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GEMS - GLOBAL ENVIRONMENT MONITORING SYSTEM

URBAN AIR POLLUTION MONITORING

REPORT OF A MEETING OF UNEP/WHO GOVERNMENT-DESIGNATED EXPERTS
GENEVA, 5 - 8 NOVEMBER 1991

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UNEP/WHO GOVERNMENT-DESIGNATED EXPERT MEETING ON URBAN AIR POLLUTION MONITORING

GENEVA, 5-8 NOVEMBER 1991

I. INTRODUCTION

1. It has been the practice since the formation of the GEMS health-related monitoring programme in the mid 1970s that it is periodically reviewed by Government-designated Expert Meetings. In line with this practice, UNEP and WHO convened from 5 to 8 November 1991 in Geneva a meeting of Government-designated Experts to review the GEMS Air Quality Monitoring and Assessment Programme (GEMS/Air), its outputs and to agree on its further development.

2. The purpose of this meeting was multifold. In addition to conducting a thorough review of the GEMS/Air Programme and to advise on its further development, the Government-designated Experts were also asked to review four recent technical reports which had been prepared by the Programme. These were:

GEMS/Air Data Report

Urban Air Pollution in Megacities of the World

Urban Air Quality Monitoring - Methodology and Quality Assurance Implications

Representativeness of GEMS/Air Stations in the National Network - Methodology

3. The meeting was opened by Dr Kreisel, Director of the Division of Environmental Health on behalf of WHO and by Dr Peterson, Director of the UNEP Monitoring and Assessment Research Centre (MARC) on behalf of UNEP. They stressed the importance that both of the Organizations accorded to this Programme and underscored the partnership that existed between them in implementing it. The present meeting was timely in view of the forthcoming UN Conference on Environment and Development (UNCED) and its recommendations would be critical in shaping future global efforts in dealing with environmental pollution. Also, the Programme would benefit from the review of the technical documents which were submitted to the meeting.

4. Mr Hickman, Director General, Environmental Health Directorate, Health and Welfare, Canada, and Eng. Gonzales Garcia, Director of Air Quality, Mexico, D.F. were elected Chairman and Vice-Chairman respectively and Mr Bower, Head of Air Monitoring Networks, Warren Spring Laboratory, UK was appointed as Rapporteur. The list of attendees is attached as Annex I and the meeting agenda is shown as Annex II.

II. OVERALL REVIEW OF THE GEMS/AIR PROGRAMME

5. Introduction. The meeting had before it a report entitled *GEMS/Air - The Next Decade, 1992-2001* which had been prepared by the Secretariat. It contained a brief review of the Programme as it had developed in the past and its accomplishments, and an analysis of the problems of air pollution in present day context. The report culminated in a presentation of proposals for changes in the Programme for the future. The report was introduced by Dr Mage, GEMS/Air Coordinator. The report is included in this report as Annex III.

6. Previous reviews of GEMS/Air. The recommendations of two previous meetings concerned with GEMS/Air were briefly reviewed by the meeting. They were the Government-designated Expert Meeting on Health-related Monitoring in Geneva in April 1988 and the GEMS/Air Meeting on Data Handling at Research Triangle Park, North Carolina, USA in September 1989 (copies of the relevant recommendations are included as Annex IV). The meeting noted that these recommendations were still valid and should be taken into account in the development of Phase II of the GEMS/Air Programme. In this context, while agreeing with the recommendations of the previous Government-designated Expert Groups that the number of pollutants measured under the Programme be expanded, they felt that priority should be given to achieving a more adequate global coverage with respect to SO_2, particulate matter and CO. As regards the data handling meeting, the Group commented that data submitted to the GEMS/Air Programme should continue to be validated by contributing countries prior to submission, revalidated after processing by GEMS/Air and that the raw data be archived by the submitting countries.

A. Major Recommendations

7. The Government-designated Expert Group reviewed the proposals contained in the report in detail. It endorsed the approach proposed for Phase II of the GEMS/Air Programme. The Government-designated Experts highlighted certain aspects of the proposals which they considered particularly important and proposed that only a few changes be made in the plan as presented. These are given below according to the following 7 issue categories:

- the overall plan
- the objectives
- participation of countries
- harmonization of methods and quality assurance
- assessments
- mobilization of resources
- programme implementation and review

8. The overall plan. The Group emphasized the importance of obtaining supplementary information for better interpretation and use of air quality data collected through the GEMS/Air Programme. The Group:

- **strongly recommended that the GEMS/Air Programme should encompass the computation of emission inventories and the development of appropriate modelling methodologies, in order to facilitate the development of cost-effective control strategies**

- **recommended that where possible, information on air quality and management policies being actively pursued by countries participating in GEMS/Air be collected alongside air quality data in order to help its interpretation.**

9. Objectives. The Group agreed with the objectives of the Programme for its Phase II as they were stated in the Secretariat's proposal, e.g.

- **The long-term objective of the Programme is to provide the comprehensive information needed for rational air quality management**

The following sub-objectives of the new programme were endorsed:

- **to provide an international framework for coordinated, comparable and valid monitoring of urban air quality, effective data management and reliable information dissemination**

- **to develop methodologies, adapted to the specific needs of the participating countries, required for the comprehensive monitoring and assessment of urban air quality**

- **to produce comprehensive assessments which include levels and trends of urban air quality, pollution sources, and options for abatement, as well as potential health and environmental effects**

- **to strengthen urban air quality monitoring networks and assessment capabilities in developing countries**

10. Participation of countries. The Group noted that the global coverage of GEMS/Air was insufficient with significant gaps in the availability of data for Africa and for northern latitudes of Eurasia, in particular. The Group recommended that

- **in order to carry the GEMS/Air Programme forward it was necessary to expand the coverage to more countries**

- **all countries should recognize the contribution that the new GEMS/Air Programme can make to managing their air quality problems and that they be invited to actively participate and support the Programme**

- **the GEMS/Air involvement be made more attractive to potential participating countries. Novel incentives such as equipment designation/testing and network intercalibrations should be promoted. Also the meeting agreed that different levels of monitoring infrastructure appropriate to each country - ranging from simple baseline studies to complex multi-species research evaluations - should be incorporated under GEMS/Air**

11. Selection of pollutants. The Group reviewed the proposals for adding new pollutants to the GEMS/Air Programme. It felt that because of the limited resources, it was most important that priorities be established particularly for the developing countries.

12. In its discussion, the Group agreed that:

(i) increased emphasis on size-fractionated particulate measurements was appropriate as regards particulate measurements. It noted that comparability between black smoke (BS) and gravimetric particulate estimates had never been established and that an expert meeting would be needed to review and to provide recommendations for particulate monitoring.

(ii) carbon monoxide (CO) together with NOx and its components (NO and NO_2) be considered as priority pollutants with CO of higher priority. Since 90-95% of all CO urban emissions are usually from motor vehicles as compared to only 2/3 for NOx, measurement of CO can provide a capsule picture of the effect of motor vehicle usage and the efficacy of motor vehicle controls. It was noted that measurements of CO may be most appropriate in traffic oriented and roadside locations.

(iii) lead also should be considered as a priority pollutant. Although its levels were declining in developed countries, this was not the case elsewhere.

(iv) measurements of ground-level ozone were practical and desirable. It was noted that siting criteria for ozone need to be developed as maximum concentrations usually occur 'downwind' of urban areas at locations removed from emissions of NO.

(v) it was premature to extend measurement to speciated volatile organic compounds (VOCs) as precursors of ozone formation. There were still methodological problems in continuously measuring trace VOCs such as benzene in ambient air.

(vi) air toxics, greenhouse gases and ozone depleting species could not at this time be considered as high priority for measurement under GEMS/Air.

13. As a consequence the Group recommended that

- **cities participating in GEMS/Air need not cover the complete range of priority pollutants when this is not appropriate or in situations where there are serious resource constraints**

- **it would be desirable to expand GEMS/Air from SO_2, BS and TSP by adding the measurements of size fractionated suspended particulate matter, O_x, Pb, CO, NO_2, NO, and in the long-term to other components such as PAH, VOC's, etc. The provision of data from other sources to supplement GEMS/Air data should be adopted where appropriate**

- **GEMS/Air stations which do not measure the complete range of cited pollutants are encouraged to give first priority to the measurement of particulate matter, SO_2 and CO. Where feasible and applicable, measurement of the other pollutants should be considered, taking into account the local situation and air quality issues**

- **for new countries and new cities in the GEMS/Air Programme, first priority should be given to monitoring of particulate matter, SO_2 and CO at representative urban sites**

- **WHO/UNEP convenes, as soon as practicable, a working group to consider the harmonization of particulate measurements. It may be appropriate that this meeting be held in Munich at HEM in 1992.**

14 Monitoring methodology and quality assurance. The Group considered the methodological aspects of monitoring and underscored the importance of data harmonization through quality assurance (QA) and quality control (QC) in maximizing the utility of future and historic GEMS/Air collected data. The adoption of these revised procedures will strengthen their usefulness for assessment purposes and lead to the development of more reliable air pollution management strategies. It agreed that a QA plan to provide validated data - achieved by QC techniques such as network audits and intercalibration - was essential if data were to be comparable and compatible. Among the problems to be solved is the best way for quantifying and expressing air quality data: e.g., what is the appropriate averaging time for integrated sampling? How should continuous O_3 data be reported, 1-hour, 4-hour, 8-hour averages? etc.

15. The Group recommended that:

- **quality assurance and quality control measures of the GEMS/Air Programme should be strengthened**
- **simple, locally sustainable monitoring methodologies be adopted where appropriate to meet monitoring objectives and that a manual be compiled to provide practical advice on the use of such methodologies**
- **publication of documents on monitoring methodologies and related topics be continued under the GEMS/Air Programme with the documents including technical manuals on network design, sampling and analytical methods, and assessment methodologies**
- **the dissemination and exchange of information gained from practical experience in participating countries, together with advice on the selection of appropriate monitoring and management methods, be included as an element of the GEMS/Air Programme.**

16. Assessments. In reviewing the types of assessments GEMS/Air should conduct, the Group noted that the possibility of developing air quality indices and their utility should be looked into. It also suggested that some work be done in applying the WHO Air Quality Guidelines in terms of their application for mixtures of pollutants and for special conditions such as the high altitude situations of Mexico City. The Group acknowledged that the new WHO European Centre for Environmental Health in Bilthoven might also provide a valuable contribution to GEMS/Air in developing health risk assessments.

17. The Group recommended that:

- **The GEMS/Air Programme undertake assessments of urban air pollution and its environmental and health effects at the city and global scale based on information from the GEMS/Air network and additional data such as national emission inventories**
- **special studies be undertaken, as appropriate, within the framework of GEMS/Air in order to improve understanding of current and emerging key issues related to global, regional and local air pollution.**
- **data usages should include provision of a sound scientific basis for the development of cost-effective and appropriate air pollution control policies and risk management**

18. Resource mobilization. The Group noted that the present resources for the Programme were grossly insufficient to carry out even the existing programme, much less to initiate new activities. Low priority is given to air pollution in many developing countries as there are usually many other serious health issues. As such the required funding and infrastructure necessary for air quality management, including monitoring, are not made available. Implementation of the GEMS/Air Programme in these countries must be funded in order that they can assess their air pollution problems and assign proper priorities. It was emphasized that technical support is expensive and must be organized on a secure and sustainable basis to be successful. It is necessary to provide assistance in sample analyses where such are necessary to establish pollution control urgency and priorities. It recommended that

- **WHO/UNEP undertake an aggressive campaign to mobilize new financial and other resources, including exploration of "indirect" financing (non-monetary programme support). The Group suggested the following activities:**

  a. **the use of laboratories participating in the GEMS/Air Programme for training participants in other countries and the use of analytical facilities for limited sample numbers from special investigations**

  b. **"twinning" of GEMS/Air cities to provide direct support from developed to developing countries**

  c. **provision of national experts for assisting with specific monitoring and assessment activities**

  d. **establishment of a central exchange mechanism for spare parts and equipment which could be made available to developing countries**

  e. **hosting and supporting attendance at meetings of national GEMS/Air coordinators**

  f. **supporting the performance of QA/QC activities including audits, network intercalibration and preparation of primary standards**

- **support for the Programme should be actively sought from other relevant international organizations, industry and NGOs**

- **GEMS/Air explore new avenues of gaining technical support for network operations and air quality management in order to strengthen national air quality monitoring and assessment capabilities, and to encourage use of these data in national control programmes**

19. Programme implementation and review. The Group recommended that

- **in order to promote the programme aggressively, WHO/UNEP whould proceed quickly to develop an implementation plan**

- **a means for improving communication and feedback mechanisms among participating countries and the GEMS/Air Secretariat be strengthened. At the regional and global level this could be achieved through such activies as a newsletter, and the compilation of regional registers of monitoring authorities and their capabilities, and a register of station/network managers. Regional meetings of participants in the programme should be encouraged**

- **the GEMS/Air Programme itself be reviewed, at mid-term (1997), and at the end of the decade (2001), to assess its performance against these programme objectives**

B. Comments on Part 4 - "GEMS/Air Activity Area Description"

20. Introduction. Part 4 of the Secretariat's report contains a description of the five programme elements to be implemented as part of Phase II of GEMS/Air. The meeting endorsed the proposed expanded programme and the approaches outlined in the document which will lead to a strengthening of urban air quality management world-wide. Since this part of the report will provide the framework for the Programme in the future, the Government-designated Experts reviewed these in detail and made specific suggestions for changes. These are presented in the next paragraph which should be read in conjunction with part 4 of the Secretariat's report (Annex III, page 24).

21. Section 4.1 Network Operations

(i) reword the objective to read: "to provide an international framework for coordinated comparable and valid monitoring of urban air quality, effective data management/utilization and reliable information dissemination"

(ii) reword Activity 2 to read: "Promote the collection in GEMS/Air cities, as a minimum measure, of concentration data of suspended particulate matter, CO and SO_2. In addition, guidance should be provided to participants on additional measurements which may be relevant to specific local/regional issues, such as NO, NO_2, O_3, Pb, VOCs and PAHs.

(iii) with respect to Activity 7, the Group stated: "a useful increased role for collaborating centres was noted in relation to this activity. Countries should compile a list of ongoing activities and research which could be useful for GEMS/Air and/or transferable to other countries". In this context, the UNEP International Environment Technology Centre, to be established in Osaka in 1992, was introduced by the Japanese delegate and a document describing the centre was circulated

(iv) reword the first item under Activity 8 to read: "routine monitoring of agreed sets of pollutants (which might be different in different regions) using agreed site types and monitoring methodologies"

(v) reword the second item under Activity 8 to read: "ongoing implementation of QA/QC programmes".

22. Section 4.2 Methodology Development. The description of activities should be modified to reflect the following comment: "It was agreed that information should also be made available, under Activity Area 2, on GEMS/Air participants practical experience with monitoring methodologies. Suggestions on the applicability of generic monitoring methods would also be welcome. It was noted that information of this nature could usefully be made available in regular GEMS/Air newsletters".

23. Section 4.3 Assessments. The Group made the following observation:

"the need to be aware of potential overlaps between the sub-programme and some other international activities was noted. In relation to proposed activities, a variety of potential problems in addressing socio-economic impacts of air pollution were identified. As a result, it was agreed that the text relating to this activity would be amended to reduce the emphasis placed on this activity. Similarly, the text on 'control strategy operations' and 'scenario modelling' should be revised to reflect the closely inter-related nature of these functions".

24. Section 4.4 Technical Support.

(i) it was noted that the text relating to outputs did not actually reflect subsequent description of individual activities and should, therefore, be revised.

(ii) the first item under Activity 1 should be reworded to read: "assessment of the existing monitoring capabilities"

(iii) Activities 3 and 4 should be merged under the heading of "Quality Control" with explicit reference to other QC activities such as network intercalibration. The text should also reflect the demarcation between locally implemented and centralized network QC functions"

(iv) delete item 2 under Activity 5 since no such data base is known to exist

(v) with respect to activity 6 it was noted that projects financed by the World Bank may include provision for new equipment and spare parts

25. Section 4.5 Special Studies. A new Activity 6 should be added on establishment of relationships of GEMS/Air data with data from BAPMON.

III. REVIEW OF REPORT *SYNOPSIS OF CITY AIR QUALITY TRENDS*

A. General Comments

26. The ten-city report *Synopsis of City Air Quality Trends* was introduced by Dr Vandeweerd, Programme Officer, GEMS/PAC. The aim of this report is to use monitoring data from GEMS/Air stations, in cities with a wide range of climatic and socio-economic conditions, to draw attention to the seriousness of their problems of air pollution. After a short introduction section, the report contains a brief summary - city by city - of these data on suspended particulate matter (SPM) and SO_2 reported by GEMS/Air monitoring stations in ten cities up to 1989. A situation analysis, review of results and recommendations are given for each city. The results are based on summaries of submitted data, validated by GEMS/Air and the reporting authority for each city.

B. Recommendations

27. The meeting was asked for comments on the report and advice on the scope and presentation of a final summary/conclusion section. The following points were agreed:

- **the synopses provide valuable outlines of air quality issues in a range of cities**
- **the front page should include an explicit statement that the data sets are those from GEMS/Air sites only**
- **statements should be included in the introduction and country section emphasizing that data from GEMS/Air sites may differ from corresponding results obtained from other monitoring networks in the city**
- **explicit reference should be made in the introduction (and where appropriate in city sections) to the problems of interpretation of SPM data (due to natural sources or non-comparable measurement methodologies)**
- **statements in the report should be supported by facts or rephrased as postulates**
- **although prior agreement on data validity has been obtained from all reporting cities concerned, the relevant city section of the document will be returned to those participating countries whose representatives did not attend the meeting. A deadline of 4 weeks will be given for response. The cover letter should state that if no response is received within this period, the report is considered to be correct as it stands**
- **the report should end with a brief conclusion, including several general trends and implications, but without explicit comparisons or graphs, and making clear that these data are not necessarily completely comparable**
- **The Ten City report should be completed and made available by GEMS/Air, noting the changes recommended in the body of this report**

IV. REVIEW OF REPORT ON *URBAN AIR POLLUTION IN MEGACITIES* OF THE WORLD

A. General Comments

28. In introducing the report, Dr Peterson, Director, GEMS-MARC indicated that its intended primary functions were to analyse air quality in the world's megacities (ten million or more inhabitants by year 2001), identify future trends, evaluate human/ecosystem exposure and foster the development of measures designated to control emissions. As such it should provide warnings to other cities that will reach megacity status in the 21st century of the problems they may face unless air quality management plans are followed. This report, in addition to assessing information from GEMS/Air monitoring stations within cities, also incorporates and analyses relevant data from a variety of other sources.

29. Feedback was invited from the Group on general issues relating to the report. It was accepted that many issues relating to the megacity reports may require subsequent consultation with Governments prior to finalization. In any circumstance, however, final amendments to the report were required within one month of the meeting, in order to enable final publication by June 1992. The individual city reports were reviewed in the meeting and conclusions and overall recommendations for the megacity report are described in the following section.

B. Recommendations for the Megacities report

30. One-page summaries. General discussion called for a harmonization of the 20 one-page summaries in terms of graphical and situation analysis structure. Several delegates asked if the Secretariat could add national air quality standards (NAQS) to the annual concentration trends together with WHO guidelines.

31. The Group recommended that

- **NAQS be presented in a separate table with each city summary, and to present WHO guidelines on the figures for easy comparison. In addition, NAQS be also presented together as an Annex to the main document together with details of how and when WHO guidelines were formulated**
- **where available, distinctions between emission sources (e.g., natural, mobile and stationary) should be made in the "Emission Estimates" section of the summaries**
- **a breakdown of motor vehicle types should also be included if space is available**

32. The Group expressed a wish for general conclusions and recommendations to be included in the one-page summaries.

33. The Group agreed that all city specific drafts should be submitted to national Governments for review and comments. A deadline of 4 weeks from receipt was agreed for Governments to send comments directly to GEMS/MARC. If no comments are received by the deadline, the documents should be finalized.

34. Discussion of General Conclusions. The importance of comparing prevalent air quality trends in terms of level of development of countries/regions (e.g., Rapidly Industrializing, Slowly Industrializing,

etc.) was stressed. It was agreed that interpretations of levels and trends should be viewed in terms of control strategies such as changes in fuel use.

35. The Group suggested that the conclusions should highlight the problems associated with motor vehicle emissions and the fact that even many developed countries have found it difficult to control pollutant emissions and ambient concentrations from this source. Given the increasing rate of vehicle usage in developing countries, motor vehicle emissions pose an increasing threat to health, both locally and regionally.

36. The discussion section of the report should focus on the underlying factors which put a strain on urban infrastructure and which ultimately lead to air quality problems. The importance of land use planning was stressed. A need to slow migration of people into megacities was highlighted.

37. The Group would like the conclusions of the megacities assessment to include mention of transboundary and global effects of air pollution from megacities, especially in terms of tropospheric ozone, and acid deposition.

38. The discussion section of the report should raise the need for coordinated urban planning which would take into account energy use, environmental policy and development needs. This would apply at national and city levels.

V. CONSIDERATION OF REPORT ON *URBAN AIR QUALITY MONITORING - METHODOLOGY AND QA/QC IMPLICATIONS*.

A. General Comments

39. This report was introduced by Dr Murray, Senior Scientist, GEMS-HEM, Munich. It addressed the practical aspects of monitoring and QA/QC methodologies that are required to ensure GEMS data harmonization. Harmonization of measurements is essential for data to be comparable and compatible, and for maximizing their utility. The adoption of a consistent approach to QA/QC is identified as a primary tool for data harmonization.

40. The Group identified a number of approaches which could usefully contribute to the practical implementation of an extended GEMS/Air effort:

(i) the adoption of simple and sustainable monitoring technologies, where these are capable of meeting overall monitoring objectives

(ii) the separation, where appropriate, of pollutant sampling and analysis functions for species such as PAHs and Pb. Where expensive and complex analysis methods are required, these may be performed in developed countries with appropriate facilities

(iii) the compilation of a manual providing practical user-advice on simple monitoring methodologies

(iv) the provision of "packaged" monitoring systems based on simple samplers

(v) fostering direct bilateral dialogues between local monitoring authorities and technical institutions with both GEMS/Air and appropriate expert laboratories

(vi) the establishment within GEMS/Air of a "clearing house" to provide an interface between developing countries and potential funding/support donors

(vii) the encouragement of private sector support for monitoring in developing countries. Possible donors may include equipment/computer manufacturers and chemical companies

(viii) the development of QA/QC guidelines appropriate to different levels of monitoring systems within countries

(ix) the compilation of regional registers of monitoring authorities, and the encouragement of regional meetings between network managers

B. Recommendations

41. The overall approach to data harmonization suggested in the report was supported as essential for establishing data validity. The Group recommended that

- **the report be published as a GEMS/Air operational guideline, after appropriate amendment**
- **implementation plans for the expansion of the GEMS/Air Programme should include practical implementational components such as those detailed in the report, as well as the additional issues as indicated above.**

VI. CONSIDERATION OF REPORT ON *REPRESENTATIVENESS OF GEMS/AIR STATIONS*

A. General Comments

42. The report was introduced by Dr Kretzschmar, GEMS/Air Secretariat, who emphasized the importance of ensuring that GEMS/Air stations are genuinely representative of air quality in the cities in global, spatial and demographic terms. A variety of techniques are available for this purpose. One specific example, involving the spatial (200 km^2) and temporal (1974-1988) intercomparison of sulphur dioxide results (yearly averages and 98th-percentiles of daily levels) from 18 different stations belonging to two different networks within a city (Brussels), was presented. Other techniques, involving screening surveys, mobile and indicative monitoring strategies, are detailed in the methodology QA/QC report previously discussed in section V.

B. Recommendations

43. It was recommended that participating countries should be encouraged to initiate similar representativeness studies in GEMS-monitored cities.

ANNEX I

UNEP/WHO GOVERNMENT-DESIGNATED EXPERT MEETING ON URBAN AIR POLLUTION MONITORING

GENEVA, 5-8 NOVEMBER 1991

LIST OF PARTICIPANTS

Government-designated Experts:

Argentina:	*Mr Vicente Barros, Comision Nacional de Politica Ambiental, Buenos Aires
Australia:	Mr Peter N. Browne-Cooper, Director, Pollution Control Division, Environmental Protection Authority, Perth, Western Australia
	Mr Tim Kahn, Assistant Director, Air Noise and Nuclear Section, Environmental Protection Division, Department of the Arts, Sports, The Environment Tourism and Territories, Canberra
Canada:	Mr J. Roy Hickman, Director General, Environmental Health Directorate, Health and Welfare, Ottawa, Ontario
China:	Mr Liang Xi-yan, Beijing Municipal Environmental Monitoring Centre, Beijing
Egypt:	Dr Mahmoud M. Nasralla, Professor and Head of Air Pollution Research Department, National Research Centre, Cairo
Germany:	Mr Werner Rudolf, Scientific Adviser, Federal Environment Agency, Offenbeck, Mein
India:	*Mr Virondra Singh, State Pollution Control Board of Delhi Administration, Delhi
Japan:	Mr Yoshiaki Nishimura, Special Assistant, Permanent Mission of Japan to the U.N., Geneva
Mexico:	Eng. Rogelio Gonzales Garcia, Director of Air Quality, Secretariat of Urban Development and Ecology
Netherlands:	Dr Leendert Van Bree, Ministerie van Buitenlardse Zaren, Section OIO/YS, Den Haag
Nigeria:	Dr Modupe Olusola Oresegun, Technical Director, Federal Radiation Protection Service, Physics Department, University of Ibadan, Ibadan
Saudi Arabia:	Dr Ali Al Thowaini, Director General of Environmental Standards, Riyadh
Thailand:	Mr Jumpol Siriswasdi, Chief of Air Monitoring Section, Air and Noise Subdivision, Environmental Quality Standards Division, Office of the National Environmental Board, Bangkok
United Kingdom:	Mr John Bower, Head of Air Monitoring Networks, Warren Spring Laboratory, Stevenage, Herts
USA:	Dr Christopher G. Saint, Multi Media Research Coordinator, Modeling and Monitoring Systems, ORD, US Environmental Protection Agency, Washington, D.C.

* Unable to attend the meeting

Agency Representatives:

CEC	Mr M. Houssiau, Commission of the European Communities, Brussels, Belgium
UNCHS	Mr Lars Peter Ludvigsen, Head of UNCHS (Habitat) Office, Geneva, Switzerland
World Bank	Dr Jose C. Carbajo, Economist, Transport Division, Urban Development Department, World Bank, Washington, D.C., USA
WMO	Mr Frederic Delsol, Director of the Research and Development Programmes Department, World Meteorological Organization, Geneva, Switzerland

Secretariat:

Dr Wilfried Kreisel, Director, Division of Environmental Health, World Health Organization, Geneva, Switzerland

Dr Jan G.V. Kretzschmar, Programme Manager, Information System, Nuclear Research Centre, Mol, Belgium (consultant)

Dr David T. Mage, Scientist, Prevention of Environmental Pollution, Division of Environmental Health, World Health Organization, Geneva, Switzerland (co-secretary)

Professor Peter Peterson, Principal Programme Officer, UNEP/GEMS and Director, Monitoring and Assessment Research Centre (MARC), London, United Kingdom

Mr G. Ozolins, Manager, Prevention of Environmental Pollution, Division of Environmental Health, World Health Organization, Geneva, Switzerland

Dr Veerle Vandeweerd, Programme Officer, GEMS/PAC, United Nations Environment Programme (UNEP), Nairobi, Kenya (co-secretary)

Mr Tony D. Webster, Research Scientist, GEMS Monitoring and Assessment Research Centre (MARC), London, United Kingdom

Dr Anne Beatrice Murray, Senior Scientist, GEMS-HEM, c/o GSF, Munich

Dr Richard Stern, WHO Regional Office for Europe, Copenhagen, Denmark

ANNEX II

UNEP/WHO GOVERNMENT-DESIGNATED EXPERT MEETING ON URBAN AIR POLLUTION MONITORING

GENEVA, 5-8 NOVEMBER 1991

AGENDA

TIME	TUESDAY 5 NOVEMBER	WEDNESDAY 6 NOVEMBER	THURSDAY 7 NOVEMBER	FRIDAY 8 NOVEMBER
9.00 9.30	Registration 1. Opening Addresses: WHO, UNEP 2. Election of Officers Introduction of participants	3. continued Programme Objectives and Activities	5. continued Discussion continued Formulation of conclusions	Reading of draft reports
10.30	COFFEE/TEA			
10.45	3. GEMS/Air: The Next Decade Introduction (10 mins) DM General discussion on GEMS/Air Past and Present (Sections 1, 2.1)	3. continued Programme Structure (Section 3.3) Financing	6. Methodology & Quality Assessment Introduction (10 mins) BM Discussions & recommendations 7. Brussels Report Introduction (10 mins) JK Discussion & recommendations	Discussion of reports
12.30	LUNCH			
14.00	3. continued Air Pollutants of Concern (Section 2.2) (1 hr) Global Coverage (Section 2.3) (1/2 hr)	4. Urban Air Quality - Ten City Report Introduction (10 mins) VV Discussion on Structure Conclusion of report	8. Drafting Groups A & B A. Conclusions of Megacities Report B. Report of Meeting	Any other business Adoption of reports
15.30	COFFEE/TEA			
15.45 17.00	3. continued Strategic Framework Agreement on Programme Objectives and Activities (Sections 3.1, 3.2, 4)	5. Urban Air Pollution in Megacities Introduction (10 mins) PP Discussion on Structure City by city review and comments	Drafting Groups (contd.)	

EARTHWATCH

GLOBAL ENVIRONMENT MONITORING SYSTEM

GEMS/AIR
The Next Decade
1992–2001

WORLD HEALTH ORGANIZATION

UNITED NATIONS ENVIRONMENT PROGRAMME

UNEP

EARTHWATCH

GLOBAL ENVIRONMENT MONITORING SYSTEM

GEMS/Air 1992-2001

PROPOSALS FOR A REVISED GLOBAL PROGRAMME FOR URBAN AIR POLLUTION MONITORING AND ASSESSMENT

Date: 27 September 1991

Foreword

Monitoring is the basis for understanding the impact of air pollution on the urban environment. The data are used as a measure of exposure for the purposes of documenting status and trends of air quality. They are also useful as a measure of performance to determine if technical and legislative controls are working. Together with emission inventories, monitoring is useful to prioritize which pollutants and sources should be controlled; together with models it is useful to predict future environmental problems and with population characteristics and effects data, it is of use in evaluating risks to human health and ecosystems.

This working document prepared by WHO and UNEP contains draft proposals for a revised and strengthened GEMS/Air programme to meet the demands of the future. It is presented to the meeting of Government-designated Experts for advice and guidance on overall programme directions for the coming decade and for priority programme activities. Possible methods of implementation and collaboration with national and international organizations also need to be addressed during the meeting.

The objectives, contents and structure of the proposed expanded programme have been prepared by reviewing the achievements of the GEMS/Air programme during the last 15 years and the recommendations for a programme update as given by Government-designated Experts in 1988 (section 1). The major issues to be considered in a future programme are addressed in section 2. The strategic framework and the main activities of the proposed new GEMS/Air programme for the period from 1992 to 2001 are outlined in section 3. Section 4 describes the different proposed programme activity areas in detail.

The aim of the document is to outline the overall strategic and operational framework for the revised GEMS/Air programme. Furthermore, it is the scientific basis for a successful definition and implementation of the redirected GEMS/Air programme to provide the comprehensive information needed for rational urban air quality management world-wide.

Executive Summary

Since 1974, WHO and UNEP have been collaborating on the Urban Air Quality Monitoring Project (GEMS/Air), a component of the Global Environment Monitoring System (GEMS). At the outset of the project, the following objectives were defined i) to strengthen air quality monitoring capabilities in participating countries, ii) to improve the validity and comparability of monitoring data and iii) to prepare assessments of air pollution in urban areas and to identify the associated health effects. At present, standardized data on sulphur dioxide (SO_2) and suspended particulate matter (SPM) are submitted to WHO by 55 cities in 33 countries. Two global assessments have been produced since the onset of the project and a third - *Urban Air Pollution in Megacities of the World* - is currently in production.

In more recent years, a need to re-orientate the existing GEMS/Air project so that it more directly addresses the changing and emerging urban air pollution concerns and issues has been identified. Factors such as rapid urbanization (without adequate growth in urban infrastructure), signs of worsening air quality in many cities (in particular in relation to traffic-related pollutants), and the lack of integrated urban air quality management and control programmes in many cities worldwide have provided the driving force for proposing a restructuring of the GEMS/Air project. More specifically, reviews of the GEMS/Air project by government - designated experts have recommended that GEMS/Air activities should be expanded and improved to include other key air pollutants of concern not already monitored, to collect additional data to support assessment activities, to improve global coverage especially in developing regions, to introduce quality assurance systems, and to improve data analysis and assessments with the introduction of appropriate modelling techniques.

In light of the above, a revised agenda for the GEMS/Air project for the 1990s is outlined for consideration. A modified overall programme objective is proposed; that is, to provide the comprehensive information needed for rational urban air quality management. This broad objective may be achieved by adopting the following project activities.

1. **Network Operation**: Continue to operate the existing GEMS/Air network but expand the data gathering activities to cover other key air pollutants (e.g., PM_{10}, NO_2, CO, O_3, Pb) and additional information (e.g., on pollutant sources, emissions inventories, demographic data and meteorological data); to expand the geographical coverage of the network.

2. **Methodology Development**: Provide new and updated information on air quality monitoring methodologies, including QA/AC procedures in the form of manuals, handbooks and computer software.

3. **Assessments**: Prepare and disseminate comprehensive assessments of global, regional and national trends in air quality levels, with particular reference to potential human health and ecosystem effects.

4. **Technical Support**: Provide increased technical support in the form of expert advice and training with respect to both air quality monitoring network operation, assessment of data and formulation of appropriate control programmes and policies including the compilation and use of emission inventories.

5. **Special Studies**: Perform special studies in order to improve understanding of key air pollution issues: the emphasis will be on integrated studies which will require the co-operation of a range of institutions.

In terms of management of the revised GEMS/Air programme, it is proposed that the WHO and UNEP continue to hold responsibility for the overall management and structure of the programme. However, to ensure that the programme retains and develops a sound scientific basis, it is further proposed that a Standing Committee of Experts be established to advise WHO and UNEP on the scientific aspects of the project operation. Successful implementation of the revised GEMS/Air project will require an intensified effort on the part of the current participants and, moreover, a greater degree of co-operation with other organizations and programmes.

CONTENTS

1. GEMS/AIR: THE PAST DECADE

GEMS/AIR is a component of the United Nations System Wide "Global Environment Monitoring System" (GEMS). GEMS is a collective effort of the world community to acquire through monitoring and assessment the scientific data and information needed for the rational and sustainable management of the environment. The GEMS/AIR programme is jointly implemented by WHO in association with UNEP/GEMS.

1.1 Programme Objectives

During the past 15 years although the objectives of the GEMS/AIR programme have been subject to several amendments they have remained essentially unchanged. Overall, the three main goals of the programme were:

* to initiate and strengthen urban air quality monitoring networks in participating countries/cities

* to improve the validity and comparability of data among countries/cities

* to provide global assessments (levels, trends and effects) of urban air quality

1.2 Programme Components

Results of the programme have been published in a number of reports, including data compilations, comprehensive assessments, guidelines on monitoring methodology and network development as well as reports on indoor air pollution in selected cities.

Generally, during the first 15 years of operation GEMS/AIR programme results have contributed to raising awareness leading to national and international responses, stimulating research, and providing policy makers with sound information required to alleviate pollution problems. The following results have been achieved:

Network operations

The backbone of the GEMS/AIR programme is a global air quality monitoring network. At present, 48 countries around the globe, with different climatic zones, different levels of socio-economic development and different pollution situations participate in the monitoring network (Figure 1.). From these 48 countries, 55 cities in 33 of the countries regularly provide data on sulphur dioxide (SO_2) and suspended particulate matter (SPM). These two pollutants were selected at the onset of the programme because of their importance with respect to respiratory illnesses and because they were the two pollutants most often measured. Generally, data are collected from at least three different stations within cities, one each in an industrial, commercial and residential area.

The data from the approximately 240 sites in 48 countries are stored in a central database operated by the WHO Collaborating Centre for Environmental Pollution Control, USA/EPA Research Triangle Park, North Carolina.

Methodology Development

To ensure a common basis for monitoring, guidelines on monitoring methodology and network development have been developed and published. More recently, special software is under development to transfer data to the global database (GEMS/DATA) and to analyse, validate and report the compiled information at the national level using internationally compatible software (GEMS/ASYST).

Assessments

Two comprehensive assessments have been produced to date. The first assessment, *Urban Air Quality 1973-1980* (UNEP/WHO 1984), contained a scientific analysis and synoptic interpretation of the sulphur dioxide (SO_2) and suspended particulate matter (SPM) monitoring data. A second comprehensive *Assessment of Urban Air Quality* (UNEP/WHO 1988) was produced in 1988, addressing five common priority air pollutants: SO_2, SPM, lead (Pb), nitrogen oxides (NOx) and carbon monoxide (CO). Indoor pollution, a growing problem in industrialized and developing countries alike, was also covered. Detailed data on SO_2 and SPM were derived from the GEMS/AIR network, while other data on Pb, NOx and CO were culled from national reports, open literature and from a questionnaire. A new assessment, *Urban Air Pollution in Megacities of the World*, on air quality conditions in 20 of the world's megacities is in preparation and will be published by the end of 1991.

The past GEMS/AIR assessments showed that much of the world's population lives in urban areas where pollution levels exceed recommended WHO guidelines, thereby exposing inhabitants to substantial threats. For instance, more than 1,200 million people may be exposed to excessive levels of SO_2; 1,400 million people to excessive levels of SPM and smoke; and 15-20 per cent of urban populations in North America and Europe could be exposed to excessive levels of NOx. The air in half of the world's cities contains excessive levels of carbon monoxide (CO) and people in up to one-third of all urban agglomerations may be exposed to excessive lead levels.

With respect to the trends of air pollution, the following conclusions were reached:

* Pollutant control strategies are beginning to take effect in most industrialized countries, where trends in SO_2, SPM and Pb emissions are generally downward. However, controls on CO and NOx have been less effective mainly because pollutants are produced by road traffic which is increasing almost everywhere

* Data from developing countries are incomplete. Yet the few available data indicate that, although pollution levels are already very high, emissions and ambient concentrations of all five pollutants are growing

Technical Support

GEMS/AIR has assisted developing countries in establishing and strengthening their air quality monitoring operations through expert advice, the provision of monitoring equipment, training courses and regional workshops. In addition, regional audit mechanisms are being established in different regions to calibrate the equipment, validate the monitoring process and provide on-site training for participating institutes. Analytical quality assurance support is also provided.

Programme component	Achievements
Network Operation:	Assisted with the creation of monitoring network 55 cities in 48 countries reporting regularly on SO_2 and SPM
Methodology Development:	Guidelines on monitoring methodology and network development GEMS/DATA software for data transfer (under field testing) GEMS/ASYST
Assessments:	Comprehensive assessments on monitoring data *Urban Air Quality 1973-1980* (UNEP/WHO 1984) *Urban Air Quality* (UNEP/WHO 1988). *Urban Air Pollution in Megacities of the World* in preparation.
Technical support:	* Provision of monitoring instruments * Expert advice * Audit visits: Malaysia, China * Training: Inter-regional training courses in Lima/Peru (1977); Nairobi/Kenya (1977); Bangkok/Thailand (1977) and Sofia/Bulgaria (1978) Workshops in Malaysia (1979), China (1981) and Paris (1981) * Supplies: Spare parts, chemicals * Four regional audit teams being formed

1.3 Call for change

In September 1988, a Government-designated Expert Group reviewed the programme and recommended a general restructuring of the GEMS programme to align it with the changing needs of the decade ahead. With respect to the overall GEMS programme, the experts recommended that:

* the geographical coverage of the GEMS programme should be expanded, particularly with respect to developing countries;

* reliability of monitoring data should be increased by improving quality assurance procedures;

* more emphasis should be given to the integration of monitoring data with other relevant information.

With respect to the GEMS/AIR programme, the experts recommended that:

* the monitoring programme should be extended to other air pollutants (NOx, CO, Pb, O_3);

* the SPM should be better characterized. Specifically, the inhalable portion of SPM (PM_{10}) should be determined, its chemical composition analyzed and the contributions of natural sources to urban SPM concentrations quantified;

* the assessments should be based not only on the GEMS/AIR network data but additional information should be compiled from scientific literature and national reports;

* special attention should be given to the air pollution situation in developing countries;

* the assessment of the potential health impacts of urban air pollution on the population should specifically be addressed;

* the siting of monitoring stations and their respective representativeness should be carefully considered when data are evaluated to assess human exposure.

In addition, the experts also discussed the need:

* to include studies on indoor air quality;

* to broaden the scope of the programme assessments by including emerging issues like stratospheric ozone depletion, acid rain, global climate changes and the greenhouse effect;

* to assess the health consequences of high pollution days;

* to assess the implication of increased diesel use throughout the world.

A GEMS/AIR meeting on data handling activities, held at the global database centre, US EPA, North Carolina, 1989 (UNEP/WHO, 1990), supported the above-mentioned recommendations and stressed the need to expand the information collection to include supporting statistics on topics such as population, emissions, climate, city topography, etc. It was further agreed to:

* phase out, where appropriate, the transmission and storage of raw data and move towards the use of nationally prepared data summaries;

* to prepare three types of publications (detailed global assessments, special reports and annual data summaries) on a pre-established schedule;

* to include data available in the open literature in the comprehensive assessment process.

2. GENERAL CONSIDERATIONS FOR A REVISED GEMS/AIR PROGRAMME 1992-2001

To complement the recommendations of the Government-designated Experts meeting of 1988, and further align the GEMS/AIR Programme with the needs of the coming decade, some major considerations which the programme must address are enlarged upon below. They designate the major activities of the programme.

2.1 Issues of concern

There are four main areas for concern with respect to urban air pollution: (i) the rapidly expanding urban populations, (ii) the already high air pollution levels in many cities of the world, (iii) the gross insufficiencies in the capabilities of many of these cities and the national governments in coping with the problems, and (iv) the regional and global effects of air pollution. Each of these concerns is briefly discussed below.

Rapid urbanization

World populations, and even more proportionately the populations residing in urban areas are increasing. An important accelerating factor is the rural to urban migration as people in economically depressed areas drift to the cities to find work. In the absence of effective control measures this will inevitably result in deteriorating air quality.

The world population is expected to increase from 4.8 billion in 1985 to over 6 billion in 2000. By the year 2025,

every second person on earth will be an urban resident. The growth in urbanization is most pronounced in Africa, South Asia and Latin America. An indication of the rates of growth expected in individual cities may be obtained from the projection shown in Figure 2. However, due to urban spread air pollution will not be confined by city limits but will also encroach on surrounding areas and settlements.

Concomitant with the growth of urban population, there will be an increase in transport, industrial development and energy conversion for domestic and industrial purposes. This will lead to more pollutant emissions and a deteriorating air quality which finally results in an increased threat to health and well-being of the urban population.

Worsening air quality

Although information concerning current air quality in the cities, particularly in the developing countries, is grossly lacking, the data which are available show that air pollution levels pose a significant threat to the health and well being of the urban population.

In 1988, WHO and UNEP estimated that over 1,200 million people live in urban areas where average sulphur dioxide concentrations exceed or are within WHO recommended guidelines. For suspended particulate matter the situation is worse; more than 1,400 million people may be living in areas where the particulate pollution is within or exceeds WHO guideline levels. The average concentrations for total suspended particulate matter are presented in Figure 3. While for the other major pollutants there are even fewer data, there are indications that these too are of concern.

Strengthen Capabilities for Air Pollution Control

Major efforts will be needed to improve and strengthen the infrastructure in many countries for dealing with air pollution problems. A 1989 WHO survey of 168 countries showed that 80 per cent of the newly industrialized and limited development countries do not meet the requirements for protection against environmental health hazards.

As shown in Figure 4, the capabilities for the control of air pollution lags behind the capabilities for dealing with water pollution or solid waste problems, and the developing countries have only a fraction of the capabilities of the industrialized countries. There is a clear and urgent need to strengthen air quality monitoring capabilities, as well as legislation, enforcement and abatement strategies.

Regional and Global Effects of Urban Air Pollution

A major share of the global anthropogenic emissions of air pollutants results directly from urban activities (energy conversion, transportation, production). Thus urban air pollution plays an important role in regional and global air pollution effects, and will increase with the anticipated

continued and increasing urbanization. The main problems to be considered are acid deposition, tropospheric ozone accumulation, stratospheric ozone depletion and the greenhouse effect.

2.2 Key Air Pollutants of Concern

All substances which alter the natural composition of ambient air must be regarded as air pollutants. Thus the term "air pollutants" refers to a wide variety of substances ranging from natural compounds (like CO_2 or CH_4) to purely anthropogenic compounds (like CFCs), with concentration ranges of parts per hundred (per cent) down to less than parts per billion. Furthermore, air pollutants can be gaseous or particulate (aerosols). There is no definitive and consistent simple classification comprising all possible air pollutants.

Air pollutants may be of natural origin (e.g. wind-blown soil, forest fires, volcanoes) or of anthropogenic origin. Of course, for urban air pollution anthropogenic sources are predominant. Anthropogenic sources include industrial processes, power generation, waste disposal, mobile or stationary combustion processes, and agricultural practices.

In the 1970s sulphur dioxide (SO_2) and suspended particulate matter (SPM) were the pollutants most commonly monitored in urban areas. However, to characterize the urban air quality, besides SO_2 and SPM, many other pollutants are now being considered. As it is certainly not possible to include all air pollutants into a routine monitoring programme, a selection of priority key pollutants must be made taking into account the measurability of the pollutants and their relative importance.

With respect to urban air pollution and the resulting problems thereof, the following major groups of air pollutants are of importance:

Ubiquitous gaseous pollutant

This group contains primary gaseous air pollutants which are directly emitted from combustion processes and which have been known for many years to be a major urban/industrial problem. Ubiquitous air pollutants include carbon monoxide (CO), sulphur dioxide (SO_2), and oxides of nitrogen (NO, NO_2). Generally, monitoring instrumentation is well developed, and air pollution data are widely available in many countries.

Particulate pollutants

Air particulates (dust, smoke, aerosols) may be of anthropogenic and/or natural origin. Until a few years ago, only the total amount of suspended particulate matter (SPM) had been monitored. Due to its heterogeneous character SPM data have only limited value for air quality assessments. Thus nowadays monitoring objectives have been narrowed to determine specific size fractions (e.g. particulate matter <

10 µm, PM_{10}) and chemical characteristics of PM_{10} (e.g., heavy metals such as Pb, Hg or Cd, or organic matter).

Lead

Lead (Pb) is a most important component of urban particulate matter due to its toxicity, e.g., subtle but significant effects on the mental development of children. Lead is primarily emitted by motor vehicles burning leaded motor fuel. Lead acts through the ingestion of swallowed and inhaled particles so that even the larger conglomerations of particles that do not penetrate into the lower respiratory tract can be trapped in the nose or throat and be absorbed. The monitoring of Pb therefore requires a capture of the total particulate matter (TSP) so that a TSP collection may still be required for Pb, even though a switch to PM_{10} may be called for to measure those particles that affect the respiratory system.

Photochemical oxidants and their precursors

Photochemical oxidants are secondary air pollutants formed in complex atmospheric chemical processes, driven by sunlight and the presence of other air pollutants (precursors). The most important photochemical is ozone (O_3), which is measured as the main indicator of photochemical air pollution. As photochemical oxidants are not directly emitted from pollution sources it is necessary to trace the precursor air pollutants, which are mainly nitrogen dioxide (NO_2) plus photochemically reactive volatile organic compounds (VOC). Volatile organic compounds are emitted mainly from traffic, combustion processes and solvent evaporation. Although instruments are well developed, only a few countries actually monitor O_3 as an indicator of photochemical air pollution. With respect to VOC, reliable monitoring instrumentation has only recently been developed and urban air VOC data are scarce.

Toxic pollutants

There are a vast number of chemical compounds with high toxicity or carcinogenic potential which are emitted to the atmosphere by various industrial and combustion processes (e.g., dioxins, benzene, polycyclic aromatic hydrocarbons, chlorinated phenols, etc.). Although emissions are low compared with other air pollutants, these pollutants may pose a high health risk to urban populations in certain locations due to their high toxicity. There are only a few toxic pollutants for which routine analytical procedures for ambient air quality analyses have been developed.

Aside from the key urban air pollutants discussed above, there are others which are of general concern. They include various greenhouse gases and ozone depleting gases.

Greenhouse gases

Greenhouse gases are air pollutants which contribute to the radiative forcing potential of the atmosphere and thus enhance the greenhouse effect. The major greenhouse gases are carbon

dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Carbon dioxide is emitted from biomass degradation and fossil fuel combustion; CH_4 is emitted mainly from agriculture and waste generation, N_2O and CFCs are emitted from combustion processes and industrial activities respectively. There are almost no urban monitoring programmes for them, as greenhouse gases have only a very low toxicity.

Ozone depleting gases

Chemically stable compounds containing chlorine or bromine atoms, such as chlorofluorocarbons (CFCs), chlorinated hydrocarbons and brominated hydrocarbons (Halons) disturb the natural chemical equilibrium in the upper parts of the atmosphere (stratosphere) and cause degradation of the protective ozone layer. The amounts of ozone depleting gases released to the atmosphere are relatively low, thus ambient air monitoring is difficult. Again, most ozone depleting gases have low toxicity, so health-related monitoring is not performed except in occupational settings.

2.3 Global Coverage

Being a global programme it is vital for GEMS/Air to achieve global coverage. All climatic regions in the northern and southern hemisphere should be represented. At present, many cities in developed countries and some cities in developing countries already have good monitoring networks. On the other hand, there are still many regions in the world where there is poor monitoring or no monitoring at all. This fact is even more disturbing, as some of the biggest gaps in monitoring are found in cities with (presumably) the biggest pollution problems.

It will probably not be a problem to enlarge the global network by incorporating city monitoring networks from developed countries. However, the primary goal of the network expansion is to include as many developing countries as possible, particularly in regions not yet sufficiently covered (U.S.S.R., Africa, Latin America, South-East Asia). One way of enlarging the global coverage in developing countries could be the increased technical support to establish and maintain monitoring networks, and to manage and evaluate data.

Contacts with the GEMS/Air officials in the 15 non-reporting countries need to be re-established to encourage their participation on a continuing basis. Use of the GEMS-DATA computer program will facilitate the entry of past data into the data bank and to simplify their continued participation.

It is also proposed to enlist the participation of new countries that already have functioning urban air quality monitoring networks. Those countries which presently have no data in the GEMS/Air data bank, (e.g.., Czechoslovakia and Mexico) will be asked to submit their air quality data for the

cities and sites chosen, on a continuing basis from 1992 onwards, and wherever possible to provide the historical data for the chosen sites so that trends can be evaluated. The emphasis on developing countries is twofold: 1) to initiate focussed monitoring programmes, and 2) to establish a comprehensive global coverage.

The most difficult task will be to collaborate with countries that now have no routine air quality monitoring network in operation. These are primarily in Africa with some in Asia and Latin America. This task will call for GEMS/Air to assist with establishing stations in those cities where problems exist or are anticipated, and to provide the technical support in monitoring network operation, quality control, analytical techniques, etc. necessary to obtain reliable air quality data.

A goal of the GEMS/Air network is to phase out the current raw data handling process by encouraging participating countries to archive and analyze their own data, using the GEMS/DATA and GEMS/ASSIST software. This will allow the data base to be streamlined. GEMS/Air would provide QA/QC audits to help establish the reliability of the data so that participating countries would only need to submit annual summaries and reports to GEMS/Air in a standard format. This simplification should make it easier to enrol new participating countries as the staff time required will be minimized.

2.4 Air Quality Management

I Monitoring and Modelling

Monitoring programmes constitute the first step in determining the magnitude, scale and characteristics of the air pollution problem. Once the air quality situation in a city is defined, control or abatement strategies can be introduced based on sound data. Even more important, monitoring is necessary for enforcing compliance with environmental and health guidelines.

For most pollutants there is a large choice of monitoring techniques ranging from simple-inexpensive to sophisticated-expensive. There are new developments for impact-oriented monitoring systems like bio-indicators or similar systems which deserve attention. Methods for sampling and measuring air pollutants must be chosen carefully, taking into account the measurement purposes (e.g., long-term average data or short-term episode data), precision and accuracy required, possibilities for calibration and comparability available manpower and technical resources, and economic feasibility.

It is not desirable to apply a centralistic monitoring procedure throughout the global network; on the contrary, different countries will use different methodology depending on their specific objectives for monitoring and the resources and manpower available. Yet, there is a strong need for international co-ordination and data quality assurance. Data

submitted to the programme must be valid and of known quality. Data quality assurance procedures, covering the whole monitoring process from sample site selection to data reporting, require due consideration. This comprises activities such as verification of the representativeness of the data for the area under study, equipment calibration, analytical quality assurance and data verification.

Monitoring stations provide data about a city's air pollution levels at the specific time and specific site of sampling. Yet, as air quality is a highly complex spatial and temporal concentration field a sparse set of observations at several place-time co-ordinates cannot give an accurate picture of the extent and severity of the urban air pollution problem in an area. Even highly developed countries are limited in the number of observation sites that can be maintained due to the high cost of the sophisticated equipment required.

Recent experiences in several cities and countries showed that monitoring data can be complemented with calculations and estimations (e.g., emission inventory models, dispersion models, deposition models, effects models). Models allow the extension of monitoring data and to dynamically estimate ambient air pollution levels and depositions over differentiated emission and receptor areas. Some of these models, which generally are combined with Geographical Information Systems (GIS), can be very simple and aggregated; others may be very sophisticated. However, even simple models compliment monitoring data and are a valuable tool to assess effects of urban air pollution and develop the most effective abatement strategies.

To successfully utilize GIS-models for assessment purposes, it is necessary to know the spatial relevance of factors influencing pollutant emission, dispersion, transformation and deposition and thus affecting ambient air quality and pollution impacts. This applies to basic information like urban topography and physiognomy, emission characteristics, and meteorological and climatological features.

II Emissions and Controls

In addition to the compilation of urban air pollution monitoring data world-wide, data banking and reporting of trends, an analysis of pollution emission sources is needed for the development of targeted control strategies designed to reduce atmospheric concentrations of such pollutants. Furthermore, emission data will be used not only for urban air quality management, but as the majority of emissions leading to regional and global problems arise from urban areas, they can also be useful for assessments related to national, regional and global planning strategies. Regional and global problems such as tropospheric ozone accumulation, acid deposition, greenhouse effect and stratospheric ozone depletion can all be connected to urban emissions.

Internationally comparable emission data based on emission measurements and models serve as important pollutant abatement tools at local and national levels. Rapid methods for estimating emissions at the national and regional level based on aggregated major source quantification using representative emission factors also forms a useful management tool on a large scale.

Harmonization and standardization of emission inventory procedures is just as necessary for inventory compilation as analytical quality control is for monitoring air quality parameters. A minimum set of basic emission generation data by category is required for management purposes, i.e., public power generation, commercial and industrial activities, road transport and agricultural emissions. Extended reporting of emission data can also be provided including, e.g., geographical parameters, seasonal variations, emission heights, etc.

Pollutants of concern relate to the proposed enlarged GEMS/Air monitoring network (see section 2.2), i.e., CO, SO_2, NO_x, VOC. Anthropogenic vs natural emissions need to be considered separately.

Emission inventories for modelling purposes, particularly at the local and national level, need spatial resolution with agreed grids as well as agreed repeating intervals. Technical measures using appropriate technology, including technology transfer, to reduce emissions can then be implemented.

In order to develop management options for emission reductions to reduce pollution below the guideline targets, emission inventories and urban ar pollution monitoring data can be supplemented with background air pollution data and models. Background (upwind) air quality data are a necessary input to help evaluate what portion of an urban air quality measurement is caused by local sources within the community and what portion is from natural sources and upwind areas which may have different jurisdictions. Models can be used in a two-step process. In the first phase, the urban air quality data are analysed by extrapolation/interpolation in time and space so that the extent and severity of air quality guideline exceedances can be mapped. In the second phase the emission inventory of the urban area is analysed to determine what control programmes and emission limitations are required to bring the air quality into accord with the target guideline values. Spatial analyses of emissions are also useful for land use planning or industrial zoning as an air quality management tool.

Air quality monitoring and emissions inventory data can be used for air quality management plans which take into account source-oriented control measures (emission controls) as well receptor-oriented measures (industrial zoning in predominantly leeward areas). With respect to emission controls, structural measures (e.g., public transport

enforcement) may be adopted in addition to technical controls (e.g., stack filters).

At the international level, particularly in rapidly developing areas, the provision of expert advice to strengthen national and municipal authorities' ability to develop comprehensive action plans for the urban environment will need to be provided.

2.5 Assessment of Air Pollution Effects on Human Health and the Environment

For a monitoring programme to make an impact at country level it must provide for the interpretation of air quality data in terms of the health of the residents of the monitored areas. Assessment of air quality for public health purposes consists essentially of examining the prevalent air quality against the established WHO guidelines and national ambient air quality standards. If guidelines are exceeded a health effect is likely to occur. However, standards differ between various countries and even between cities in a country. Therefore, it is useful to apply a general criterion (e.g., a WHO guideline) for such an assessment on a global level.

In the case of health effects assessment, at present only general air quality guidelines are available, which do not always take into account the variable sensitivity of the overall population. There is a need for the implementation of specific standards for various population groups such as children, the elderly, those suffering from respiratory disease and other sensitive sectors of the population. Another issue which has to be considered is that several pollutants may act in combination, causing more severe health effects than might be expected from the individual effects of each pollutant. Such synergistic effects have yet to be properly determined and are not addressed in most air quality guidelines and standards.

Air pollution can affect human health by direct inhalation and by other routes of exposure, such as drinking water (fall-out into reservoirs), food contamination (either direct or through the fall-out on the soil), by non-dietary intake (children ingesting lead particles through hand-to-mouth contact with contaminated soil), and skin transfer (pesticide droplets, oil droplets from oil well fires, etc.). Until recently, assessment of health effects was based mainly on "average" breathing rates, as little was known about exposure. In recent years new methods have been developed to better characterize total human exposure to air pollutants and assess it accurately (GEMS/Human Exposure Assessment Locations project (HEAL)). The HEAL methodology can be used to evaluate the exposures of people living near GEMS/Air locations to validate the severity of the problems caused by WHO Guideline exceedance.

The assessment of the effects of air pollution on ecosystems is quite similar. Until recently average guideline

values have been used to assess risks to forests, agriculture, and other sensitive ecosystems. However, research shows that ambient air pollution levels do not sufficiently explain damaging effects. Factors such as actual deposition should be taken into account together with predisposition, the synergistic effects of various ecosystem stresses as well as the overall sensitivity of an ecosystem. Links should be established with the GEMS Integrated Background Monitoring Programme which specifically addresses the effects of air pollutants on ecosystems. With respect to the growing importance of air pollutant effects on ecosystems, an expansion of GEMS/Air to non-urban areas would provide valuable data.

In order to produce comprehensive assessments, monitoring data need to be combined with additional data and/or information relating to emissions (e.g., traffic patterns, fuel use), the factors influencing the urban air quality (e.g., meteorological factors, urban topography), and the characteristics of the effected receptors (e.g., population distribution and sensitivity).

The urban environment is a complex interaction of many factors. Air quality is only one facet of urban environmental quality and must be seen in the context of the general urban environment (housing, food, fresh water, education, etc.). Controlling air pollution alone cannot solve the wider environmental problems faced by today's cities. With respect to this, the specific assessments of urban air quality must be complemented by integrated assessments of the urban environment as a whole. Therefore, close contacts should be established with those international programmes addressing such issues.

Ultimately assessments are used to direct the control strategies aimed at safeguarding human and ecosystem health at the local, regional and global level. The establishment of early warning systems in cities frequently affected by high pollution days deserves special attention. Translating the scientific assessments into publications addressed to policy makers is required to raise awareness on the seriousness of the air pollution situation amongst all levels of society, in all regions of the world, and to encourage air quality monitoring and appropriate corrective action.

3. GEMS/AIR Strategic Framework 1992-2001

After 15 years of operation there is a need to reorientate the GEMS/Air programme in order to meet the challenges of the next decade. The following proposals for a redirection of the programme have been drawn up, taking into account the experiences of the present GEMS/Air programme, the experts recommendations for modification of the programme activities and current key issues and problems. Thus the major strategic expansion of the programme should:

* increase the number of air pollutants monitored and the geographic coverage of the programme especially in developing countries;

* broaden the scope of the programme by emphasizing the use of air quality data for assessing potential health and environmental effects and complement the monitoring programme with modelling activities of use in emission reductions;

* improve the structural framework of the programme in order to streamline data handling and communication and to establish closer links with "users" of data and assessments;

* complement the ongoing monitoring programme with modelling activities.

The following section contains details of the programme proposals.

3.1 Programme Objectives

The proposed long-term objective of the programme is to provide the comprehensive information needed for rational urban air quality management.

Within this objective, the programme aims to:

i) provide an international framework for co-ordinated comparable and valid monitoring of urban air pollution, effective data management and reliable information dissemination;

ii) develop methodologies, adapted to the specific needs of the participating countries, required for the comprehensive monitoring and assessment of urban air quality;

iii) produce comprehensive assessments on levels and trends of urban air pollution, pollutant sources, the options for abatement and the potential health and environmental effects;

iv) strengthen urban air quality monitoring networks and assessment capabilities in developing countries.

3.2 Programme Activities

To achieve the goals outlined above it is proposed to divide the implementation of the programme into five main activity areas. Each activity area is independent, though interrelated, and serves predominantly to support one of the programme goals.

The successful implementation of the programme activities will require an in-depth review of the present GEMS/Air network and also municipal and national urban air quality monitoring networks and will also involve scrutiny of the handling, availability, reliability and comparability of data. Data needs and gaps will have to be identified as well as reviewing the representativeness of on-going monitoring operations. Emissions inventories for all participating cities are required together with details of available abatement strategies (legislation and control technologies).

Note: Activities, especially at the city level will need to be completed by all programme partners (participating cities, national environment agencies, collaborating institutes, other international programmes). The GEMS/Air core programme, however, will help the cities implement the necessary monitoring capabilities and take responsibility for data analysis and assessment. The following paragraphs contain an overview of the proposed activity areas.

I. Network Operation - Revitalize, Expand and Operate GEMS/Air Network

It is proposed to continue operating the current network and to expand and improve it by the addition of other key air pollutants (e.g., PM_{10}, O_3, Pb, CO, NO_2, PAH...) and additional information (e.g., emissions inventories, meteorological data, census data, etc.), to produce more frequent data summaries (due to improved data handling procedures), to improve the QA/QC capabilities of the network.

It is also intended to increase the number of participating cities, therefore expanding global coverage. This may involve collecting data from existing monitoring networks or alternatively directing funds towards initiating and maintaining monitoring sites in new participating cities.

Ultimately, the provision of data will improve the timeliness and quality of assessments.

II. Methodology Development - Provide Appropriate Air Quality Monitoring Methodologies

This area has received little attention in recent years. The development of new monitoring methods and the intention of GEMS/Air to monitor additional pollutants mean that there is an important need to update and to improve existing information on methodologies. Technical manuals, handbooks and software are seen as the basis for establishing and improving monitoring, analysis and assessment methodologies.

It is proposed to produce a continuously updated technical handbook with details of network design, monitoring methods, analytical analysis methods, QA/QC procedures and assessment procedures. This will require contributions from all participating organizations including the UNEP

Harmonization of Environmental Measurements and national authorities.

III. Assessments - Conduct National, Regional and Global Assessments of Air Quality Levels and Trends and Potential Effects

Assessments are the principal output of the programme and draw together most activity areas. Future assessments will attempt to interpret air quality and additional data in terms of potential health and environmental effects as well as evaluating the reliability of data. As with past assessments data from a variety of sources will be used; therefore, not only GEMS/Air data will be used in these assessments.

In addition to global air quality assessments, which GEMS/Air has produced in the past, city-level assessments will be produced with greater emphasis on relating air quality data to health and environmental effects. City-specific assessments will demand greater liaison with national and local authorities.

Production of topic-specific assessments will rely on contributions from expert institutes and consultants as well as expertise within the programme. All assessments will be subject to expert review. Direct links between the central data centre operated by US EPA, other data centres and GEMS MARC (and those organizations assisting in assessment production) are essential in order to improve the accuracy and timeliness of reports.

IV. Technical Support - Provide Technical Support for Urban Air Quality Monitoring and Pollution Control Programmes

This is essentially a new addition to the programme, the main aim of which is to strengthen national air pollution monitoring capabilities and to encourage and support the use of air quality (GEMS/Air and non-GEMS/Air) data for decision making.

It is proposed that technical support should consist of expert advice and training with respect to both network operation and air pollution control measures. Technical support for the monitoring network will involve: quality assurance support (provision of reference standards, etc.); regional audit teams (validation and calibration); technology transfer and equipment maintenance. Technical support for air quality management will involve assisting participating countries with emissions inventories and the collection of additional supporting information and to encourage the use of these data in models which can then be used to determine control strategies.

V. Special Studies - Perform Special Studies Integrating All Above Actions

Specific studies aimed at improving the understanding of key air pollution issues are required. Co-operation with participating cities will be sought to examine the efficacy of control programs, to determine human exposure in relation to ambient air quality data at GEMS/Air stations, and to evaluate GIS techniques in relation to air quality assessments, etc.

3.3 Programme Structure

The successful implementation of the new GEMS/Air programme will require an intensified effort on the part of those organizations currently participating. In addition it will be necessary to enlist new institutions and organizations to assist in the various activities. Much greater emphasis will need to be placed on co-ordinated action with other international programmes concerned with air pollution and with urban environmental problems in general. Lack of resources makes task sharing and joint co-ordination of activities an essential basis for the implementation of the programme.

The responsibility for the management and direction of the programme will continue to be shared between WHO (Division of Environmental Health) in Geneva, and the GEMS Programme Activity Centre of UNEP in Nairobi. They will be concerned with the overall planning and budgeting, programme direction, review and approval of outputs, mobilization of resources and liaison with other organizations. It is clear that increased staff time will need to be devoted to the programme. Secondment of national staff would bolster the existing staff capacity of both WHO and UNEP and should be considered.

To ensure that the GEMS/Air programme retains and develops a high scientific basis and credibility, it is proposed that a Standing Committee of Experts is established for the GEMS/Air programme. The function of this Committee would be to advise WHO and UNEP on the scientific aspects of the programme and help to establish priorities. The Committee would comprise approximately ten experts who would meet annually and would also advise on an individual *ad hoc* basis.

Much greater effort will be needed to establish working relations and, where appropriate, co-ordinated action with other organizations and programmes, such as WMO, UNDP, UNCHS, World Bank, UNECE. Earthwatch would provide a forum for fostering these and other co-ordinated activities.

4. GEMS/AIR ACTIVITY AREAS DESCRIPTION

4.1 Network operations

Objective

To provide an international framework for co-ordinated, comparable and valid monitoring of urban air pollution, effective data management and reliable information dissemination.

Outputs

1. Regular data summaries for use in assessments.

2. Annual report on network status.

Activities

1. Expansion of membership with emphasis on developing countries

2. Expansion to include additional key air pollutants to data base (PM_{10}, O_3, Pb, CO, NO_2, PAH...).

3. Evaluate representivity of GEMS/Air stations by comparing with local network data where available.

4. Add new station classifications (e.g., "upwind" for background levels, "downwind" for ozone maxima, etc.).

5. Provide quality assurance (QA) and quality control (QC) oversight for GEMS/Air network through audits, round-robins, etc. with Collaborating Centres. Auditing by regional mobile teams for the validation of the monitoring process on-site, the calibration of equipment and the on-site training. Distribution of standard reference materials.

6. Initiate the collection of emission inventories and supporting data (e.g., meteorological data, motor vehicle densities, industrial units, etc.) for inclusion in data base.

7. Prepare biannual newsletter to all GEMS/Air members.

8. Network operation, which at the city level involves:

   - Routine monitoring of agreed sets of pollutants (which might be different in different regions) using agreed sampling frames and methodologies;

   - Routine participation in QA programme;

   - Routine collection of additional (e.g., topographic, socio-economic and climatological) data;

- Reporting of monitoring and QA results as well as the additional information to global databases;

Resources

Costs include: staff time (WHO, UNEP, MARC); data base operation; consultancy fees; staff visits; QA materials; monitoring equipment for developing countries; workshops.

4.2 Methodology development

Objective

Provision of methodologies for urban air quality monitoring, and data analysis, interpretation and use.

Outputs

1. Technical manual of available monitoring techniques for GEMS/Air pollutants, analytical procedures (QA details), safety bulletins, etc.

2. Publication of handbooks, manuals and software for planning and operating urban air pollution networks and pollutant analysis methodology.

Activities

1. Expert review of available publications and technology, compilation of information, recommendation of methods, preparation of a technical manual covering:

   - **Network Design**: location and representivity of stations; communication requirements; system analysis and logistics.

   - **Sampling and Analytical Methods**: frequency of sampling; monitoring methods; quality assurance.

   - **Assessment Methodology**: data handling and management; data analysis and integration; supportive techniques (e.g., emissions inventories, modelling tools, GIS application).

2. Maintain a current library of relevant air quality monitoring instrument literature, specifications and prices.

Resources

Costs include: staff time; publication costs; consultancy fees; expert meeting costs.

4.3 Assessments

Objectives

1. To provide global, regional and national comprehensive assessments on urban air quality (levels and trends) and potential environmental and health effects.

2. Where possible to determine relationships between pollutant emissions and air quality and to identify management options.

3. To provide information on the contribution of urban air pollution to regional and global problems.

Outputs

1. City-specific assessments (periodic)
2. Specific issue-related reports (annual)
3. Global air quality assessments (every five years)

Activities

Compilation of network data plus other available data related to urban air pollution (e.g., emissions inventories) and production of comprehensive assessments.

1. Comprehensive city-specific assessments

These assessments will be prepared in co-operation with local monitoring, health and planning authorities. They will include the following information:

- Description of the urban environment and pollution sources;
- Emissions inventories for all key air pollutants (including those not monitored) in each city;
- Levels and trends of pollutants;
- Potential effects on health;
- Potential effects on ecosystems;
- Socio-economic impacts of air pollution;
- Control strategy options (including early warning system options);
- Scenario modelling (prediction) and management/policy option analysis;
- Recommendations.

2. Topic-specific regional/global assessments

Co-operation with other international and national programmes, especially with respect to global/regional environmental effects and background monitoring may be required. All assessments will be subject to review by expert groups before publication and distribution. Assessments will attempt to cover the following (where appropriate):

- Synopsis: the state of the urban air environment in densely population areas;
- Potential health effects of urban air pollution exposure;
- Potential environmental effects of urban air pollution on sensitive ecosystems;
- Contribution of urban air pollution to global and regional environmental problems;
- Local, national and international air pollution (and integrated) control strategy options.

Resources

These will have to be decided on a case by case basis, depending on the expertise available within institutes associated with the programme. Costs include: staff time; computer time; publication costs; consultancy fees; contracts with collaborating centres; expert meetings.

4.4 Technical Support

Objective

To strengthen national air quality monitoring and assessment capabilities and to encourage the use of these data in national pollution control programmes.

Outputs

Biennial report indicating number of national authorities monitoring air quality and those using air quality data in support of emissions control strategies.

Activities

To provide support to city networks with respect to standardized monitoring methodologies, data management, QA procedures and equipment support and also by provision of

expert advice and training not only on monitoring methodology but also on assessment and air quality management if required. Activities can be divided into support for monitoring networks and for air quality management.

I. **Technical Support for Network Operation**

1. Expert Advice:

   - Assessment of the monitoring capabilities
   - Preparation of action plans for establishing or improving air quality monitoring and assessment systems
   - Assistance in the establishment/improvement of an urban air quality monitoring network by:
     a) advice on site selection, sampling/analysis methodology and QA procedures
     b) advice on data management and on assessment methodologies (e.g., supplementary data requirements, assessment tools)

2. Training:

   - National/regional workshops and training courses at participating institutes or at collaborating centres covering monitoring strategies and analytical techniques

3. Quality assurance (QA):

   - Distribution of standard reference materials and evaluation of analysis results

4. Auditing:

   - Mobile regional teams for validation of the monitoring process on site, the calibration of equipment and on-site training

5. Technology transfer:

   - Regional and global information exchange with regard to monitoring technologies
   - Providing developing countries with access to existing data bases about environmental monitoring equipment (e.g., NETT)
   - Support and training with regard to acquisition, installation, use and maintenance of monitoring equipment and assessment tools

6. Equipment maintenance:

- Development of regional or global mechanisms to support maintenance of, and supply spare parts for, monitoring installations in developing countries

II. **Technical Support for Air Quality Management.**

1. Expert Advice:

- Evaluation of urban air quality problems in participating cities

- Provide practical assistance with emissions inventories and air quality modelling techniques

- To develop modelling techniques to predict the reductions in air pollutant emissions required to meet WHO air quality guidelines and/or national air quality standards

2. Training:

- National/regional workshops and training courses at participating institutes or at collaborating centres covering assessment methodologies (e.g., conducting emissions inventories) and pollution control strategies

3. Technology transfer:

- Regional and global information exchange with regard to producing emissions inventories and using air quality modelling techniques

- Providing developing countries with access to existing data bases about pollution control equipment (e.g., NETT)

- Support with respect to identification, implementation and enforcement of suitable and economically feasible abatement strategies and pollution control technologies

Resources

This programme activity area is expensive and will require long-term, on-going financial support.

4.5 Special Studies

Objective

To improve understanding of key global, regional and local air pollution issues.

Outputs

Issue specific assessments undertaken in co-operation with participating cities.

Activities

Possible topics which could be undertaken include:

1. Pilot project in a number of participating cities where air quality data are interpreted and control programmes have been initiated - to evaluate effectiveness.

2. Interface with HEAL programme to determine exposures surrounding GEMS/Air monitoring stations - to determine what percentage of exposure is from ambient air, etc.

3. Relation of SO_2 and NO_x emissions to acid precipitation in selected areas.

4. Relation of precursor emissions to ozone and photochemical smog formation and influence of "urban plume" on down-wind urban and rural areas.

5. GIS study in one or several cities to relate ambient air quality data and emissions data to other spatial data sets such as health statistics, socio-economic factors, etc.

Resources

These will have to be decided on a case-by-case basis, depending on the expertise available within institutes associated with the programme. Costs will include: staff time; consultancy fees; publication.

5. References

Schaefer, M. 1991 *Combatting environmental pollution*: national capabilities for health protection, WHO/PEP/91.14, World Health Organization, Geneva.

UN 1986 *Urban and Rural Population Projections 1950-2025, the 1984 Assessment,* United Nations, New York.

UNEP/WHO 1984 *Urban Air Quality 1973-1980,* United Nations Environment Programme, Nairobi and World Health Organization, Geneva.

UNEP/WHO 1988 *Assessment of Urban Air Quality*, World Health Organization, Geneva and United Nations Environment Programme, Nairobi.

UNEP/WHO 1990 *GEMS/Air Data Handling Activities,* United Nations Environment Programme, Nairobi and World Health Organization, Geneva.

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6. Annex

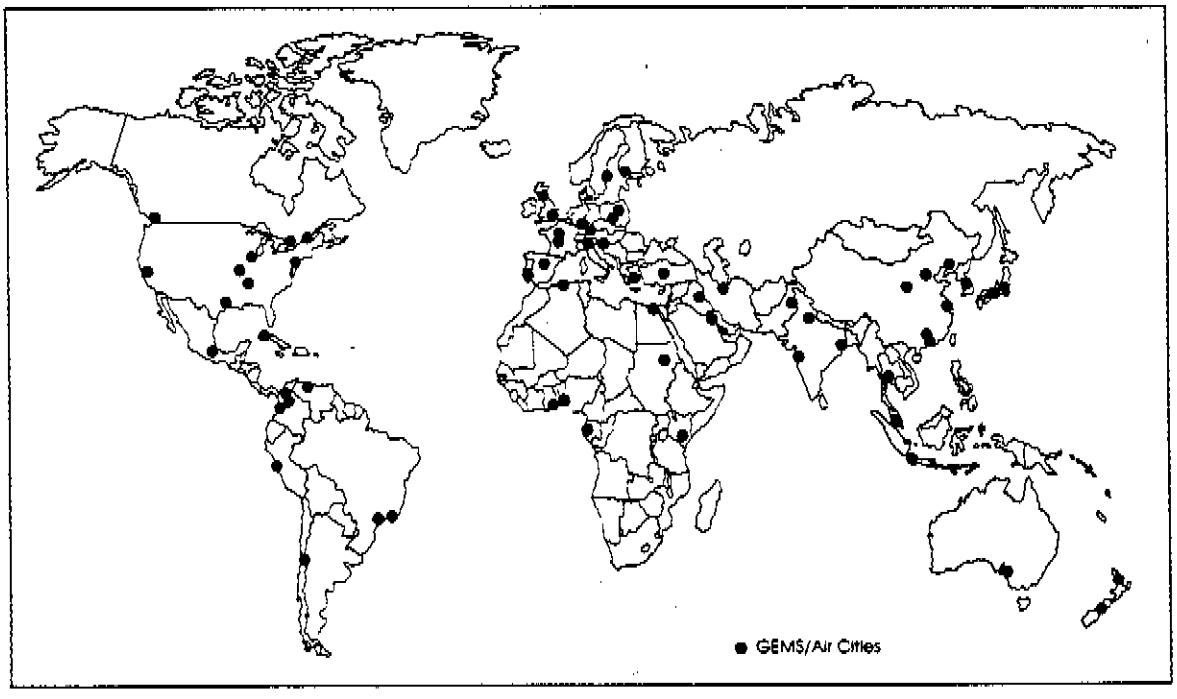

Figure 1 Location of GEMS/Air monitoring cities

Source: UNEP/WHO 1988 *Assessment of Urban Air Quality*, World Health Organization, Geneva and United Nations Environment Programme, Nairobi.

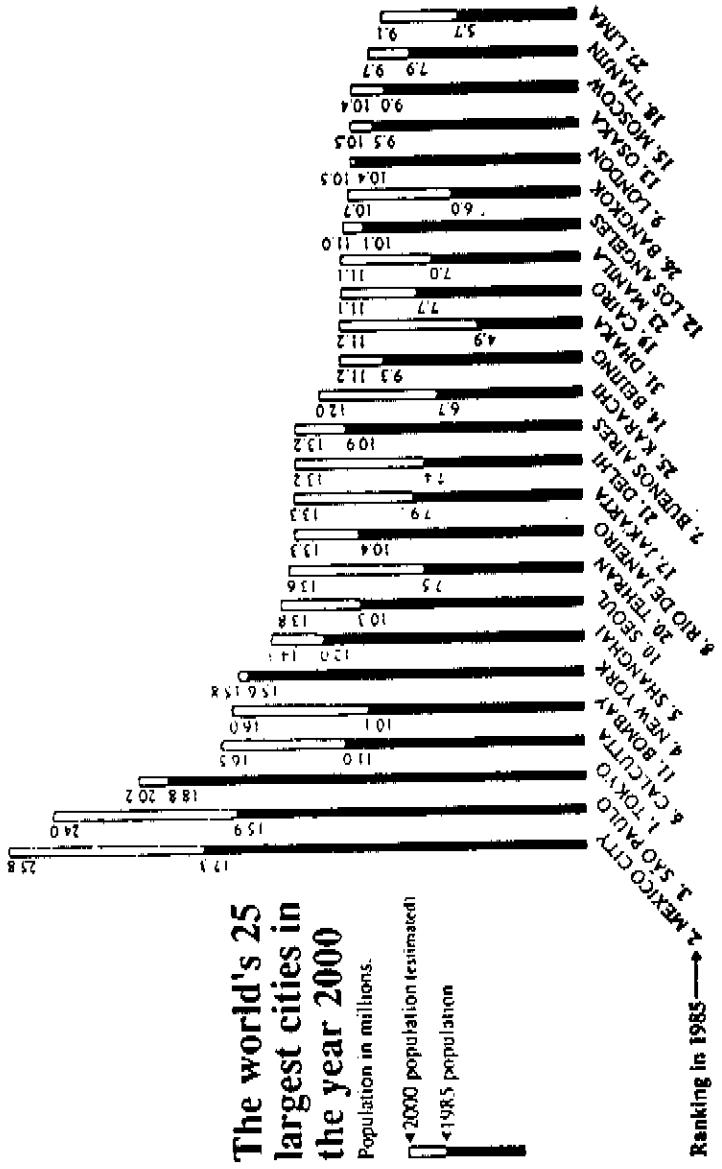

Figure 2 The world's 25 largest cities in the year 2000

Source: UN 1986 *Urban and Rural Population Projections 1950-2025, the 1984 Assessment*, United Nations New York.

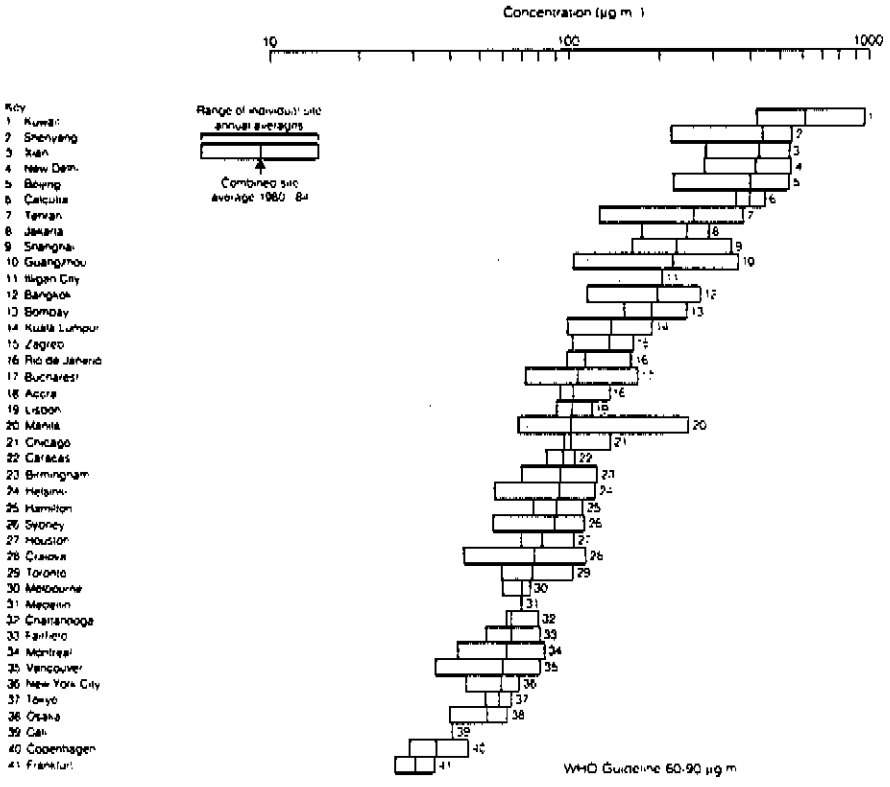

Figure 3 Range of annual average concentrations of suspended particulate matter (high-volume sampling method) in cities of the GEMS/Air network, 1980-1984

Source: UNEP/WHO 1988 *Assessment of Urban Air Quality*, World Health Organization, Geneva and United Nations Environment Programme, Nairobi.

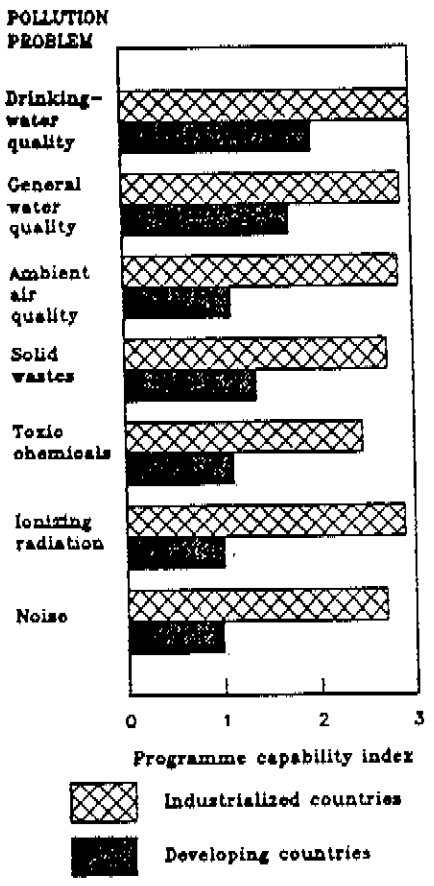

Figure 4 National capability indices

Source: Schaefer, M. 1991 *Combatting environmental pollution: national capabilities for health protection*, WHO/PEP/91.14, World Health Organization, Geneva.

ANNEX IV

RECOMMENDATIONS FROM PREVIOUS REVIEWS OF GEMS/AIR

A. Meeting of UNEP/WHO Government-designated Experts Geneva, 12 - 16 September 1988

Recommendations on Urban Air Quality

1. There is concern that pollutants other than those included in GEMS/Air can have adverse effects on human health. Based on the information presented in the assessment of urban air quality, it is recommended that available data on nitrogen dioxide, carbon monoxide, and lead continue to be included in future assessments. Ozone should also be included, given its toxicity and reports of increasing levels in urban areas. It is further recommended that, to the extent possible, these data be gathered as a component of the GEMS/Air Project. Any additional information should be compiled from the scientific literature and national reports to provide as complete a data base as possible.

2. Given the highly variable nature of suspended particulate matter, it is recommended that efforts be made by participants of the GEMS/Air Project to obtain information on the inhalable portion (PM-10) and the chemical composition of suspended particulate matter. Attention also needs to be paid to determining the contribution that natural sources make to the urban concentrations of suspended particulate matter. This is particularly true in areas where wind-blown dust is prevalent.

3. GEMS/Air data on sulfur dioxide and suspended particulate matter and other information available for carbon monoxide, nitrogen dioxide and lead suggest that emissions of these pollutants are increasing in developing countries. However, in many such countries data are sparse or not yet available, and verification of such trends is required. It is therefore recommended that, to the extent possible, GEMS/Air should actively encourage participation of additional countries.

4. It is recommended that further work be undertaken to assess the potential health impact on populations residing in cities where the estimated number of high pollution days exceeds the WHO guidelines. This may be accomplished in conjunction with the GEMS/HEAL project by choosing the HEAL sites in urban areas identified with frequent high pollution exposure days.

5. The data gathered from fixed monitoring sites are not always directly applicable for conducting human exposure assessments. For example, concentrations of traffic-related air pollutants decrease rapidly with increasing distance from the roadway, both horizontally and vertically. It is therefore recommended that the siting of monitoring stations be carefully considered when the data are to be used to assess human exposure.

B. Meeting on GEMS/Air Data Handling Activities
Research Triangle Park, NC, USA, 26 - 29 September 1989

Recommendations on Urban Air Quality

The following general recommendations are proposed for future consideration and resolution by appropriate consultation and working groups, and are in addition to the recommendations and courses of action agreed to and described in the main body of the report:

(a) That new member countries and additional cities be brought into the GEMS/Air data network to improve global and geographical coverage and to include more major population centres in the network. An attempt should be made to include the largest cities and industrial centres in participating countries and to ensure that they are properly monitored. Attention should also be given to obtaining as broad a continental coverage as possible.

(b) That the GEMS/Air criteria for cities be reviewed to include classifications for categories such as megacities, industrial corridors and for specific population and industrial types and distributions. In the classification of such categories, a determination should also be made on whether different provisions and site selections for the different categories can result in a better monitoring network and the production of more reliable up-to-date health assessments.

(c) That consideration be given on how other data bases can be used to complement assessments of GEMS/Air data. Additional data sets should enhance GEMS/Air assessments by providing new insights, greater completeness and the ability to perform additional analyses. Potentially valuable data sets include population and health statistics, atmospheric parameters and land use data. Such data can be found in other UN organizations and/or in member country data banks. The above recommendations are made with the intention of expanding the present scope and improving the utilization of the GEMS/Air data.

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