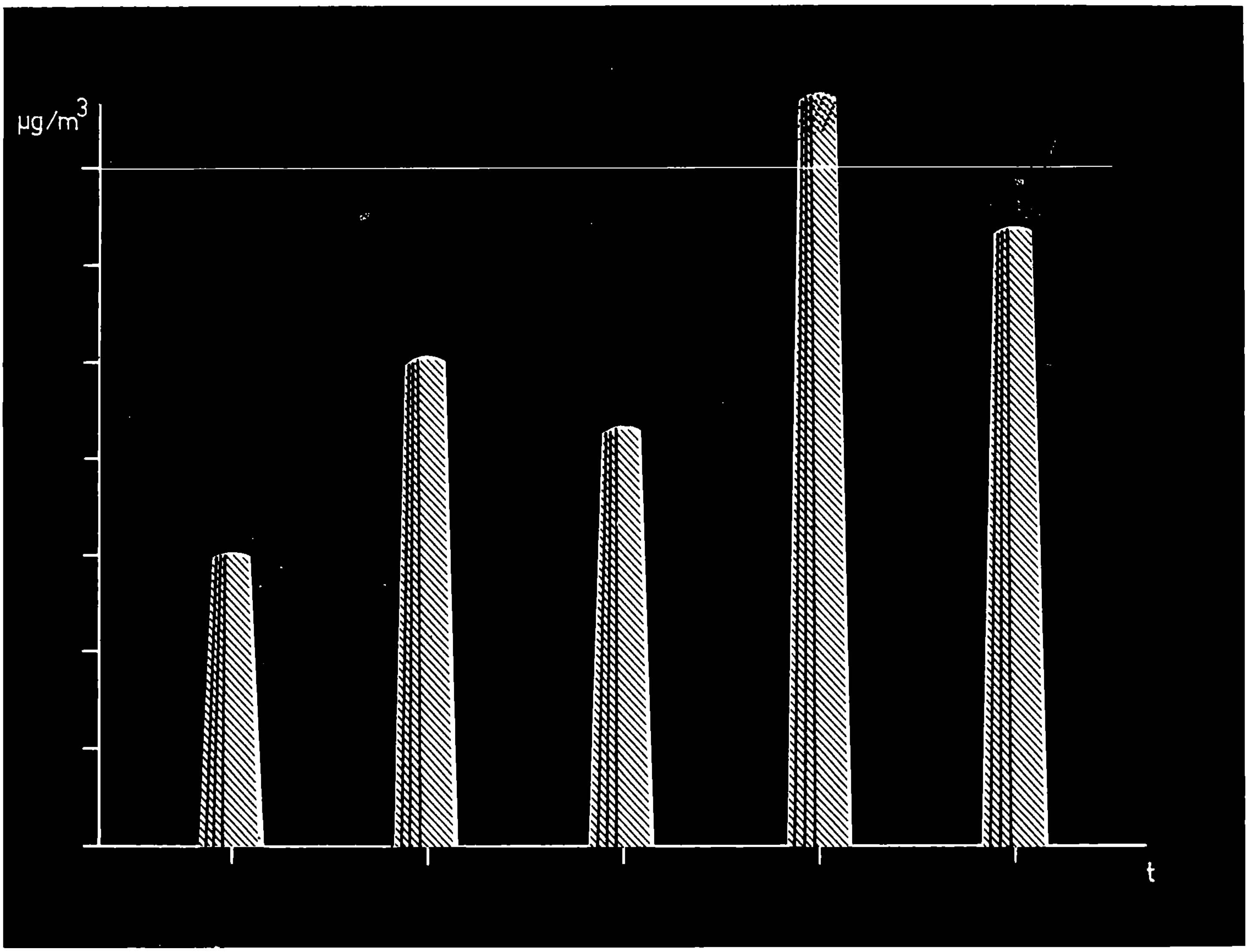
Tutkimuksia Undersökningar Studies
No. 102

Air Quality Statistics: methods and principles Finland · Hungary · Sweden

HELSINKI 1983



Tilastokeskus
Statistikcentralen
Central Statistical Office of Finland

Tutkimuksia Undersökningar Studies
No. 102

Air Quality Statistics: methods and principles

Finland · Hungary · Sweden

Tilastokeskus
Statistikcentralen
Central Statistical Office of Finland
HELSINKI 1983

ISSN 0355-2071
ISBN 951-46-7473-1

Helsinki 1983. Valtion painatuskeskus

FOREWORD

A co-operation agreement entered into force in March 1981 between the Finnish, Hungarian and Swedish Central Statistical Offices concerning methodological work on environmental statistics. The idea of this trilateral co-operation evolved from the recognition that work on environmental statistics was at about the same level in the three countries with regard to both problems and results. It can be expected that co-ordination of efforts in the methodological field will lead to speedier and broader development, thus enhancing the possibility of producing relevant statistics.

This co-operation, which covers the most important areas of common interest in the environmental and methodological fields, is directed by the heads of the Central Statistical Offices. The practical work is decided upon and organized by a tripartite Working Group operating through regular exchange of information, identification, planning and execution of co-operation projects by correspondence and by meetings every other year.

The present publication contains the papers prepared for the second meeting of the Working Group held in Helsinki in April 1983. The three studies concentrate on the statistical description of air quality, its methods and principles.

Air quality statistics is considered one of the most important issues of environmental research and analysis. Air quality influences most, if not all, environmental media and is at the same time influenced by a great variety of human activities. The principal causes of air pollution are certain types of industrial technologies and motor vehicle traffic.

128303413S—12

Quality consequences of discharges from these sources can also be felt in areas far from the sources themselves due to certain meteorological conditions prevailing the broader regions of the earth or the continents. Cases in point include the acid rains in Scandinavia which are polluting the water of many lakes and endangering forest ecosystems.

It was mainly for these reasons that the expert teams executing the cooperative agreement between the Central Statistical Offices of Finland, Hungary and Sweden in the field of environmental statistics have commenced their methodological activities in air quality measurement and analysis. There are several important aspects to consider in this connection, only some of which are addressed in the papers presented here. The papers respond mainly to the needs arising in the participating countries, depending on the different points of view and on the different meteorological and geographical conditions.

However, some general focal points emerge from the three papers. One of them relates to the objectives of air quality statistics. It seems clear that besides objectives concerned with spatial aspects, changes in time, early warning, etc. there are also more policy oriented goals which should be taken up when considering the role of national official statistics.

It is expected that official statistics should evaluate general and local air quality and should throw light upon the underlying causes of possible deteriorations and improvements. This will mean the building up of a rather sophisticated statistical mechanism, including an appropriate methodology for analysis. This is the second issue emerging from the papers which could arouse the interest of statisticians, especially of those working in national statistical agencies. It appears from the country reports that all participating countries attach great importance to statistical measures which describe air quality and its changes in more general terms. The approaches seem to be different and manifold but the objective is clear. Policy makers and decision makers are in general interested in advice concerning appropriate actions and their possible consequences. A prerequisite for such advice is the existence of a composite methodology for statistical measures and for the evaluation of changes and their causes. This is the reason why the idea of composite indexes and measures is taken up in the papers. It is well known that there are no generally accepted methods of this kind at present and that all statistics used in different countries have their shortcomings. However, the papers suggest that there should be a break-through at this point and that methods satisfying the requirement should be worked out.

The relation between monitoring data and statistics and the conversion of monitoring information into air quality statistics, as well as statistical considerations in the setting-up of air quality monitoring networks are other common points of interest in the national reports.

The monitoring systems of the participating countries seem to differ considerably, and this is the reason why the approaches concerning the relation between monitoring and statistics are far from each other. One cannot argue for any single approach, but the reader might be interested in acquainting himself with them all.

It is hoped that the publication of these papers on air quality statistics will be helpful to statisticians working in national and international agencies and will contribute to the common thinking of statisticians working in this field.

Prof. Olavi E. Niitamo,
Director General

Central Statistical
Office of Finland

Dr. Vera Nyitrai,
President

Hungarian Central
Statistical Office

Dr. Lennart Fastbom,
Acting Director General

Statistics Sweden

AIR QUALITY STATISTICS: METHODS AND PRINCIPLES

CONTENTS Page

FOREWORD		3
1.	FINLAND: The State of Air Quality Monitoring and Statistics in Finland	9
2.	HUNGARY: Air Quality Statistics	29
3.	SWEDEN: Parameters for Air Quality Statistics	59
ANNEX I		93
ANNEX II		94
ANNEX III		100

CENTRAL STATISTICAL OFFICE OF FINLAND AND
FINNISH METEOROLOGICAL INSTITUTE

THE STATE OF AIR QUALITY MONITORING AND STATISTICS IN FINLAND*

* Prepared by Mr. Tapani Säynätkari, Finnish Meteorological Institute, and Mr. Kari Nevalainen, Central Statistical Office of Finland.

1. Introduction

The representativeness of air quality statistics has long been interlinked with the national standard of air quality monitoring. The creation of systematically compiled and reliable air quality statistics requires that air quality monitoring and monitoring methods in particular are, statistically speaking, adequately representative and uniform. In this respect the means to acquire data through air quality monitoring and the nature of the statistical requirements set for monitoring methods are key factors for environmental statistics.

The fact that the air pollution control act did not enter into force until 1982 is illustrative of the development and state of air quality monitoring in Finland. Prior to this, public health legislation chiefly served to regulate air quality monitoring and control measures. In practice this shifted the responsibility for air quality monitoring onto individual local government authorities. Air quality monitoring on the local goverment level has not been performed, however, on a consistent and broad scale, except in a few larger cities.

Air quality research and monitoring conducted by central goverment authorities are primarily performed in two research institutes: the Finnish Meteorological Institute and the State Technical Research centre. The Finnish Meteorological Institute, and in particular its aerology department, which bears the responsibility for research on atmospheric physics and chemistry within the scope of meteorology, has participated in municipal-level air quality inventories, but at the same time carried the entire responsibility for air quality measurement at background stations in Finland. The State Technical Research Centre has focused on pollutant source surveys.

Systematic air quality measurements and research have been conducted since the mid-1960s in Finland. (Measurement at some background stations was initiated in the latter part of the 1950s). This primarily concerned deposition measurement, its composition and sulphur dioxide. The measurement of other pollutants, such as suspended particulates, its composition, nitrogen oxides and carbon monoxide, was not begun until the 1970s. In addition to these pollutants, the concentration levels of hydrosulfide, mercaptan, fluorides and hydrocarbons have been measured sporadically for short periods of time.

Generally speaking, air quality monitoring has to date not been adequately systematic to ensure the development of reliable and uniform air quality statistics. It is to be born in mind, however, that characteristic meteorological conditions, such as seasonal variation, a prolonged cold winter, air currents and the nature of pollution sources, by and large dictate air quality monitoring objectives and the terms of monitoring in Finland.

2. Official recommendations

The National Board of Health has issued recommendations on monitoring air quality (National Board of Health, 1978). These recommendations govern the planning and performance of air quality monitoring, guideline values for air pollutants and the interpretation of measurement results. The character of the pollution source and monitoring objectives are factors affecting the performance and scope of air pollution monitoring. The scale of monitoring may range from once pinpointing a source of pollution through measurement or calculation to continuous air quality monitoring based on the measurement of short term values.

The recommendations on air quality monitoring as a rule only require measurement of sulphur dioxide in air and, when called for, suspended particulates.

The siting of measurement points is done in accordance with monitoring objectives, the pollutant concerned and area conditions. The potential to monitor the exposure of the largest possible segment of the population is to be taken into consideration in siting. Other factors that are to be taken into account are e.g.:

- the magnitude, altitude and location of pollution sources,
- topographical factors, and
- meteorological factors.

From the standpoint of measurement network representativeness, it is important that measurement points are not repositioned. Another factor bearing on measurement is that a network designed for a specific purpose cannot in general be altered to serve some other purpose.

Two measurement points, one of which is to be sited where probable peak concentrations occur, are in most cases considered adequate for point pollution source monitoring. In large population centres, 3-5 measurement points are generally adequate.

The recommendations do not specifically regulate measurement equipment. The duration of a sample collection test and measurements depend on the objectives and tragets set for monitoring. The recommendations lay down exact specifications for coverage regarding measurement representativeness in terms of time. To obtain representative mean values in time terms, measurement values must be approximately 75 per cent of the theoretical number of results.

The recommendations issued by the National Board of Health (Circular No. 1664, 1978) include the following examples of target and performance levels set for monitoring in order to eliminate health hazards:

Target	Measure
Observation of a low or scarcely detectable level of pollution	Computation of pollution level
Monitoring of source of pollution damage or accidental source of air pollution	Reporting on plant operations and air pollution control equipment in use and notification of occurrence of pollution
Monitoring of a measurable but substantially lower level of pollution than guideline values	A series of daily measurement tests extending for a period of one year and repeated, when required, at fixed intervals, e.g. every three years, or monitoring of pollution

Monitoring of pollution levels near guideline values and emitted mainly by a single source	Daily or short-term measurement tests repeated at fixed intervals or continuously
Monitoring of pollution levels near guideline values and emitted by several regional or point sources (e.g. a large industrial town)	Combination of a single measurement continuously measuring short-term values and several measurement stations monitoring daily values, or several stations measuring short-term values

Public health recommendations concerning sampling periods of varying lengths have been issued for sulphur dioxide, suspended particulates, nitrogen dioxide and carbon monoxide. Guideline values are expressed as arithmetic means, percentile values and values that can be exceeded once within a certain time frame. The recommendations specify total deposition and list several organic and inorganic substances for which the National Board of Health provides upon request expert statements regarding guideline values and the basis for monitoring.

Table 1 introduces National Board of Health guideline values for four air pollutants.

Table 1. Air pollution guideline values

Pollutant	Concentration	Time	Comparative method	Calculated determinations
Sulphur dioxide	(SO_2) 70 µg/cu.m,	1 a	Thorin (SFS 3864)[x]	- arithmetic mean
	300 "	1 d	"	- [xx](n - 1) results/30 d under 300 µg/cu.m. = number of daily results
				- 98 % of results/a under 300 µg/cu.m.
	650 "	1 h		- 99 % of results/30 d under 650 µg/cu.m.
Suspended particulates	80 "	1 a	Intensive sampling method (SFS 3863)	- arithmetic mean
	240 "	1 d		- (n - 1) results/60 d under 240 µg/cu.m.
				- 98 % of results/a under 240 µg/cu.m.
Nitrogen dioxide	(NO_2)200 "	1 d	Griess-Salzmann	- (n - 1) results/30 d under 200 µg/cu.m.
	500 "	1 h	"	- 99 % results/30 d under 500 µg/cu.m.
Carbon monoxide	(CO) 10 "	8 h	Infrared method	- arithmetic mean
	40 "	1 h	"	- arithmetic mean

x) standard of Institute of Finnish Standards

xx) highest value excluded

3. Air quality control in Finland

Air pollution control in Finland can be divided into two main endeavours: air quality research in 1) population centres and 2) in areas outside population centres at background stations. The methods employed in and research targets for these activities are diverse. The following describes air quality monitoring operations both for population centres and background stations. The Finnish Meteorological Institute assumes the main part of responsibility for these activities.

3.1. Population centres

Air quality inventories of populated centres have in most cases been conducted jointly with the Finnish Meteorological Institute and local goverment authorities or industrial plants. In the broadest sense, inventories have regionally covered several municipalities. Regional representativeness also varies according to the object of survey, e.g.:

- a survey of air quality in the municipality in question (in addition to heating plants, only a single relatively dominant source of pollution is surveyed),
- a study of the impacts of a single point source of pollution (heating plant, industrial plant, etc.),
- a study of a pollution source area, or the impacts of several different sources of pollution, and
- a study of a linear pollution source, such as the impacts of air pollution on traffic routes.

Inventories draw, either singly or in combination, from test measurement results for pollutant concentrations, estimates of concentrations arrived at in pollution dispersion models and results from biological impact studies. Pollutant source studies have been employed as basic data in air quality surveys. Meteorological and topographical data as well as traffic volume data are important constituents in conducting these surveys.

According to the pollution level and the nature of the area to be monitored, air quality inventories are conducted as single-event or continuous studies or are repeated at fixed intervals. In Finland inventories are as a rule based on short-term studies covering at most a few years. Statistics covering a longer time frame are mainly available on deposition and sulphur dioxide measurements and small-scale measurement of dust. Until recently, large-scale measurements of suspended particulates, nitrogen oxides and carbon monoxide have ranged from a few days to some months. Additionally single studies using dispersion models have been conducted to investigate, for instance, the impacts of an individual pollution source.

The views of the party commissioning or initiating an investigation on the kind of air quality study required are decisive in carrying out joint surveys. The Finnish Meteorological Institute has co-ordinated studies made in population centres in order to provide comparable results.

National Board of Health recommendations are the cornerstone for air quality research. Measurement and corresponding action seek to determine whether given guideline values are exceeded in the area under investigation. These recommendations do not apply in detail to the measurement station networks used for continuous monitoring. The question of the statistical respresentativeness of such networks has largely been left unanswered.

Measurement points have by and large been selected subjectively on the basis of available initial data. Two main criteria used to site monitoring points can be distinguished in the background. The first may be termed the emission approach. Accordingly, this approach endeavours to determine the location of measurement points with the intent to discover with the greatest possible degree of accuracy the impacts of a particular pollution source or cluster of sources on the quality of air in an area by means of pollution source analysis, studies of pollution dispersion employing dispersion models or by charting the biological impacts.

2 1283034135—12

In the exposure approach, measurement points are selected to cover areas that differ with respect to the pollutant concentration levels recorded in population centres and the consequent exposure risk to the population. Measurement tests have been made long enough to span both annual and short-term variations in the pollution levels and meteorological conditions.

The Finnish Meteorological Institute has investigated a method to select points in a measurement network (KAJOSAARI, 1977). The method is based on a model constructed by HOUGHLAND and STEVENS (1976), and it has been further improved to take into account a wider range of meteorological conditions.

According to this method, potential siting points in the measurement network are first ordered e.g. into an interval lattice. Then the impact function values for each pollution source and wind direction sector are calculated for each potential point. In the impact function A_{ijk} represents the measurement of the coverage of point j for the effect of source i with the wind in sector k. These values are obtained using the formula

$$A_{ijk} = \sum_{s=1}^{S} F_{ks} + \frac{Cis}{1+D_{ijks}}$$

where F_{ks} represents the frequency of meteorological condition s with the wind direction in sector k,

C_{is} represents the largest ground surface concentration caused by pollution source i in meteorological condition s, and

D_{ijks} represents distance of point j from the location of concentration C_{is} with the wind direction in sector k.

Each pollution source i and wind direction sector k are used to select the point with the highest impact function value to describe the effect of a pollution source. A subgroup containing a desired number of points can furthermore be selected from among this set of points by determining the subgroup with the highest sum of point impact functions.

In the context of inventories conducted with dispersion models and assays of biological effects, values are obtained in most cases for interval lattice points. Regional analysis have generally been outlined in map format. Indices describing air quality have not been used.

The lack of officially approved measurement methods has constituted a serious drawback in monitoring air quality. Uniform measurement methods have not always been employed to measure the same pollutants in Finland nor has equipment calibration been systematic. Permanent measurement network, some of which operate with automatic equipment, or monitors, have recently been taken into use in several centres of population. Two towns have fully automated measurement station networks, and networks collecting short-term samples at a number of stations operate in the neighbourhood of industrial plants.

The Ministry of the Interior has had an investigation carried out about suitable methods for calibration of air quality monitoring. On the basis of this investigation a safety system for air quality monitoring is being established in Finland.

3.2. Background stations

A Background station is a measurement point having no pollution source directly affecting the results of measurement in its vicinity. Air quality has been monitored at background stations in Finland since the latter part of the 1950s. The Finnish Meteorological Institute has drawn up a publication of observations made in the 1970s (KULMALA et al., 1982). Background stations belong to one national and four international networks. The data on the fourth international network IMI (Internationella Meteorologiska Institutet, University of Stockholm) is not presented in the publication. On the widest scale, more than ten stations, most belonging to more than one measurement networks, have been simultaneously in operation. Table 2 lists background station measurement networks and programmes.

Table 2. Measurement networks and programmes

Abbreviated name	Function	Scope	Pollutants measured in Finland: in air	Pollutants measured in Finland: deposited
LRTAP	1972-1975 study project of long-range transport of air pollutants co-ordinated by the Organization for Economic Co-operation and Development (OECD).	76 stations in 11 West-European countries	SO_2, SO_4^{2-}	pH, H^+, SO_4^{2-}
EMEP	1977 co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (study of long-range transport of air pollutants) by the United Nations Economic Commission for Europe (ECE).	60 stations in 16 European countries	SO_2, SO_4^{2-}	pH, H^+, SO_4^{2-}
BAPMoN	A global network of regional background air pollution monitoring stations initiated in 1973 by the World Meteorological Organization (WMO).	83 stations in operation and 64 under construction in about 70 countries		pH, H^+, SO_4^{2-}, γ, NO_3^-, NH_4^+, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+}
National level	A national network of background stations, established by the Institute of Occupational Health	Eight stations in Finland	SO_2, suspended particulates	Total deposition, soluble insoluble, H^+, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}

The LRTAP network (Long-Range Transport of Air Pollutants) set up by the OECD operated in the years from 1972 to 1975 to investigate the long-range transport of air pollutants. Five stations were established in Finland, four in the southern part of the country. They were sited at fixed distances from each other to ensure regional coverage. Stations took daily air and deposition samples.

In 1977 the ECE began the EMEP measurement project (ECE co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe). This project also focused on the long-range transport of air pollutants by resorting to the same measurement programme as that used in the LRTAP project. Four stations, two of which were previously LRTAP stations were put into operation. Three of these stations were located in southern Finland. Today the network consists of three stations, two functioning on the original sites.

The WMO initiated the BAPMoN programme (Background Air Pollution Monitoring Network) in 1973 to monitor long-term changes in the quality of air with potential impacts on the climate. In this context diverse meteorological observations have necessitated the siting of two stations in Finland to operate in conjunction with the Finnish Meteorological Institute observatories. One of these stations is located in southern Finland and the other in the northern part of the country. Both dry and wet depositions are sampled monthly at these stations.

The national measurement network was established by the Institute of Occupational Health in 1969 initially for the purpose of compiling comparison material for measurements taken in population centres. The network was later handed over to the Finnish Meteorological Institute which co-ordinated sections of it with other background station networks. Measurement programmes have to a degree varied from station to station. New stations were set up to replace some of those that had been closed earlier. Measurement programmes were standardized in the beginning of 1981 at the five sites in operation today. Samples are collected either weekly or monthly.

A publication introducing measurement results draws some comparisons of observations obtained at different stations. A full regional statistical analysis has not yet been performed, as the regional representativeness of the measurement networks remains incomplete for this purpose. Modifications within the networks also detract from representativeness. Pollutants most seriously affecting the quality of air are relatively evenly distributed regionally, thus reducing the need for a regional analysis.

Measurement programmes have mainly focussed on the observation and investigation of changes in air quality in terms of time, involving short and long-term changes recorded both at individual stations and between stations. The publication presents monthly, annual and longer term statistics (mean, standard deviation, percentile, etc.) as well as maximum and minimum values. Data on annual variation and variation between different years are also listed, and the trends are examined.

4. Future prospects

The air pollution control act came into force on the first of October, 1982. The act prescribed the objective to collect data on air pollution control and to guide the planning of activities that constitute the risk of air pollution. Detailed application of the act is carried out by means of a notice procedure. Operations defined by the act on air pollution control must be reported to a provincial board in good time before the operation in question is begun. A provincial board can issue air pollution control regulations in the decision finalizing the notice procedure. According to statute, approximately 1 300 establishments are obliged to submit notice of activity potentially causing pollution during 1984 - 1986.

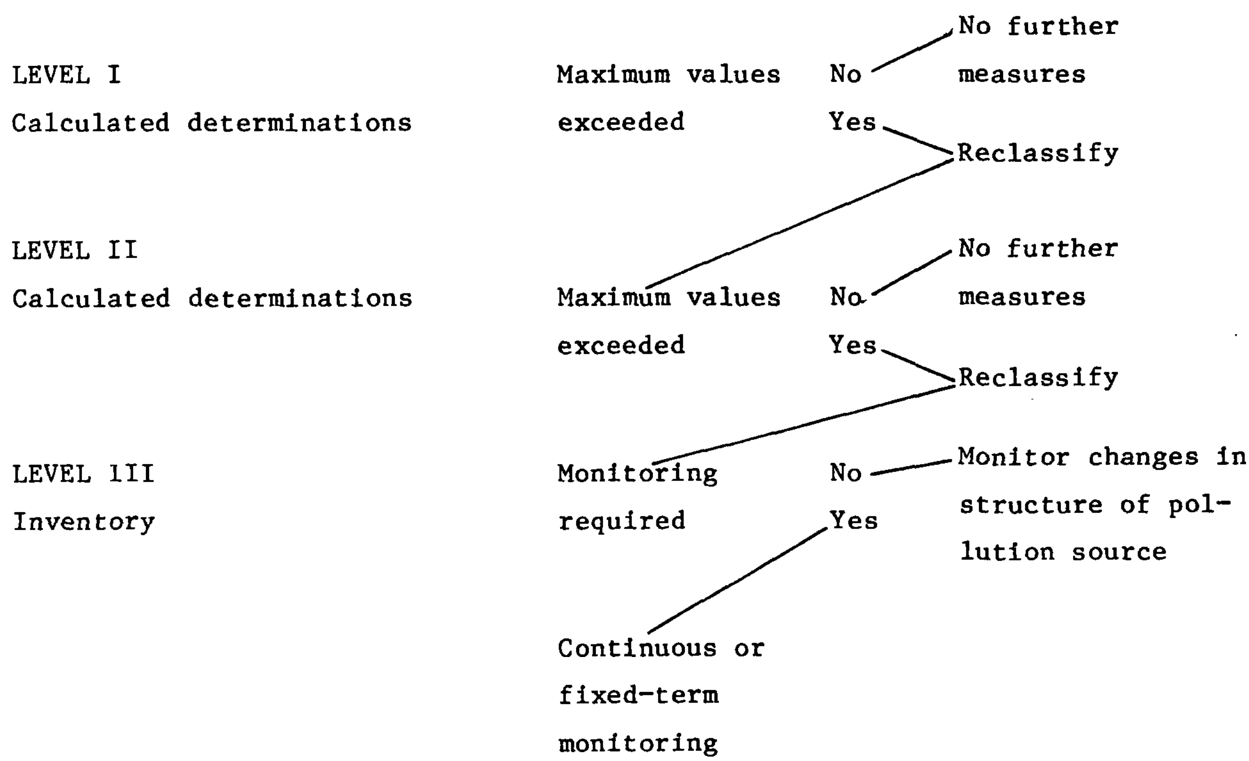
The act on air pollution assigns the responsibility for air pollution control and monitoring to local government air pollution control authorities, who are charged with the monitoring of air quality on a scale dictated by local conditions. A party operating so as to cause air pollution, who is to be cognizant of the effect of his action on the quality of air, is as a rule obliged to participate in municipal monitoring activity and share in the cost so incurred.

The options for air pollution control inventories on the municipal level have been studied at the Finnish Meteorological Institute against the backdrop of a research agreement between the Ministry of the Interior and the Institute. This study has resulted in a proposal for classifying population centres on three levels, each requiring measures of different character and scope. This classification into levels seeks to establish inventory methods most appropriate for each municipality.

The level on which each municipality is classified is arrived at via a simple choice procedure using e.g. data on pollution sources as initial information. No additional surveys are called for in municipalities classified on level I, because no problems in air pollution control are expected to arise there. A relatively uncomplicated survey is carried out in municipalities classified on level II. On the basis of this survey, the municipality either remains on level II requiring no further investigation or it is reclassified onto level III, calling for a thorough study of necessary further measures in the municipality. Further measures can be restricted to monitoring changes in the pollution source structure. In the case monitoring is necessary in a municipality, a decision as to whether it is performed for a fixed term or continuously must be taken.

Figure 1 depicts the interrelationship between the strategy levels and the choice of these levels. The figure also illustrates when it is necessary to initiate air quality monitoring.

Figure 1. Interrelationship between strategy levels



To date regulations have not been issued on monitoring methods. Questions relating to the coverage of a measurement network are dealt with in methods planning. Monitoring undertaken in a municipality or an individual population centre where the structure of pollution sources is complex imposes stringent requirements on the measurement network. The distribution of different air pollutants generally varies both regionally and in time due to the diverse structure of pollution sources. Individual measurement equipment error and its effect on the network are difficult to uncover. Error may vary over time, with the substance measured or according to the current level of concentration. Immediate or more permanent changes in the pollution source structure and changes occurring in meteorological conditions are among the factors affecting the regional coverage of a measurement point.

If the regional coverage of a measurement point is viewed from the perspective of the exposure risk to the population, population movement is a factor to be considered. Regional differences in pollutant concentration levels are usually distinct in population centres, which is to be taken into consideration in the planning of a measurement network. The availability and coverage of meteorological data, both in regional and time terms, are to be taken into account in determinating measurement coverage. Monitoring targets as well as economic and other resources are also naturally factors to be weighed in planning a measurement network. A cost-benefit analysis is important in network planning.

The Finnish Meteorological Institute is going to perform a study of the socalled measurement strategy, in which special attention is going to be paid to the temporal and regional representativeness of measurements, and their statistical criteria. The study will be completed in 1984.

In accordance with the act on air pollution control, the Ministry of the Interior is obliged to maintain a data register of submitted notices. This register is to be composed of two sections, one being a register of air quality and impacting factors kept by the Finnish Meteorological Institute and the other a register of pollution sources and decisions maintained by the State Computer Centre. The input of data from notices into the register will begin in 1984. The register will be ADP based.

REFERENCES

HOUGLAND, ERIK S., STEPHENS, N. THOMAS: Air Pollutant Monitor Siting by Analytical Techniques. Journal of Air Pollution Control Association 26:1, 1976.

KAJOSAARI, SAKARI: Menetelmä ilman epäpuhtauksien tarkkailuverkoston pisteiden valitsemiseksi ja sen sovellutus Helsingin alueella. (A method to select air pollutant monitoring points in a network and its application in the Helsinki area.) Finnish Meteorological Institute, Study Report No. 61, Helsinki 1977. (in Finnish)

ANTTI KULMALA, ALEC ESTLANDER, LIISA LEINONEN, TUIJA RUOHO-AIROLA, TAPANI SÄYNÄTKARI: Ilman laatu Suomen tausta-asemilla 1970-luvulla. (Air quality at Finnish background stations in the 1970s.) Finnish Meteorological Institute, Report No. 36, Helsinki, 1982. (in Finnish)

NATIONAL BOARD OF HEALTH CIRCULAR No. 1664, Helsinki 1978.

REPORT BY THE AIR QUALITY WORKING GROUP 1979:14, Helsinki 1979.

HUNGARIAN CENTRAL STATISTICAL OFFICE

AIR QUALITY STATISTICS

1983.

Introduction

The process of air pollution covers three phenomena: emission, transmission and immission. Emission means the outlet of pollutant matters from the source of pollution into the air. Transmission means the connection between emission and immission; it is a process when pollutant matters, as a result of meteorological conditions, diffuse and become diluted in the air. Immission means the concentration of pollutants in the air.

The present paper deals with air quality statistics, with the possibilities of using immission measurement results for statistical purposes. Thus the paper does not touch upon the questions of transmission and it covers only a few aspects of emission measurements which may have some effect on air quality statistics.

The quality of air can be described by data of immission measurements. The lover is the measured concentration of pollutants, the better is the quality of ambient air. Required level of air quality is reflected by the immission standard. The aim is to assure that immission would not exceed the required level.

These requirements cannot be fulfilled without the regulation of emissions. Thus the objectives of emission measurements can be summarized as follows:

- emission measurements should inform about the sources of pollution which influence the immission of a given area; about the degree of their pollution - by pollutant components - in space and in time
- emission measurements should give the possibility to control: are emission standards, determined individually, kept or not, and if they are not, what the degree and statistical duration of the exceedence is.

Emission statistics is based on two sources in Hungary. The main source is the data mass coming from declarations of enterprises which are classified as sources of air pollution. The other source is the series of control measurements carried out by responsible authorities, controlling data reported by the enterprises. Emission statistics does not cover some important issues as emission from traffic, from household heating, and does not give clear information on the connections between production levels and level of emission.

From the point of view of the objectives of immission measurements, the role of an immission measurement network is quite different if it is operating alone, or parallelly together with regular emission measurements.

In the last case the control of emissions of the sources, the establishing of responsibility for pollution is the task of emission measurements. On the basis of emission measurements the location, degree and frequency of discharge are more or less known. Knowing these data and some theoretical connections, the distribution and variation of air pollution in space and in time can be drawn up. In this case immission measurement serves as empirical control of the theory.

As it was mentioned before, emission statistics cannot be considered complete in Hungary. Thus the immission measurement network has to answer a lot of questions and fulfill several tasks.

Objectives of air quality control

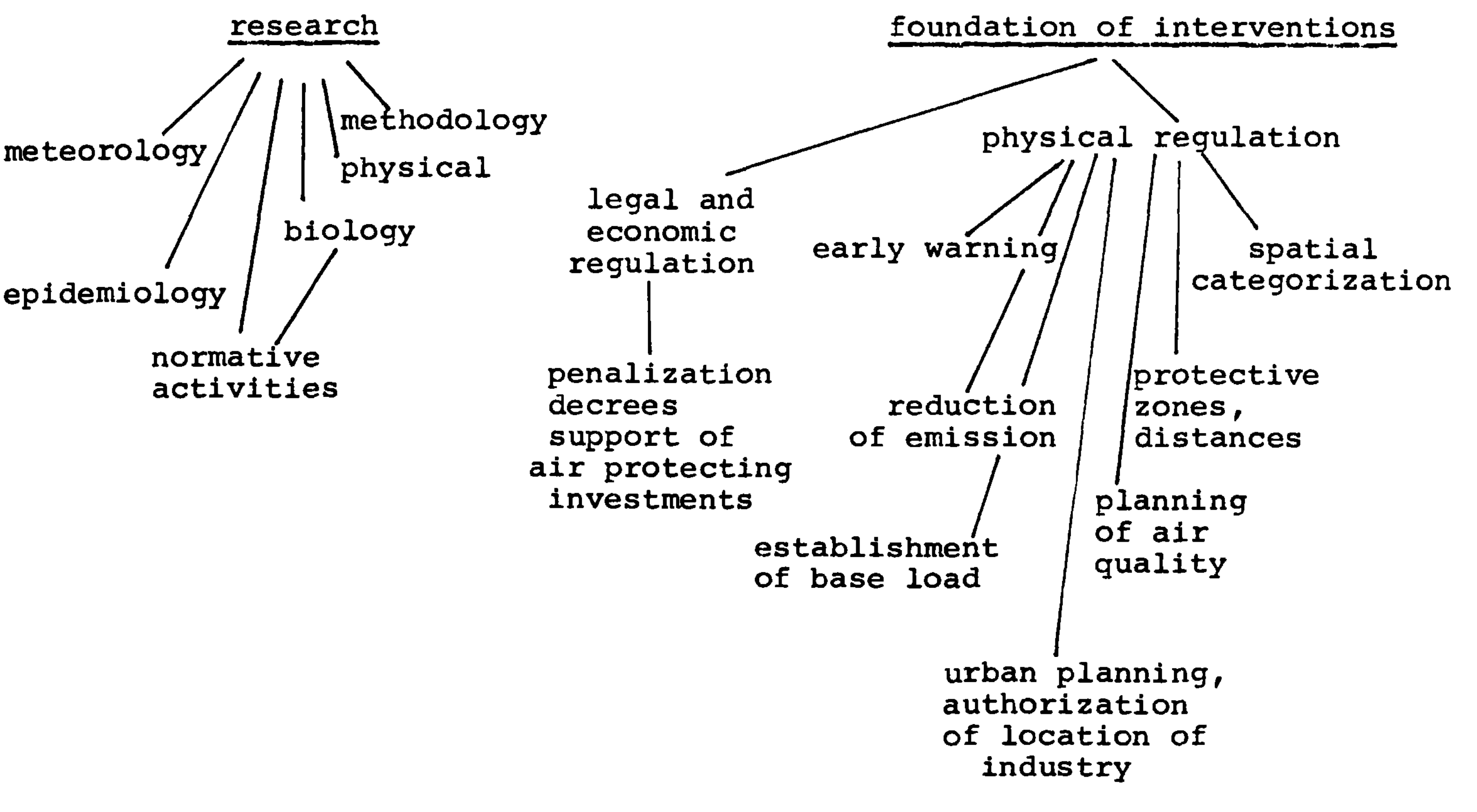
The observation of air pollution, the assessment of its degree and quality is possible by the measurement of immission. The knowledge on the distribution of immission in space and time gives the basis for any measures protecting the cleanness of air. Therefore the measurement of immission takes precedence of all other, similar activities. Immission at the same time is a result of different measures protecting the quality of air: the final goal of any measures is to assure the compliance with the standards. Immission control provides information on the effectiveness of different interventions.

The objective of the measurement of immission could be:

- to get a picture of the spatial distribution of air pollution
- to get knowledge on the trends and distribution of air pollution in time
- early warning
- the exploration of the sources, centres of air pollution
- the examination of inhabitants' complaints, the strengthening of expert's opinion in damage suits
- to provide data for the planning of air quality
- to provide data for regional and urban planning
- to provide data for the establishment of permissible pollution levels /norms/

- to provide basis for measures taken by authorities /licensing, penalization/
- to control and assess the effectiveness of air protecting measures
- to provide data for scientific activities /the exploration of health-, biological, agricultural, physical, economic effects, of meteorological, geographical interrelationships, etc./.

The objectives of air quality control



Types and characteristics of air quality control

The spatial extension of air pollution, depending on the sources of pollution and atmospheric conditions, can show a high degree of variation. From this aspect

- local
- urban
- regional
- continental
- global

air pollution can be distinguished. Their horizontal and vertical extension is shown in the following table

Spatial extension	Horizontal extension, km	Vertical extension, m
Local	0,5	10...1000
Urban	0,5...40	30...1500
Regional	10...400	100...3000
Continental	400...5000	3000...7000
Global	5000	7000...16 000

The spatial extension of air pollution is a determinant factor in the planning and establishment of air quality control. In the case of measurement methods, going from the local to the global level one should count on lower and lower concentrations, thus the method of measurement to be applied should be more and more sensitive.As far as the location of the measurement sites is concerned, the most dense network and the most frequent sampling is needed in local examinations; proceeding towards the global level the frequency of either the network or the sampling can be scarced. The indication of the place of measurement should be carried out most carefully in the case of global measurements. At the same time, the longest time series of measurements /for decades/ are needed in global investigations.

Local, urban and regional examinations are of primary interest from the point of view of environment protection, public health and planning.

According to its execution the measurement can be of

- mobile
- periodical
- fixed periodical and
- continuous

character.

Mobile measurements are usually carried out by registering or continuous sampling instruments, truck-mounted. The method is useful and applicable for a quick, rapid survey of the distribution of air pollution over a larger area. Mobile measurements are made from plain, balloon - sound or captive balloon as well, first of all for the assessment of the vertical distribution of air pollution /air-pollution-meteorology/.

The method of periodical measurements means that the fixed sampling points are visited occasionally /but by all means in a planned way/ with the registering or sampling instruments. Another solution if the instrument is set out at the sampling point and it comes into gear automatically at the given time /for one day once a week, for example/.

Fixed periodical measurements are usually carried out by automatic sampling instruments. The programmable device takes the samples over a longer time /eg. a week/ by the way that it couples a new sampling receiver or filter at a given point of time. Thus the results refer to each averaging period, but the successive samples cover the entire observation period /e.g. a year/. Fixed periodical sampling can be executed by non-automatic shifts as well.

Continuous measurements are carried out by registers, by air monitors. Depending on its flexibility and lost time the instrument can provide such data that can be evaluated for short periods /for some minutes or even for seconds/ permanently.

The system of measurements

Immission is a result of a process which is determined and effected by several, changing factors. Consequently, the air pollution of an area cannot be described on the basis of a few, occasional measurement. Measurement should be carried out regularly in space and in time.

Criteria for the location of measurement stations

Criteria for the indication of the point of measurement depend on the objective of the measurement. The measuring point should be located always in a place which is representative. Samples taken at a congested intersection, in the rush hours, at the height of the human respiratory zone are representative from the aspect of loading of people staying there. The same samples are not representative at all for the given part of the settlement as a whole.

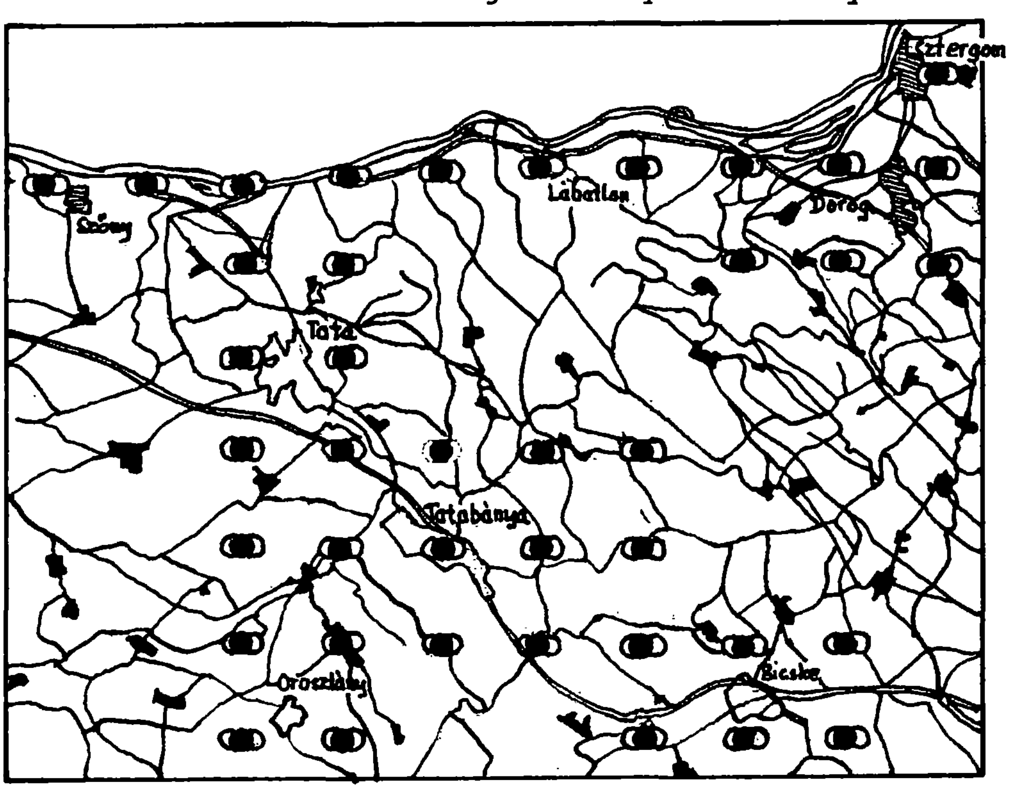
Sampling points can be indicated without preliminary planning, through field-survey or on a map. However, this procedure inheres the danger that because of subjective aspects the characteristic points will be defined incorrectly, and the overall picture will be misleading. The effectiveness of a measurement network which was set up without a system will be worse than that of a systematic network. This is why the location of measurement sites should be made in a planned, systematic way. The criteria for the definition of sampling points differ according to the objective of the study. Criteria are different in the case of global, continental or regional measurements, when the objective is to measure background levels of air pollution.

Regional observations lead us to the field of measurements which are oriented to environment protection or air-hygieny purposes. The control of air quality may be necessary for larger areas which need special protection, e.g. recreation areas, nature conservation areas, historical sites etc. An even more frequent case is, when air pollution goes beyond the narrow surroundings of a settlement, endangering larger areas. Converging polluted air of a number of settlements, with the help of topographic conditions, might develop a continuous polluted region of several hundred or even some thousand square kilometers. In such cases in order to assure representativity the criteria of the location of sampling points will differ from that of the meteorological background measurements.

See the maps in Annex II.

For the study of background pollution a relatively small number of stations may be satisfactory; in case of environment protection control studies a more dense network is needed. As far as regional examinations are concerned, the measurement sites can be located in a geometric system, with a square-net suitably applied to the map. The sampling points will be located to the intersections of the square net. The density of the net depends on the extension of the area, the density of sources of pollution, population density, topographic conditions and the available instruments and labour force. In general, a distribution to squares of 2-10 km side length may be suggested, with the rider that the less characteristic intersections need not be supplied with stations /so called flexible square-net system/. If the station due to inaccessibility or disturbing factors etc., cannot be located to the ideal point /intersection/, a 10 % deviation is permissible.

Draft regional square-net system



In several cases the application of the square-net system is not reasonable /e.g. an industrial region located in a narrow river-valley/. Under such circumstances the objective is to cover the area uniformly and to select the characteristic representative points.

One of the most frequent tasks is the control of the air quality of settlements. The definition of sampling points based on the square net system can be applied for settlements as well, in a flexible form if needed. The density of the net varies between 250-1000 meters, depending on the conditions mentioned earlier. This system is advantageous because of the uniform distribution of the stations and in case of computerized processing it offers the possibility for exact definition of the place. Disadvantage of the system that in practice the station can be located to the defined point very rarely: the mentioned 10 % deviation is permissible. A well-located station, if it is clear of the direct effect of local sources of pollution, /e.g. it is placed at least 100 meters away from chimneys and traffic, to a well aired point /city park, for instance/ can provide representative data on a larger part of a settlement /of about 1 km^2/.

The main advantage of the square net system is the uniform density of stations over a given area. All stations represent an area of uniform size. This is an ideal system which can only be reasonably applied if topographic conditions are uniform. In other cases the most fruitful way is to define characteristic, relatively homogeneous districts within a settlement or the area under study and to select representative points within these districts where the stations will be located.

For purposes of data collection on the health conditions of inhabitants, the following locational criteria are recommended by the WHO /within a settlement/: one station in the city, one in the industrial zone and one in an outer residential area.

According to Soviet recommendations the following location is reasonable in a settlement:

1. station	Residential area in the city centre.
2., 3.-"-	Residential area in the outskirts of the town, opposite direction from the centre; one in polluted, the other in clean area.
4. -"-	Beside a main road with high traffic.
5. -"-	Area strongly loaded with industrial pollution.
6. -"-	Nearby a railway station.
7. -"-	Open area belonging to a plant.
8. -"-	Control point outside the town, in a clean area.

The Hungarian National Immission Control Network is based on a location order described in the following table. The location of the station offers a high possibility of comparability among settlements as the characteristic points are strictly defined. The system makes international comparisons possible as well.

Uniform immission control system

Type	The number of the station	The name of the station	Definition of the station
I.	1.	City centre	Business, office and residential area in the centre of the town. "Protected" area.
	2.	Residential area	Up-to-date building estate farther from the centre, directly not polluted. "Protected" area.
	3.	Industrial area	Residential area in the neighbourhood of industry or endangered by industrial pollution. "Protected" or "other" area.
II.	1-3.	See Type I	See Type I
	4.	Residential area	Earlier, densely built residential area, far from station 2, and more polluted. "Protected" area.
	5.	Traffic centre	Residential area endangered by car traffic or railway station. "Protected" or "other" area.
	6.	Recreational area	Area with clean air in the town or near the town, suburb or recreational zone "Especially protected" or "protected" area.
III.	1-5.	See Type II	See Type II
	6.	Recreational area	Recreational zone or control area. "Especially protected" or "protected" area.
	7.	City centre	See station 1.
	8.	Residential area	See -"- 2.
	9.	Industrial area	See -"- 3.
	10.	Residential area	See -"- 4.
	11.	Industrial or traffic area	See 5 or 3 depending on which is characteristic
	12.	Suburb	Loosely built residential area with family houses.

The number of the stations located in a settlement depends on the size of the settlement, the number of its inhabitants and the degree of endangering of its air. Accordingly, a system of 3, 6 and 12 sampling points can be planned. /I, II and III Type/ The proportion of places with polluted and clean air is equal within the individual types, thus the urban averages are comparable. Comparability is even better if one compares the stations of the same code number in each settlement. The three types can be converted into each other /developed or reduced/ easily, without a break in comparability.

In case of measuring local pollution the stations should be located with a view to the general aspects and to the objective of the measurement.

Period and frequency of measurement

The number and frequency of measurement should be defined within the frames of reasonability. Frequent measurements in large numbers provide extra information to a certain level, but the advantage of extra information is limited by economical aspects. In case of early warning systems continuous measuring is needed. For the calculation of the annual mean of concentration data we need measurements from all seasons. If measurement was carried out at least on 20 % of days of the seasons, our data series is satisfactory.

The approximation of the actual concentration is based on data gained from measurements of different frequency. The exactness of approximation has been determined theoretically and calculated from data of operating networks. Evidently, a decrease in the

number of measurements results in the decrease of exactness of the approximation.
The next table shows that to the estimation of the annual mean of SO_2 concentration at a 10 % exactness we need 123 24 hours'measurement.

The deviation of the annual mean of 24 hours' SO_2 concentration from the actual mean value, at 95 % reliability intervall, at decreasing number of measurements
/Budapest/

Number of measurements	Deviation of the actual and sample mean value, mg/m^3	Exactness %
123	± 0,026	10
61	± 0,042	16
52	± 0,047	18
26	± 0,073	28

The 10 % exactness is satisfactory for assessing the quality of air of settlements or an area.

The level of immission varies in time at a great extent, due to the variation of emissions on the one hand and due to meteorological factors on the other. Therefore regular measurements, taken over a year are considered as acceptable. In exceptional cases six months' measuring can be accepted as well, if winter and summer /heating and non-heating/ seasons are equally represented.

If the objective is to determine the level of pollution for one given day, a sample of 24 hours should be taken or registering instrument should be applied for 24 hours. 24 hours' samples, taken at least eight times a month are required to describe the pollution of a given month. 24 hours' samples should be repeated every other week /as to say 26 times annually/ as a minimum to determine the average of a year's pollution. Results coming from such infrequent sampling should not be broken down /to monthly averages, for instance/. Continuous registering or series of successive 30 minutes' measurements is needed to trace the daily variation and the daily maximum level of pollution.

The time-period of the measurement depends on the objectives. The permissible pollution /concentration/ standards usually refer to 24 hours and 30 minutes' maximum. Consequently, if the comparison of the measured values to the standards is an element of the evaluation, the sampling period should be 24 hours or 30 minutes. Other periods are not comparable with the standards.

Immission control network

The development of an immission control network is reasonable if there is a need for regular measurements over a long time, covering a large area or settlement, or major administrative units /counties, the country etc./.

Immission control network means a system in which unified methods, instruments, emplacement criteria and data processing are applied, in order to assure comparability.

Three types of the control systems can be distinguished:

1. Telemetric measurement network supplied with registering instruments /on-line system/
2. Non-telemetric, settled instrumental network /off--line system/
3. Periodical sampling at fixed sampling points.

The Hungarian national immission control network falls under type 2. Its main principles are, that settled instruments are operating at fixed /stable/ sampling points; the instruments are registering, or automatic, semi-automatic or manual devices; the results are evaluated monthly. The information provided by the system are adequate for most purposes but the system does not give the possibility for immediate intervention.

Some data on the Hungarian immission measurement network:

Number of observed settlements in 1981: 76 + 12 regional

Number of stations measuring	SO_2	: 276
-"- -"- -"-	NO_2	: 276
-"- -"- -"-	soot	: 276
-"- -"- -"-	particulate matter	: 636
SO_2 registering		: 12
CO registering		: 6

/From 1982 ozone is measured at several stations/

Number of measurement data in 1980
and 1981

Total measurement data 1980: 300 700
-"- -"- 1981: 323 160

	NO_2	SO_2reg.	COreg.	Particulate matter	Soot	SO_2
1980	48 000	89 300	53 300	7 600	48 000	48 000
1981	50 000	120 000	46 300	7 600	50 000	50 000

Regional measurements	1980	1981
Lake Balaton, South[a/]	10	9
Lake Balaton, North[a/]	19	22
County Heves[b/]	18	18
Valley Zagyva[b/]	7	7
Lake Velencei[a/]	4	4
County Baranya[b/]	57	33
Beremend[b/]	20	13
Hortobágy[c/]	-	3

a/ Recreational area
b/ Industrial region
c/ Nature conservation area

Processing and interpretation of measurement data

Unified instructions to evaluate immission data cannot be given. The individual studies, research fields require different special processing and interpretation methods. Here the data processing of regular network measurements will be dealt with first of all. As there are already data series for several years at the experts' disposal, the need for detailed processing and interpretation of measurement results has emerged.

The simple presentation of air quality data a little requires more than the results of the actual measurements. But processing and interpretation is impossible without the knowledge of meteorological and climatic data, the characteristics of the sources of emission, relief and building up conditions.

Measurements for a whole year are accepted for the assessment of immission. Assuming up-to-date measurement technics, several thousands of data pile up during one year and this great amount of data is practically unusable in its original form. Therefore the use of the simple arithmetic mean has become widespread. For instance, the annual average of the concentration of a pollutant for the settlement as a whole has been calculated. The oversimplification has shown a situation much more advantageous than reality, due to the concealment of extreme values.

For processing and interpretation of immission data one needs indicators which, within the frames of lucidity, provide enough information for the valid judgement of the air quality of a settlement or an area.

Simple arithmetic mean can be applied for smaller areas, short periods. In any case, the calculation of arithmetic mean requires for other information: extreme values which occured during the averaged time period and the time of their occurance, if it is characteristic.

Besides the arithmetic mean, the median /the value belonging to the 50 % probability of the empirical distribution function/ and the modus /the most frequent value/ are often used as the index of concentration data. In the data processing of pollutant matters the use of geometric mean /the characteristic number of central tendency/ is widespread.

The characterization of concentration data cannot be finished by the calculation of one, calculated or positional mean value. More information can be gained by analyzing the deviation of data around the medium values.

Concentration data generally show a great variability in space and in time due to the variability of emission and transmission factors. Measuring concentrations at different points of a measurement network, the highest variability can be experienced at stations that are affected by a near emitter. Less variability can be observed in the natural environment, or at places where the joint effect of several sources of pollution counteracts the modifying meteorological factors.

The most frequently used index of deviation in processing immission data is corrected deviation. If geometric mean was used as average, geometric deviation should be applied.

Data on concentration are generally described in statistical tables or by diagrams. The most general descriptive method is the table of cumulative frequency, containing cumulative distribution in the form of frequency, relative frequency and percentage relative frequency. Cumulative frequency shows the occurence of a given concentration value /air quality standard/ or the occurence of concentrations exceeding this limit.

The easiest way to explore the characteristic features of data series is graphic presentation. To make diagrams one does not need to know the distribution of the measured data. Frequency distribution of concentration data can be presented by histogram. The frequency histogram already reveals the shape and symmetry of the distribution of concentrations. The majority of frequency histograms presenting immission data shows a lognormal distribution.

Values of 50 % and 98 % cumulative frequency are generally used for the characterization of air quality.

Changes of pollution in time

The variability of pollution in time depends on emissions and meteorological conditions. That kind of analysis of measurement results provide information

- on the origin of pollution
- on the operation of the source of pollution
- on meteorological interrelationships
- on danger situations
- on possibilities of prevention or remedy.

4 128303413S—12

Data of registering instruments, summarized monthly, describe changes of pollution during one day. In the Hungarian settlements the main maximum can be experienced in the early morning hours, and a second /sub/ maximum can be observed late in the afternoon. The maximums are outstanding in winter and obscure in the summer. Seasonal variations are characteristic: winter concentrations exceed many times the summer values in the case of the most important pollutants. The grouping of data by workdays and days of rest gives some information on the part of industry, traffic and household heating in the generation of immission.

On the long run the tendency, the trend of pollution has to be analysed. Trend analysis needs continuous data series for at least three years. The trend reveals the behaviour of pollution in time. It can be determined by selecting the adequate function type, by analytical equation, by the method of moving averages, by estimating changes in time and by simple qualitative description. The actual trend and its possible interpretations depend on a lot of factors, each of which should be taken into account in the explanation. Statistical significance of the trend is generally determined by the correlation of the concentration values. The Daniel-test, using Spearman's rank correlation coefficient is often applied for trend analysis. For the trend analysis of extreme values and concentration values gained from short sampling periods the χ^2 - test is generally used.

Spatial distribution of air pollution

One of the primary objectives of the examinations is to clear up the spatial distribution of air pollution. The tabulation of data by measurement points

/characteristic averages, extreme values etc./ is an important basis but not too much clear-cut and transparent. Therefore the spatial distribution of air pollution is often presented on maps. A general method for the presentation is the iso-curve. Iso--curves may refer to the average concentration of a given pollutant over the period under study or to the absolute frequency of exceeding the limit values. There are cases when iso-curves cannot be applied: e.g. if the network of stations is not dense enough, or if the task is to present the pollution of individual settlements within a larger area or region. For such cases the use of diagrams /columned or circle/ can be suggested. If the sampling points are located in a square-net system, the average of data measured by the stations at the four poles of each square can be calculated and this average will be relevant to the area of the square, as a whole. Repeating the calculation for each square, data of the individual stations are taken into account several times, and thus the data will characterize not measurement points but areas.

Exceeding of limit values

The qualification /classification/ of pollutedness means in the narrow sense the comparison of data with the limit values of air quality prescribed by legal orders. When comparing values one should always use the permissible limit values prescribed for the given area and period /in Hungary: "especially protected" "protected" and "other" areas, 24 hours' average and 30 minutes' maximum permitted once a day/. For the analysis it is necessary to have information on the percentage of measurements which exceed the limit value, and on the duration of these concentrations.

The use of indicators makes the classification easier and clearer. These indicators are usually based on the comparison of measured concentrations to the limit values. The most simple indicator is

$$\frac{I}{I_n} = M,$$

where I = the measured immission, I_n = the permitted limit value. If limit values are prescribed for the 50 % or 98 % frequency, the respective indicators /M_{50} and M_{98}/ should be used.

A calculus for the qualification of immission, worked out and prescribed in the GDR, has been tested in Hungary. The degree of immission is characterized by the following functions:

a./ In case of durable loading

$$I_t = \bar{c} + \frac{tS_o}{\sqrt{2z}}$$

b./ In case of short loadings

$$I_r = \bar{c} + tS_o$$

$$S_o = \pm\sqrt{\frac{\sum/c_i - \bar{c}/^2}{z - 0{,}5}}$$

Where $\bar{c}$ is the arithmetic mean of measurement results, c_i means the individual measurement values, which exceed $\bar{c}$, z is the number of measurements where the value exceeds $\bar{c}$, t is the factor of the Student distribution /here 1,3/.

Classification:

Classification number	Classification	Concentration interwall
1	Clean	$I_t \leqq 0{,}5 \; I_n$ $I_r \leqq 0{,}5 \; I_{n\,max}$
2	Slightly polluted	$0{,}5 \; I_n < I_t \leqq 1 \; I_n$ $0{,}5 \; I_{n\,max} < I_r \leqq 1 \; I_{n\,max}$
3	Polluted	$1 \; I_n < I_t \leqq 1{,}5 \; I_n$ $1 \; I_{n\,max} < I_r \leqq 1{,}5 \; I_{n\,max}$
4	Heavily polluted	$1{,}5 \; I_n < I_t \leqq 2{,}5 \; I_n$ $1{,}5 \; I_{n\,max} < I_r \leqq 2{,}5 \; I_{n\,max}$
5	Very heavily polluted	$2{,}5 \; I_n < I_t$ $2{,}5 \; I_{n\,max} < I_r$

To characterize the air hygieny of a settlement the I_t and I_r values should be calculated for all measurement stations and compared to the limit values.

The applicability of the method has been tested in a settlement and in a county in Hungary. The transformation of the figures gained from the calculations into verbal classification has provide transparent and valid information. A similar method is used now in the interpretation of measurement data and for the classification of settlements.

The air of a settlement or an area is usually polluted by several kind of pollutants. The following indicator was tested for combined calculation:

$$L_m = \sqrt{\frac{\left(\frac{I}{I_n}\right)^2_{So_2} + \left(\frac{I}{I_n}\right)^2_{No_2} + \left(\frac{I}{I_n}\right)^2_{Co} \ldots .}{Z} + \frac{\sum \mathrm{int} \frac{\%}{10}}{10}}$$

where L_m is the indicator of air quality, I is an average of the measured immissions, I_n is the respective norm /permissible limit value/, So_2, No_2 etc. are the pollutant matters, Z is the number of the measured components.

If L_m exceeds 1, at least one of the pollutants exceeds the permissible value. The numerical value of L_m should give a good basis for the comparison of areas, settlements from the point of view of their general pollutedness, and thus it should help in decision making concerning the justification, order of importance and urgency of intervention. The number of pollutants taken into account can be changed, but of course one should deal with the characteristic pollutant matters. If one compares settlements with the help of this indicator, the same components should be taken into consideration. If there is no data on one of the pollutants or the value of

$$\frac{I}{I_n} < 1, \text{ a } \frac{I}{I_n} = 1 \text{ value should be applied.}$$

The first time only the first component of the calculus had been tested. It turned out that the calculus was not enough sensitive for exceedness of limit values, despite the use of geometric mean. Thus a correction factor was applied, which tried to weight the percentage of measurements when limit values were exceeded. The percentage of these measurements are divided by 10 and added up in such a way that only whole numbers are taken into account. /Integer = whole number./

Classification:	1,00 -	1,10	satisfactory
	1,11 -	1,50	slightly polluted
	1,51 -	2,00	polluted
	2,01 -	4,00	heavily polluted
	4,00 -		very heavily polluted

A similar method was applied in a study dealing with the measurability of the effects of environment protection measures. In the study an attempt was made towards the elaboration of an aggregate environmental index and the above described indicator was tested with some modifications, using data of the regional immission measurements at Lake Balaton. The test was based on data of three years for four pollutant matters, given by 7 stations on the Northern, and 3 stations on the Southern beach of the lake. The aim was not the classification but to trace changes of pollution in time. The method - for that special purpose - needs longer time series.

The described calculus should be looked upon as a first attempt to develop an aggregate indicator for measuring the combined presence of different pollutant matters. Work is going on to find more sensitive and useful methods to qualify the air quality of settlements or an area by one composite indicator.

Local knowledge, investigation on the spot is indispensable in the classification but it does not substitute for measurements. General main aspects which should be taken into account in a verbal classification of air quality are the following:

a./ Description of the area under study:

- delimitation of the area
- sources of emission, the quantity and types of emission
- meteorological and transmission conditions
- relief, topographical conditions
- data on the inhabitants of the area
- natural and artificial environment

b./ Circumstances of measurement

- time and duration of the measurement
- the measured pollutant matters
- measurement points
- methods and instruments applied
- the frequency, system and characteristics of measurements

c./ Detailed measurement results

- by pollutants
- by measurement stations
- broken down to periods

d./ Processing of measurement results

- characteristic mean values
- extreme values /maximums/
- distribution in time
- spatial distribution
- frequency distribution
- exceeding of limit values
- indicators

e./ Classification

- characteristic pollutants
- degree of pollution
- characteristics of spatial and time distribution
- dangerous character of pollution for the given environment
- necessary interventions

Of course in the individual cases only a few aspect is important out of the above list. But to promote comparability and general usability, uniform aspects and the system of evaluation and iterpretation has to be developed.

Sources:

/1/ Polgár, I.: A levegőtisztaság védelme /Protection of the cleanness of air/ OMKDK, Budapest, 1973.

/2/ Várkonyi, T. - Cziczó, T.: A levegőminőség vizsgálata /The study of air quality/. Müszaki Könyvkiadó, Budapest, 1980.

/3/ Az Országos Immisszióméró Hálózat időszakos közleményei /Periodical Reports of the National Immission Measurement Network/ OKI 7/1982.

/4/ Szepesi, D./ed./: A levegőkörnyezet /levegőminőség és humánkomfort/ tervezése /Planning of air environment/ air quality and human comfort//. Müszaki Könyvkiadó, Budapest, 1981.

/5/ Várkonyi, T. /ed./: A levegőszennyeződés /Air pollution/. Müszaki Könyvkiadó, Budapest, 1982.

/6/ Vukovich, G.: A környezeti minőség jellemzése - a környezeti gazdasági veszteségek mérése /Characterization of environmental quality - measurement of environmental economic losses./ In: Környezeti kár, gazdasági veszteség a Balaton-régió vizsgálata alapján. MTA VEAB, Veszprém, 1982.

STATISTICS SWEDEN

PARAMETERS FOR AIR QUALITY STATISTICS*

*Prepared by Thomas Polfeldt, Statistics Sweden, with the partial support of the Department of Statistics, Stanford University, Stanford, California.

1 INTRODUCTION

The background for air quality measurements is a concern about human health and environmental problems. Air quality is being monitored in many countries, mainly in larger localities, and in a number of countries there are also air quality standards. These can be expected to reflect the current knowledge of tolerable levels of pollution.

Such air quality standards, and the underlying reasoning, will contain valuable information when the particulars of a statistical description of air quality are discussed. In this context, the structuring of the standards is of the greatest interest, whereas the actual limit values will be of secondary importance. In this paper, the U.S.A. standards have been used as the basis of the discussion. However, similar principles are used in other countries with air quality standards, and the discussion here does not lose in generality by the use of this particular set of standards as a starting point and as an illustration. In fact, a very brief review of some standards and statistics from eight other countries (Australia, England, Finland, German Federative Republic, Hungary, Netherlands, Norway and Sweden) did not add any new principles to the discussion, although some further presentation ideas might have been extracted.

Thus, the first sections (2 and 3) have the function of introducing the problems and the reasoning which is used to solve them. Section 2 contains a review of the U.S.A. standards, and the underlying spatial considerations, which are mainly expressed in terms of the rules for network design. Section 3 shows how the data are converted into statistics in the U.S.A. In section 4, we take up a more general point of view, and provide mathematical formulations which bring out the basic problems in defining air quality parameters for statistical use. This section and its practical counterpart consisting of a plan for air quality statistics (section 5), contain the main results of this paper.

2 AIR QUALITY AND AIR MANAGEMENT

2.1 The standards

The definition of air quality will certainly vary to some extent, depending on the context. However, the concerns of citizens and government agencies do focus on some air pollution problems: negative health effects and health risks, the negative impact on vegetation, ecosystems, and some materials. A number of relevant air quality specifications can be deduced from these concerns.

In the formulation of standards for air pollutants, the Environmental Protection Agency (EPA) in the U.S.A., and corresponding agencies in some other countries, have endeavored to watch and limit the important known pollutants. These standards are primarily used for managing air pollution, but they clearly also describe a desired air quality. While it is necessary to retain the possibility of considering other aspects of air quality, those pollutants for which standards exist can be expected to be of primary importance. The statistical aspects studied here will be relevant for many other pollutants as well.

The current (1982) federal American standards were set up by the EPA under the Clean Air Act (1963, 1970, 1977). They are formulated as follows (from [5], p. 25):

Table 2-1 National Ambient Air Quality Standards

Pollutant	Averaging time	Primary standard levels	Secondary standard levels
Particulate matter	Annual (geometric mean)	75 $\mu g/m^3$	60 $\mu g/m^3$
	24 hrs [b]	260 $\mu g/m^3$	150 $\mu g/m^3$
Sulfur oxides	Annual (arithmetic mean)	80 $\mu g/m^3$ (0.03 ppm)	—
	24 hrs [b]	365 $\mu g/m^3$ (0.14 ppm)	—
	3 hrs [b]	—	1300 $\mu g/m^3$ (0.5 ppm)
Carbon monoxide	8 hrs [b]	10 mg/m^3 (9 ppm)	10 mg/m^3 (9 ppm)
	1 hr [b]	40 mg/m^3 [a] (35 ppm)	40 mg/m^3 [a] (35 ppm)
Nitrogen dioxide	Annual (arithmetric mean)	100 $\mu g/m^3$ (0.05 ppm)	100 $\mu g/m^3$ (0.05 ppm)
Ozone	1 hr [b]	240 $\mu g/m^3$ (0.12 ppm)	240 $\mu g/m^3$ (0.12 ppm)
Hydrocarbons (nonmethane) [c]	3 hrs (6 to 9 a.m.)	160 $\mu g/m^3$ (0.24 ppm)	160 $\mu g/m^3$ (0.24 ppm)
Lead	3 mos	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$

[a] EPA has proposed a reduction of the standard to 25 ppm (29 mg/m^3).
[c] A nonhealth-related standard used as a guide for ozone control.
[b] Not to be exceeded more than once a year.

Source: Information provided by the U.S. Environmental Protection Agency.

The primary standards refer to health effects, the secondary to so-called welfare effects, e.g. effects on vegetation, animals, buildings.

It should be noted already here, that what we may call the status of some standard values is very much a question of debate. Should the standard designate a level which must never be exceeded, or exceeded at most once a year (as in the U.S.A. federal standards above), or perhaps it could be allowed to exceed the standard a certain small fraction of the total time? This question is of course very important for the management practice. Its impact in the present search for statistical parameters will become clear in section 4.

In passing, we note here some other pollutants which may have to be considered at a later stage. Emission standards in proposed or final form have been issued by the EPA for asbestos, berryllium, mercury, and vinyl chloride, cf. [4], p. 177. Other air pollutants which may be designed as hazardous include polycyclic organic matter, cadmium, ethylene dicloride, perchloroethylene, acrylonitrite, methylene chloride, methyl chloroform, toluene, and trichloroethylene ([4], p.

177). Benzo(a)pyrene and some 20 metals and ions have been measured irregularly in the U.S.A. Some results are reported in [12] and [14]. There are no precise formulations of air quality standards (as opposed to emission standards) for any of these substances.

The setting of the standards has been supported by extensive investigations, including numerous medical and health studies and reports, animal experiments, studies of vegetation, ecosystems, and decay of materials. EPA reports summarizing the findings appeared in 1969--1970 (cf. [15] p. 34930, refs. 16-20). New reports, [7], [8], [9], [10], [11], have been published beginning in 1979, for the revision of the standards which is required every five years. However, it is generally not explained in detail which factors were decisive in fixing a standard. The standards are not explicitly tied to certain effects, in other words, and maybe this is necessary, given that so many different effects and possible effects have been taken into account.

The standards reflect, however, two kinds of problems: (a) The <u>long term effects</u> of air pollution, which are covered by the annual averages requirements for SO_2, total suspended particulates (TSP), and NO_2. These effects include decay of material, like sandstone and some metals, the deterioration of waters, and decline in forest growth due to acid rains. The long term medical effects are not discarded, but they are more difficult to establish.1) (b) The <u>short term effects</u>, covered by the 1-hour to 24-hour averages. Most of the critical effects are physical problems experienced by humans, but there are also results showing, e.g., how vegetable crops don´t survive certain short episodes of heavy air pollution.

The following table, from [19], where the exposure times are linked to effects, illustrates the kind of discussion on which the standards are based.

---

1) cf. the discussion of SO_2 at the end of section 2.2.

The exposure time required to cause a particular pollutant effect depends upon the type of effect (Table 1). Odor, for instance, can be detected in a 1-second whiff.[6] On the other hand, a much longer exposure to carbon monoxide is required to cause a different type of effect, impaired judgment. An 8-hour exposure to a carbon monoxide concentration of 12 to 17 milligrams per cubic meter, mg/m^3 (10 to 15 parts per million, ppm) can impair a person's judgment of time intervals.[2] Vegetation can be damaged by an exposure of less than 1 hour if the concentrations of oxidant, sulfur dioxide, or some other toxicant are high enough; however, because of the pattern of pollutant concentration variation in urban atmospheres, plant damage is usually caused instead by long exposure (such as 8 hours) to low concentrations.

Table 1. RELATIONSHIP BETWEEN AIR POLLUTANT EXPOSURE AND EFFECTS

Approximate exposure duration	Effect	Pollutant			
		Carbon monoxide	Oxidant	Particulate matter	Sulfur oxides
1 sec	Sensation				
	Odor	--	x	--	x
	Taste	--	--	--	x
	Eye irritation	--	x	--	--
1 hr	Student athlete performance impaired	--	x	--	--
	Visibility reduced	--	x	x	x
8 hrs	Judgment impaired	x	--	--	--
	Heart patients stressed	x	--	--	--
	Vegetation damaged	--	x	--	x
1 day	Health impaired	--	--	x	x
	Soiling	--	--	x	--
4 days	Health impaired	--	--	--	x
1 yr	Health impaired	--	--	x	x
	Vegetation damaged	--	--	x	x
	Corrosion	--	--	x	x
	Soiling	--	--	x	--

It is apparent from Table 1 that in order to relate pollutant effects to pollutant concentrations, the concentrations should be analyzed as a function of exposure duration. This can be accomplished by averaging ambient pollutant concentrations over time periods such as an hour, a day, or a year.

The linkage of air pollution levels and health effects is carried one step further in the Pollutant Standard Index (PSI). This index is based on the five major pollutants (the first five in the table of standards). It is computed daily in most U.S.A. metropolitan areas, and if the PSI is too high, a warning is issued on radio and television. Some details are given in the following table (from [5], p. 31):

Table 2-2. Health effects associated with levels of pollutant standards index (PSI)

PSI value	Descriptor	Health Effects	Warning
400 and above	Hazardous	Premature death of ill and elderly. Healthy people will experience adverse symptoms that affect their normal activity.	All persons should remain indoors, keeping windows and doors closed. All persons should minimize physical exertion and avoid traffic.
300-399	Hazardous	Premature onset of certain diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons.	Elderly and persons with existing diseases should stay indoors and avoid physical exertion. General population should avoid outdoor activity.
200-299	Very unhealthful	Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population.	Elderly and persons with existing heart or lung disease should stay indoors and reduce physical activity.
100-199	Unhealthful	Mild aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population.	Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity.
50-99	Moderate		
0-49	Good		

Source: U.S. Environmental Protection Agency, "Guideline for Public Reporting of Daily Air Quality—Pollutant Standards Index," 450/2-76-013 (Washington, D.C., 1976).

Particulars about the computation of the PSI are given below in section 4.6.

2.2 Spatial considerations

The standards as such do not express any spatial considerations. There is, however, a set of rules, issued by the EPA, for the design of the network of monitoring stations. The discussion of these rules - which can be found in [15] - will help to understand some relevant spatial aspects of air quality.

The basic monitoring objectives are, according to [15],

(1) to determine highest concentrations expected to occur in the area covered by the network

(2) to determine representative concentrations in areas of high population density

(3) to determine the impact on ambient pollution levels of significant sources or source categories

(4) to determine general background concentration levels.

From objective (1), it is clear that there is an interest in keeping the pollutant under control everywhere in an area. Objective (2) leads to average pollution levels in certain areas. Objective (3) is mainly concerned with pollutant levels in places where they may be expected to be particularly high; averages and maxima or high percentiles for fairly restricted areas close to expected sources are thus of special interest. Objective (4), on the other hand, focuses on the pollution in larger areas, where the conditions may be expected to be similar over the entire area, and where therefore the average may well describe the conditions.

These considerations will all be useful in the sequel. They are complemented in [15] by a discussion of spatial scales of interest, described in the following terms. The corresponding objectives of interest, numbered as above, are indicated in each case.

- microscale, air volumes with dimensions ranging from a few metres up to about 100 metres (-)

- middle scale, up to several city blocks, 100-500 metres (1,3)

- neighbourhood scale, some extended area of a city, with relatively uniform land use, 0.5-4 kilometers (1,2,3,4)

- urban scale, citywide conditions, 4-50 kilometers (1,2,4)

- regional scale, usually for a rural area of reasonably homogeneous geography, up to several hundreds of kilometers (4)

- national and global scales (-)

The spatial discussion should also include some hints on what is known about the behaviour of the various pollutants. This depends partly on background information, covering emission sources, climate, and geographical characteristics, and partly on the chemical properties of the pollutants. Background information can also be obtained by applying diffusion models to the conditions of an area.

The discussion in [15] relates the five main pollutants to the various scales. Generally, it is necessary to relate the effects to areas of relevant size. Let us give an example of the required type of reasoning. The effects of sulphur dioxide are several, in fact there is a 1000 page EPA report on it [11], a set of reports from a working group within the Economic Commission for Europe [6], and many other papers. Some of the most important long term effects are

- corrosion (various metals; sandstone and limestone, plastics and rubber)

- vegetation damage (lichens, beech and oak; agricultural crops in experiments)

- soil and groundwater acidification (secondary effect)

- health effects (aggravation of respiratory diseases, including asthma, chronic bronchitis, emphysema; reduced lung function; possibly increased mortality)

Corrosion is most marked within a distance of about 10 kilometers from major emission sources [6]. This means that the neighbourhood or urban scales are relevant for this effect. The observation that corrosion and SO_2 levels often dwindle further away from the source, also describes the likely behaviour of the SO_2 concentration field. Levels over about 20 $\mu g/m^3$ provoke increased corrosion.

Vegetation damage can be tied to SO_2 levels mainly if it occurs in not too small areas, again on the neighbourhood or larger scales. Critical levels are from 40-60 $\mu g/m^3$.

Health effects are of interest for such areas where persons would normally stay for the long periods (years) we are discussing. For most people, at least the middle or neighbourhood scale is involved, often enough the urban scale. For persons in rural areas, the regional scale is relevant. The indoor/outdoor differences cannot be taken into account unless indoor pollution is also measured, and patterns of moving around vary tremendously. In fact, this had led to a current interest in personal exposures, see [21, 22, 26]. Unhealthful outdoor levels are commonly thought to be those over 40 $\mu g/m^3$ (annual average).

Among meteorologists and air quality managers, it is possible to find a good deal of knowledge about the spatial variation of SO_2 long term averages as well as other pollutants, although not much of this knowledge is documented. For SO_2, the "lore" is that the variations are fairly small, with expected maxima over urban agglomerations. This again points to the neighbourhood scale or larger as a resonable reporting area.

Similar and more detailed considerations can be made for all the pollutants. It is not unexpected to find, roughly, that while the long term averages are connected with fairly large scales, some short-term values are mainly of interest in the microscale, particularly automobile exhausts like NO_2 and CO. For O_3, which is formed in large volumes of air under certain climatic conditions, the neighbourhood and urban scales are relevant.

3 ACTUAL MEASUREMENTS AND STATISTICAL REPORTING

3.1 The measurements

The following facts from the Californian air quality measurements will serve an illustrative purpose in the further discussion.

Measurements are carried out at fixed monitoring stations, of which the San Francisco Bay Area (15800 sq. km, population about 5 million) has about 30; California (411000 sq. km, population 22 million) about 260.

The gaseous pollutants which are being measured are ozone, carbon monoxide, nitric ocide, nitrogen dioxide, sulphur dioxide, in some instances also hydrogen sulphide, total hydrocarbons and nonmethane hydrocarbons. There is generally an automatic continuous registration on paper of the concentrations of these pollutants. For each period of 60 minutes, beginning at a full hour, the average level of the continuous registration is judged by eye and noted down. The recorded figures, which constitute the raw data, are given in the same units as the standard, while the judgments of the averages can often be made within one tenth of that unit.

When averages for 3, 8, and 24-hour periods are required, such averages are computed from the 1-hour data, for each period beginning at a full hour. An average is considered to belong to the day when it starts, and thus for each day there are 24 averages, no matter the length of the time period covered. - The calculation of maximum values is then straightforward.

For high volume particulate pollutants, there are measurements for TSP, lead, sulphate, and nitrate (ions). For all of these, every 6 days a filter is exposed during 24 hours, air is sucked through it, and the weight of the particles that attach to it are recorded and related to the amount of air ($\mu g/m^3$). These figures, thus usually one for every 6 days at each site, are the raw data. The extremes, the arithmetic mean (quarterly for lead) and the geometric mean (for the others) are based on the raw data.

3.2 Published statistics

It is difficult to explain the statistical reporting of air quality data without going into some detail. The brief review here serves to show how the statistical reports in California, in the San Francisco Bay Area and on a national level in the U.S.A., have been based on the standards and the existing measurement stations. It will be argued in sections 4 and 5 that this is an air quality management oriented reporting, which covers some but not all aspects of what is relevant. Naturally, other types of reporting will occur elsewhere, but many reports from other sources are similar to those described here.

California. This account is based on the 1981 annual summary of California air quality data, [3]. A good overview of the entire reporting system for California is given by the following excerpt from a table for nitrogen oxide.

Table 10 cont'd

CALIFORNIA AIR RESOURCES BOARD
AEROMETRIC DATA SYSTEM

05/28/82

1981 ANNUAL STATISTICS AND NUMBER OF OCCURRENCES OF HOURLY CONCENTRATIONS GREATER THAN OR EQUAL TO .25 PPM

NITROGEN DIOXIDE

BASIN NAME, COUNTY AND STATION NAME AND ID CODES		METHOD	- - ANNUAL STATISTICS - - HOURLY CONC. 1ST HIGH	2ND HIGH	ANNUAL MEANS PPM ALL HOURS	DLY MAX HOUR	- - - - OCCURRENCES OF HOURLY CONCENTRATIONS > OR = .25 PPM - - - - JAN DY / HR	FEB DY / HR	MAR DY / HR	APR DY / HR	MAY DY / HR	JUN DY / HR	JUL DY / HR	AUG DY / HR	SEP DY / HR	OCT DY / HR	NOV DY / HR	DEC DY / HR	ANNUAL DY / HR	NUM OF OBS
SAN DIEGO (CONT.) SAN DIEGO COUNTY - 80 (CONT.)																				
CHULA VISTA	00114-I11	CH	.15	.14	.024	.049	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	8056
EL CAJON	00104-I11	CH	.14*	.13*	.035*	.057*	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0					0 / 0	5443
EL CAJON-REDWOOD AV	00131-I11	CH	.14*	.13*	.033*	.065*									0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	2309
ESCONDIDO-VALLEY PK	00115-I11	CH	.17*	.16*	.027*	.050*	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	7141
OCEANSIDE-SO CLEVEL	00121-I11	CH	.19*	.17*	.018*	.045*	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	7682
SAN DIEGO-ISLAND AV	00120-I11	CH	.27*	.24*	.043*	.076*	0 / 0	1 / 1	0 / 0	0 / 0	0 / 0						0 / 0	0 / 0	1 / 1	4424
SAN DIEGO-OVERLAND	00123-I11	CH	.22*	.22*	.025*	.053*	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	7341
COUNTY SUMMARY ---------------			.27	.24	.027	.052	0 / 0	1 / 1	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	1 / 1	
BASIN SUMMARY --------------			.27	.24	.027	.052	0 / 0	1 / 1	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	1 / 1	

The variables are given station by station, with a summary for counties, for so-called air basins, and for the whole state. These summaries consist of maxima, or means, of the data <u>from stations</u> within the county, basin or state.

The standard for nitrogen dioxide is based on 1-hour averages (this applies to the state of California only) and on annual averages (federal standard). The reported variables are, as can be seen in the excerpt, the annual max and sec max of the 1-hr values; the annual mean of the 1-hr values and of the daily max values; and the number of occurrences of certain high values - for NO_2, 1-hr values over 0.25 ppm, which is the state standard. Another table for NO_2 reports the number of 24-hr averages over 0.15 ppm. Such an occurrence is defined as a "stage 1 air pollution episode".

Similar tables are presented for ozone, the most important pollutant in California, with the number of hours/days in exceedance given for four different levels, further for carbon monoxide, sulphur dioxide and several particulates (TSP, lead, sulphate, nitrate).

There is no summary or overview except the "summary" lines in the tables, and there are no statistical maps. However, there is a final table giving the dates and sites of the six serious epidodes which occurred during 1981.

San Francisco Bay area. This account is based on the monthly reports issued by the Bay Area Air Quality Management District (cf. [1]). The following table will show the type of these reports.

BAAQMD HIGH-HOUR NITROGEN DIOXIDE CONCENTRATIONS (IN PPHM), OCT. 1981

DATE	SF	SR	RI	PT	CC	FR	LI	SJ	RC	ST	NP	VA	DIST.
T 1	8	4	6	4	7	9	5	8	4	6	6		9
F 2	4	4	3	4	5	6	4	5	2	4	4	3	6
S 3	4	3	3	1	3	3	2	4	1	3	3	3	4
:	.	.	.	.	.	.	.	.	.	.	.	.	:
W 28	3	3	3	2	4	5	2	4	2	3	3	3	5
T 29	4	4	4	2	4	4	3	4	2	3	3	3	4
F 30	6	4	5	3	4	4	4	10	3	4	4	4	10
S 31	10	5	5	5	5	4	5	6	3	5	5	5	10
MAX.	10	8	11	7	12	13	14	22	4	8	8	8	22
MEAN	5.4	4.3	4.9	3.8	5.3	5.7	4.8	6.8	2.5	4.1	4.3	4.2	

OCT. 1981, PAGE 5

The max 1-hr average is given daily for each station, with a summary for the district, and the over all max and the mean max of the month for each station. There are similar tables for ozone, carbon monoxide, TSP (less frequent measurements) and SO_2, and a final table with the number of days when standards (either state or federal) were exceeded at each station. The report for October, 1981, also contains a summary of lead quarterly means for 1980, and the 1980 averages for NO_2 and SO_2.

There are no statistical maps or other overviews.

U.S.A. National values. There are some summaries in the Environmental Quality reports. For 1981, [5], there are two tables, one with averages for five pollutants for each of the years 1960 (or later) - 1980. The averages are based on 100-300 sites throughout the country. From the other table, we give an excerpt:

Pollutant Standards Index (PSI) in 24 Standard Metropolitan Statistical Areas, 1973-1980

Table A-51
Air Quality

	Days of year in PSI interval							
Standard Metropolitan Statistical Area[1]	1973	1974	1975	1976	1977	1978	1979	1980
Buffalo, New York								
PSI 0-99[2]	NA	308	314	335	325	342	NA	348
PSI 100-199[3]	NA	47	40	23	37	20	NA	12
PSI 200-299[4]	NA	10	10	8	3	3	NA	6
PSI 300 or more[5]	NA	0	1	0	0	0	NA	0

In the corresponding volume for 1980, [4], - there is also a table showing the frequency of violations of national standards, by regions; and a chart showing the estimated national exposures to pollutants. The exposures occur when standards are exceeded, and they are counted as the number of person-days.

4 STATISTICAL AIR QUALITY PARAMETERS

4.1 Introduction. - Pollutant densities

In this section, we shall use the standards, and their background, and also the published statistics, as the basis for a mathematical formulation and a discussion of the corresponding parameters. We consider some possible spatial specifications. Since the standards are primarily a tool for environmental management, they may not always reflect the most relevant statistics from the point of view of health effects and other effects. On the other hand, precisely because they are used for management, some quantities are also of interest as statistics. The discussion of this topic is started here, and continued in section 5.

A useful tool when trying to pinpoint the definition of air quality parameters is the density $m(r,t)$ of the pollutant at time t and at the point $r = (x,y)$ or $= (x,y,z)$ in the plane or in space, respectively - cf. [24]. If necessary, the particular pollutant P can be indicated as a superscript ($m^{(P)}(r,t)$).

4.2 Long term averages

Annual arithmetic means are included in the standards, for the concentration of sulphur oxides and nitrogen dioxide. If the paramter t

is scaled to be 0 in the beginning of the year and T at the end, such a mean at the point r is

$$\overline{m}(r) = \frac{1}{T}\int_0^T m(r,t)dt \qquad (4.1)$$

The lack of spatial specifications in the standard becomes obvious in this notation. Considering the objectives (1) - (4) of section 2.2, we can conclude that there are two possibilities. First, it is required that the standard should hold <u>everywhere</u> in space (objective (1), cf. also [13]). From a management point of view, those r values where the standard, S, is exceeded are of particular interest. Both max m(r) (the maximum in the whole region) and the location and size of the area with m(r) > S are related parameters of interest. From a factual point of view, if m(r) is high at a particular location r, it will be suspected that adverse effects on vegetation, or buildings, occur at that particular spot. The problem for humans is <u>not</u> tied to one particular spot - humans move around, and there is also the further complication of the variation between indoor and outdoor exposure.

The second possibility is tied to objectives (2) and (4) of section 2.2 - average concentrations over certain areas, in the neighbourhood, urban or regional scale, are relevant when health aspects come to the fore, and, of course, for management on another level. Such averages, over the area A with size |A|, can be written

$$\overline{m}_A = \frac{1}{|A|}\,\frac{1}{T}\int_{r\varepsilon A}\int_0^T m(r,t)dt\;dr \qquad (4.2)$$

The actual statistics for m(r) are given for specified stations, i.e. specific values of r. There are also averages over counties, basins, etc:

$$\overline{m} = \frac{1}{n}\,\Sigma_{i=1}^{n}\; m(r_i),$$

which are clearly designed to estimate parameters like $\overline{m}_A$.

Similar arguments apply to the <u>annual geometric mean</u>, which is used in the standard for particulate matter. Using m(r,t), this is expressed as

$$m_G(r) = \exp\left(\frac{1}{T}\int_0^T \ell n\; m(r,t)\;dt\right).$$

A spatial average will also be of interest.

All the other standards refer to averages over periods of 24 hours or less with the exception of lead, where 3-month averages are used. The seasonal variations are thus not generally considered in the standards. This is one instance where the standards do not cover certain important aspects of air quality. It is well known that in places with cold winters, winter concentrations of sulphur dioxide are much higher than those in the summer. Annual averages will therefore tend to obscure the picture for such areas - a winter average would be more informative about the air quality. In Sweden, where cold winters and fair summers prevail in the whole country, the SO_2 standard is expressed in terms of the average for October through March (cf. the Annex!).

4.3 Short term values

Where the standards are concerned with short term variations, averages for 1, 3, 8 or 24 hour periods are considered. Using the pollution density m(r,t), these averages can be written as

$$\bar{m}(r,\tau) = \frac{1}{\Delta\tau}\int_{\tau}^{\tau+\Delta\tau} m(r,t)\, dt$$

where τ and $\tau+\Delta\tau$ indicate the beginnings and the end of the respective time periods, and $\Delta\tau$ could thus be 1, 3, 8, or 24 hours.

What about the spatial dimension? For short term values $\bar{m}(r,\tau)$ there is likely to be a considerable local variation, at least for some pollutants like carbon monoxide and nitrogen dioxide, which depend to a large extent on automobile exhausts (cf. the findings in [23]). High local 1-hour averages, e.g. along streets with heavy traffic, are important for the health of traffic policemen and others who may work in the exposed area, and the pollution will also influence the indoor conditions in the neighbourhood. High local values could also have an impact on vegetation and material like sandstone.

As we shall see in more detail later, there is, however, often a tendency, in pollution management, to disregard the most extreme values. This reflects a sound awareness that even a pollution situation which would be termed satisfactory, may have occasional, perhaps accidental, high values. It is likely that the inertia and resistance of living organisms prevent short and scarce high value episodes from causing permanent harm. Also, alarms and restrictions should not be triggered too easily. Assuming that the medical evidence supports this, we can conclude that also the local maxima in space are likely to be of limited interest. Thus, a spatially smoothed version of $\bar{m}(r,t)$ will be a reasonable measure of the pollution at r, and of the risks in most cases. The scale on which the smoothing should be performed should certainly be the microscale, in the terminology of section 2.2.

If the smoothing area is denoted by B, and its size by |B|, and the weight function for the smoothing by $w_B(s)$, the smoothed parameter is

$$\bar{\bar{m}}(r,\tau) = \frac{1}{\Delta\tau} \int_{s\varepsilon B} \int_{\tau}^{\tau+\Delta\tau} w_B(s)\ m(r+s,\ t)\ dt\ ds \tag{4.3}$$

(assuming that $\int w_B(s)ds = 1$). It will usually be convenient to think of B as a circular area. - Note that the process of smoothing, producing (4.3), is different from the area averaging which gave (4.2). The smoothing still attaches a value to each point r, but a value which is a weighted mean of the original values in a neighbourhood B of the point r.

For these smoothed quantities, it may be assumed that the standards should hold everywhere, i.e. for each r (objective (1) of section 2.2). In this case too, however, area averages of $\bar{\bar{m}}(r,\tau)$ will also be of interest (objectives (2) and (3)). The areas concerned will generally not be very large. The difference between area averages over $\bar{m}(r,\tau)$ and $\bar{\bar{m}}(r,\tau)$ depends on the relative sizes of the areas A and B, but it may be expected to be small. We therefore prefer using the simpler expression,

$$\bar{m}_A(\tau) = \frac{1}{|A|} \frac{1}{\Delta\tau} \int_{r\varepsilon A} \int_{\tau}^{\tau+\Delta\tau} m(r,t)\ dt\ dr$$

If seasonal variations are of interest, they are easily taken care of by reporting statistics for various values of τ. This is not a formulation problem.

4.4 Extreme values

Some of the standards in Table 2-1 have the note, "not to be exceeded more than once a year". The California standards are not to be exceeded at all. This means that extreme values in a set of short term averages, say for a year, are important tools for decisions and judgement, and it may be reasonable to consider them as statistical parameters which are of interest also in statistical reporting. This holds, of course, only in those countries or regions where the standard has this requirement. From the point of view of health, however, the entire distribution of short term averages during a year will be much more informative, and in a number of countries the standard is to some extent adapted to this point of view: it refers to a high percentile (90 % or 95 %) of all the short term averages of the year. As we have seen in section 3, the statistics which are published in the U.S.A. take care of both extremes and distributions.

The mathematical formulation of the extreme value parameters is of special interest, but it will not be treated in detail here. Let us note, however, that it is easy to define maxima, second maxima, fifth highest values (cf. [17]) and percentiles for the discrete values which constitute the raw data (i.e., the hourly averages). From a management point of view, the maximum or percentiles of the continuous process m(r,t) might be more relevant (cf. [13], issue 7A) but the difference can be expected to be slight (cf. [18] for some theoretical results). - When we are concerned with averages over 3, 8 or 24 hours, based on 1-hour values, the overlapping of successive averages introduces a further problem, which also is of theoretical interest. In practice, second maxima for 8-hours averages have been required not to overlap the maximum period at all.

For the spatial aspect, we should also primarily be guided by the management considerations. From the published statistics, we see that the maximum value from several stations (in a county, a basin) is computed, and some decisions are taken depending on the value of that aggregated maximum[1], or sometimes, of the second maximum (or, in other countries, of a high percentile). These extreme values are again based on a discrete set of values, and the definitions are clear.

---

1) We note here an apparent contradiction in the management process: the more stations in an area, the higher their maximum observation - and the worse does the area seem to be! Of course, the correct conclusion is that the monitoring is better.

4.5 The ozone standard

We finally turn to the ozone standard, where the expected number of exceedance days in a year is required to be at most one. (See [16], p. 26971. The ozone standard is thus incorrectly described in Table 2-1.) For a station located at r, a particular day is in exceedance of the standard value S if

$$\max_{i=1,\ldots,24} \bar{m}(r,\tau_i) > S.$$

Here, the τ_i mark the hours of the day. The discussion holds for spatially smoothed values $\bar{\bar{m}}$ as well as for $\bar{m}$.

The shift to "expected number" apparently introduces an idea of randomness in the standard which has so far been absent, although sometimes, e.g. in [19], the maximum hourly (etc.) average of the standards is also considered a random variable. In the previous definitions, it has been possible to consider m(r,t) as a number, the "state" of the pollution at the point r and time t. The sources of random variation are expressed in [19] as (1) measurement errors, (2) missing data, and (3) meteorological differences between years, and, certainly, the last of these causes important variation. In [25], the effect of emission variability is pointed out. The spatial variation, on the other hand, seems not to be discussed. However, the expected number of exceedances is computed as the average number of exceedances for the last three years. This rule confirms the temporal variation aspect, but on the other hand, it takes away the impression that a random element has been introduced. Instead, it shows that once again, what we have is an administrative wish to avoid that single out-of-the-way episodes have too much weight. While in most of the American federal standards, one extreme situation in a year was allowed to pass without notice, here at most three extreme situations in three years are accepted. Thus, from a health point of view, the same discussion as in 4.4 applies to this standard.

We note here a new type of parameter - the number of exceedance days, or more generally, periods. The mathematical formulation may be made using indicator functions

$$D(r) = \Sigma_i 1_{\{\bar{m}(r,\tau_i) > S\}} \tag{4.4}$$

where S indicates the standard value, and $1_{\{C\}}$ equals 1 if the condition C holds and 0 otherwise. This number is directly tied to the standard and constitutes a suitable statistic for comparing actual performance with the standard.

For the daily exceedances, involved in the ozone standard, the conditions take the form $\{\max_j \bar{m}(r,\tau_{ij}) > S\}$, where τ_{ij} refers to the j-th hour during day i.

The D(r) values are of course easily reported for specific stations (at r_i), and regional summaries will usually count an exceedance day for the region as soon as the standard is exceeded in one station. Again, these quantities are also suitable for statistical purposes.

4.6 Pollutant Standard Index

In order to summarize the air quality information provided by daily data on the various pollutants, the Pollutant Standard Index (PSI) has been operative in the U.S.A. since 1978. To compute this index, measurements for five pollutants are converted to a common scale ranging from 0 to 500; the value 100 corresponds to the national primary standard. This gives five numbers between these limits. A sixth number is obtained by converting the product of SO_2 and TSP values. The PSI (for a certain station and a certain day) is then the maximum of the six converted values.

The measurements to be included are defined in the following table (from [15]).

Table 1. BREAKPOINTS FOR PSI (ψ) IN METRIC UNITS[a]

Breakpoints	PSI value (ψ)	24-hr. TSP $\mu g/m^3$	24-hr. SO_2 $\mu g/m^3$	TSP x SO_2 $(\mu g/m^3)^2$	8-hr. CO mg/m^3	1-hr. O_3 $\mu g/m^3$	1-hr. NO_2 $\mu g/m^3$
50% of primary short-term NAAQS	50	75[b]	80[b]	c	5	80	c
Primary short-term NAAQS	100	260	365	c	10	160	c
Alert level	200	375	800	65×10^3	17	400[d]	1130
Warning level	300	625	1600	261×10^3	34	800	2260
Emergency level	400	875	2100	393×10^3	46	1000	3000
Significant harm level	500	1000	2620	490×10^3	57.5	1200	3750

[a]At 25°C and 760 mm Hg.

[b]Annual primary NAAQS are substituted here and are interpreted on a 24-hour basis.

[c]No index value reported at concentration levels below those specified by the alert level criteria.

[d]For the PSI index 400 $\mu g/m^3$ appears to be a more consistent breakpoint between the descriptor words "Unhealthful" and "very unhealthful" than the O_3 alert level of 200 $\mu g/m^3$.

For each of the measurements, the parameters are thus basically the same as those discussed in sections 4.1 - 4.5, say p_1, p_2, p_3, p_4, and p_5, and

$$PSI = \max(g_1(p_1), \ldots, g_5(p_5), g_6(p_1 x p_3)),$$

where the g_i are the piecewise linear conversion functions, which are defined by the breakpoints in the table.

4.7 Further parameters

The statistics reviewed in section 3.2 are all closely tied to the standards and the PSI, and the definition of corresponding parameters has, on the whole been covered above. There is one major exception and one minor one.

The minor exception consists of the monthly and annual means of daily maxima, which were reported in California. This is a combination of previous parameters (daily maxima), but it is of independent interest. Mathematically we can write

$$\overline{M}(r) = \frac{1}{n} \Sigma_{i=1}^{n} \max_j (\overline{m}(r,\tau_{ij})),$$

where again τ_{ij} indicates the j-th time period of day i, and n is the number of days in the month or year of interest.

The major new parameter is possibly slightly out of focus for air quality - it is the last one reported in section 3.2, the chart of person-days of exposure. Here, the population in the polluted areas is taken into account, thus making the effects of the air pollution easier to grasp. This is sometimes called the population-at-risk. We note that these numbers can be obtained by computing weighted sums of the quantities D(r) defined in (4.6):

$$E = \Sigma_r W(r) D(r)$$

The problem is how to identify a certain number of persons, W(r), with the point r where the exceedance has been observed. This would ideally require a spatial distribution for D(r), and therefore for the corresponding pollutants. However, it appears that the American estimates were based on counties, and a small number of observed values in a county decided whether the county as a whole was in exceedance of the standard during a certain day.

4.8 Use of mathematical parameter formulations

The discussion here has shown how the use of the pollutant density m(r,t) brings out relevant issues, like the spatial aspect. The further use of the formulae in this section will be tied to the discussion of estimation procedures for them, and the accuracy and precision of those procedures. Some of the problems in this context are mentioned in section 5, but generally, estimation is not discussed in this paper.

5 A PLAN FOR AIR QUALITY STATISTICS

5.1 The prerequisites

The important parts of the previous discussion for making suggestions for air quality statistics are the following.

1. The observation that the effects of air pollution can be described as either long term, which brings annual or seasonal pollution levels into focus, or short term, where the daily or hourly pollution levels are important.

2. The predominant interest in spatial averages, though over areas of varying scales. The most interesting of these are the neighbourhood, urban and regional scales.

3. The difference between management data and health (etc) effect oriented data. The management data are directly tied to the national or regional standards when these serve as a basis for interventions and other decisions. The effect oriented data are not always available. They should serve to throw more light upon the health effects, and the effects on vegetation, material, etc. of air pollution. Even if the management strives to control these effects, the management data are usually limited to certain key values.

5.2 The pollutants

In the following plan, the best known harmful pollutants have been included. They are the ones for which American federal standards exist - particulate matter (TSP), sulphur oxides (SO_x), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), hydrocarbons (HC), and lead (Pb). For European conditions, one might prefer SO_2 to SO_x. Clearly, it is not difficult to add to the plan. In many cases, the basic pollutants mentioned here are not regularly measured at the present time.

5.3 Long term averages

These are the annual averages of SO_x, NO_2 and TSP (geometric mean), and seasonal averages of SO_x (October - March) and of Pb (3-month periods). A table like L.1 seems natural.

6 128303413S—12

Table L.1

Station/ area	SO_x		NO_2	TSP	Pb	
	Annual average	Seasonal average	Annual average	Annual average	Annual average	Max 3-month average
AA						
AB						
AC						
.						
.						
.						
ZZ						

The heading "station/area" in this table needs some comments. Reporting by station is done now, it is easy and straightforward, but not quite satisfactory. Some improvement is achieved if the type of each location is described. There may be too many stations for this to be a readable report (this is the case in the California report [3], in my opinion); this can be solved by reporting the data of selected stations only. More to the point, it is areas rather than stations that are of interest. What areas? The discussion in section 2.2 showed that areas on the neighbourhood or urban scale are of interest in any case, regions for the background levels. The problem of how to find good estimates for the area averages, expressed by formula (4.2), is not easy. It is reasonable to use a weighted mean of the station values in the area, possibly also with the inclusion of some stations outside the area. The weights will depend on the location of the stations, the characteristics of the area (called "background information" above in section 2.2) and the expected variations in the pollutant "field", i.e. m(r,t) or $\bar{m}(r)$.

The main difficulty for the estimates of area averages, is to check how good the estimates actually are, or how well theoretical assumptions actually hold, and we are not yet able to make precise measurements of m(r,t) in order to do this.

It could be mentioned here, however, that new laser-based instruments are being developed which could measure the field m(r,t) over a circle with a diameter of about 20 kilometers (in the U.S.A. and in Sweden, among other countries, cf. [2]; [27]).

Even with relevant areas, Table L.1 is of limited use alone - it would become to large. A suggestion is to include only a) selected neighbourhoods from large cities (central, industrial, suburban), b) selected smaller urban areas, c) regional background levels for fairly large regions. A necessary complement would be a set of four to six maps of urban areas (L.2), one for each pollutant, and four to six background maps (L.3).

Map L.2. SO_x, annual average, urban areas:

Each neighbourhood or urban area is represented by a dot. The colour of the dot indicates the level of SO_x. Red dots are used where the standard (if any) is exceeded.

Map L.3. SO_x, annual average, background:

Isopleth map, or map by regions, where the colour or marking of each region indicates the SO_x level.

It is possible that the L.2 and L.3 maps could be combined.

The construction of good isopleth maps is a new generalization problem, different from the area average estimation. Again, it will be easy to suggest possible constructions (for a very brief review, see [24]), and quite difficult to assess their properties.

A further representation would involve the <u>population-at-risk</u>. If the neighbourhood or urban averages have been found, it is easy to multiply them by population numbers and obtain the population-at-risk. It is perhaps best shown in a simple histogram, one for each pollutant.

<u>Trends</u> are an important complement to the data of Table L.1 and maps L.2 och L.3. The calculation of trends will not be discussed here. Assuming they have been calculated, they could be represented in the table by a sign, say +, -, ~, next to each entry, and in separate maps indicating areas with increasing, decreasing and stable pollutant levels.

5.4 Short-term averages

These are the 24-hr averages of TSP and SO_2, the 8-hr averages of CO, the 1-hr averages of CO and O_3, and the 6AM to 9AM average of HC. To this, I would like to add the 1-hr NO_x average, giving seven pollutant variables in all. A natural table again has the structure with pollutants by stations/areas. However, in each cell, it is suggested to use the idea of the PSI-table reported in section 3.2: to give the percentage of the observations in four different classes - low, medium, high, and extra high pollution levels.[1)] If the standard has a corresponding construction, the "extra high" levels could be defined as those above the standard.

Table S.1

Station/area	TSP 24-hr				SO_2 24-hr				...
	LO	ME	HI	XH	LO	ME	HI	XH	
AA	25	40	30	5					
.									
.									

Here, XH would thus comprise values over the standard value.

Of course, such a table would be quite difficult to read. It would be slightly easier if the XH columns were shaded. The number of rows would have to be reduced, at least in a yearbook, following the same principles as for the long term Table L.1.

Which are the interesting areas in this case? While the microscale or middle scale is certainly relevant for city planners and for local management, it is not useful for national or state statistics. Some kind of summary for at least a neighbourhood scale, usually an urban scale is desirable. The following type of area summary may be useful.

Each neighbourhood or urban area is divided into microscale or middle-scale plots. For each plot, or for a sample of plots, the LO/ME/HI/XH

---

1) The raw data will of course be kept for other purposes.

distribution is computed. For the urban area, the means (possibly the weighted means, if the sample requires this) of the percentages in each class are given. Thus, there is an average LO/ME/HI/XH percentage distribution for the larger area.

If required, e.g. if the urban area contains a wide variation, the average distribution could be complemented by the "best" and "worst" microscale distribution within the urban area. The exact definition of "best" and "worst" will not be discussed here.

This kind of summary assumes that there are many microscale stations in an urban area. When this is not the case, the reporting by stations is probably the only feasible way to give a fair picture of what is known.

Summaries for larger regions of the form described would probably not contain much information of interest, and they should therefore be avoided. Background values are also less interesting, except for ozone.

Here too, corresponding maps would be useful. In order to illustrate with coloured dots, like in map L.2, one value has to be computed out of the four LO/ME/HI/XH percentages. The best choice is probably to take just the XH percentage, at least if extra high values are not too infrequent. Otherwise, the HI + XH percentage could be used. This now mirrors the management concerns.

Map S.2. TSP, 24-hr average

Each station or area is represented by a dot. The colour of the dot indicates the percentage of the observations which are above the standard. Except when this is zero, different red and orange colours should be used. - If the HI + XH percentage is used, colouring should help to indicate whether XH is zero or not.

Regional summaries may be based on these dots, or the corresponding percentages - at least in broad terms, stating e.g. the frequency of different colours of the dots. A related idea is to design a small number of typical LO/ME/HI/XH distributions, and to assign each observed distribution, or each urban summary, to one of these types. The regional summary would then state how many distributions of each type that had been observed in the region.

Another variable, which is closely tied to the management of air quality (at least in the U.S.A.), is the maximum at each station, or a larger area. We discussed the maximum in section 4.4. The drawback of the max, and also of the sec max, is that they are fairly unstable quantities, fluctuating wildly between days or at least between seasons. As we noted, there is a tendency to use order statistics, and perhaps even percentiles slightly further down in the distribution. Such values would also be more suitable for statistical representation, since they would generally contain better information about the quality of the air.

The population-at-risk could be computed, e.g. as the number of person-days in the XH levels. The microscale areas should not be used, since most people move in and out of so small areas. Instead, the neighbourhood and urban averages, will probably yield resonable estimates. Rural population will generally be considered as not having any XH days.

Trends are important. These may be computed for XH, or HI + XH percentages, but there are many other possibilities. The presentation can follow the same pattern as for long term averages.

It cannot be avoided that seven different air pollutants tend to give a confusing picture. Is the air quality good, or bad, in the end? Although we have left it to the end of this discussion, the PSI, or a similar index (for other countries) is perhaps the best way of summarizing the short-term air quality. The index values should be reported before any of the detailed data of Table S.1 and the maps. The established form, see section 3.3, is useful. Three dot maps with the percentages of observations above 100, 200, 300 would make a good complement to the table.

5.5 A general remark

The air quality parameters are not immediately understandable by the public. In order to make the statistics which have been suggested here meaningful, they require a brief introduction (SO_2 pollution causes corrosion, vegetation damage, acidification, certain health effects;

all of this in some more detail) and an orientation about, say, what levels may be considered good/moderate/unhealthful/hazardous.

When standards exist, as they do in the U.S.A., they will also provide some guidance.

REFERENCES

[1] Bay Area Air Quality Management District (1981) Contaminant and Weather Summary, October 1981. San Francisco, CA.

[2] Byer, Robert L, Shepp, Lawrence A. (1979). Two-dimensional remote air-pollution monitoring via tomography. Optics Letters, pp 75-77. March 1979.

[3] California Air Resources Board (1982) California Air Quality Data. Annual Summary 1981 (Vol XIII).

[4] Council on Environmental Quality (1980) Environmental Quality 1980. The 11th Annual Report. Washington DC.

[5] Council on Environmental Quality (1982) Environmental Quality 1981. The 12th Annual Report. Washington DC.

[6] Economic Commission for Europe (1981) Interim Executive Body for the Convention on Long-range Transboundary Air Pollution. Working Group on Effects of Sulphur Compounds on the Environment. First session, 27-30 April 1981. Documents ENV/IEB/WG.1/R.1 to /R.5.

[7] EPA (1979) Air quality criteria for Carbon Monoxide. (Preprint.) Oct 1979. EPA 600/8-79-022.

[8] EPA (1977) Air quality criteria for lead. Dec 1977. EPA-600/8-77-017.

[9] EPA (1979) Air quality criteria for Oxides of Nitrogen. June 1979. Environment Critera and Assessment Office, USEPA, Research Triangle Park, NC.

[10] EPA (1978) Air quality criteria for ozone and other photochemical oxidants. April 1978. EPA-600/8-78-004.

[11] EPA (1981) Air quality criteria for particulate matter and sulfur oxides. Draft final. Vol I-IV. Dec 1981. Environmental Criteria and Assessment Office, USEPA, Research Triangle Park, NC.

[12] EPA (1978) Air quality data for non-criteria pollutants, 1971--1975. Jan 1978. EPA-450/2-78-001. (Data for 1957--1970 in EPA-450/2-77-020. Nov 77.)

[13] EPA (1977) Guidelines for the interpretation of air quality standards. USEPA. Office of Air Quality Planning and Standards. February 1977. OAQPS 1.2-008. Research Triangle Park, NC.

[14] Faoro R and Manning J (1978) Trends in Benzo(a)Pyrene, 1966--1977, Prepared for the USEPA, Washington. DC.

[15] Federal Register (1978) Air quality surveillance and data reporting. Proposed regulatory revisions. Federal Register, Vol 43, No 152, pp 34892-34934. August 7, 1978. - Taken as Rules with slight modifications. Federal Register, Vol 44, No 92, pp 27557-27604. (The references are to the preliminary version in Vol 43.)

[16] Federal Register (1978) Photochemical Oxidants; Measurement of Ozone in the atmosphere; Requirements for Preparation, Adoption, and Submittal of Implementation Plans. Federal Register, Vol 43, No 121 - Thursday, June 22, 1978. Part II, pp 26962-26971.

[17] Federal Register (1982) Revisions to the National Ambient Air Quality Standards for Carbon Monoxide. Federal Register, Vol 47, No 118 Friday, June 18, 1982. Proposed Rules, pp 26407-26408.

[18] Grivet, Cyril D (1980) Modeling and anlysis of air quality data. SIMS Report No 43, Department of Statistics, Stanford Univ (Ph D thesis).

[19] Larsen, R I (1971) A mathematical model for relating air quality measurements to air quality standards. EPA Office of Air Programs, Publ No AP-89.

[21] Ott, Wayne R (1981) Exposure Estimates Based on Computer Generated Activity Patterns. USEPA. Paper No 81-57.6.

[22] Ott, Wayne R (1980) Models of Human Exposure to Air Pollution. SIMS. Technical Report No 32. Dept of Statistics, Stanford Univ. July 1980.

[23] Ott, Wayne, and Eliassen R (1973) A survey technique for determining the representativeness of urban air monitoring stations with respect to carbon monoxide. J of the Air Pollution Control Association 23 685-690.

[24] Polfeldt, T (1979) Some considerations on the definition and estimation of environmental quality parameters. Proc of the 42nd ISI Session, Bull.I.S.I. Vol XLVIII, Book 1, pp 341-350. Manila 1979.

[25] Switzer, P (1981) Comments on the calculation of the expected number of exceedandes of a standard (1981). SIMS. Working paper No 18, Dept of Statistics, Stanford Univ.

[26] Wallace, Lance A, and Ott, Wayne R (1981) Personal Monitors: A State-of-the-Art Survey. USEPA. Also in J Air Pollution Control Association, Vol 32, No 6, pp 601-610.

[27] Wolfe, David C Jr, and Byer, Robert L (1982) Model studies of laser absorption computed tomography for remote air pollution measurement. Applied Optics, pp 1165-1178. April 1982.

ANNEXES[1]

1 The annexes are intended to show the forms in which measuring results are usually available. The figures do not allow direct comparisons between the three cities with respect to the state of their air quality. This is due to the fact that the results relate only to certain measuring stations and therefore do not reflect the general state of the air quality of these cities.

ANNEX I

Table Sulphur dioxide concentrations (µg/m³) at Helsinki, March 1983

The name of the station / Day	Hermanni = Industrial and recidental urban				Länsi-Pakila = Sub-urban		
	Average	Max.1)	Min.1)		Average	Max.1)	Min.1)
1	34	91	0		37	107	0
2	164	278	80		71	101	16
3	84	139	32		44	80	11
4	63	128	27		22	32	11
5	19	37	5		3	11	0
6	13	43	0		3	16	0
7	64	123	0		19	69	0
8	25	64	0		24	59	0
9	39	117	5		17	48	0
10	130	203	84		43	91	0
11	97	203	21		30	69	0
12	24	64	5		6	48	0
13	30	69	11		10	27	0
14	56	91	11		10	27	0
15	39	123	5		7	16	0
16	52	123	18		27	59	5
17	55	117	5		8	18	0
18	50	139	27		11	37	0
19	23	59	5		6	32	0
20	12	32	0		2	11	0
21	38	75	0		16	48	0
22	11	16	0		--	-	-
23	11	32	0		3	16	0
24	32	72	8		3	24	0
25	24	51	3		8	40	0
26	16	32	8		--	-	-
27	32	67	0		3	24	0
28	48	61	16		--	19	0
29	40	101	8		-	16	0
30	16	37	0		4	19	0
31	32	109	3		3	32	0
Month	44	278	0		14	107	0

1) The maximum and minimum values refer to 1-hour averages.

Source: Helsinki City, Healt Department.

Table Sulphur dioxide concentrations (mg/m^3) at Budapest, March 1983[1)]

The name of the station / Day	V. Banjsy-ZS				II. Szena-Ter				XXII. Facan-U				XV. Korakas-P			
	Ave-rage	Max.	Min.	Devi-ation	Ave-rage	Max.	Min.	Devi-ation	Ave-rage	Max.	Min.	Devi-ation	Ave-rage	Max.	Min.	Devi-ation
1.	.289	.377	.221	.058	.153	.211	.101	.034	**.***	**.***	**.***	**.***	.105	.146	.066	.023
2.					.121	.196	.092	.026	.034	.103	.069	.031	.104	.213	.047	.048
3.	.189	.320	.130	.046	.145	.227	.097	.032	.106	.171	.074	.027	.107	.214	.059	.036
4.	.139	.171	.103	.019	.113	.142	.092	.015	.075	.089	.067	.006	.138	.183	.094	.029
5.	.208	.327	.092	.064	.139	.241	.074	.046	.127	.209	.054	.050	.139	.243	.023	.068
6.	.066	.147	.041	.018	.098	.140	.057	.024	.084	.162	.055	.027	.058	.121	.034	.021
7.	.058	.103	.039	.019	.106	.239	.048	.062	.033	.063	.017	.013	.047	.075	.031	.009
8.	.089	.133	.056	.025	.067	.124	.031	.026	.058	.142	.025	.028	.077	.114	.050	.016
9.	.126	.512	.037	.121	.100	.341	.015	.100	.066	.151	.020	.041	.087	.201	.035	.046
10.	.082	.195	.038	.044	.066	.195	.011	.046	.037	.094	.012	.021	.080	.176	.031	.033
11.	.062	.163	.015	.037	.064	.231	.008	.048	.031	.083	.015	.014	.058	.151	.021	.032
12.	.038	.098	.007	.020	.063	.152	.001	.050	.028	.101	.007	.024	.032	.081	.011	.017
13.	.093	.213	.031	.038	.062	.143	.008	.032	.043	.145	.012	.036	.042	.140	.010	.032
14.	.170	.452	.045	.111	.091	.305	.025	.065	.046	.152	.012	.027	.071	.187	.029	.040
15.	.209	.438	.058	.087	.100	.292	.039	.051	.032	.125	.016	.025	.046	.156	.019	.032
16.	.183	.328	.052	.079	.122	.254	.030	.060	.080	.283	.015	.081	.058	.176	.023	.041
17.	.231	.597	.081	.122	.151	.392	.045	.091	.123	.338	.027	.087	.082	.226	.029	.045
18.	.159	.323	.067	.069	.098	.189	.028	.038	.071	.118	.035	.021	.094	.227	.037	.045
19.	.072	.139	.029	.029	.060	.210	.001	.051	.044	.082	.018	.016	.073	.126	.029	.031
20.	.054	.097	.025	.021	.026	.101	.000	.031	.030	.050	.011	.012	.054	.093	.020	.022
21.	.125	.402	.041	.098	.065	.322	.000	.072	.046	.209	.007	.045	.109	.305	.021	.088
22.	.066	.125	.037	.022	.039	.097	.000	.025	.037	.087	.014	.016	.065	.137	.019	.027
23.	.047	.112	.013	.027	.033	.145	.000	.038	.035	.119	.008	.027	.042	.149	.012	.026
24.	.056	.128	.039	.019	.032	.080	.000	.028	.017	.036	.002	.010	.039	.095	.009	.020
25.	.048	.334	.000	.088	.047	.306	.000	.085	.024	.117	.002	.028	.039	.086	.016	.024
26.	.005	.027	.000	.007	.054	.148	.000	.055	.008	.027	.000	.008	**.***	**.***	**.***	**.***
27.	.021	.066	.001	.013	.103	.204	.027	.051	.035	.044	.023	.005	**.***	**.***	**.***	**.***
28.	.072	.297	.000	.077	.083	.327	.020	.077	.063	.203	.018	.049	**.***	**.***	**.***	**.***
29.	.119	.362	.016	.072	.108	.251	.025	.059	.040	.080	.023	.015	.056	.128	.036	.019
30.	.059	.217	.000	.056	.069	.259	.000	.063	.034	.111	.011	.022	.088	.188	.033	.036
31.	.091	.255	.017	.065	.090	.236	.000	.075	.060	.121	.010	.033	.030	.108	.001	.032
Month	.103	.597	.009	.000	.086	.392	.000	.000	.052	.338	.000	.000	.072	.305	.001	.000

Table continues

The name of the station / Day	X. Zalka-Ter				VIII. Baross				XXI. Deli-U				XII. Rege-U			
	Average	Max.	Min.	Deviation	Average	Max.	Min.	Deviation	Average	Max.	Min.	Deviation	Average	Max.	Min.	Deviation
1.	.178	.283	.108	.038	.104	.137	.076	.020	.250	.330	.160	.056	**.***	**.***	**.***	**.***
2.	.125	.209	.077	.028	.081	.122	.061	.014	.163	.290	.070	.055	**.***	**.***	**.***	**.***
3.	.143	.203	.101	.030	.096	.143	.071	.018	.101	.220	.050	.042	**.***	**.***	**.***	**.***
4.	.124	.155	.105	.012	.082	.106	.066	.012	.108	.190	.060	.039	**.***	**.***	**.***	**.***
5.	.135	.233	.040	.055	.106	.158	.060	.027	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
6.	.047	.139	.023	.021	.073	.102	.062	.007	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
7.	.045	.076	.028	.011	.061	.080	.048	.008	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
8.	.064	.093	.042	.015	.071	.104	.039	.020	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
9.	.096	.325	.028	.084	.134	.460	.025	.131	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
10.	.060	.117	.028	.024	.076	.170	.041	.038	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
11.	.061	.190	.022	.040	.058	.201	.024	.038	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
12.	.033	.102	.018	.021	.034	.093	.016	.017	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
13.	.038	.111	.017	.019	.054	.196	.013	.040	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
14.	.066	.159	.021	.039	.063	.140	.010	.039	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
15.	.064	.133	.034	.023	.047	.163	.020	.026	**.***	**.***	**.***	**.***	**.***	**.***	**.***	**.***
16.	.080	.179	.027	.042	.118	.235	.025	.060	.058	.220	.020	.068	**.***	**.***	**.***	**.***
17.	.152	.324	.041	.085	.189	.416	.076	.095	.152	.470	.020	.118	**.***	**.***	**.***	**.***
18.	.103	.201	.040	.050	.134	.372	.051	.080	.055	.140	.020	.030	**.***	**.***	**.***	**.***
19.	.049	.108	.024	.020	.060	.137	.020	.029	.022	.050	.010	.012	**.***	**.***	**.***	**.***
20.	.040	.094	.019	.014	.038	.095	.011	.022	.012	.030	.000	.010	**.***	**.***	**.***	**.***
21.	.090	.377	.018	.085	.087	.286	.001	.080	.041	.120	.000	.038	**.***	**.***	**.***	**.***
22.	.056	.121	.026	.026	.054	.123	.029	.024	.014	.040	.000	.011	**.***	**.***	**.***	**.***
23.	.039	.071	.012	.017	.040	.089	.006	.027	.012	.060	.000	.014	**.***	**.***	**.***	**.***
24.	.038	.093	.003	.025	.032	.092	.000	.027	.021	.040	.010	.008	**.***	**.***	**.***	**.***
25.	.044	.192	.006	.047	.067	.283	.000	.078	.022	.100	.010	.021	**.***	**.***	**.***	**.***
26.	.022	.045	.005	.016	.015	.034	.000	.012	.018	.040	.010	.009	**.***	**.***	**.***	**.***
27.	.054	.078	.032	.011	.041	.068	.026	.010	.031	.050	.020	.007	**.***	**.***	**.***	**.***
28.	.105	.314	.028	.070	.084	.318	.002	.078	.068	.150	.020	.034	**.***	**.***	**.***	**.***
29.	.067	.128	.036	.024					.065	.120	.030	.024	**.***	**.***	**.***	**.***
30.	.069	.211	.019	.049					.036	.080	.020	.016	**.***	**.***	**.***	**.***
31.	.101	.221	.027	.056					.084	.190	.030	.045	**.***	**.***	**.***	**.***
Month	.077	.377	.003	.000	.075	.460	.000	.000	.067	.470	.000	.000	**.***	**.***	**.***	**.***

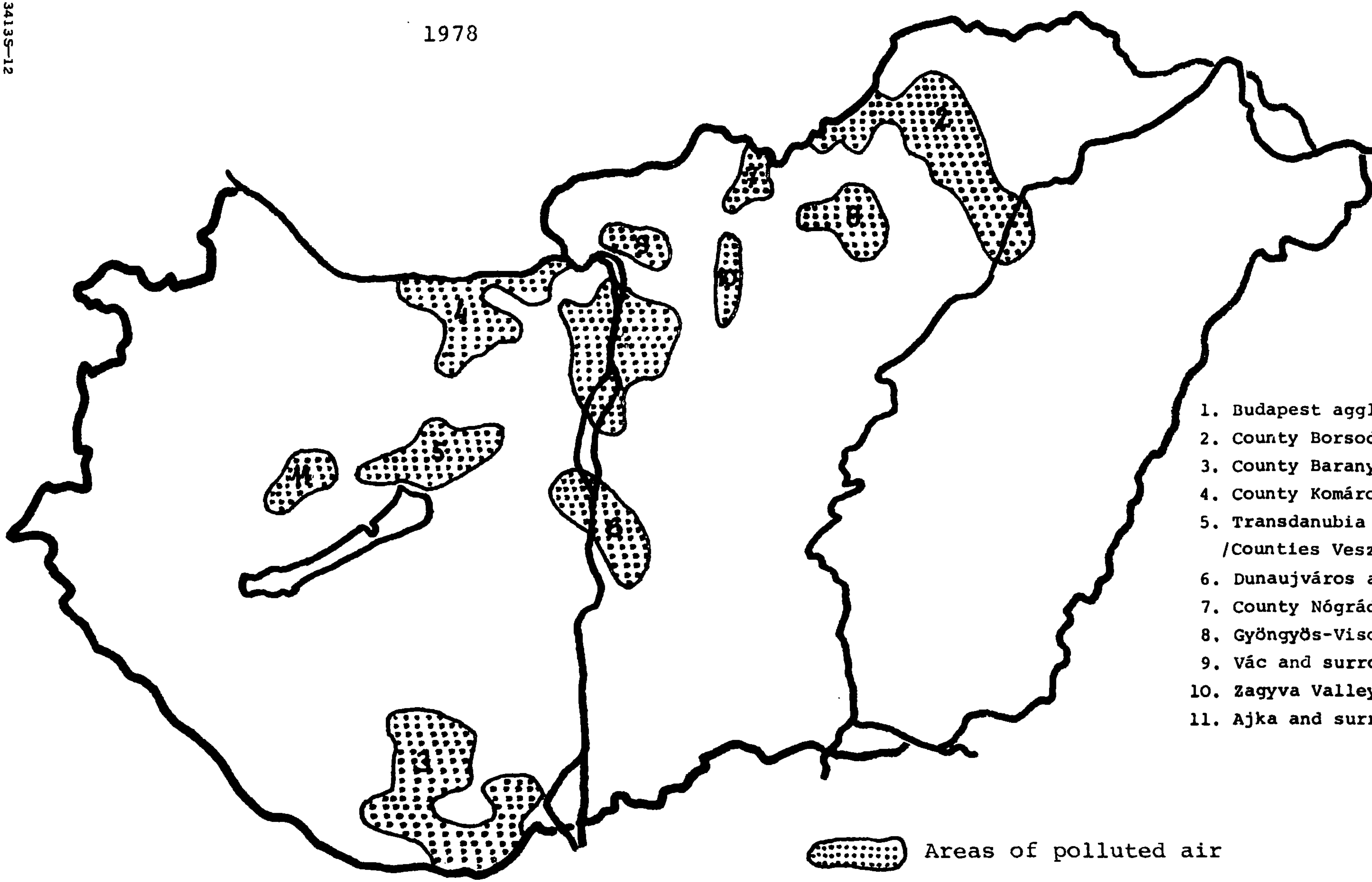
1) Based on data of the monitoring network.
The maximum and minimum values refer to 30 minutes' averages.

Source: Hungarian Central Statistical Office.

HUNGARY:

REGIONAL AIR POLLUTION

1978

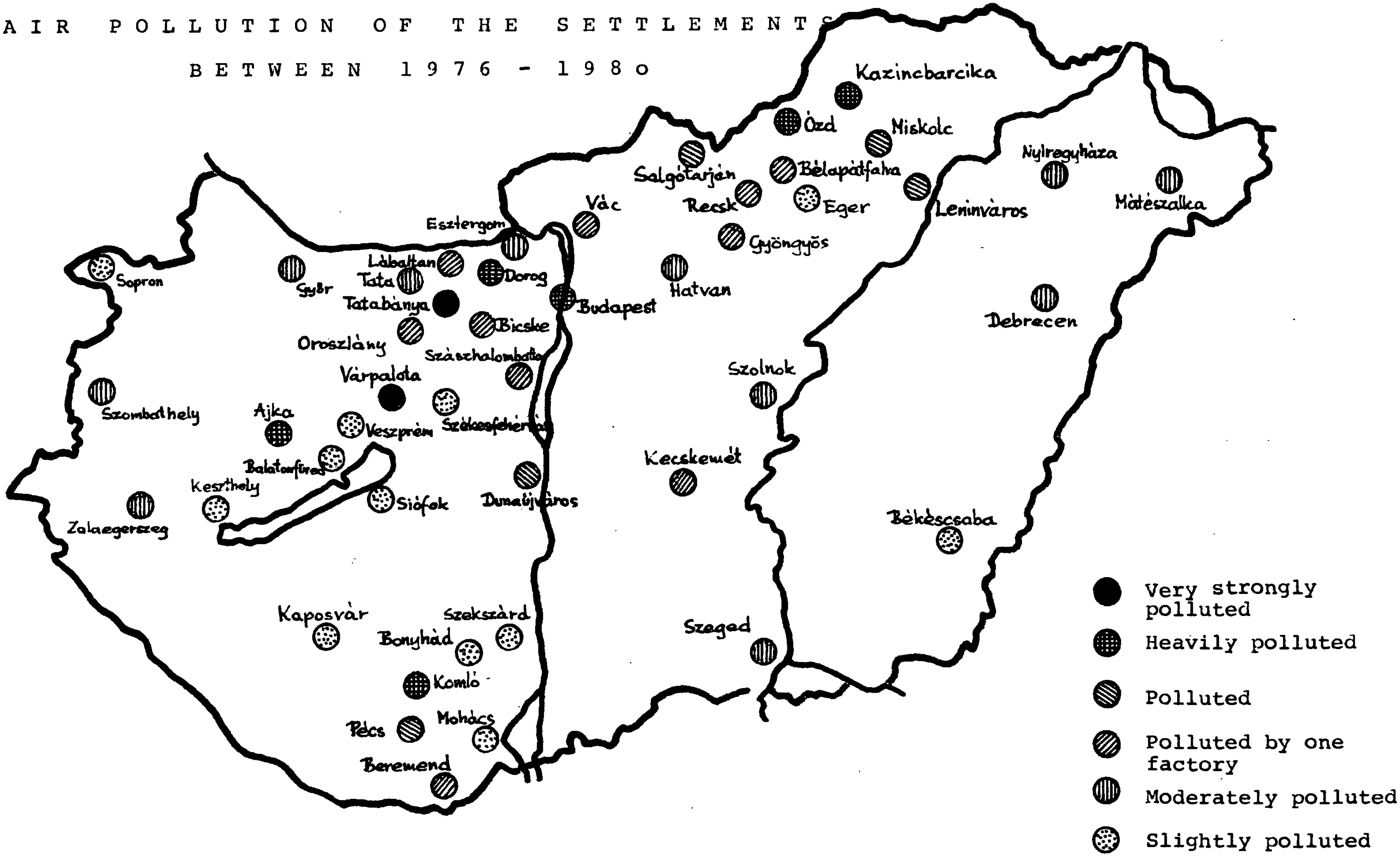


1. Budapest agglomeration
2. County Borsod-Abaúj-Zemplén
3. County Baranya
4. County Komárom
5. Transdanubia Middle /Counties Veszprém and Fejér/
6. Dunaujváros and surroundings
7. County Nógrád
8. Gyöngyös-Visonta
9. Vác and surroundings
10. Zagyva Valley
11. Ajka and surroundings

HUNGARY:

AIR POLLUTION OF THE SETTLEMENTS

BETWEEN 1976 - 1980



ANNEX III

SULPHURE DIOXIDE MEASUREMENTS IN STOCKHOLM, OCTOBER 1982 - MARCH 1983

Table Sulphure dioxide concentrations (μg/m^3) at the fixed stations, October 1982 - March 1983.
The percentiles refer to 1-hour averages.

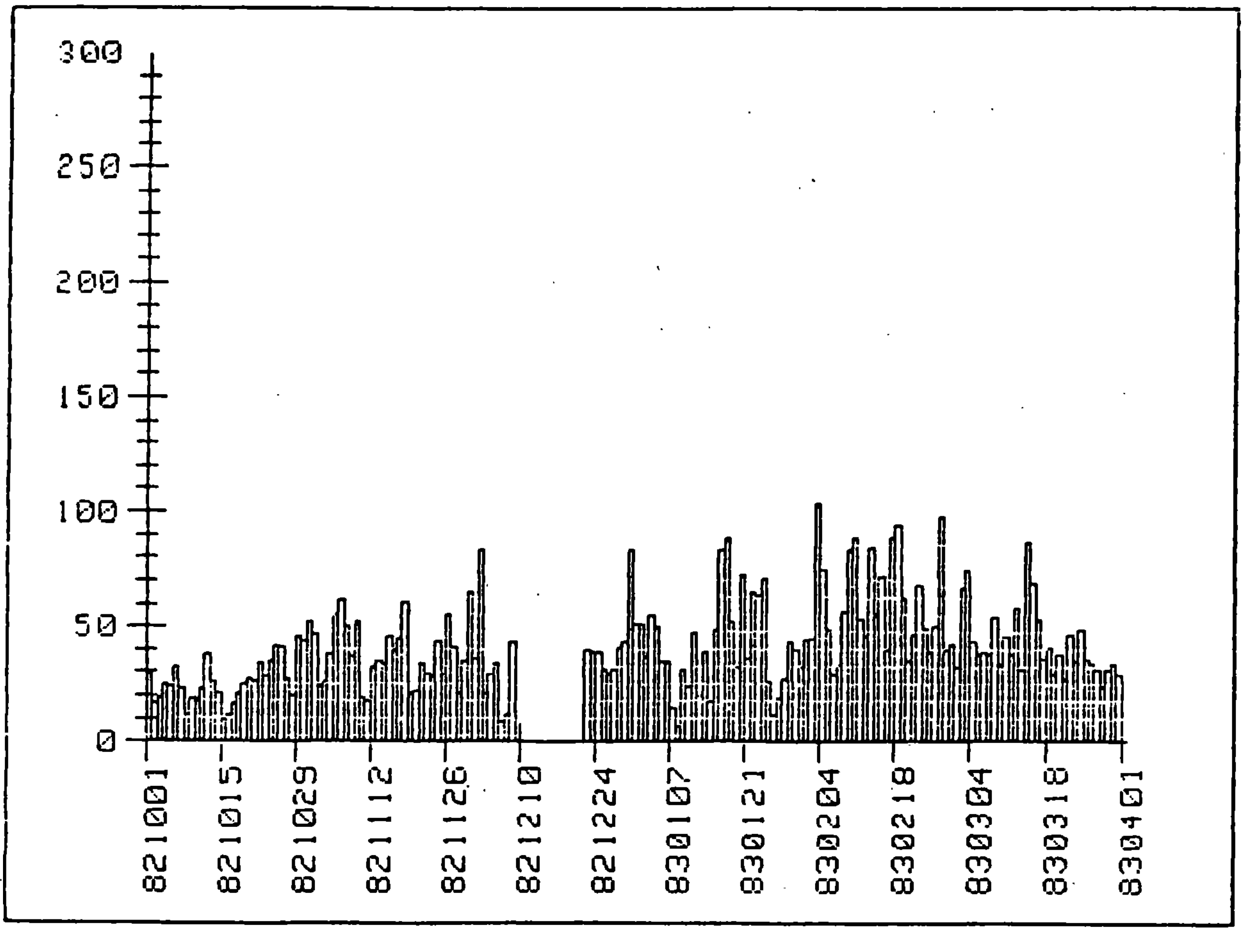
Measurement station	50 percentile	95 percentile	Highest 1-hour average during the period	Highest 24-hour average during the period	Mean
Tork.Knuts.g.	35	99	210	104	41
Kanaan	9	32	157	79	11
Sergels Torg	41	107	523	110	46
Västberga	22	80	231	99	28
Värtan	21	71	243	100	26

The standard of 100 μg/m^3 has not been violeated. The suggested planning target of 60 μg/m^3 has not been exceeded either.

Source: Local environmental authorities of Stockholm, Report No. 311-619-83.

Figure 24-hour averages of sulphur dioxide (μg/m³), October 1982 - March 1983.

Name of measurement station: Torkel Knutssonsgatan



Mean for period = 41

Percentiles for 1-hour averages

50 %	35
75 %	53
90 %	80
95 %	99
98 %	122
99 %	141

Highest 24-hour average during the period = 104
Highest 1-hour average during the period = 210

Source: Local environmental authorities of Stockholm, Report No. 311-619-83

TILASTOKESKUS

TUTKIMUKSIA

Tilastokeskus on julkaissut Tutkimuksia v. 1966 alkaen, v. 1980 lähtien ovat ilmestyneet seuraavat:

55. *Carita Putkonen,* Tupakkatuotteiden kulutus, Tupakkatuotteiden kokonaiskulutus Suomessa vuosina 1960–1978. Tammikuu 1980. 23 s.

56. *Pentti Tuominen,* Tuottajahintaiset indeksit, Menetelmät ja käytäntö, Teollisuuden tuottajahintaindeksi 1975=100, Kotimarkkinoiden perushintaindeksi 1975=100, Vientihintaindeksi 1975=100, Tuontihintaindeksi 1975=100. Maaliskuu 1980. 124 s.

56. *Pentti Tuominen,* Producer Price Indices, Methods and Practice, Producer Price Index for Manufactured Products 1975=100, Basic Price Index for Domestic Supply 1975=100, Export Price Index 1975=100, Import Price Index 1975=100. August 1980. 125 p.

57. *Risto Kolari,* Kuolleisuus, Kohorttikuolleisuus Suomessa v:sta 1851 lähtien. Maaliskuu 1980. 94 s.

58. *Vihavainen – Valppu – Suokko – Björk,* Kansantalouden tilinpito, Pääomakanta vuosina 1965–1977. Huhtikuu 1980. 101 s.

59. *Pekka Mäkelä,* Maatalouden yritystilastojärjestelmän kehittäminen. Toukokuu 1980. 35 s.

60. Tuotantomenetelmien kehittäminen, Tilastokeskuksen pitkän tähtäyksen suunnitelman erillisselvitys. Joulukuu 1980. 38 s.

61. *Pekka Mäkelä – Raimo Nurminen,* Kansantalouden tilinpito, Maa-, metsä- ja kalatalous sekä metsästys kansantalouden tilinpidossa. Syyskuu 1980. 129 s.

62. *Uotila – Leppä – Katajala,* Kansantalouden tilinpito, Neljännesvuosittainen kansantalouden tilinpito. Marraskuu 1980. 58 s.

63. *Heikki Sourama – Olli Saariaho,* Kansantalouden tilinpito, Rakenne, määritelmät ja luokitukset. Joulukuu 1980. 87 s.

64. *Hannu Pääkkönen,* Työttömyyden keston mittaaminen Suomessa. Maaliskuu 1981. 35 s.

65. *Iiris Niemi – Salme Kiiski – Mirja Liikkanen,* Suomalaisten ajankäyttö 1979. Maaliskuu 1981. 143 s

65. *Iiris Niemi – Salme Kiiski – Mirja Liikkanen,* Use of time in Finland 1979. September 1981. 143 p.

66. *Sinikka Askelo,* Opettajien työmäärätutkimus 1979, Peruskoulu, Lukio, Harjoittelukoulut, Iltakoulut. Huhtikuu 1981. 234 s.

66. *Sinikka Askelo,* Lärarnas arbetsmängd 1979, Grundskolan, Gymnasiet, Övningsskolorna, Aftonläroverken. April 1982. 226 s.

67. *Ari Tyrkkö,* Palkansaajien ansio- ja tulotason kehityksen mittaaminen. Toukokuu 1981. 74 s.

68. *Olavi E. Niitamo,* Tilastollinen tietohuolto 1980-luvulla. Elokuu 1981. 40 s.

69. *Juha Pietilä – Aku Alanen,* Valtion tulot ja menot lääneittäin 1978. Elokuu 1981, 88 s.

69. *Juha Pietilä – Aku Alanen,* Statens inkomster och utgifter länsvis, December 1981. 86 s.

70. Rakennuskustannusindeksit 1980=100. Elokuu 1981, 59 s.

71. Tilastokeskuksen pitkän tähtäyksen runkosuunnitelma. Syyskuu 1981. 49 s.

71. *Niitamo, O.E. – Laihonen, A. – Tiihonen, P.,* Long-Term Planning in the Central Statistical Office of Finland, November 1981. 70 p.

72. *Raili Broas,* Kansantalouden tilinpito, Yritykset kansantalouden tilinpidossa. Huhtikuu 1982. 62 s.

73. *Veli-Jukka Leppänen – Henry Takala,* Kansantalouden tilinpito, Rakennustoiminta kansantalouden tilinpidossa. Huhtikuu 1982. 112 s.

74. *Heli Jeskanen-Sundström,* Kansantalouden tilinpito, Teollinen toiminta kansantalouden tilinpidossa. Huhtikuu 1982. 55 s.

75. Tie- ja maarakennuskustannusindeksit 1980=100. Toukokuu 1982. 15 s.

76. *Matti Parkkinen,* Teollisuustuotannon volyymi-indeksin laskenta. Kesäkuu 1982. 80 s.

77. *Kari Ritvanen,* Kansantalouden tilinpito, Voittoa tavoittelemattomat yhteisöt kansantalouden tilinpidossa, Kesäkuu 1982. 70 s.

78. *Reino Hjerppe – Jouko Kaartinen,* Markkinaton tuotanto, hyvinvointi ja kansantalouden tilinpito. Elokuu 1982. 71 s.

79. *Pertti Marjomaa,* Väestökehitys ja kotitalouksien kulutusmenot. Elokuu 1982. 60 s.

80. *Lättilä – Heiskanen – Komulainen – Niskanen – Siren,* Tapaturmat ja väkivalta 1980, Haastattelututkimus tapaturmien ja väkivallan yleisyydestä sekä terveyshaitoista. Syyskuu 1982. 277 s.

80. *Lättilä – Heiskanen – Komulainen – Niskanen – Siren,* Accidents and Violence 1980, A Survey of the Incidence of Accidents, Criminal Violence and the Resulting Injuries. April 1983. 177 p.

81. *Wolfgang Lutz,* Demographic Transition and Socio-economic Development in Finland 1871 – 1978 – a Multivariate Analysis. November 1982. 81 p.

82. *Mauri Nieminen,* Muuttoliike, Maassamuuton syyt 1977 – 78. Marraskuu 1982. 90 s.

83. Suomen kansantalouden tilinpitoa sata vuotta. Joulukuu 1982. 93 s.

84. *Risto Kolari,* Korkeakouluopiskelu, Korkeakoulututkinnot ja opintojen keskeyttäminen 1966 – 1979. Joulukuu 1982. 100 s.

85. *Eeva Hamunen,* Kansantalouden tilinpito, Liikenne kansantalouden tilinpidossa. Joulukuu 1982. 79 s.

86. *Jarmo Hyrkkö – Ilkka Lehtinen,* Nettohintaindeksi 1977=100. Tammikuu 1983. 37 s.

87. *Veli-Matti Lehtonen – Timo Puustinen – Pentti Tuominen.* Vuoden 1980 kuntien kalleustutkimus. Maaliskuu 1983. 176 s.

87. *Veli-Matti Lehtonen – Timo Puustinen – Pentti Tuominen.* Dyrortsundersökningen 1980. Mars 1983. 194 s.

88. *Markku Tahvanainen – Markku Lindqvist,* Talonrakennustoiminnan volyymi-indeksi 1980=100. Huhtikuu 1983. 79 s.

89. *Olavi E. Niitamo,* Johdonmukaisuus ja ristiriita. Huhtikuu 1983. 54 s.

90. Future Trends of Data Management, *Olavi E. Niitamo,* Data Management in the 1980s. *Olli Janhunen,* Integration of Data, Applications and the Mass Media. May 1983. 23 p.

91. *Iiris Niemi,* The 1979 Time Use Study Method. May 1983. 27 p.

92. *Heikki Havén – Risto Syvänperä,* Aikuiskoulutukseen osallistuminen 1980. Toukokuu 1983. 100 s.

93. *Lättilä – Heiskanen,* Piilorikollisuus 1980, Haastattelututkimus henkilöön kohdistuneesta ilmitulleesta rikollisuudesta ja piilorikollisuudesta. Toukokuu 1983. 99 s.

93. *Lättilä – Heiskanen,* Hidden Criminality 1980, A Survey on Reported and Unreported Offences Against the Person. December 1983. 92p.

94. *Aila Repo,* Väestön tutkinto- ja koulutusrakenne-ennuste 1981 – 1995. Toukokuu 1983. 154 s.

95. *Hilkka Vihavainen – Seppo Varjonen,* Kansantalouden tilinpito, Investoinnit kansantalouden tilinpidossa. Toukokuu 1983. 75 s.

96. *Tuomo Niskanen,* Rikosvahingot 1980, Otantatutkimus poliisin tietoon tulleista omaisuus- ja väkivaltarikoksista. Kesäkuu 1983. 99 s.

97. *Risto Kolari,* Ammatillinen liikkuvuus Suomessa 1970/1975. Heinäkuu 1983. 127 s.

98. *Mauri Nieminen,* Suomen ruotsinkielinen väestö vuosina 1980–2020. Heinäkuu 1983. 51 s.

99. *Carita Putkonen,* Luotettavuustutkimus Väestö- ja asuntolaskenta 1980 osa I, Selvitys mittaus- ja käsittelyvirheistä. Marraskuu 1983. 215 s.

100. *Carita Putkonen,* Luotettavuustutkimus Väestö- ja asuntolaskenta 1980 osa II, Peittävyysselvitys.

101. *Rudolf Andorka – Istvdn Harcsa – Iiris Niemi,* Use of Time in Hungary and in Finland, Comparison of results of time budget surveys by the Central Statistical Offices of Finland and Hungary. November 1983. 62 p.

102. Air Quality Statistics: methods and principles Finland. Hungary. Sweden. December 1983. 103 p.

103. *Esa-Jukka Käär – Veli-Jukka Leppänen,* Kansantalouden tilinpito, Aluetilinpito 1976 ja 1978: Menetelmät ja tulosten analyysi. Joulukuu 1983. 106 s.

Tätä julkaisua myy

VALTION PAINATUSKESKUS

Postimyynti
PL 516
00101 HELSINKI 10
Vaihde (90) 539 011

Kirjakaupat Helsingissä
Annankatu 44
(Et. Rautatiekadun kulma)
Vaihde (90) 17 341

Eteläesplanadi 4
Puh. (90) 662 801

Denna publikation säljes av

STATENS TRYCKERICENTRAL

Postförsäljning
PB 516
00101 HELSINGFORS 10
Växel (90) 539 011

Bokhandlar i Helsingfors
Annegatan 44
(i hörnet av S. Järnv.g.)
Växel (90) 17 341

Södra esplanaden 4
Tel. (90) 662 801

This publication can be obtained from

GOVERNMENT PRINTING CENTRE

Mail-order business
P.O.Box 516
SF-00101 HELSINKI 10
Phone (90) 539 011

Bookshops in Helsinki
Annankatu 44
Phone (90) 17 341

Eteläespianadi 4
Phone (90) 662 801

ISSN 0355-2071
ISBN 951-46-7473-1