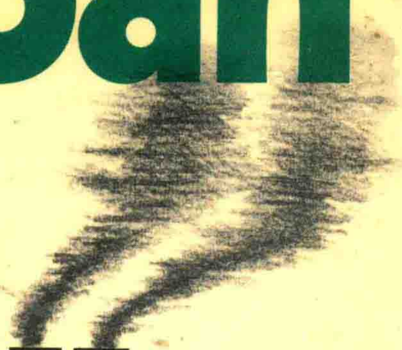
Global Environment Monitoring System (GEMS)

urban air pollution



1973-1980

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Global Environment Monitoring System

Urban air pollution 1973–1980

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Preface

Following the United Nations Conference on the Human Environment, held in Stockholm in 1972, the World Health Organization established a global health-related environmental monitoring programme. This programme includes air, water, food and biological monitoring projects, all of which are also part of UNEP's Global Environment Monitoring System (GEMS).

The global air monitoring project is implemented through widespread cooperation with Member States and involves technical cooperation in air pollution measurements as well as the mutual exchange of information. The goal of the project is to monitor and understand the quality of the urban air environment and to improve the general level of public health. The air monitoring project produces biennial reports of summarized data.

The present publication, however, represents the first attempt at a complete analysis and interpretation of the urban air pollution data that have been gathered up to 1980. It aims to inform government officials and the scientific community on the concentrations of the two air pollutants most commonly associated with the combustion of fossil fuels, namely, sulfur dioxide and suspended particulate matter. The analyses have been made as comprehensive as possible in order to provide the reader with a better insight into the underlying reasons for the global phenomena observed.

The first two sections present some general information on the global air monitoring project and on the data that were available during the preparation of this publication. Following these are four sections that describe the results of the analyses. These sections include detailed statistical analyses of the complete set of data and also present in-depth analyses of some local urban situations. The comparisons with exposure limits suggested by WHO and the analysis of trends give an overview of the more common features of air pollution in many urban areas and as such attempt to present a global picture. The final part of the report contains a summary and conclusions. For details of measurement methodologies, the quality assurance procedures, and a complete data summary, the reader is referred to the annexes to this report.

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Contents

Introduction

Air pollution in urban areas arises from a multitude of sources. The importance of a particular type of source depends to a certain extent on the location and the climate. For example, domestic heating makes a considerable contribution to air pollution in temperate regions but much less in tropical regions. On the other hand, the photochemical conversion of automobile exhaust gases into pollutants with strongly oxidizing characteristics is much more prevalent in tropical regions than in the more temperate zones. No matter where an urban area is situated, however, it will have in its atmosphere a mixture of pollutants from a variety of sources, such as heating plants (both industrial and domestic), industrial processes, waste incinerators, automobiles, and other transport vehicles. The so-called air pollution profile can vary considerably from one location to another.

The concentrations of air pollutants depend not only on the quantities that are emitted but also on the ability of the atmosphere to either absorb or disperse excess amounts. Urban areas have special characteristics in this regard. For example, they may be located in river valleys, in coastal areas, near a lake, or be surrounded by mountains. All these settings can strongly influence atmospheric dispersion characteristics and may cause distinctive pollution patterns to occur. Within cities, there are also many features that affect the concentrations of air pollutants. Examples of this are limited ventilation in the built-up or central areas of a city, and source groupings in certain areas, particularly in industrial and commercial sections, along highways, etc.

The combined effects of the source configurations and of meteorological and topographical factors are that air pollution concentrations vary over the map of an urban area. In addition, there are important temporal variations in source strengths and meteorological conditions, causing the air pollution patterns to change with different times of the day, week, or year. To measure variations in air pollution concentrations in a city, it is necessary to use a number of stations spread out over the area in question, and to make frequent or continuous measurements. To be fairly representative of the surrounding area, the air that is sampled by such stations should not be unduly affected by a nearby source. Depending on the area in which the stations are located, the sites can be classified as either industrial, commercial, or residential.

It is clear from the foregoing that as a person goes about his or her daily activities he or she will move through zones with different air pollution concentrations. The total amount of pollutants inhaled during a day constitutes the total exposure. If the exposure is high enough, it may produce either acute or immediate effects or, at lower or more persistent concentrations, chronic effects.

The exposure of urban populations in different parts of the world will vary considerably because of factors mentioned above, such as geography, climate, and type of source. Also, different life-styles and associated living conditions will contribute to widely varying human exposures to air pollution.

The WHO/UNEP air monitoring project has been designed to assess air pollution conditions on a global scale, to observe trends, and to begin to examine the relationship between pollution and human health. There are certainly problems in achieving these broad objectives. Nevertheless, it is hoped that a global view of urban air pollution can make a significant contribution towards understanding this important component of man's environment and improving the general level of public health.

The WHO/UNEP air monitoring project

The WHO/UNEP air monitoring project was set up to assist countries in operational air pollutant monitoring, to improve the practical use of data in relation to the protection of human health, and to promote the exchange of information. The data accumulated in the network can be used to assess the air quality of urban areas throughout the world and to investigate trends in air pollution levels. This report presents an analysis of data obtained during the period 1973–1980.

Development of the project

The air quality monitoring project was begun in 1973 by WHO. From 1973 to 1975 the project was operated on a pilot basis, during which time data reporting and handling procedures were developed and improved. The harmonization of siting, sampling, and measurement methodologies and techniques also received special attention, and a manual of selected methods of measuring air pollutants was prepared (*16*). During this first phase, 15 countries participated in the project by supplying data on sulfur dioxide (SO_2) and suspended particulate matter (SPM) from selected sites of their national networks. In each country, information was routinely collected from three sites of primarily industrial, commercial, and residential character, in at least one major urban area.

In 1976, the air monitoring project was expanded and included within the Global Environment Monitoring System (GEMS). Since then, financial support provided by the United Nations Environment Programme (UNEP) has been utilized to extend the network to developing countries, obtain more reliable data, and achieve an increased level of harmonization in monitoring and in data analysis and interpretation. Also in 1976, the World Meteorological Organization became a cooperating agency in the project and has since then assisted in the preparation of guidelines and in organizing workshops to train staff from developing countries (*5*). Among other international agencies participating in the project is the Commission of the European Communities (*3*), which provides the GEMS network with air monitoring data from some 40 stations operated by the member states.

The expansion of the air monitoring network took several years. Contacts were made with some 100 countries, of which 50 were visited by WHO staff or consultants to make arrangements for participation, to assist in choosing the monitoring sites, and to give practical information on the sampling and analytical techniques to be used. Sixty sets of monitoring equipment, complete with spare parts, filters, and chemicals for one year of operation, were provided and installed by experts who also trained the local staff.

After the extensive expansion and development of the network during 1976–1978, the network now changes only very slightly each year. Table 1 illustrates the growth of the network from 1973 to 1980. During this period, the number of participating countries more than doubled and the number of sites tripled. In more recent years, 25 000–30 000 daily values have been added each year to the data file for each pollutant. Not all stations report daily, since specific discontinuous sampling schemes are used at certain sites. Overall, the completeness of the data for the network as a whole has nevertheless improved with time.

Table 1. Number of countries, number of sites and number of 24-hour values in the years 1973–1980 in the WHO/UNEP air monitoring project

Year	Number of countries	Number of sites	Number of 24-hour values[a]	
			SPM	SO_2
1973	14	42	7446	9936
1974	14	42	7263	8833
1975	15	44	10839	13831
1976	23	97	20773	24874
1977	27	101	27525	31448
1978	30	106	25651	27760
1979	34	146	29986	33770
1980	33	136	25408	29135

[a] Hourly values were aggregated to form 24-hour averages where appropriate.

The geographical coverage of the network at the end of 1980 is illustrated by the map in Fig. 1. It may be noted that the coverage is better in the northern hemisphere where a number of industrialized countries supply an important number of data from their national, regional, and local networks. Since most of the sites in the developing countries became operational after 1976, fewer data are available from these locations.

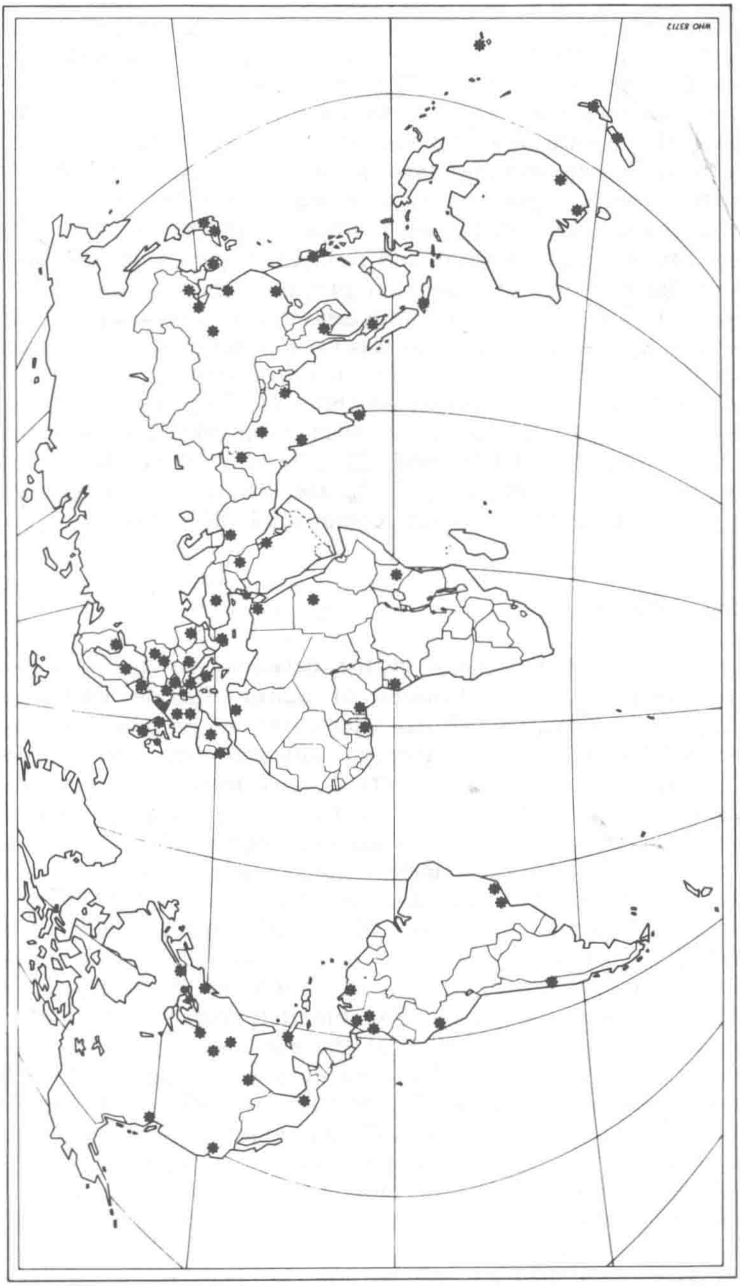

Fig. 1. Monitoring locations of the WHO/UNEP air monitoring project at the end of 1980

Monitoring sites

The monitoring sites are classified as either city-centre (CC) or suburban (S) and are further specified as commercial (C), industrial (I), or residential (R). The classification system is based on the SAROAD code (*23*), which takes into account the land use in the area immediately surrounding the monitoring stations. It must be stressed that sites classified in the same way by type might have completely different characteristics from the point of view of local air pollution.

In cities where monitoring sites already existed, three principal stations, of commercial, industrial, and residential type, were selected for inclusion in the network. In cities that previously had no air pollution monitoring sites, only two stations were established—one at an industrial site and one at a residential site. This was done in order to save resources and to allow more cities to participate in the project.

The network at present consists of about 60% city-centre sites and 40% suburban sites. Of the city-centre sites, some 50% are commercial (CCC), 25% industrial (CCI), and 25% residential (CCR). In the suburban category, approximately 50% are industrial (SI) and 50% residential (SR), with only very few commercial (SC) sites.

Monitoring methods

The monitoring of pollutants in the network has thus far been limited to using the concentrations of sulfur dioxide (SO_2) and suspended particulate matter (SPM) as indicators of pollution in urban environments. There are a number of different but well accepted methods for monitoring these pollutants. A brief description of methods used in the project is given in Annex 1. A more complete description and discussion of the various alternatives has been published by WHO (*16*).

The most frequently used method for determining SO_2 is the acidimetric titration or hydrogen peroxide method (36%), followed by the colorimetric pararosaniline or West-Gaeke method (27%), the amperometric or coulometric method (21%), and the conductometric method (12%). A very limited number of stations use flame photometry or pulsed fluorescence detection. For the determination of SPM, a gravimetric method is used at 50% of the sites, with the high-volume sampler accounting for 46% and the membrane sampler for 4%. The smoke-shade method is used at 43% of sites for SPM determinations. Only a few (7%) of the stations are fully automated and use continuous measuring methods such as nephelometry or beta-absorption.

The range of sophistication of monitoring techniques used in the network varies widely. Fully automated, continuous monitoring devices, such as the flame photometric detector for SO_2, and the nephelometer for SPM, give very detailed information, as half-hourly or hourly outputs, on the temporal variation in the measured levels. Commonly used manual techniques, such as the hydrogen peroxide method for SO_2 and the smoke measurement technique for SPM, do not provide this temporal resolution, since they integrate sampling over 24 hours. This information is adequate for the network, however, and is very useful in studying weekly cycles, seasonal influences and trends, and for making comparisons with air quality criteria or standards.

To overcome difficulties with the interpretation of data produced by different measuring techniques, comparison stations have been set up at various sites in the network. Different equipment is operated in parallel for limited periods. In addition to these field experiments, some inter-laboratory comparison studies for SO_2 have also been undertaken. Quality assurance is an important part of any monitoring network. Additional details of the quality assurance for the GEMS air monitoring project are given in Annex 2.

Project implementation

The air monitoring project is implemented through the WHO Regional Offices, where operational contacts with the national agencies and institutes participating in the project are established and maintained. In each of the participating countries, a government agency or institution (national centre) is identified as the focal point for carrying out the project in that country. In addition, a number of WHO Collaborating Centres assist in project implementation by providing consultants, conducting quality assurance exercises, operating the data bank, and preparing data reports. Extensive support is provided by the Environmental Monitoring and Systems Laboratory of the Environmental Protection Agency, Research Triangle Park, USA, which operates the data bank and assists in the production of data reports for the project. A complete list of the WHO Collaborating Centres and the national agencies and institutes is given in Annex 3.

Data presentation

Statistical summaries

Daily SO_2 and SPM concentration measurements produce large amounts of data which are best managed and reported after statistical analysis. It is most convenient to summarize annual sets of daily measurements for each site in a cumulative frequency table and in corresponding cumulative frequency plots.

The annual statistics for each pollutant at each site in the air monitoring network have been published in biennial reports (*17*, *18*, *20*, *22*). An illustration of the format in which the data are presented is given in Table 2. This table shows the summary of SO_2 concentrations at the city-centre commercial site in Tokyo and gives the number of valid measurements made during the year. In this example, the records are fairly complete, with no more than 11 days missing in any one year. The minimum and maximum recorded daily averages and the percentiles of the cumulative frequency distribution are also given. Finally, the arithmetic and geometric means, and standard deviations are listed.

Data completeness and representativeness

Not all stations have reported data with sufficient completeness to allow representative annual variables (means, percentiles etc.) to be determined. A distinction must be made between data sets that are incomplete because a discontinuous sampling scheme was intentionally selected, e.g., one measurement every five days, and data sets that are incomplete despite all efforts and precautions. The former, if properly planned, provide representative annual values. The latter require individual evaluation to judge the representativeness of each set.

Loss of data may be due to malfunctioning or breakdown of sampling or measuring devices, to elimination of questionable data before recording, or to errors during transfer or processing of data. Representativeness of the available data set depends on the nature of the problem and on the distribution of valid data. If, for instance, some 15%

Table 2. Daily averages of sulfur dioxide concentrations ($\mu g/m^3$) recorded at the city-centre commercial site, Tokyo, 1973–1980[a]

Year	Number of values (n)	Minimum value	Percentile									Maximum value	Arith-metic mean	SD	Geo-metric mean	SD
			10	30	50	60	70	80	90	95	98					
1973	363	LD[b]	38	55	70	75	83	94	108	122	140	149	71	28	65	1.6
1974	363	LD	44	57	68	72	78	85	93	106	118	152	68	21	65	1.4
1975	363	LD	38	53	64	68	75	80	91	104	124	186	65	23	60	1.5
1976	366	LD	42	52	63	68	73	81	92	107	118	210	66	23	62	1.4
1977	358	LD	45	58	68	76	79	84	92	97	110	144	68	20	64	1.5
1978	364	LD	34	47	52	58	60	65	76	84	100	123	54	18	51	1.5
1979	363	LD	37	52	55	58	60	65	73	81	102	183	56	18	53	1.4
1980	355	LD	37	50	55	58	60	63	71	79	97	126	55	17	51	1.5

[a] The conductometric method is used at this site.
[b] LD = lower than detection limit (here 26 $\mu g\ SO_2/m^3$).