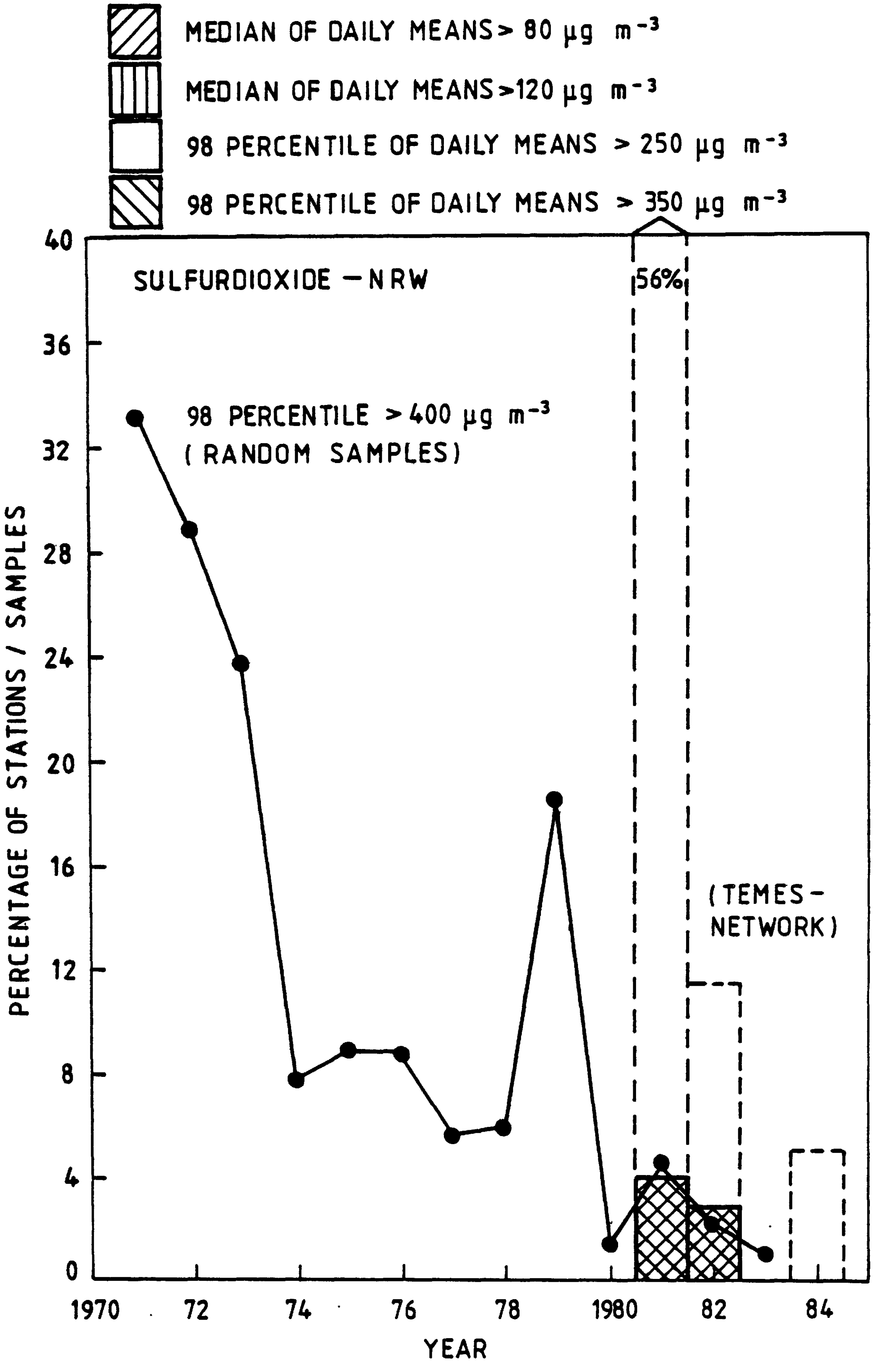

FIG. 21 NRW: TREND IN 98 PERCENTILE EXCEEDANCES

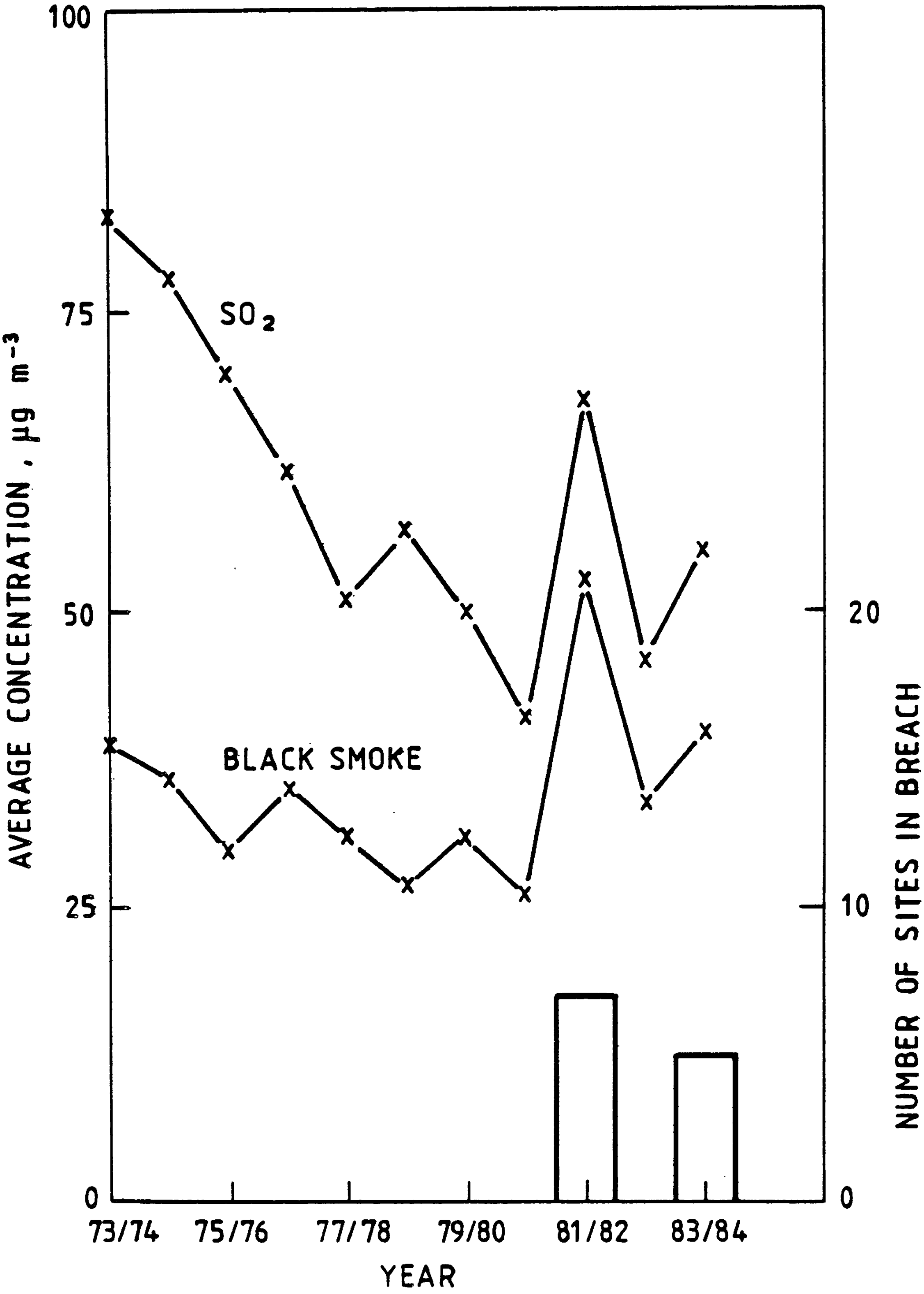

FIG. 22 DUBLIN: ANNUAL NETWORK AVERAGES

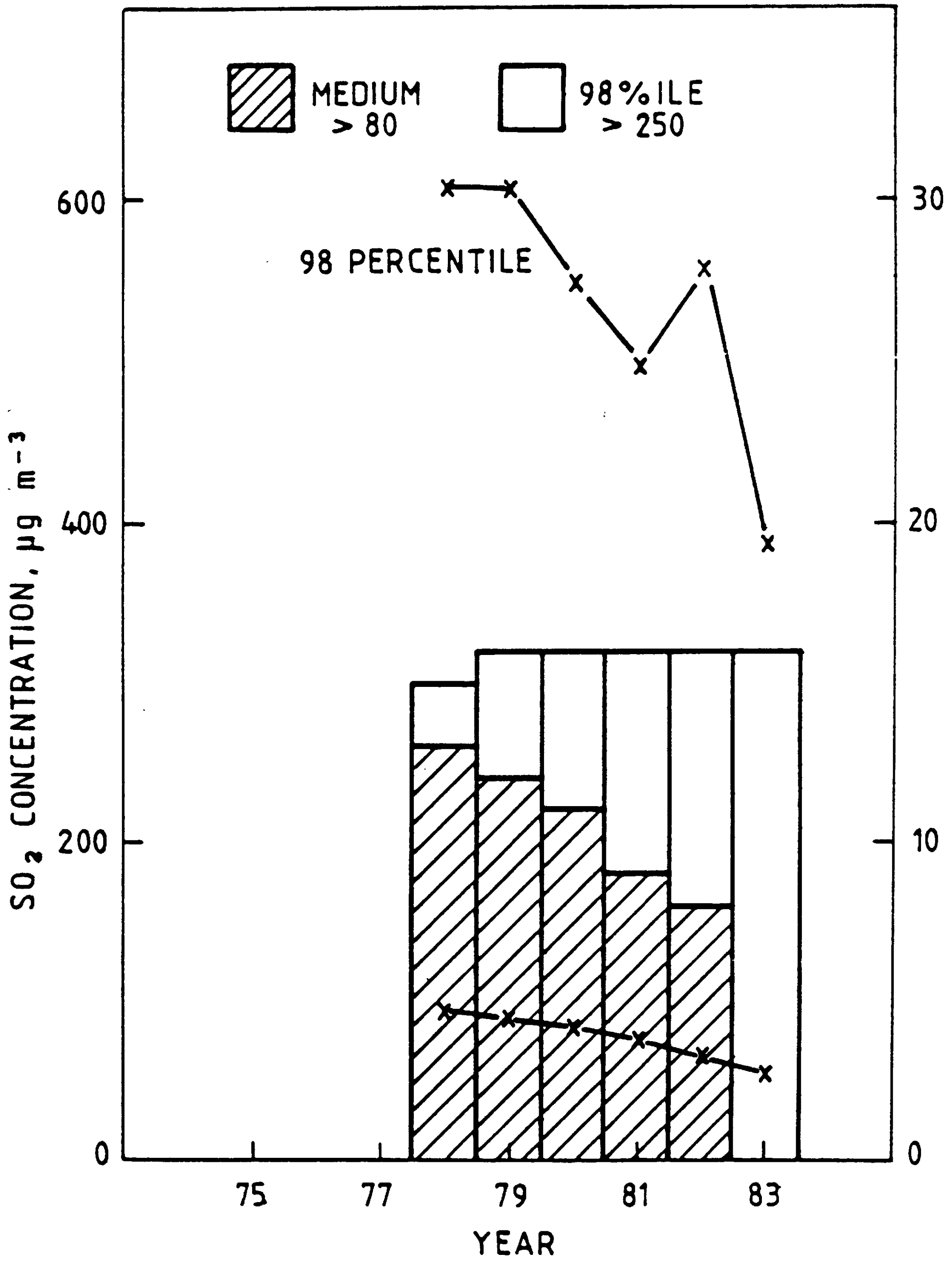

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FIG. 23 MILAN: 17-SITES ANNUAL AVERAGES

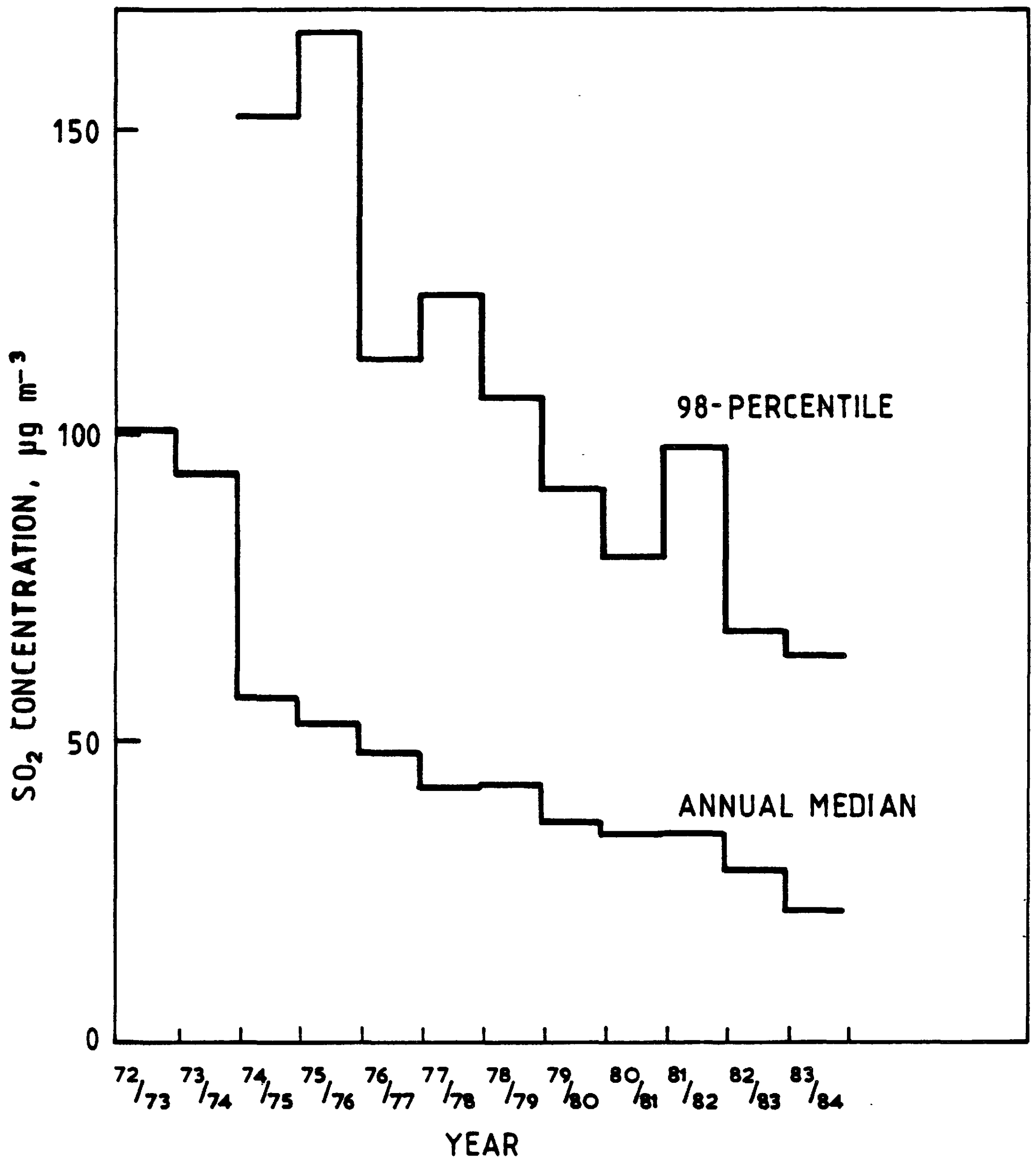

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FIG. 24 LUXEMBOURG ANNUAL NETWORK AVERAGES

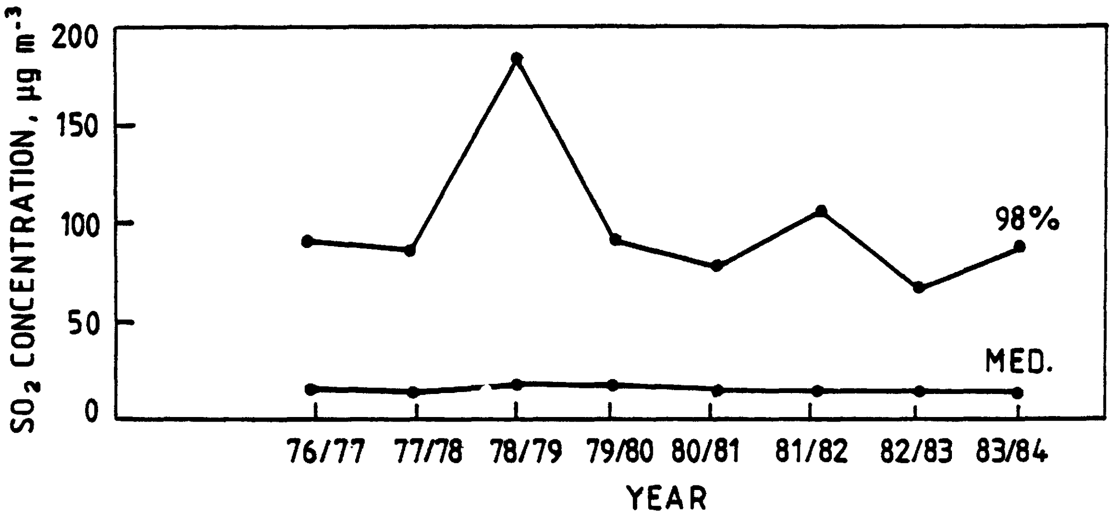

FIG. 25 NETHERLANDS FULL NATIONAL NETWORK

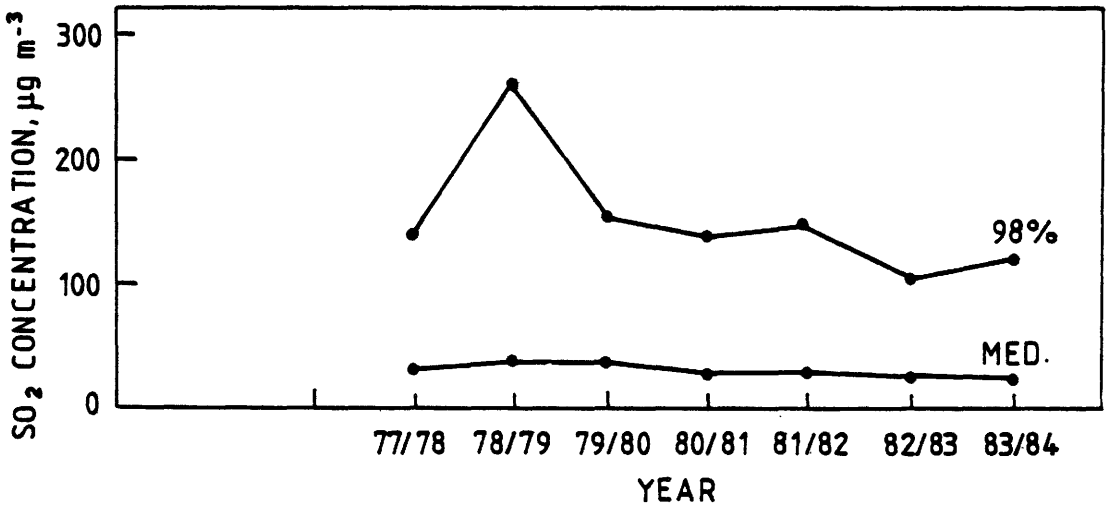

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FIG. 26 NETHERLANDS. RIJNMOND AREA OF NATIONAL NETWORK

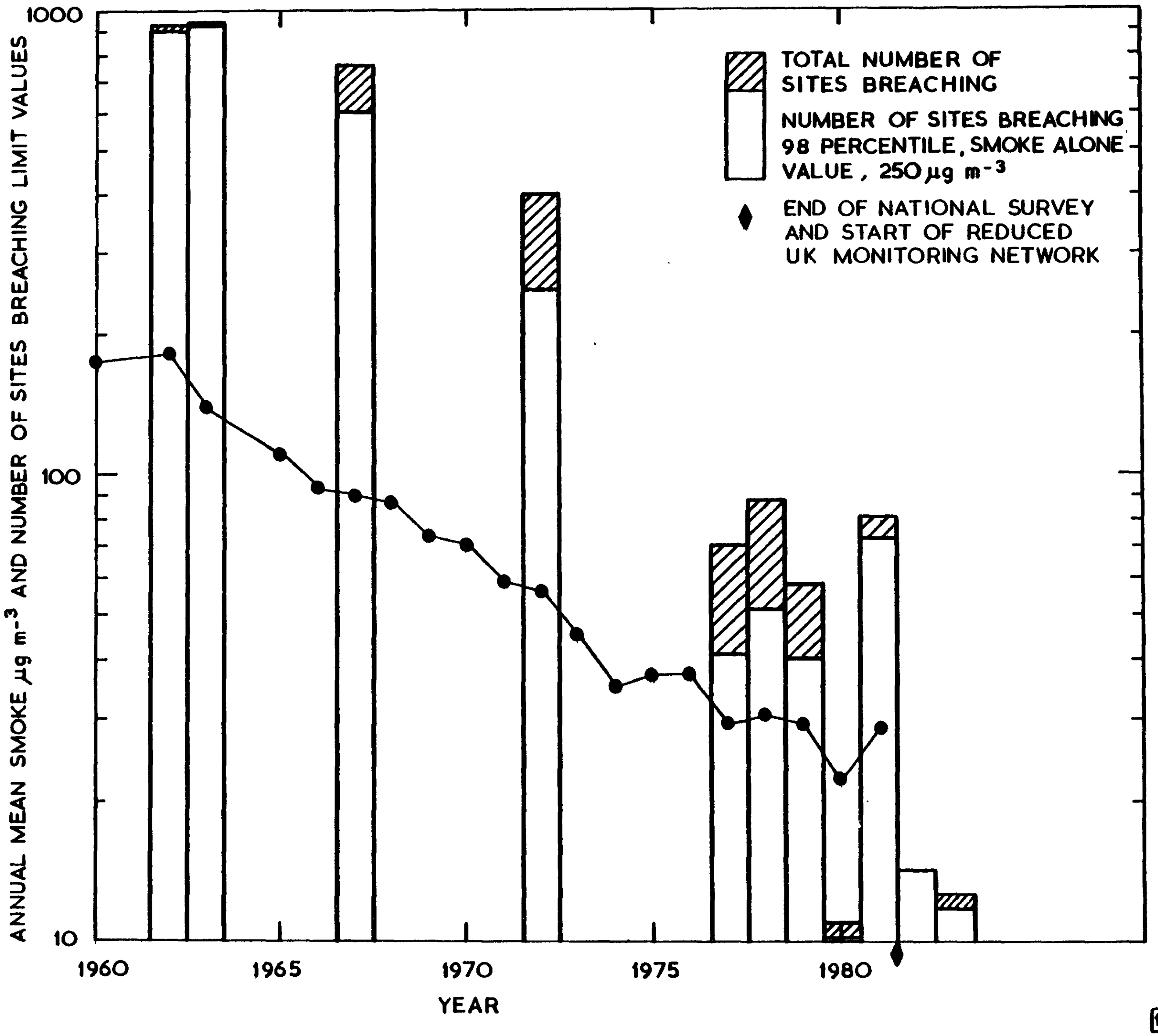

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FIG.27 UNITED KINGDOM ANNUAL NETWORK AVERAGES FOR BLACK SMOKE

PROFORMAS FOR REPORTING EXCEEDANCES OF LIMIT VALUES TO THE COMMISSION

TABLE 1: Proforma

to inform the Commission according to article 10(2) of the Directive 80/779/EEC of instances in which the limit values of Annex IV have been exceeded

---

1. Name of Member state:

2. Organisation responsible for measurements:

Sulphur dioxide

3. Name of the area:

Code number (where appropriate):

4. Location of the stations, addresses:

5. Instrument/method used:

6. Distance to next SO_2-subarea monitored: (km)

7. Distance to next SPM station: (km)

8. Duration of sampling: (min)

9. Periods longer than one month in which no random sampling at one of the indicated 16 subpoints were carried out (please give dates, from, to, No of days):

10. Distances between the grid-points: a to b (km)

a to c (km)

c to d (km)

b to d (km)

Suspended particulates

11. Name of the station:

Code Number (where appropriate):

12. Location of the station, address:

TABLE 1 (contd)

13. Instrument/method used:

(indicate also type and size of filters used)

14. Distance to next SPM-station: (km)

SO_2-subarea monitored: (km)

15. Duration of sampling: (h,min)

16. Starting time of sampling periods: hrs

17. Periods longer than 5 consecutive days in which the station was not operating: (please give dates, from, to, No of days)

A2

TABLE A

Measured values for sub-area ...

Values for sulphur dioxide expressed in $\mu g/m^3$ (1)

Reference period	Number of measured values	Value for sulphur dioxide
Year (1 April to 31 March)		(arithmetic mean of 30 minute values taken throughout year)
Year (1 April to 31 March, made up of units of measuring periods of 30 minutes)		(95 percentile of all 30 minute values taken throughout the year)

The methods of sampling and analysis for sulphur dioxide applicable within the context of Article 10 (2):

- Method of sampling: measuring stations permitting "random" sampling are used within a grid network of the type represented by Fig. 1. At each point of the network at least 13 samples per year are taken between 8 am and 4 pm on working days. The different samples are collected for 30 minutes continuous duration at regular intervals through the year, for example as follows;

  On the first day, samples are taken at the points marked 'a' in Fig. 1, on the second day on the points marked 'b' on the third day at the points marked 'c' on the fourth day at the points marked 'd'. These samplings are repeated for each point at intervals of four weeks for different periods of 30 minutes chosen 'at random'.

evaluation period:	one year,
number of points:	16 in a grid network,
sampling duration:	30 minutes continuous between 8 am and 4 pm, on working days,
number of samples per point:	at least 13,
total number of samples:	at least 208.

A3

Fig. 1

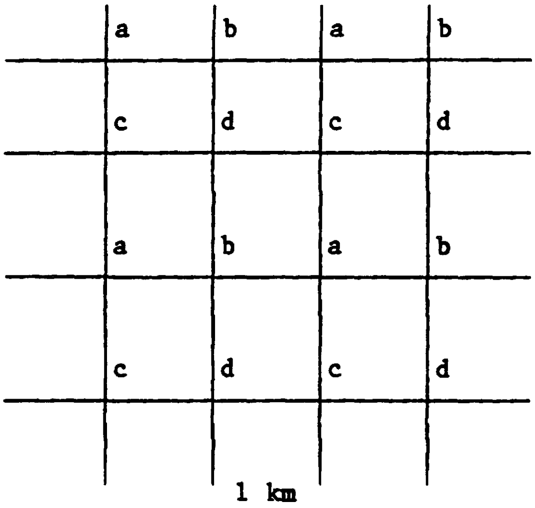

TABLE B

Measured values for station: ...
Values for suspended particulates (as measured by the gravimetric method) expressed in µg/m³
(1)

Reference period	Number of measured values	Value for sulphur dioxide
Year (1 April to 31 March)		(arithmetic mean of daily mean values taken throughout year)
Year (1 April to 31 March, made up of units of measuring periods of 24 hours)		(95 percentile of all daily mean values taken throughout the year)

Calculation of the arithmetic mean and the 95 percentile

This procedure is valid for 30 minute values as well as for daily mean values. The 95 percentile is an actually measured value, not derived from any interpolation or function (*). Round up of all measured values to nearest $\mu g/m^3$.

1. Calculation of the arithmetic mean

The arithmetic mean is calculated by the formula:

$$\frac{1}{N} \sum_{i=1}^{n} X_i \qquad (1)$$

where N is the total number of taken measurements and X_i are the individual measured values.

2. Calculation of the 95 percentile

Bring all the values of one area in order:

$$x^{(1)} < x^{(2)} < x^{(3)} < X^{(k)} < x^{(N)} \qquad (2)$$

The 95 percentile is the value of the k^{th} element where k is calculated from:

$$k = \text{integer}\ (0.95\ N) + 1 \qquad (3)$$

where N is the total number of measured values, e.g. for N = 208 the 95 percentile is the 198th value, for N = 209 the 95 percentile is the 199th value.

(*) See R. Beier: "Zur Kennzeichnung von Immissionsbelastungen durch Quantile von Schadstoffverteilungen, Landesanstalt fur Immissionsschutz, 1982.
H. Buning, G. Trenkler: "Nichtparametrische Methoden", Kap. 3, de Grayter, Berlin 1978.
E.J. Grumbel: "Statistics of Extremes" - Chap. 2, Columbia University Press,

TABLE 2. - Proforma

to inform the Commission according to article 7(1) of instances in which the limit values laid down in Annex I of the Directive 80/779/EEC have been exceeded

---

1. Name of the Member state:

2. Organisation responsible for measurements:

3. Name of the station:

   (National) code number (where appropriate):

4. Location of the station, address:

5. Instrument/method used for SO_2:

   for black smoke:

6. Distance to next station: SO_2 (km)

   black smoke (km)

7. Duration of sampling SO_2: (h/min)

   black smoke: (h/min)

8. Integration to achieve 24h-averages starts at: hrs

9. Periods longer than three days in which the station was not operating (please give dates, from, to, No of days):

A6

Measured values of Station ...

Values for sulphur dioxide in μg/m^3 with the associated values for suspended particulates (as measured by the black smoke method (1) expressed in μg/m^3 e.i.s.s.)

Reference period	Number of measured values	Value for sulphur dioxide			Associated value for suspended particulates
Year (1 April to 31 March)		(median of daily mean values taken throughout the year)			(median of daily mean values taken throughout the year)
Winter (1 October to 31 March)		(median of daily mean values taken throughout the winter)			(median of daily mean values taken throughout the winter)
Year (1 April to 31 March)		(98 percentile of all daily mean values taken throughout the year)	Number of consecutive day on which the value 350 was exceeded	Number of consecutive days on which the value 350 was exceeded	(98 percentile of all daily mean values taken throughout the the year

Values for suspended particulates (as measured by the black smoke method (1)) expressed in μg/m^3 e.i.s.s.)

Reference period	Number of measured values	Value for suspended particulates	
Year (1 April to 31 March)		(median of daily mean values taken throughout the year)	
Winter (1 October to 31 March)		(median of daily mean values taken throughout the winter)	
Year (1 April to 31 March, made up of units of measuring periods of 24 hours		(98 percentile of all daily mean values taken throughout the year)	Number of consecutive days on which the value 250 was exceeded

(1) The results of the measurements of black smoke taken by the OECD method have been converted into units of equivalent international standard smoke (e.i.s.s.) as described by the OECD.

NOTES

1. CALCULATION OF THE MEDIAN AND THE 98 PERCENTILES OF DAILY VALUES TAKEN THROUGHOUT THE YEAR

The median and the 98 percentiles are actually measured values, not derived from any interpolation or function (*).

Round up all measured values to nearest $\mu g/m^3$.

Bring all the daily values of one site in order:

The median is the value of the kth element, where k is calculated from:

$$k = \text{integer}\ (0.5\ N) + 1 \qquad (2)$$

Where N is the total number of measured daily values, e.g. for $N = 300$ the median is the 151th value, for $N = 301$ it is the 152th value.

The 98 percentile is the value of the kth element, where k is calculated from:

$$k = \text{integer}\ (0.98\ N) + 1 \qquad (3)$$

e.g. for $N = 300$ the 98 percentile is the 295th value, for $N = 301$ it is the 295th value.

Do this for SO_2 as well as for black smoke.

2. CHECK WHETHER THREE CONSECUTIVE DAYS EXCEED LIMIT VALUES FOR PERCENTILES

The check has to be done on the basis of daily comparison of measured SO_2 and black smoke values.

To do so, count the number of days with values for:

black smoke > 150 and $SO_2 > 250$,

black smoke > 150 and $SO_2 > 350$,

and black smoke > 250

separately.

European Communities — Commission

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The results of an assessment of network design in the Member States for monitoring ambient sulphur dioxide and suspended particulates, particularly with respect to EEC Directive 80/779/EEC, is presented. The report includes details on legal provisions, national objectives and strategy, how the design strategy addresses the requirements of the Directive, sampling and analytical methods, station siting criteria and costs of monitoring. Reports on networks visited in Belgium, France, the Federal Republic of Germany, Italy, the Netherlands and the United Kingdom during the course of the study are also presented. Finally, recommendations are made for concentrating effort on areas 'at risk' of exceeding the limit values of the Directive, and on harmonizing practice, in particular data interpretation, with respect to the Directive.

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