WMO RA-II/RA-V GAW URBAN RESEARCH METEOROLOGY AND ENVIRONMENT (*GURME*) WORKSHOP

Meeting Summary and Recommendations

BACKGROUND

The WMO GAW Urban Research Meteorology and Environment (*GURME*) project was developed in response to the recognition that NMHSs have a critical role to play in the study and management of urban environments, in part because the NMHSs are in possession of information and capabilities that are essential to the forecasting of urban air pollution and the evaluation of the effects of different emission control strategies, and that for many this role will be expanded in the future. While the expanded roles of the NMHSs will follow different paths, they will be centered on the traditional activities related to meteorological monitoring, forecasting, and modelling (both meteorological and chemical) and their application to air quality problems. WMO established GURME as a means to help enhance the capabilities of NMHSs to handle the meteorological and related aspects of urban pollution, and is designed to do this through co-ordination and focus of present activities, and selected new endeavors.

The first workshop of GURME was held 1-4 November 1999 in Beijing, China. The objectives of the workshop were to identify relevant activities for the implementation of GURME aimed at improving the NMHSs capabilities to manage urban meteorology and air quality. Specific objectives of the workshop included:

- Review urban-related activities underway and/or planned in Regions II and V.
- Identify what meteorological and air quality measurements are needed to support such activities.
- Discuss urban-related modelling activities and needs.
- Identify potential avenues for co-operation and partnerships to help facilitate GURME initiatives.

Participants from the regions and invited experts presented on-going and planned measurement and modelling activities related to urban-environments. Working groups were then formed to discuss specific questions:

- In what ways can GURME assist National efforts to address urban environmental issues, especially those related to forecasting (including those in support of early warning of pollution events, etc.) on shorter and longer time-scales, and research/assessment of urban environmental quality (e.g., air quality, heat/cold waves, etc.)?
- What (special/additional) meteorological and air quality measurements are needed to support National efforts related to the above? In what ways (if any) does the design of measurements to support these efforts differ from that for environmental protection monitoring? What guidance should GURME provide in regards to such measurements?
- What are the National modelling needs in regards to early warning and forecasting of urban environmental quality? What are the ways in which GURME can assist these efforts?
- What National/Regional/International programmes are relevant to GURME? And what types of GURME linkages should be considered/pursued?

WORKSHOP CONCLUSIONS

Through presentations and working group deliberations, the following conclusions were reached:

(a) Many NMHSs have a breadth of activities related to urban environments, and these activities include a variety of meteorological and air quality measurements, and modelling and forecasting activities ranging from meteorological to chemical, and statistical to dynamic; while others are at a very early stage in developing these activities. Results from the GURME survey of NMHSs presented at the meeting indicated substantial interest in urban environmental issues within many of the Services.

(b) GURME offers significant opportunities to assist NMHSs in their pursuit of urban initiatives; but also faces important challenges. These challenges are largely related to the fact that the responsibility for urban environments often falls within several agencies. Thus there is a need to find ways to effectively co-ordinate activities with other agencies. In addition NMHS's urban activities need to be conducted in the context of National social/economic priorities. There is a clear need for capacity building in the areas of problem definition, optimising monitoring programs based on a balance of measurements and modelling, and quantifying the economic benefits of improved air quality for all relevant compounds.

(c) GURME needs to consider the regional context of urban influences in its planning. For example, the impacts of urban activities are not limited to air quality, but include such issues as water resources (through deposition). In addition, regional influences can profoundly influence urban environments (e.g., smoke in SE Asia and dust in East Asia).

(d) There is a need to assist NMHSs in providing air quality services of high quality. One aspect involves enhancing capabilities to provide meteorological and air quality forecasts of urban environments. Forecasting is an important focus since it builds upon traditional strengths of the NMHSs in terms of meteorological forecasting, and helps to define GURME programme boundaries and to concentrate efforts. This need also entails measurement efforts that support operational and verification aspects of forecasting, and performed in co-operation with appropriate agencies.

(e) Passive samplers offer a variety of valuable applications in urban environments. These include enhancing a suite of species measured, enhancing/providing spatial resolution of the measurements, and in selecting/evaluating appropriate locations for monitoring sites.

(f) GURME offers an excellent opportunity to strengthen co-operation with important WHO activities, such as the Air Management Information System (AMIS).

WORKSHOP RECOMMENDATIONS

The following recommendations were forwarded:

1) GURME should assist NMHSs in providing air quality services of high quality. A spectrum of activities should be pursued. These should include activities such as: illustrating and promoting the linkages between meteorology and air quality; building awareness with end-users (customers) through applications related to compliance, trend analysis, and industrial/city planning; and providing opportunities for twinning and facilitating expert assistance.
2) GURME should assist NMHSs in developing urban-environmental forecasting capabilities by providing guidelines on available models, conducting inter-comparisons, and facilitating training activities. GURME should organize a workshop focused specifically on forecasting, with emphasis on presenting the spectrum of forecasting tools, ranging from meteorological to chemical, and statistical to dynamic, and an appropriate uses (including examples of model uses and limitations).
3) In the area of urban measurements GURME should focus specifically on those that support urban forecasting. This focus may require different measurements than those at present. GURME should formulate guidelines to: better define meteorological and air quality measurements (including contemporary techniques to obtain vertical structure; i.e., wind profilers, and satellite products); to help optimize the number of and placement of monitoring sites, and which measurements are needed at each site. Activities should include making available guidelines, assisting in QA/QC analysis, inter-calibrations, and extending these efforts to include key meteorological parameters.
4) GURME should promote the use of passive samplers to augment chemical measurements in urban-environments, to aid in site selection, and provide added spatial resolution in support of model evaluation.

5) GURME should fully utilise the Internet, and do so though the development of GURME Website designed to assist in its activities. These activities could include a catalogue of appropriate measurement and modelling techniques, with examples of successes, failures, and various degrees of applications for new measurement techniques and models, and as a forum to exchange information on a variety of issues is encouraged. Furthermore GURME should consider utilizing the Internet to create or link to common data bases, and data archive for those parameters of interest to GAW and WMO, and that includes both meteorological data and chemical data. Such an activity should be done carefully to avoid unnecessary duplication and should include links to other existing data bases. The GURME web site should also house archives and updated information on models, including examples of use and limitations, and contact person information for each model, where the contact person would provide feedback to users and potential users for specific models.
6) GURME should promote a series of pilot projects to demonstrate how NMHSs can successfully undertake/expand urban environment issues. The Chinese CMA "Beijing project" presented at the workshop represents an excellent example. GURME also needs to consider other ways to promote its activities. These could include highly visible studies such as an up-date to the UNEP/WHO *Air Pollution in the MegaCities of the World*, showcasing new technologies at appropriate conferences, and developing illustrative examples.
7) GURME should pursue linkages with National/Regional/International programmes (e.g., Environmental Agencies, Municipalities, International Global Atmospheric Chemistry (IGAC) programme, etc.), in addition to other WMO programmes. The success of GURME activities will rest heavily on these linkages.
8) GURME should pursue efforts to enhance the already strong links between WMO and WHO. A strong co-operation will help to convey that meteorological, health and environmental agencies can and must work together in the successful management of urban environments.
9) WMO needs to identify ways to facilitate NMHSs initiatives related to urban environments. These will include twinning relationships, facilitating the use of experts, as well as pursuing additional funding channels (e.g., such as The Asian Development Bank and The World Bank, through such programmes as their *Clean Air Initiative*).

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1. OVERVIEW

The first workshop of GURME was held 1-4 November 1999 in Beijing, China. The objectives of the workshop were to identify relevant activities for the implementation of GURME aimed at improving the NMHSs ability to manage urban meteorology and air quality. The WMO GAW Urban Research Meteorology and Environment (*GURME*) project was developed in response to the recognition that NMHSs have a critical role to play in the study and management of urban environments, in part because the NMHSs are in possession of information and capabilities that are essential to the forecasting of urban air pollution and the evaluation of the effects of different emission control strategies, and that for many this role will be expanded in the future. While the expanded roles of the NMHSs will follow different paths, they will be centered on the traditional activities related to meteorological monitoring, forecasting, and modelling (both meteorological and chemical) and their application to air quality problems. WMO established GURME as a means to help enhance the capabilities of NMHSs to handle the meteorological and related aspects of urban pollution, and is designed to do this through co-ordination and focus of present activities, and selected new endeavors.

The thirteenth World Meteorological Congress (May 1999) concurred with actions taken by the Executive Council and the Commission for Atmospheric Sciences to establish the GURME project. To initiate GURME, WMO intends to hold regional workshops to review existing relevant activities and facilities in specific regions and to prepare action plans for further development of GURME. The first such workshop, the WMO RA II/RA V GAW Workshop on Urban Environment, was held in Beijing, China from 1 to 4 November 1999 and kindly hosted by the Chinese Meteorological Administration (CMA). At this inaugural GURME workshop there were ~30 invited experts and participants from the area, representing 22 countries and WHO. Reports were given on country activities, after which the participants divided into groups to work closer on selected topics. This report summarizes the activities of this workshop.

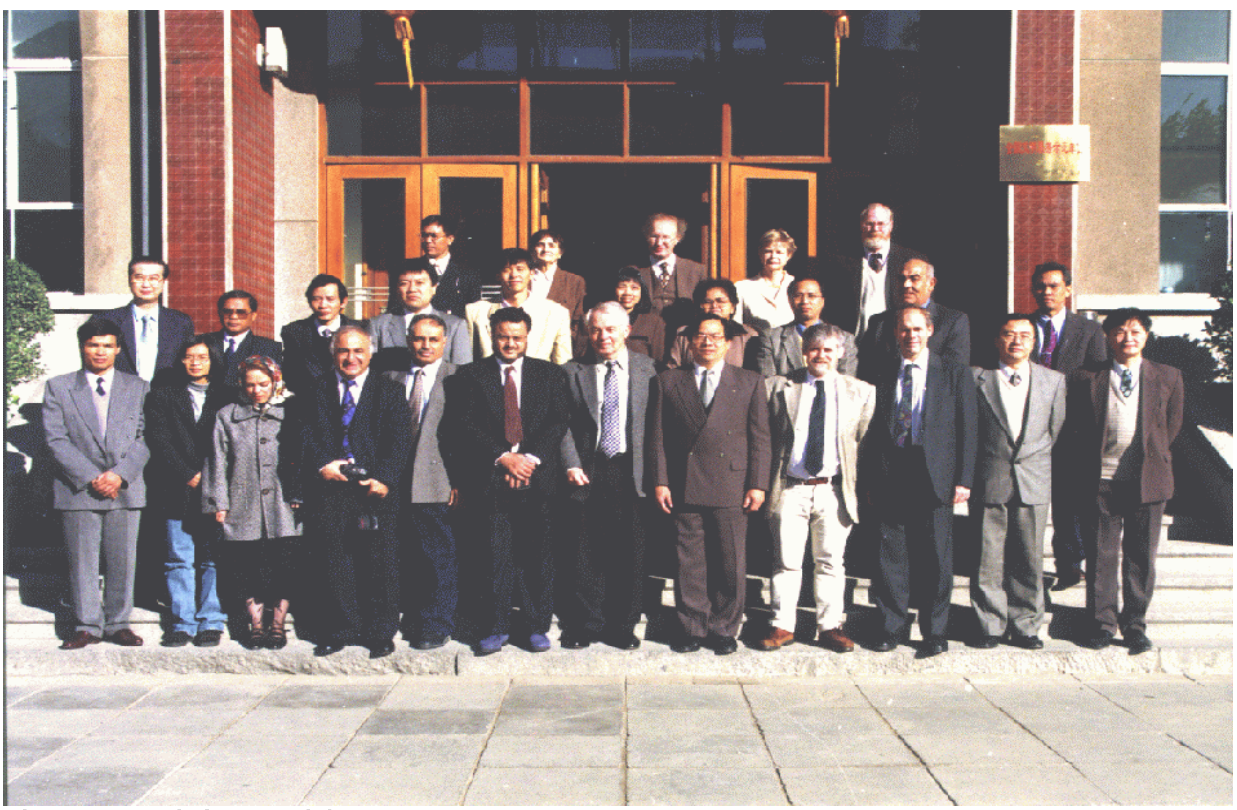


Figure 1. Workshop participants.

2. OPENING OF THE MEETING

Professor Yan Hong, Deputy Administrator of the China Meteorological Administration (CMA) opened the meeting. On behalf of CMA and Mr. Wen Kegang, the Administrator of CMA, he expressed his congratulations on the opening of GURME workshop and extended a warm welcome to all. He went on to discuss the changing role of meteorological agencies in respect to management of the atmospheric environment. He noted that meteorology is a science that grows in accordance with the requirements of users. Today as societies enjoy an improvement in living quality, they place a high priority on protecting the atmospheric environment. As a result, environmental protection will become one of the greatest challenges of the 21st century. This challenge requires meteorologists to be involved in many associated (and often rather unfamiliar) scientific disciplines. Therefore, the new research program on urban environmental meteorology (GURME) is needed and should be implemented as an urgent matter. The Chinese government has paid great attention to the challenges of urban environments. The China Meteorological Administration has planned and established several projects to meet the new requirements. For example, an urban meteorological data collecting system for some big cities has been planned. This system includes intensified observations in: UV radiation; pollen; and boundary layer parameters. These new data, in addition to the conventional meteorological elements, will be saved in a special data base. Modeling related to air quality will also be carried out. He thanked WMO for its excellent work in facilitating the development of this project, and expressed his confidence that this project will play a very important role in organizing and coordinating the activities of related research. He expressed his pleasure that the China Meteorological Administration had the opportunity to host this WMO RA II/RA V Global Atmosphere Watch (GAW) workshop on GURME in Beijing. He stated that only through the international cooperation and joint efforts, can research on urban environmental meteorology be accelerated. He closed by wishing the workshop a great success and all a pleasant stay in Beijing.

3. WMO/GAW ACTIVITIES

3.1 Overview of the GAW Program

John Miller from the WMO Secretariat conveyed his greetings from the SG and welcomed the participants. He then presented an overview of the WMO/GAW program. Many urgent environmental problems confronting society, such as global warming, depletion of the stratospheric ozone layer, acid rain, urban pollution and transport of hazardous material are connected with the man-made changes in the state and composition of the atmosphere and its interactions with other environmental media. Within the United Nations system the World Meteorological Organization (WMO) has a continuing responsibility for providing authoritative scientific information and advice on the state and behaviour of the earth's atmosphere and climate using a number of its operational observation networks, one of which is the Global Atmosphere Watch(GAW).

The GAW system is designed to co-ordinate two related atmospheric chemistry environmental problems: 1) To understand the relationship between changing atmospheric composition and changes of global and regional climate 2) To describe the regional and long-range atmospheric transport and deposition of natural and man-made substances.

The GAW measurement programme includes ozone (total column, vertical profile and near the surface), greenhouse gases (CO_2, CFCs, CH_4, N_2O), solar radiation including UV, aerosol characteristics, reactive gas species (SO_2, NO_x, CO), chemical composition of rain, radionuclides and meteorological parameters. To ensure the required quality of data a number of measurement manuals have been and are being prepared and a data quality assurance/quality control plan for GAW has been recently developed.

To collect, process, analyse and distribute data obtained from the GAW stations, six World Data centres have been established by WMO: on ozone and UV (Toronto, Canada), greenhouse gases (Tokyo, Japan), precipitation chemistry (Albany, USA), solar radiation (St. Petersburg, Russia) and on aerosols (Ispra, Italy). A new data centre has been established for surface ozone at NILU in Norway. Poster presentations from these data centres are displayed at this conference. The GAW data are regularly published and are available directly from the Centres upon request to all organizations, scientific institutions and individual scientists.

A most important aspect of the GAW has been the establishment of Quality Assurance Science Activity Centres (QA/SAC) to oversee the quality of the data produced under GAW. Three centres have been established in Germany, Japan and the United States. The QA centres play a major role in training, quality control and establishing protocols for measurements. In co-ordination with the QA/SACs, system of World Calibration Centres have been designated for specific measurements.

3.2 Overview of GURME and Workshop Objectives

Liisa Jalkanen from the WMO Secretariate presented an overview of the GURME project. The GURME project arose in response to the requests for assistance by many NMHSs dealing with urban issues, and in recognition that the management of urban environments requires special attention. The genesis of the project began in the Twelfth World Meteorological Congress (1995) where it was determined that meteorological and climatological aspects of urban environments should receive increased attention within WMO programmes. In response, the Executive Council added the field of the urban atmospheric environment to the terms of reference of the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry. A meeting of Experts on Atmospheric Urban Pollution and the Role of the National Meteorological Services was convened in Geneva in October 1996 to help define issues and needs and to plan for future WMO activities related to urban environments. This meeting confirmed that many NMSs have important roles to play and that capabilities in this area need to be strengthened (GAW Report No. 115). Internal discussions on this subject at WMO led to the preparation of the WMO Fact Sheet entitled *The Global Atmospheric Watch: Urban Environments – An Emerging Focus* (No. 14 September 1997). The findings of the meeting of Experts and the issues articulated in the WMO Fact Sheet were reported at the Commission for Atmospheric Sciences (CAS) meeting in Skopje Macedonia (February 1998). CAS made a recommendation, which was subsequently endorsed by the WMO Executive Council, to establish and develop an urban environment meteorological research programme within GAW. To help define this project a WMO GAW Workshop on Urban Environments was convened (Paris, November 1998). The issue was also raised at a series of workshops, conferences and meetings on air pollution held in Europe, Africa and Asia. The GURME project builds upon these discussions. To initiate GURME, WMO intends to hold regional workshops to review existing relevant activities and facilities in specific regions and to prepare action plans for further development of GURME. This Beijing Workshop is the inaugural meeting.

She went on to present the workshop objectives. The specific objectives of the workshop were to:

- Review urban-related activities underway and/or planned in Regions II and V.
- Identify what meteorological and air quality measurements are needed to support such activities.
- Discuss urban-related modelling activities and needs.
- Identify potential avenues for co-operation and partnerships to help facilitate GURME initiatives.

4. URBAN ENVIRONMENTAL RESEARCH ISSUES AND CHALLENGES

A series of papers were presented on the research challenges and needs in urban environments.

4.1 The Emerging Focus of Urban Environments

Gregory Carmichael discussed urban challenges in the context of Asia. Asia is one of the most dynamic and diverse regions of the world. As the poorer regions strive to catch up to the more developed ones, the environment is often caught in the middle, and in some cases given cursory attention. Awareness is mounting for the need for cooperation at local/regional/international levels in solving Asian environmental problems, as Asian development will have profound impacts on the environment both near and far.

Fueled by high population growth and vibrant economies, energy consumption in Asia currently represents ~20% of the world total, and its share is estimated to grow to 30% by 2015. Because fossil fuels will provide much of this energy, emissions of greenhouse gases and air pollutants such as sulfur and nitrogen oxides and particulates are projected to dramatically increase. During 1990-1996, total energy-related carbon emissions in East Asia grew at an average rate of 4.5% per year, compared to the world average of 0.6% per year. Over the last two decades, China's SO_2 emissions have grown by more than a factor of three, and this trend is expected to continue, with Asia-wide emissions projected to increase by another factor of two to three between now and 2020.

A key dynamic in Asia (and elsewhere around the World) is the urban environment. There is growing awareness that the management of urban environments requires special attention. The urban environment is where an increasing share of the world's people live, where most energy is consumed, and where the impacts of pollution are hardest felt. Urban populations are growing faster than the national averages, as subsistence workers migrate from rural areas to the cities in search of disposable income. Asia presently has ~1 billion urban dwellers, expected to rise to nearly 3 billion in 2025, and the ten Mega Cities (populations greater than 10 million) account for ~40% of their countries GNP. Though reliable monitoring and health effects data are often lacking, indications are that damage to human health and well-being from poor air quality (both in and out of doors) is extensive. Without strong intervention the situation will inevitably worsen.

The impacts of urban activity on the environment are many with one person in five exposed to levels or air pollutants that exceed the minimum standards recommended by WHO. The poor air quality in many cities in Asia is the result of both high emissions and meteorological conditions associated with stagnation/inversion. Sources of pollutants include vehicles (cars, diesel buses and trucks, two-stroke engines), industrial (both traditional and more modern chemical-based), energy production, domestic cooking and heating (coal in China, biofuels in India), and high ambient dust levels due to local construction and long range transport from the arid regions. Economic growth will not be equal across economic sectors, and the energy-intensive industrial sector is projected to grow slower than the service sector, which has lighter energy demands. Unfortunately, growth in the transportation sector in Asia is one of the largest and as a result photochemical smog problems in Asian cities are on the rise. Without new policies the contribution of motor vehicles to energy use and emissions will rise dramatically.

While many of the impacts of high pollution levels are centered in the urban areas, the impacts of urban actiivties are not confined within urban boundaries. Acid precipitation is an illustrative example. China's National Environmental Protection Agency (NEPA) recently released a report indicating that economic losses due to acid rain damage to forests and farmland are five times higher than initially assessed in 1996, and are now estimated at $13.25 billion annually. The long range transport and fate of pollutants in Asia is an area of increasing scientific interest and political concern, as countries receive growing amounts of pollutants from neighboring and even distant countries. The recent episodes of severe smoke and haze in Southeast Asia underscores this point.

The growth in tropospheric ozone concentrations provides a another clear example of this globalization of pollution. The basic ingredients in the formation of ozone in the urban atmosphere are now well-established: partially-burned hydrocarbons, nitrogen oxides, and sunlight. The motorization of urban environments all around the world has produced local smog, including ground-level ozone, in hundreds of cities. Ozone formation continues downwind from the cities in which emission occurs until the components are diluted below the critical levels. However, when the dilution has not been completed when the plume enters the next city, the pollution is converted from a local problem into a regional problem. The growth in these emissions has now advanced so that the regional problems are coalescing further into zonal problems affecting all locations within a particular latitude zone, e.g. between 25 N and 50N latitudes. A similar zonal problem exists in the southern-hemisphere, driven largely by the extensive burning there of forests and agricultural wastes.

The pressing environmental problems of urban pollution and climate change in Asia should not be treated as distinct problems, but rather as closely linked problems sharing common causes and solutions (as depicted in Figure 2). The fact that air pollution problems and greenhouse gas emissions arise largely from fossil fuel combustion and the important role of aerosols in both air pollution and climate change are illustrative examples. In Asia it will be particularly important to develop energy/emissions policies which recognize the need for near-term benefits and that choices made in changing energy usage may have different climate change and health outcomes. In the urban environments of Asia, efforts to reduce emissions and to use less energy have significant health benefits at rather low per capita costs ($10 to $50 per person protected). From a health perspective the benefits of a one ton reduction in particulate emissions from household stoves are estimated to be at least 40 times greater than those from coal-fired power plants. Furthermore, shifting from coal fired power plants to natural gas has larger health benefits than climate benefits, while shifting from coal power to hydroelectric results in the same percentage reduction in health effects and greenhouse gas emissions reductions.

For these reasons the urban environment is becoming recognized as a critical area of focus. Meterological Services have a critical role to play in the study and management of urban environments, in part because the NMHSs are in possession of information and capabilities without which forecasting of urban air pollution or evaluation of the effects of different emission control strategies cannot be undertaken. There are great challenges and opportunities for expanded roles of the NMHSs in this area, centered on the traditional activities related to meteorological monitoring, forecasting, and modelling (both meteorological and chemical) and their application to air quality problems.

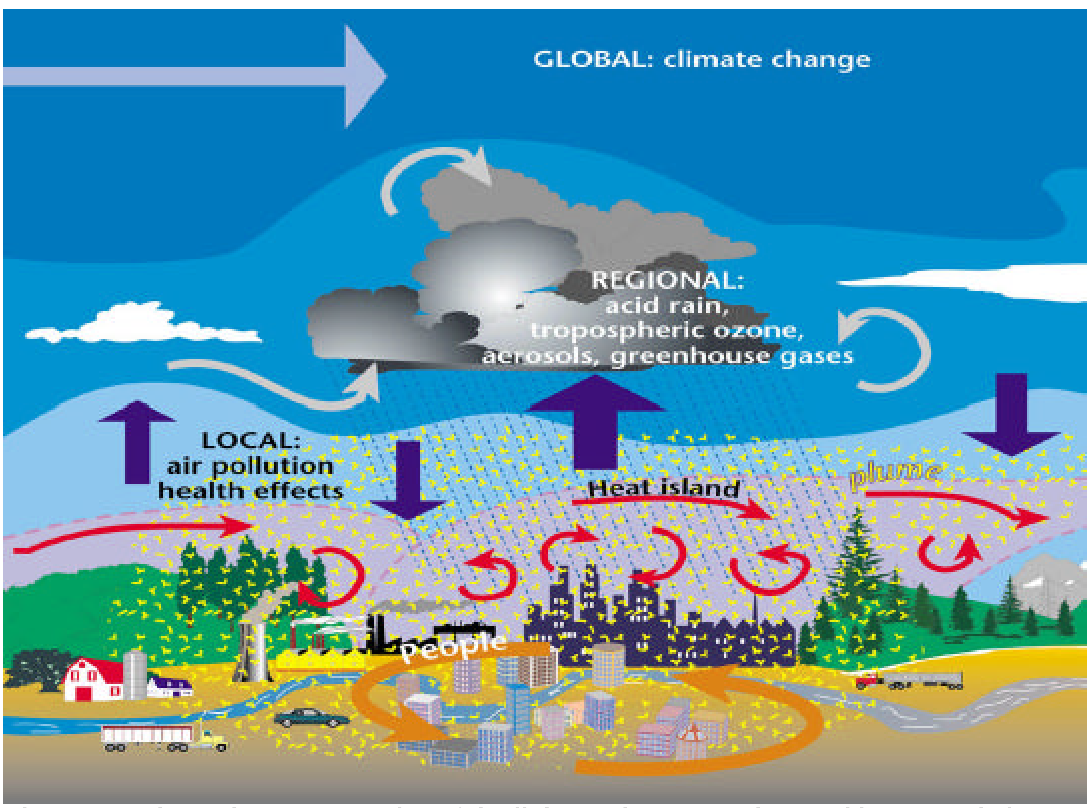


Figure 2. Schematic representative of the linkages between urban and larger scale issues.

4.2 Monitoring, Modelling and Forecasting Air Pollution from Mesoscale Down to Individual Houses

Gary L. Geernaert commented on the changing role of modeling in the management of air quality. During the past five years, the air pollution sector has been exposed to major technological opportunities. These opportunities have also been accompanied by challenging environmental problems and higher societal expectations. As a consequence, the scientific and policy communities are participating in a self-made “revolution” in how we do business and formulate strategies. Air pollution modelling and monitoring are part of this revolution, where the actors in research, operations, policy analysis, and the public are fully integrated.

Less than a decade ago, air pollution modelling was considered to be a research activity limited to the more advanced research and development centers. Not so today. These models are used in university courses, they are used as on-line demonstrations on television, and they are easily downloaded free off the internet for private use. Data to drive these models, such as EMEP, GEIA, and global meteorological data fields (from NCEP, USA) are in the public domain, and accessible over the internet. A cultural transformation of how we do business has taken place: the scientific and policy communities are now expected to work together, and the public prides itself on its participation in defining and helping to solve environmental problems.

How can we all benefit from these changes? Among the most prominent technological opportunities, the scientific community now has available an enormous capacity of computer power (in comparison to five years ago) and the expanded use of the internet has provided open exchange of data. To compensate for the much lower computer costs, models have systematically increased in complexity and sophistication to tackle higher resolution scales, provide on-line assessments, and carry out scenario calculations for policy studies. Models can now be constructed as nested systems, for use on portable PC’s. However, with all this high tech, the performance of models and monitoring systems remains limited – limited by the quality of the input data and by the assumptions behind parameterizations used in the models. Furthermore, as we move to higher resolution (as expected by the public) and a greater focus on the worst episodes, the model performance is not necessarily any better. There are also scientific challenges.

The environmental problems we face today exhibit a far greater complexity than we imagined in our youth. During the 1970’s, sulfur and ozone were the dominant health concerns in the largest urban centers. In many regions (e.g., Europe and the U.S.), legislation has forced sulfur emissions down, thus reducing the ambient concentrations of SO_2 and sulfate. However, with population growth and with the rapid industrialization of many regions, NOx and VOC emissions have dramatically increased. Thus, the ozone levels are far from being reduced to acceptable levels, in spite of legislation to reduce NOx and VOC’s. In much of the third world, and in particular in those regions where sulfur emissions have not been reduced significantly, air pollution problems have worsened considerably.

To complicate matters more, the World Health Organization has identified particulates as a more serious health concern than we previously realized. In most studies, the particulates of concern are not the largest ones (as previously assumed). Instead, the smallest particles are the ones which are now believed to cause most health damages. Most models do not include any information on particulate size distributions, particulate emissions, transformations, and/or transport. In most regions, traffic is a major source of the fine particulate number concentrations, and as traffic increases, so does the particulate emission function. Together with the scientific challenges of modelling and monitoring particulates, the policy communities are now faced with the challenging task of how to assess and reduce the particulate emissions.

Besides trends in technology and industrialization, there is a social dimension we face, which acts as a major force in how we carry out systems development and strategic planning. Societal views and their familiarity with and concern over environmental issues is more widespread. People, on average, are much better educated than in the past, and they are expecting high tech solutions to be noticed in the environmental sectors, in the same way as high tech advances have been noticed in, for example, telecommunications, materials, medicine, gene technology, and computing. As in all these other high tech sectors, the environment is living off public funding and the institutes carrying out environmental research and monitoring are becoming increasingly privatized. The same business principles of efficiency, effectiveness, spinoff, and customer satisfaction face the environmental sector as in the other sectors. Because “environment” is both a high tech sector and also because it is a part of society’s view of “quality of life”, most citizens want solutions to environmental problems to be derived quickly and efficiently. There are high expectations. Environmental research, monitoring, and policy analysis are all under pressure to respond with rapid high tech solutions.

Air pollution systems

In direct response to the technical and societal changes facing the scientific community, we must not think in terms of individual models but rather in terms of systems. We are moving from the linear way of thinking to the nonlinear multi-scale view of the world. The problems to solve are health damages, traffic optimization, economic competitiveness, and quality of life (including environmental aesthetics). Because much of air pollution (especially toxic pollution) is transboundary in nature, diplomacy and regional security are also relevant here.

Based on recent trends, one of the goals of the air pollution modelling community is to develop low cost accurate model systems which can be integrated into the decision making process of both the private and public sectors. This implies that air pollution systems (combining measurements and modelling) must be robust, flexible, adaptable, and linked to the effects sectors. There are four immediate applications of such air pollution systems:

* the models within the system must be linked in order to assess the “state of the environment”, including effects. They must be linked to the sectors responsible for assessing economic damages due to health, traffic planning and control, agriculture, recreation, and tourism;
* the system must be convertible to a scenario policy tool in order to be used to evaluate either governmental or industrial policy options, such as emission reductions or alternate emergency strategies;
* the model part of the system must be flexible enough in order to be integrated into monitoring programs, in order to add both accuracy and coverage, and also be accessible by public authorities; and
* the model part of the system must exhibit a time dependence, i.e., able to forecast future air pollution situations and potential effects.

Because air pollution systems will be accessible by the public, to varying degrees, visualization is a necessity to satisfy societal expectations. Visualization software such as VIS5D is free off the internet.

System performance issues: past, present, future

How do we prioritize the scientific research dedicated to system performance? First, a comment on recent history. In the past, and due to limited computer capacity, air pollution models have generally been used to estimate air pollution concentrations, in both time and space, for average conditions. With such uses, models were first applied to routine monitoring programs in order to add resolution and coverage. They were also used for industrial applications such as site selection and the evaluation of source-receptor relationships, and for simple mesoscale forecasting. While the scientific base has always been more advanced than what models could absorb, the available computer power forced models to limit the number of governing processes to the most necessary set which served the needs of customers. For example, dispersion models did NOT consider meandering of plumes (which requires large eddy simulation techniques); atmospheric deposition models did NOT consider the higher order turbulence terms, associated with complex topography and local field divergences (which requires that we use nonhydrostatic models); and health damage assessments assumed subgrid homogeneity of population density and air pollution concentrations (due to lack of data and data handling techniques). Models exhibited low uncertainty for the assumptions imposed on spatial homogeneity and large grid size resolution, but customers were more or less satisfied. Extreme events were difficult to forecast.

Today, however, the public has become an important actor in articulating the requirements for system performance. They want more performance and applications. One outcome is that there is greater emphasis placed on extreme events and the study of specific air pollution episodes, in finer resolution domains. This has given major challenges to the scientific research community, where there is now a focus of researchers to closely scrutinize the assumptions behind the set of parameterizations used in models. There is also a scientific need to identify which processes must be included in higher resolution models and how to parameterize the missing processes. As we move from regional, to urban, to the street scales, episodes become more and more difficult to assess and predict with any given precision. Obviously, with a focus on both extremes and higher resolution, model performance is the limiting factor to address by scientific researchers. We need to expand the set of governing processes within the models, and relax the assumptions by applying more complete theories.

Given that the primary use of model calculations during "urban" episodes is in health damage assessment and traffic planning, air pollution researchers require a close relationship to the government policymakers in constructing their model system requirements.

Construction of the THOR system

In 1998, the European Union included in the language of some new air quality legislation (going into effect in 2000) that all cities with populations greater than 250,000 people will carry out air pollution forecasts and warnings, on a daily basis. At that time, most cities in Europe did not make air pollution forecasts. In general, those few cities which did forecasting, mainly emphasized statisical forecasts with limited performance. (There are however exceptions to this generalization, e.g., Oslo, Athens, London, and a few others had dynamic air pollution forecast systems in place). Within Denmark, a series of discussions began, in order to design an advanced open architecture air pollution system, which would meet the needs of a number of present and anticipated future drivers: EU legislation, better coverage of Danish air quality monitoring, integrated forecasting, and systems analysis. With these drivers, statistical forecasting was abandoned and replaced by a strategy towards a dynamic air pollution system. To construct such a system, a series of air pollution and meteorological models must be linked and nested, and both meteorological and air quality data bases would need to become available in real time. Given that the internet is the source of the necessary data, and using the principle of open access to environmental and meteorological data derived from public investment, we constructed the THOR system in collaboration with the University of Athens (ref. Professor George Kallos).

The THOR system is designed to integrate meteorological data bases and emissions inventories covering the northern hemisphere, European scales, Danish region, and urban centers. It is to be composed of five models, each of different spatial scale and application. The THOR system has the following specific objectives:

<u>Objective 1</u>: To produce 3 day air pollution forecasts, four times each day, for all cities in Denmark which are governed by EU air quality legislation: Copenhagen, Aarhus, Aalborg, and Odense.

<u>Objective 2</u>: To support research projects which are dedicated to quantifying human exposure to air pollutants in various European cities, and other cities worldwide. In all projects, the resolution is at the house and street level, and some projects are underway to model air pollution exposure of specific individuals, where some individuals are tracked using GPS and other voluntary reporting techniques. Within Denmark, there are specific projects in place, which have the ultimate goal to assess and formulate policies to reduce air pollution exposure to key population groups (for example, children, bus drivers, postmen).

Objective 3: To support monitoring in both Greenland and Denmark, by adding coverage and temporal variability.

Objective 4: To support policy making, by carrying a variety of scenarios. For example, projects are presently in place to explore the health and other (economic, traffic, quality of life) benefits of anthropogenic emission reductions of specific sector types, both in Denmark and in other countries.

In its present form, the THOR system already satisfies the first and second objectives, and it satisfies the Greenland portion of the third objective. However, because the system is open and able to assimilate all models within its architecture, by spring 2000, the total system configuration will be completed, and overall system performance, validation and improvements will be documented as an ongoing processs.

Present capabilities of THOR

THOR consists of a weather forecast model (eta model) and several air pollution models. Most emphasis has been focussed on the forecasting of urban scale street canyons, using meteorological fields across Europe and EMEP emission inventories coupled to traffic emissions within individual street canyons. Traffic data are parameterized as a function of day of week, and hour of each day. Smog episodes represent its primary application, where photo-oxidant modelling is represented, combining both the mesoscale and local street scales. The model presently does NOT contain parameterizations of particle emissions from traffic or resuspension from road transport. These parameterizations will be added at later stages, once a sufficient data base is constructed to provide reliable estimates.

The model system operates in a forecast mode, four times each day. Northern hemispheric meteorological data are downloaded from the NCEP internet site, every six hours. Data transfer requires 30-60 minutes, using a workstation, and the meteorological and air pollution models are integrated, and are routinely able to forecast ozone, CO, NOx, benzene, and other constituent concentrations. The output is reported hourly, extending out 3 days. Together with a visualization package, the total computational time is roughly 3.5 hours. Model resolution for the meteorological fields is 38 km. For air pollution fields within the cities, the resolution is down to 10 m. At present, the THOR system combines the DEM, Urban background (eta model), and OSPM, with air pollution forecast coverage for all scales relevant to Europe. The hemispheric model (DEHM) and the specific applications concerning radioactive accidental releases (DREAM model) will be added within the next half year.

The models which are anticipated to be within THOR during the next six months will span from the global down to street scales, and their key applications, are briefly described as follows:

Danish Eulerian Hemispheric Model (DEHM). This is a 3 dimensional Eulerian (12 vertical layers) model, which emphasizes atmospheric transport pathways between and within the midlatitudes and the Arctic, using meteorological flow fields, and GEIA emission inventories. In direct support of the Arctic Monitoring and Assessment Program (AMAP), this model calculates 150kmX150km resolution concentrations and depositions of sulfur species, benzene, and mercury. The model will include ozone calculations beginning early in 2000. In the near future, persistent organic pollutants will be also systematically added to the chemical submodel of DEHM. DEHM will be integrated into THOR in mid 2000.

ETA model: This is a full three dimensional weather forecast model with 32 vertical layers and horizontal resolution of around 39kmX39km. Data to drive this model are downloaded from NCEP each 6 hours.

Danish Eulerian Model: This is presently a two-dimensional Eulerian transport model, operating on 25kmX25km resolution, for all of Europe. A 3-dimensional model is under development, and will replace the 2-dimensional version in mid 2000. Together with meteorological and EMEP emission inventory data bases, this model assesses the transboundary component of air pollution within all regions of Europe, and it is able to address many of the various policy questions associated with ozone episodes.

Meteorological fields from NCEP and the “ETA model” act as a high resolution driver for DEM. Both “ETA” and DEM are presently in THOR, in an operational mode.

DREAM model: This is a fully three dimensional mixed Lagrangian-Eulerian model, which adds accuracy to dispersion estimates which involve both long range transported and local components. It has been used to assess transboundary pollution, with an emphasis on radiaoctive tracers, accidental releases, and the role of multi-point and local area sources on downwind pollution episodes. Its resolution is 25kmX25km, with zooming to 5kmX5km near the sources. DREAM will be added to THOR as a special application during mid 2000.

Urban background model (UBM): This is a support model which interfaces the DEM and the street canyon model OSPM (see below). The urban background model estimates locally within the urban region the air pollutant concentrations at 2kmX2km resolution, at heights above buildings. The Urban background model is driven by meteorological fields derived from the “ETA” model and monitoring stations within the urban region. The UBM is presently oeprational in THOR.

Operational Street Pollution Model (OSPM): The OSPM is driven by meteorological and air pollution concentrations derived from the Urban Background Model. The street configuration, heights of buildings, and traffic statistics are required to be integrated into the model’s initial conditions, in order to produce high resolution maps of air pollution at street and house level. Presently, the model estimates: CO, NO, NO2, O3, and VOC’s (benzene). The OSPM is presently in THOR.

Atmospheric Chemistry and Deposition Model (ACDEP). The ACDEP model is a fine resolution version of the EMEP model, operating on scales of 50kmX50km over Europe. It is presently operating independently of THOR, and is driven by EMEP and DNMI data fields. Once integrated within THOR, it will derive its initial and boundary conditions from the ETA model, and it will provide chemical deposition estimates to various regions of Europe.

In principle, the THOR system is constructed by assuming that smaller scale models receive their boundary conditions from the larger scale models. The models run in a nested form, with dynamical and chemical influence extending only to the smaller scale domains. There is no reverse feedback.

Monitoring and modelling

In general, monitoring air pollution serves three purposes: assessment of the situation; determine compliance to legislation; and to provide information in support of mitigation strategies. For each of these purposes, the monitoring data alone are insufficient in providing convincing conclusions which will satisfy all stakeholders. The monitoring data therefore must also be used to both drive air pollution models, and support the research necessary to improve model performance.

The placement of monitoring stations in urban centers has been a challenging task. There are four factors to consider: time coverage; spatial coverage; accuracy; and data dissemination. For use in modelling, temporal coverage should ideally be hourly. Spatial coverage involves two issues: representativeness area of the measurement; and spatial coverage of the monitoring network of stations. In general, the representativeness area of the measurement indicates how large the spatial area is where the concentration does not deviate more than a sepcified amount from the measured value. In most street canyons, the representativeness is only for one side of the street canyon, and extending no more than 100m. For the urban background, the representativeness is governed by a radius on the order of 100-1000m. In rural regions, the representativeness area has a radius on the order of 25-150 km. Finally, accuracy of the measurement is determined both by the constraints on the sensor’s performance and on the temporal variability during the sampling period. These altogether contribute to data quality criteria of the monitoring system.

Models on the other hand produce data which have a different type of spatial representativeness area and temporal time scale. For street canyon modelling, representativeness is a function of the spatial and temproal resolution of the model. However, the accuracy of models is limited by the traffic emissions statistics and meteorological factors. With all the uncertainties and differences, there is a maximum level of accuracy one can expect when comparing monitoring data to models.

Because urban monitoring requires some balance of measurements and modelling to provide sufficient information over a larger region, the placement of stations needs to be made in reference to the utility of the data by models and representativeness of the data. This is a challenge for the monitoring systems designer.

Summary points

During recent years, there has been a rapid increase in computer power which scientists have been able to exploit. Air pollution models are more sophisticated, they are operating at higher resolutions, and data are easily obtained from the internet. However, because societies have new and higher expectations on how research and monitoring are carried out, and because society has more input on the design criteria for environmental modelling, there has been a high priority placed on producing systems which are high tech, with graphics and visualization, for both background air pollution states and extreme episodes. Some of the features of systems are:

* systems can easily be constructed today, which produce on-line effects, forecasts, and scenarios;
* with relative ease, universities can use modelling architectures are a classroom tool;
* television will begin to incorporate four dimensional animations of weather and air pollution, for use in all temporal and spatial scales;

Features still missing in most air pollution systems include the following:

* particulates, especially particulates in the fine fraction mode, i.e., below one micron radius.
* pesticides, POP's, and heavy metals (e.g., mercury, cadmium, etc.).
* health damage assessments, based on morbidity and mortality functions which treat the stress of the human condition. There is tremendous controversy how chemicals (in particulate particulates) damage humans.

In the future, these sysems will most likely be extended to include on-line abatement options, and forecasts of risks and effects. These are all challenges for scientists, technologists, and policymakers to define.

4.3 National Met Service Activities in Modelling Urban Meteorology and Air Quality

Paul Mason provided his views on the role of meteorological services in providing urban-related modeling services. Services involving urban meteorology and air quality are a growing area of the application of meteorology. Although significant interdisciplinary knowledge is required the forecasting and modelling skills involved have much in common with techniques used in other meteorological applications. For this reason such services can often be provided by the National Meteorological Service. The alternative of the National Meteorological Service passing the meteorological data onto another agency who provide such services can also work well provided there is a good relationship between the parties and the other agency has appropriate skills.

A key requirement for the establishment of sound services in this field is the availability of good verification data. Such data, whether meteorological or air quality, should be obtained from well chosen sites selected to avoid very local extremes and to be broadly representative of their general location. All the normal issues of good instrument calibration and maintenance separately apply. The appropriate skills to maintain such instruments can lie with the National Met Services but often rests with other agencies. Again, provided there are good links to ensure correct siting and maintenance, either approach can work well.

The availability of data on relevant parameters facilitates the use of statistical relations to the prevailing meteorological parameters. Such statistical methods can provide useful forecasts if well developed. Such forecasts cannot however easily deal with special circumstances of local source concentrations and topography to give forecasts which are reliable away from the observation points used to establish the statistics. They are recommended as a starting point when resources are short.

The simplest dynamical approach to the air quality modelling involves the use of so called box models, which represent the basic air flow and sources strengths. These can be used for both forecasts and scenario studies. To be successful they must have an adequate representation of the surface thermal and mechanical properties and have a reliable estimate of source strength. Reliable knowledge of source strengths is a common cause of difficulty and it usually needs good cooperation between national agencies and industry to make it available. As with all models it is bad practise to use such methods without verification data and (consequent knowledge of accuracy).

The simplest of box models can be extended in sophistication to use a simple flow models. For example, a linear flow over orography model could be used. Such extensions have been successful in some cases but the simple flow models are not usually reliable under the conditions of strong stabily stratified flow, which are of particular relevance to air quality. Such extensions are not recommended without the resources to make a detailed evaluation any benefits.

Air flow trajectory models are a form of Lagrangian box model which is essential in applications involving longer range transport. They have particular relevance when material comes form remote sources or as with ozone involves long range chemical transformation and transport.

The most advanced and often research models incorporate the air chemistry and sources into a full regional or mesoscale numerical model. Such models require a basic numerical weather prediction capability, and are usually limited in their scope for representing detailed chemistry. However, they remain problematic under the light wind and stable conditions which are critical to air quality. Even when the resources and expertise for their research consideration exists they need to be tested by verification to ensure the predictions are indeed superior to those of simple models.

In conclusion, there are important opportunities for National Meteorology Services to play a valuable role in the provision of urban air quality services. Useful services are within the scope of National Met Services with limited resources whilst those with research expertise can consider more detailed methods. A good link between model prediction and verification data is essential to ensure that services are well and professionally based.

4.4 The Australian Air Quality Forecasting System

John L McBride discussed the Australian Air Quality Forecasting System. The Australian Air Quality Forecasting System (AAQFS) is being developed as a collaborative project between the Bureau of Meteorology, (BoM), the Commonwealth Scientific and Industrial Research organisation (CSIRO) and the Environmental protection Authorities (EPA) of two States, New South Wales (EPA NSW) and Victoria. The project's short-term goal is to develop, validate and trial an accurate, next-day (24-36 hour) numerical air quality forecasting system for a three-month demonstration period in Sydney, which includes the 2000 Olympics. Currently forecasts are produced in both Melbourne and Sydney. After the Olympics, the AAQFS will be available for forecasting health- and visibility-related air quality metrics in the other major population centres of Australia.

The project has a number of specific goals: to provide the ability to generate 24-36 hour air quality forecasts twice per day (available 9 am and 3 pm); provide forecasts for a range of air pollutants including oxides of nitrogen (NO_x), ozone (O_3), sulfur dioxide (SO_2), benzene (C_6H_6), formaldehyde (CH_2O) and particulate matter (PM10 and PM2.5); provide forecasts at a resolution sufficient to consider suburban variations in air quality; and to provide the ability to generate simultaneous forecasts for a 'business-as-usual' emissions scenario and a 'green emissions' forecast. The latter may correspond to a minimal motor vehicle-usage scenario and will be used to indicate the reduction in population exposure that could result from a concerted public response to a forecast of poor air quality for the next day.

The AAQFS consists of five major components : a numerical weather prediction system (LAPS), an emissions inventory module, a chemical transport module (CTM) for air quality modelling, an evaluation module, and a data archiving and dissemination module (data package). The development of the AAQFS is proceeding in two phases: 1) the construction and operation of a pilot system using components that were available at the time of study inception; and 2) the development of a demonstration system, through the enhancement of components in the pilot system, and where necessary, through the construction of new modules (Cope, et al. 1999). We note that resources were allocated to first implement a pilot system in order to provide a preliminary indication of system performance. This has enabled important areas of development to be identified prior to the design and construction of the demonstration system.

LAPS constitutes the NWP system in both the pilot and demonstration versions of the AAQFS. LAPS is a hydrostatic model with state-of-the-art numerics and physics packages, and has been used by BoM to generate operational meteorological forecasts since July 1996 (Puri, et al. 1998). Meteorological forecasts will be provided at a horizontal resolution of 0.05? (LAPS05). Special attention will be paid to the resolution and treatment of surface processes in an effort to improve representation of local and mesoscale flows and boundary-layer growth. Accurate representation of these processes is crucial for realistic, high-resolution forecasting of air pollution dynamics.

EPA-VIC and CSIRO, with support from EPA-NSW, are undertaking emission inventory development. All emissions processing for the pilot system is undertaken offline with a resolution of 6 km with no allowance made for week/weekend or seasonal/local meteorological dependencies. The demonstration system will use size-fractionated and speciated particle emissions, 0.01? gridded area sources over the densely population regions and meteorologically dependant emissions that are generated online during LAPS operation . A power-based vehicle emissions model, being developed at CSIRO, will be used to generate road-specific vehicle emission fluxes for the purpose of near-road impact modelling.

The Carnegie Mellon/California Institute of Technology (CIT) photochemical airshed model comprises the pilot CTM (Cope and Ishtwan, 1996; Cope, et al. 1998, 1999). A notable modification is the implementation of the compact GRS photochemical mechanism, which enables rapid turn-around times for the CTM modelling. The domain is divided into 10 non-uniform levels in the vertical (extending to 2000 m above ground level). The pilot system has been used to generate 24-hour air quality forecasts (NO_x, O_3 and SO_2) using the 1100 UTC (2100 EST) LAPS05 forecasts. In the demonstration system, the CTM modelling will be conducted online using LAPS05 transport fields that are updated at 5-10 minute intervals. Note that the CTM simulations use a 0.05? outer grid, with nested inner 0.01? grids for major urban areas. Photochemical smog production will be simulated using an enhanced version of the GRS mechanism and particle transformation will be modelled using a modal-based particle scheme. A more comprehensive treatment of both processes will also be available in an offline version of the CTM.

Both the meteorological and air quality forecasts are the subject of on-going and case-specific validation. This has already commenced for the pilot system through comparison of LAPS meteorological fields with METAR/SYNOP (near-surface) and AMDAR (vertical profile) data and meteorological observations from the EPA monitoring networks. Air quality forecasts are compared against 1-hour EPA observations for NO_x (both as NO and NO_2) and O_3. This will be expanded for the demonstration system to include SO_2, PM10, PM2.5, CO and (where available) non-methanic hydrocarbons. Critical to the validation process has been the availability of EPA data sets by the end of each forecast period, enabling the on-going validation to be substantially automated.

Data archiving will evolve from use of native system formats in the case of the pilot system (already NetCDF in the case of LAPS) to unified NetCDF data packets, which will be accessible via GUI-driven Q&A software. Sufficient information will be available in a data packet to enable the CTM to be run offline at a later time. The EPAs will have access to the daily forecasts via the AAQFS Web Site and will control the dissemination of the forecast data.

5 WHO ACTIVITIES

Dietrich Schwela from the World Health Organization discussed urban air pollutiuon and health issues. Ambient air pollution is known to influence the life in urban environments of developed and developing countries. Health effects are observed in the population which are due to exposure to ambient air pollutant concentrations in particular in developing countries. According to a recent study of WHO about 1.5 billion people are exposed to increased ambient air pollutant concentrations of suspended particulate matter, sulphur dioxide and ozone (Hong 1995; Schwela 1995; Schwela 1996a; Schwela 1996b; WHO 1997a). In developed countries the health impacts of ambient air pollution are well recognised. In the populations of developing countries with an extensive use of coal for combustion and growth of the number of motor vehicles awareness of the health impacts of air pollution is still low. Ambient air pollution is only slowly recognised as a problem of daily concern for everyone living in urban areas of developing countries.

In developed countries people are exposed to air pollution from combustion products, household chemicals, airborne bacteria and viruses, radon and its daughters indoors. In developing countries, ambient air pollution is significant in urban areas. In addition, indoor combustion of coal, firewood and other biomass fuels for cooking and heating has resulted in high concentrations of suspended particulate matter, sulphur dioxide and carbon monoxide which often are above ambient concentrations of these pollutants by at least an order of magnitude.

A synopsis was presented of the health effects that are caused by air pollution in urban areas. The air pollutant situation in these countries is characterised by using the data of the Air Management Information System (AMIS) data base that contains recent summary data on air pollutant concentrations in more than 100 cities in the world (WHO 1997b; WHO 1998a).AMIS has the objective to transfer information on air quality management (air quality management instruments used in cities, indoor and ambient air pollutant concentrations, noise levels, health effects, control actions, air quality standards, emission standards, emission inventories, dispersion modelling tools) between countries and cities (Schwela 1999). AMIS data can be used for a comparison of the air pollutant situation in various urban areas of the World, as a means to estimate the exposure of the urban population to air pollutants, and to inform on the approaches in air quality management used in different urban environments.

An approximation to the magnitude of the burden of disease resulting from air pollution involves knowledge of the number of people at risk of being exposed, the crude morbidity and mortality rates, the increase of morbidity of mortality with unit increase of pollution and the actual pollutant concentrations. While in developed countries this information is sometimes available it is mostly not in developing countries and many assumptions are to be made.

Of major support to countries in risk assessment and national standard setting have been WHO´s Air Quality Guidelines for Europe, WHO, 1987. Between 1993 and 1996 they were updated (WHO 1994; WHO 1995b; WHO 1995c; WHO 1995d; WHO 1996) and are presently in press (WHO 1999a). The Air Quality Guidelines for Europe have recently been made globally applicable and extended by including guidance derived in the Environmental Health Criteria Series of the International Programme for Chemical Safety (WHO 1999b). These globally applicable guidelines take into account factors which might be influential for the health outcome in other regions, and issues of air quality monitoring and management.

While in developed countries the evaluation of the exposure and the assessment of the impact of air pollution on the health of the population has been attempted e.g. in the WHO project “Concern for Europe’s Tomorrow” (WHO, 1995e) and in the Dobric report of the European Environmental Agency (EEA 1995). Similar projects for developing countries have not yet been performed. A first attempt to systematically consider air pollution exposure and assessment in urban areas of developing countries was performed in the “Megacities Report” (UNEP/WHO 1992). This report is presently being updated. AMIS has been created to facilitate such assessments.

The objectives of this address are to delineate the air pollution situation in developed and developing countries, to discuss the health effects of air pollution, to present and discuss the updated and revised air quality guidelines of WHO and to elaborate on the disease burden caused by ambient air pollution.

Ambient Air Quality in Developed and Developing Countries

Air pollution levels and trends in developed countries

In the Dobric Report the indicators in the surveyed cities of European countries include three major air pollution situations:

1) Winter-type smog by sulphur dioxide (SO_2) and particulate matter (PM) measured by the black smoke or gravimetric methods ;
2) Summer-type smog by ozone as resulting from emissions of volatile organic compounds and nitrogen oxides ;
3) High annual average concentration levels (including benzene, benzo[a]pyrene (BaP), and lead, in addition to SO_2 and PM).

It was estimated that the 1987 air quality guidelines of WHO were exceeded during in winter-type smog in 70 to 80 per cent of all surveyed cities of more than 500 000 inhabitants. In about 28 percent of cities concentrations around or higher than twice the WHO guidelines haven been observed duirng days with poor dispersion conditions. Most of the cities had higher PM than SO_2 concentrations.

Summer-type smog is the occurrence of photochemical oxidants built up from nitrogen oxides and VOCs. Usually the produced ozone will be found downwind of the area of emissions. An exception is when cities are located in conined valleys, or when the air is trapped by special meteorological conditions for significant photo-oxidation to take place. Examples of such cities where high ozone concentrations go up to 400 ? g/m^3 include Athens, Barcelona and Mexico City.

Urban street pollution is monitored in many cities, and the measurements show that short-term maximum concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2) and particles may exceed air quality guidelines by a factor 2 to 4, depending on the actual traffic and dispersion conditions of the street. In Europe, between 9 and 18 million people are exposed to these high concentations. Smog occurrences and long-term average concentrations of compounds such as lead, benzene, PM and BaP are significantly produced from road transport. Road transport contributes on average more than half to the NO_2 concentrations and about 40 per cent to the VOC concentrations. In many cities the road traffic contribution to pollution by these compounds is even higher. All these combustion processes in road traffic produce fine and ultrafine particles less than 2.5 ? m aerodynamic diameter.

While NO_2 emissions from stationary sources have decreased in many urban areas, emissions from motor vehicles have increased because the growth in the number of vehicles and the distance travelled per vehicle has been much larger then the reduction in emission factors. As a consequence NO_2 concentations did not decrease but remained constant or were slightly increasing.

Considerable improvements in local air quality in recent decades have been achieved in many cities through substitution of coal and heavy fuel oils by cleaner fuel such as gas oil and natural gas, and by electricity and heat supplied from large electric power plants and district heating plants. Emission controls have been particularly successful in the reduction of SO_2, dust and fly ash emissions to the atmosphere, and in the reduction of the emissions of various gases from the process industries.

Air pollution levels and trends in developing countries

In a recent publication the air pollution situation of cities in developing countries was analysed (Krzyzanowski and Schwela 1999). The annual mean concentrations of SO_2 in residential areas have not exceeded 50 µg/m^3. Noticeable exceptions are several cities in China, with the SO_2 concentration of 330 µg/m^3 in Chonqing and 100 µg/m^3 in Beijing in 1994. High levels of SO_2 may be seen also in other developing countries, especially in those with cold winters, as illustrated by the report from Nepal (Sharma 1997). Daily mean concentration of SO_2 was in the range 273 - 350 µg/m^3 in residential areas of Kathmandu in

September - December 1993. In monitoring sites close to main roads, the reported range is 310-875 µg/m^3 indicating the influence of emissions from traffic. More than half of the vehicles registered in the city is equipped with two-stroke engines, many are old and ill maintained.

In most of the cities with data allowing trend assessment, a decline in mean annual SO_2 concentration was seen over the 1990s. The most dramatic reduction of air pollution with SO_2 was reported from Mexico City, where the concentration in various residential areas dropped from over 100 µg/m^3 in 1990-91 to less than µg/m^3 in 1995-96. In the most polluted Chinese cities, an annual decline rate was between 1% and 10%.

The most commonly monitored and reported indicator of suspended particulate matter is the mass of total suspended particles (TSP). In most of the cities, the TSP annual mean concentration exceeds 100 µg/m^3, with the levels exceeding 300 µg/m^3 in several cities of China and India. There is no evidence of any overall systematic and significant change in TSP levels. More consistent is the decrease in TSP concentration in Mexico City. The opposite tendency can be seen in some Chinese cities, with the most rapid increase of TSP concentration in Guangzhou (from less than 150 µg/m^3 in 1990-92 to more than 300 µg/m^3 in the more recent years).

In a limited number of cities reporting the data to AMIS, also the mass concentration of particles with aerodynamic diameter less than 10 µm (PM_{10}) is measured. The annual average PM_{10} levels ranged from 50 to 100 µg/m^3 in the years 1995-1996. The highest concentrations, exceeding 250 µg/m^3, were observed in Calcutta and New Delhi. In most towns with high PM_{10} average in the last year, an increase of the pollutant concentration was seen over the 1990s. In most cases, this increase has occurred even when a decrement in TSP was reported. An opposite trend and a decrement in PM_{10} level were seen in the Central and Southern America cities. In Mexico City, the relative decrement in PM_{10} was faster than that of TSP.

Annual mean concentration of nitrogen dioxide remains on a moderate or low, not exceeding 40 µg/m^3 level in most of the cities reporting to AMIS. However in Mexico City and in Cape Town, the annual average of 70 µg/m^3 has been exceeded regularly in the 1990s. A paper based on data from centrally located monitors in Sao Paulo indicates annual mean of 240 µg/m^3 in 1990/91 (Saldiva et al, 1995). The trends vary between the cities but a 5-10% annual increase was more common than a decrease in concentration of this pollution.

The observed pattern is consistent with the volume of car traffic in each city. The highest pollution levels, and the increasing trends, are observed in the cities with high and increasing car traffic. In Southern Asia or in Latin America, this high NO_2 concentration combined with the intensive UV radiation results in photochemical smog with high ozone contents. It is illustrated by the analysis of temporal and spatial patterns of tropospheric ozone in New Delhi (Singh et al, 1997), where the build-up of ozone over the day is faster than scavenging of ozone by the NO_2. The mixture of high NO_2 emissions from gasoline combustion with intensity of UV in Mexico City is the cause of notorious photochemical smog in that city as well. According to the data reported to AMIS, ozone concentration exceeded the AQG level in over 300 days per year in 1994-96, and the 95th percentile of maximum daily 1-hour average ozone concentration was around 500 µg/m^3. Some decrement was seen, however, in respect to the annual mean ozone concentration indicating slow improvement of air quality in non-extreme days.

Krzyzanowski and Schwela (1999) have extensively discussed the relevance for health of the observed pollution patterns in developing countries. The reported concentrations of air pollution reach levels of concern for public health in many cities of developing countries.

Health impacts of ambient air pollution

The health impacts of air pollutants are manifold and can become manifest in any compartment of the human body. Compartments affected include the respiratory system, immune system, skin and mucous tissues, sensory system, central and peripheral nervous system, cardiovascular system.

Health effects of air pollution on the respiratory system (lower airways) include acute and chronic changes in pulmonary function, increased incidence and prevalence of respiratory symptoms, sensitisation of airways to allergens, and exacerbation of respiratory infections such as rhinitis, sinusivitis, pneumonia, alveolitis, and legionnaires´ disease. Principal agents for these health effects are the combustion products sulphur dioxide, nitrogen dioxide, suspended particulate matter with a mean aerodynamic diameter below 10 µm and smaller, and carbon monoxide. In addition indoor air pollutants - fine suspended particulate matter, formaldehyde, and infectious organisms - can also act as important agents.

Effects of air pollution on the central nervous system manifest themselves in damage of the nerve cells, either toxic or hypoxic/anoxic. Principal Agents are volatile organic compounds (acetone, benzene, toluene, formaldehyde), carbon monoxide and pesticides. In infants and young children neurophysiological changes caused by lead can result in developmental retardation and irreversible deficiencies.

Effects of air pollution on the cardiovascular system develop through reduced oxygenation and result in increased incidence and prevalence of cardiovascular diseases, myocardial infarction, and consequent increase in mortality caused cardiovascular diseases. Principal agents are carbon monoxide, suspended particulate matter, and environmental tobacco smoke.

Carcinogenic effects of air pollution are associated with lung cancer, skin cancer, and leukaemia. Principal agents for lung cancer have been identified as arsenic, asbestos fibres, chromium, nickel, cadmium, polycyclic aromatic hydrocarbons, trichloroethylene, environmental tobacco smoke, and radon. Benzene is known to produce leukaemia; and ultraviolet radiation is a causative agent of skin cancer. A difficult question is that of synergism among the different carcinogenic compounds and between carcinogenic and non-carcinogenic agents. The question of synergism is largely unresolved. Also other carcinogenic effects might also exist but are not well assessed.

There is increasing scientific and medical evidence that exposure to fine and ultra fine particulate matter could have relatively more significant health implications, than exposure to larger particles or to other airborne pollutants (WHO 1999c). Fine particles are defined here as smaller than 2.5 micrometers and ultra fine as smaller than 0.1 micrometers.

WHO guidelines for air quality

The Air Quality Guidelines for Europe have been published by the WHO Regional Office for Europe, EURO in 1987 (WHO, 1987). Since 1993 they were reviewed and updated (WHO, 1994; WHO, 1995a; WHO, 1995b; WHO, 1995c, WHO, 1996). In a recent expert meeting the new Air Quality Guidelines for Europe (WHO, 1999a) were extended to become globally applicable through consideration of findings in non-European regions. The globally applicable guidelines for air quality will constitute a publication in which also the issues of air quality monitoring and management and indoor air problems are being addressed (WHO, 1999a).

Air quality guidelines have several objectives including the protection of public health from adverse effects of pollutants, elimination or reduction to a minimum of air contaminant concentrations, provision of background information for making risk management decisions, provision of guidance to governments in setting standards, and assistance in implementing local, regional, national action plans.

Air quality guidelines (AQG) should be clearly distinguished from air quality standards (AQS). AQG are derived from purely epidemiological and toxicological (or environment-related) data while. In contrast, AQS are values limiting air pollutant concentrations that are promulgated through legislation in a country or community. In the process of promulgation issues of technological feasibility, costs of compliance, prevailing exposure levels, social, economic and cultural conditions are possibly taken into consideration.

As an example a table of the updated and revised, globally applicable air quality guidelines for classical compounds are given in Table 1. The values fixed in these tables are considered to be “safe levels” of air pollutant concentrations for which the risk of a health effect is negligibly small.

Table 1. WHO air quality guidelines for “classical” compounds

Compound	Annual ambient air concentration [µg/m^3]	Health endpoint	Observed effect level [µg/m^3]	Uncertainty factor	Guideline value [µg/m^3]	Averaging time
Carbon monoxide	500-7000	Critical level of COHb < 2.5%	n.a	n.a.	100 000	15 minutes
					60 000	30 minutes
					30 000	1 hour
					10 000	8 hours
Lead	0.01-2	Critical level of Pb in blood < 25 µg Pb/l	n.a.	n.a.	0.5	1 year
Nitrogen dioxide	10-150	Slight changes in lung function in asthmatics	365-565	0.5	`200	1 hour
					40	1 year
Ozone	10-100	Respiratory function responses	n.a.	n.a.	120	8 hours
Sulphur dioxide	5-400	Changes in lung function in asthmatics	1000	2	500	10 minutes
		Exacerbations of respiratory symptoms	250	2	125	24 hours
		in sensitive individuals	100	2	50	1 year

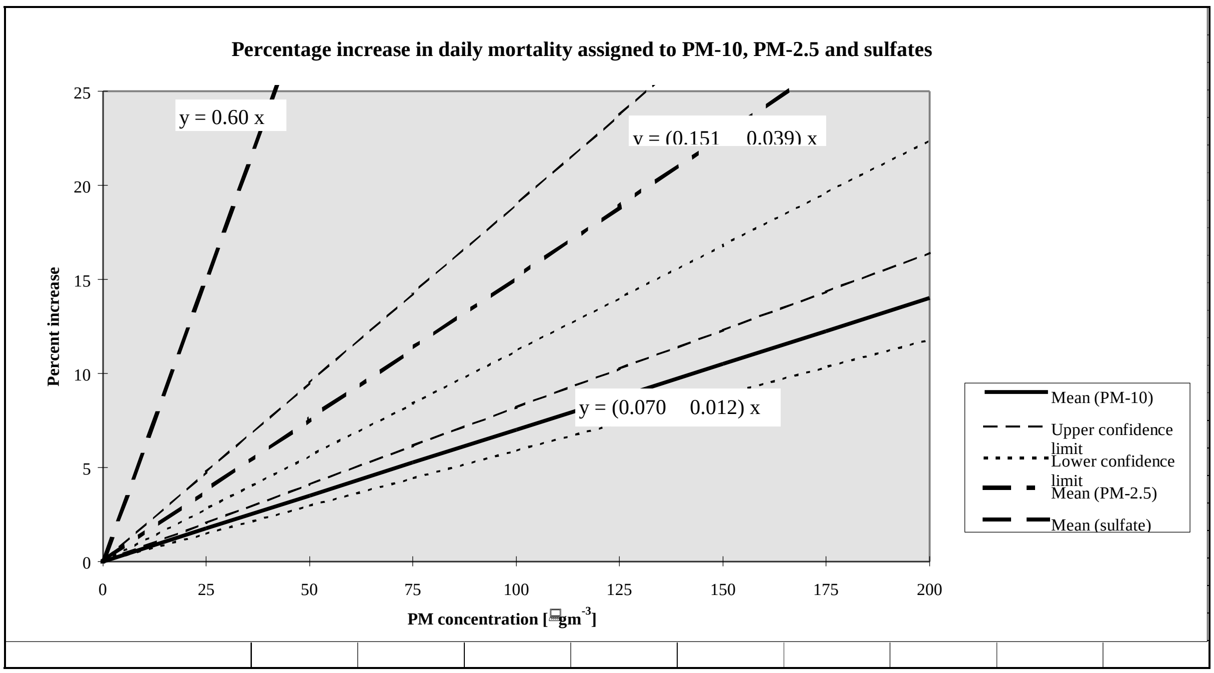


Figure 3. Percent-concentration relationship for daily mortality according to the air quality guidelines

Table 1 does not include guidelines for suspended particulate mater. It was argued that a threshold for this compound including the size-dependent fractions PM_{10} and $PM_{2.5}$ could not be established and consequently no guideline be given (WHO, 1995a). Rather it is recommended to use percent-change-concentration relationships such as indicated in Figure 1 for fixing an acceptable percent change for some kind of effect (e.g. in the case of figure 1 of mortality) in the sense of a risk consideration. This procedure is new and comparable to that for carcinogenic compounds (WHO 1999a). This concept with respect to standard derivation has been interpreted recently (Schwela and Junker 1998).

Estimates of mortality and morbidity due to air pollution

In recent years a large number of studies of the health impacts of suspended particulate air pollution have been undertaken in developed country cities (WHO, 1999a). Some data are also available for South American and Chines cities (Hong, 1995; WHO 1999b). These studies show remarkable consistency in developed countries in the relation ship between changes in daily ambient suspended particulate matter levels, changes in daily mortality, and changes in respiratory morbidity. Using the air pollution data provided by AMIS and the PM_{10} air quality guidelines within a simple model (Hong 1995) the annual number of premature deaths caused by suspended particulate matter has been estimated to range globally between 120 000 and 470 000 (Hong 1995; Schwela, 1996; WHO, 1997a). In the eight economic regions defined in the World Development Report (World Bank 1993) the regional distribution of excess mortality is shown in Figure 4. It can be seen from this figure that air pollution in urban areas of China lead to the absolute highest lower and upper bounds, followed by the Eastern European region, India and South East Asia. For the incidence of respiratory diseases the estimations are shown in Figure 5. The highest rate of incidence appears to be in China, followed by India, Southeast Asia/Western Pacific, Eastern Europe and Latin America. Globally between 21 and 57 million incidences of respiratory diseases appear to be due to ambient exposure of the urban population to suspended particulate matter.

Conclusions

The above considerations indicate the magnitude and seriousness of ambient air pollution problems in developing countries In view of the fact that for inhalable and fine particles a threshold for the onset of health effects could not be derived in the air quality guidelines the reduction of emissions of this compound is particularly important. Indoor air pollution due to biomass fuel and coal use appears to be an even more serious problem. However, indoor air pollution due to open stove cooking and heating in urban and rural areas of developing countries leads to even higher mortality rates and morbidity incidences.

The following topics deserve attention of the scientific community.

Mixtures of pollutants

Little is known about the health impacts of pollutant mixtures, be their impact synergistic or antagonistic.

Interaction of air pollution with other environmental variables

Synergistic interaction of heat and air pollution with respect to mortality and morbidity can occur. Synergistic interaction of noise and air pollution with respect to cardiovascular diseasesshould be investigated. Interaction of biological agents with air pollutants with respect to allergies is a field where little is known.

Dose-response relationships for biological agents

Guidelines are missing for biological agents in parallel to chemical air pollutants. The question is whether exposre-response relationship can be established.

Special compounds

Additional research is needed to clarify the toxicological mechanism by which fine and ultrafine particulate matter leads to adverse health effects (WHO 1999c). With respect to this compound the objective should be to develop a harmonised holistic approach to particle characterisation for the purpose of exposure and exposure-response assessments. At present, there is however, not enough information available on the exposure-response relationship for fine and ultra fine particulate matter, to consider appropriate guidelines that would protect the whole population or at least the most susceptible groups. The reasons for the current difficulties relate to the scientific complexity of exposure assessment to fine particulate matter at all levels of approaches, including: instrumentation, measurement and modelling, model validation and data interpretation. Some of the questions and problems related to exposure assessment to airborne particulate include:

- What is more important (what to measure), particle number, or mass, or both?
- How to compare readings from different instruments used in different exposure or exposure-response studies?
- What other particle characteristics (physical, chemical or biological) should be measured in addition to particle number or mass concentrations?
- Lack of correlation between different particle monitoring and measurement approaches and resulting lack of consistency and often scientific rigour in particle epidemiological studies is a problem.
- Experimental difficulties exist in validation of lung deposition models and resulting problems with dose assessment.

Developing countries

Epidemiological investigations in countries where the health effects of air pollutants have not been extensively studied previously are of particular importance. This information would be of value in characterizing the mortality and morbidity due to ambient (and indoor) air pollution in these countries.

Indoor air pollution

Monitoring and assessment of exposure should be intensified in order to be able to reliably and in a representative way assess how it affects public health in developing countries.

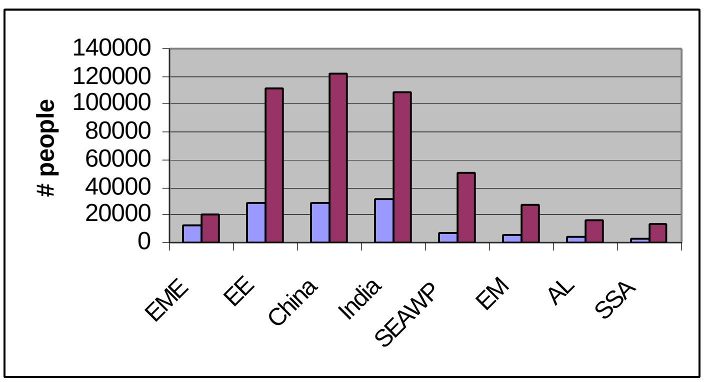


Figure 4. Upper and lower estimate for premature mortality due to suspended particulate matter in eight economic regions.

EME	Established Market Economies
EE	Eastern Europe
SEAWP	South East Asia/Western Pacific region
EM	Eastern Mediterranean
AL	Latin America
SSA	Sub-Saharan Africa

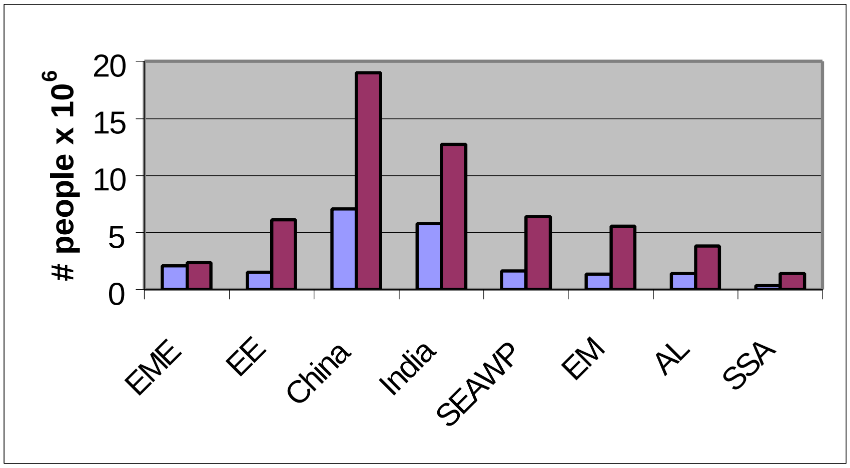


Figure 5. Upper and lower estimate for respiratory morbiditydue to suspended particulate matter in eight economic regions.

EME	Established Market Economies
EE	Eastern Europe
SEAWP	South East Asia/Western Pacific region
EM	Eastern Mediterranean
AL	Latin America
SSA	Sub-Saharan Africa

6. COUNTRY REPORTS

Workshop participants presented National reports.

6.1 China (presented by Tang Xu)

As a developing country China has paid great attention to the environmental protection and air quality improvement while focusing on the economy reconstruction. There is growing recognition that the management of the urban environment requires special attentions, and China has strengthened the research and treatment of the urban environmental pollution. He summarized some relevant research and operational works in China Meteorology Administration (CMA) and related institutes:

Part 1. The major research and operational works on urban environment and meteorology of CMA

1. Researching and Operational works on-going or completed:

- An air pollution prediction is under development. In the period from the end of the 70's to the early 80's, the Chinese Academy of Meteorological Sciences (CAMS) and other operational institutions in CMA started to conduct atmospheric environment assessment on the basis of atmospheric pollution research. Using statistical methods and an atmospheric dispersion model to assess air quality, CAMS developed a non-stable multi-box air pollutant concentration and potential weather condition prediction model in 1977 called City Air Pollution Prediction System (CAPPS). This model was used in the "Beijing-Tianjin-Hebei meso-scale meteorological experiment" as a pre-operational run. It was then ported from the mainframe computer of the National Meteorological Center to the microcomputers or workstations in Nanchang, Hebei, and Shanghai meteorological bureaus, and used to operationally forecast the air pollution index and weather potential.
- The technical criteria to formulate the local atmospheric pollutant emission standards were compiled in 1979, in which the wind direction, pollution coefficients and

atmospheric stability were identified nationwide. A simple method for total pollutant control and P-value method for point-source emission control were put into operation. The standards were promulgated and implemented formally by the authorities in 1984, and revised in 1991.

- An air pollutant source-retrieval model has been developed, and successfully applied to the atmospheric baseline monitoring station in determining atmospheric environmental capacity in the protected areas surrounding the station.
- A human comfort index has been developed, and a clothing-wearing index forecasting model is being used as an operational or quasi-operational tool in meteorological services in Beijing, Shanghai and Jiangxi province.
- In some provincial and municipal meteorological bureaus and meteorological colleges, studies on urban climate, urban environment, and the link of weather to health were conducted. A series of brochures, called "City Climate" have been published. City Climate for Beijing, Shanghai, Tianjin, Guangzhou, and NanjingIn are available in Chinese. In some cities, research on the relation of weather conditions and disease was carried out. The prediction of some type of weather conditions that may result in the occurrence or spreading of some diseases were conducted by the meteorological services; and the health-meteorological warning system and life index research were set up. In Shanghai especially, they have partly expanded the operational/quasi-operational air pollution forecasting services through computer network.
- In some big cities like Beijing, Shanghai etc, the meteorological bureau has established services in fog forecasting, pollution potential prediction, ultra-violet intensity monitoring and forecasting, comfort index reporting, and visibility and pollen pollution forecasting through television, newspaper and computer network. China EPA has issued urban pollution level index daily and weekly reports in all the big cities of China. Shanghai Meteorological Bureau (SMB) and Shanghai Health Bureau (SHB) have started to develop an early warning system on heat waves and health under the advisory of Delaware University, U.S. and this project will be a showcase project of CLIPS.

2. Related research programs

The main features of the research approaches in environmental meteorology are from the regional scale down to city complex area and typical urban areas. Major programs in CMA include:

- “Regional air quality model research”. This program developed a regional meteorological-chemical 3 dimensional model, which considers the transport, dispersion, chemical reactions, dry and wet deposition processes. It was successfully applied into urban heat-island effects, sea-land breeze, and sand dust transport researches. (1989-1994)
- “The measurement and research on atmospheric trace gases and other chemical substances over the continent and the western pacific regions of China”: This program obtained a large amount of CO_2, surface O_3, NO, NO_2, SO_2, and solar radiation data. It also discussed the continental scale variations of the species and the negative feedback effects of sulfate aerosol and sand dust on regional climate using a regional air quality model to investigate the conversions of sulfur dioxide to sulfate in the troposphere of China. (1991-1995)
- “Ozone variations and their effects on the climate and environments in China”. This national key research project sponsored by NFS of China, was the first comprehensive atmospheric ozone-related research in China. A one-year continuous in situ observation was conducted at three regional and global atmospheric monitoring stations (i.e. Lin’an, Longfengshan regional background stations, and Waliguan baseline station). The species included Ozone (surface ozone and ozone sonde), NO, NO_2, SO_2, CO, aerosol, solar radiation and meteorological elements. The results of this project expanded the knowledge about the background concentration distributions and variations of Ozone and other species, and built up the China ozone database. Furthermore, a high resolution meso-scale meteorological model and chemical model to investigate the transport and transformations of ozone, SO_2, NOx, and CO was developed. (1994-1998)

- "Acid depositions and their ecological effects study in China". A national key project for 8th five-year plan, showed the temporal and spatial distributions of acid rain in China, elucidated the distributions and variations of chemical compositions in precipitation, and calculated the deposition flux of some major ions in the rain. It also provided the basic temporal and spatial distribution features of ambient SO_2 and NOx. (1992-1995)
- "The interaction between atmospheric physical and chemical process in the lower atmosphere and the ecological system in Yangtze delta region". A national key research project sponsored by NFS of China, monitored the concentrations of surface ozone, SO_2, NOx, CO, PM2.5, and the vertical flux of N_2O, VOC, CO, H_2O from paddy field during the crops growing period. The impacts of atmospheric pollutants including the damaging of vegetation and reducing agricultural yields were studied in the Yangtze delta region. The purpose of this project is to assess that with the development and rapid urbanization of the region, how the air pollution affects the agricultural eco-system. Furthermore provide the necessary database for developing a nested fine grid regional meteorological-chemical model, which may be suitable for urban scale environmental simulation or pollution prediction.

  Based upon the experimental Metro-Agro-Plex, the main tasks in the project are to exploit the abnormal changes on MAP climate and environment and its impact on socio-economy, to understand the low level processes on physics and chemistry, to conduct an integrated experiment on the transportation and transition of water, energy and trace gases in the air-ecosystem over the MAP region, in order to develop a dynamic air-ecosystem model. The project is a cooperation project with Georgia Tech. Univ., sponsored by NASA/U.S.A. The cooperation project is called "China-MAP" which was developed by both sides in 1996, to study the city's complex environment meteorology and its interaction with the ecosystem in the region.
- Fine mesoscale model developing in a national key research project sponsored by MOST. (1998-2002)

3. Activities on urban environment in CMA and related units:

- A series of seminars on "extending special meteorological service in the big cities" have been organized to implement the air pollution potential prediction, urban meteorological element forecasting and their information distribution service network.
- A show case project for big cities' meteorological services and the related research on the key technical issues has been implemented since 1997, in which 6 big cities in China are included.

Part 2. The Pollution Monitoring Network.

There are 1800 municipal and county level monitoring stations subordinated to China EPA for urban air pollution monitoring. Among them 103 stations (belonging to national environmental monitoring network) compose the atmospheric monitoring network (only 80 cities report the data regularly), 109 stations form the acid rain observation network and 31 stations are engaged in the radio-activity monitoring. There are 22 cities equipped with automatic instruments, about 36 stations use non-automatic sampling methods to make continuous observations, and the rest of the stations take samples instantaneously (sampling five days each quarter, and data have less temporal and spatial resolution).

In addition, CMA is in charge of another China acid rain monitoring network that consists of 86 municipal and county level meteorological stations. Unlike the network of China EPA (that mainly focuses on the urban area) most of these stations are located at rural areas of China. All data are well organized and managed by using China acid-rain database. CMA also takes charge of 3 ozone stations (Kunming, Xianghe and Qingdao), 3 regional background monitoring stations (at Shangdianzi of Beijing, Lin'an of Zhejiang province, and Longfengshan of Heilongjiang province respectively), one global baseline station (at Mt. Waliguan, Qinghai province, acting as GAW continental baseline station), and 3 urban boundary layer observation stations (at Tianjin, Nanjing and Guangzhou respectively). In order to strengthen the observations in some specific locations, CMA and

China EPA also constructed several automatic air quality monitoring networks, automatic meteorological stations and other meteorological elements observation networks in big cities, such as in Beijing and Shanghai. There are 20 automatic meteorological and 12 air quality auto-monitoring stations in Beijing, and 30 automatic meteorological stations in Shanghai, over 100 automatic meteorological stations around Zhujiang delta region. There are 4 wind profile observation instruments (2 sets in Beijing, 1 in Shanghai, and 1 in Zhujiang delta region), lidar, Doppler wind radar, sonic anemometers, ozone sonde, sounding balloon, water vapor, CO_2 flux-measurement instruments in these cities. In addition, there is a 324m boundary layer meteorological tower in Beijing, and another one in Zhujiang delta region.

1. The observational elements

The required substances monitored by China EPA comprehensive stations include 61 species for atmosphere, 12 species for precipitation, 71 species for water and waste water, 12 species for soil, and several other items. The atmospheric monitoring include:

- carbon monoxide(CO), carbon dioxide (CO_2), NO_2, ammonia (NH_3), cyanide, photo-oxidants, ozone (O_3), fluoride, sulfur dioxide (SO_2), sulfate, chlorine (Cl), mercury (Hg), hydrocarbon (HCs) and non-methane hydrocarbon (NMHCs), aromatic, total suspended particles (TSP), PM10, and particulate deposition etc.

Precipitation measurements include:

- Electric conductivity, pH value, sulfate radical, nitrite radical, nitrate radical, chloride, fluoride, potassium, sodium, calcium, and magnesium etc.

The species monitored at the atmospheric baseline observatory of Waliguan include: (some of the following species are planned to be measured in 3 regional monitoring stations)

- Trace gases: carbon oxide, carbon dioxide, methane, column ozone and ozone profile, surface ozone, sulfur dioxide, nitric acid (gas phase).
- Aerosol: black carbon, aerosol chemistry, and optical depth.
- Radiation: total radiation, direct radiation, scatter radiation, and UV-B.
- Precipitation chemistry: pH value, electric conductivity, and ion concentrations.
- Meteorological and boundary layer meteorological observations: surface temperature, moisture, pressure, wind, precipitation, and 2.3m, 10m, 20m, 30m, 80m wind, temperature, and moisture gradient observations.

2. History and real time meteorological databases include:

- Air quality data (include 15-20 years air quality monitoring data and pollutant emission data).
- China atmospheric ozone and its precursor database (CAOD).
- China acid rain database.
- Yangtze delta region lowers atmosphere database.
- Beijing urban meteorological database
- Shanghai urban meteorological database

Part 3. The Future Plans.

1. Strengthen the environmental monitoring network:

- China EPA plans to strengthen 103 stations' urban air quality monitoring network, consolidate the 20 automatic urban atmospheric monitoring stations, and set up work on air quality operational forecasting.
- Reconstruct and improve urban air pollutant emissions monitoring network, obtain accurate, and comprehensive fixed and mobile emission information so as to better characterize and control the source emissions.
- Strengthen and improve the current acid rain monitoring network. Join China EPA's national acid rain network (mostly concentrated in urban area) with CAM's acid rain network (mainly in rural areas, and plan to expand to 120-150 stations). Enhance the infrastructure for monitoring acid rain issues at scales from regional to urban. Compose

an effective and well distributed acid rain network that cover the background monitoring, urban acid monitoring and acid deposition measurements.

- CMA plans to strengthen the 3 regional background monitoring stations and Global continental baseline station, and construct a new regional background monitoring station in the south west part of China. CMA also plans to increase the monitoring species and enhance the capability in sampling and analysis. Enhance the capability in air quality automatic monitoring, and expand the international cooperation in local, urban and regional environmental monitoring and data analysis.
- Construct comprehensive boundary layer observational stations focusing on the research of urban boundary layer meteorology. Accomplish the second stage of boundary layer stations reconstruction and use these to directly serve the research on urban environmental meteorology.

2. Environmental Research Activities.

- Pre-research project "Study on the mechanism and regulation principle of air, water and soil pollution in Beijing and the suburb areas", sponsored by China NFS: proposed by CMA and state resource department. On the basis of monitoring data on air, water and soil in Beijing area, this project focuses on the pollution mechanism and regulation principle study, working on the process of pollution formations, evolution and pollutant transport and transformation among and within air, water and soil. It contains theoretical prediction model and effective pollution control stratagem.
- Strengthen the air quality modeling capabilities by building a comprehensive urban environmental programming and pollution control system.
- "Weather condition prediction for urban air pollution". Key project supported by CMA: using history meteorological data and urban terrain and topographic data to study the distribution features of environmental and meteorological elements in urban areas. With statistical and dynamical methods, develop an air self-cleaning index prediction and air pollution forecasting system.
- Strengthen control techniques. Concentrate on the techniques and methods of site selection, sampling, sample carrying and preserving, sample analysis, data quality assurance and quality control (QA/QC) and data interpretation. Study the continuous automatic sampling and analyzing instrumentation for some major air pollutants (such as soot, industrial particles, and sulfur dioxide etc), and sampling instruments and sampling methods for fine particles such as PM2.5 and PM10.
- Urban air quality prediction technique study: include pollution prediction models, air quality assessment criterion standardization and pollution forecasting management systems.
- Study on emergency responses include emergency monitoring techniques and communication techniques. Emergency events such as nuclear release, forest fire, chemical matter leak, water pollution, pesticide poisoning, endangering materials explosion etc.

3. Main characteristics of the Future Plan.

- To design a conceptual system on how to monitor the urban environmental meteorology, which is linked with GAW stations in China. To establish a monitoring network on urban environmental meteorology for specific cities like Beijing, Shanghai etc, by conducting experiments on urban environmental meteorology.
- To improve mesoscale models to support potential air pollution forecast and comfort forecasts.
- To develop an interacted information system on urban Environmental Meteorology which is conceptually similar to and an extended component of the Interacted Weather Analysis & Forecast Information System.

6.2 Philippines (presented by Aida Jose)

Metro Manila is one of Asia's megacities, and is facing the range of environmental problems and issues similar to those being experienced in other megacities. Among the environmental problems, air pollution is the most pressing considering its severity and adverse effects on public health citywide and significant impacts on socio-economic conditions.

This report presents information on air quality monitoring in Metro Manila primarily conducted by the Environmental Management Bureau (EMB) under the Department of Environment and Natural Resources (DENR). This includes a brief description of the existing network of monitoring stations and initial results of the observed concentration of various pollutants consisting of Total Suspended Particulate (TSP), particulate matter of 10 microns or less (PM_{10}), sulfur dioxide (SO_2), Lead (Pb), carbon monoxide (CO), nitrous oxide (NO_x) and Ozone (O_3). The report also provide information on the existing meteorological observing station network not originally meant for air pollution research and monitoring but could augment meteorological data availability should an appropriate network for monitoring and predicting air pollution in the metropolis be carried out.

Metro Manila is situated on a plain on the southwestern coast of Luzon Island, around the mouth of Pasig River in the Manila Bay. With a land area of about 636 km^2 and a population of 9.6 million (1996) and present growth rate of 2.35% per year, Metro Manila is the largest, most densely populated and most economically advanced urban center in the Philippines. Being the major economic, political and commercial center, this area is heavily polluted compared to the other parts of the country.

Emissions from motor vehicles account for 70% of Metro Manila's air pollution, as the capital region's 3.2 million registered vehicles spew out high concentrations of dangerous fumes containing lead, sulfur and TSP. Industries and fossil fuel operated power stations and generators account for the other 30%.

At present the existing air quality monitoring network in Metro Manila is composed of eleven (11) fixed monitoring stations located in strategic areas where both ambient air pollution are expected to be high. The sites are variously exposed to road and industrial emissions. Out of the eleven (11) station network, eight (8) stations monitor only TSP and SO_2, while the remaining three (3) are automatic stations monitor pollutants such as SO_2, O_3, CO, and NO_x. Available records show the following significant information for each pollutant concentration (see Tables 2, 3, 4, 5 and Figures 6, 7, 8, 9, 10).

TSP is a major pollution problem in most of Metro Manila. It is especially acute near streets and industrial areas, and during the dry season. The Philippines has adopted the upper limit value of the World Health Organization (WHO) Air Quality Guidelines (AQG) as their National AQG. The WHO guideline is 60-90 μg/Ncm for long term (annual) average, and 150-230 μg/Ncm for short term (24 hour) average. Figure 6 provides the annual averages measured during 1993-1998. Annual TSP averages at these stations are 2 to 3 times the guideline. The highest annual average concentrations and the highest annual average maximum (Figure 7) were recorded at the Valenzuela station. This station is situated in industrial areas dominated by lumberyards and light steel industries. High concentrations have also been measured in Manila (Ermita, station), EDSA-DPWH and Makati. EDSA-DPWH has the highest 24-hour concentration of about 460 µg/Ncm measured for the period January-June 1999 (Figure 8) since this area is mostly exposed to heavy traffic. The generally increasing trend of TSP could probably be partly attributed to the growing number of diesel-fueled vehicles and industries.

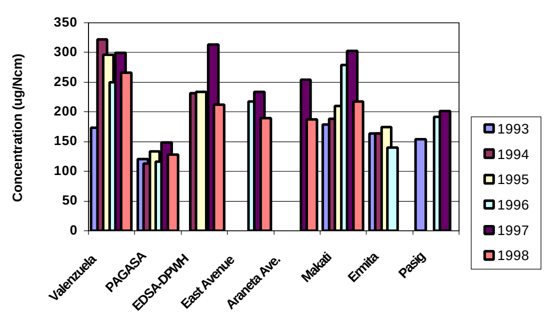
PM_{10} particles are small and they are more likely to penetrate the lungs and cause respiratory illness. Health impacts caused by air pollution are correlated more to the presence of PM_{10} than TSP. The national AQG for PM_{10} are 60 $\mu g/m^3$ for long term (annual) average, and 150 ug/m^3 for the short term average. The WHO AQG for PM_{10} is 70 $\mu g/m^3$ for the short term average. Results from the Asian Development Bank's supported project specific for PM_{10} show that the maximum 24-hour averages were more than four times the WHO AQG. This is a most pressing air pollution problem in Metro Manila.

Sulfur Dioxide (SO_2) measurements from 1987-1993 as shown in Figure 9 indicates that long term average concentration is less than half of the AQG, but maximum 24-hour values occasionally exceed the AQG. Maximum 24-hour average values up to 0.114 ppm was recorded in Pasig. The high value maybe attributed to the presence of industries which use bunker fuel.

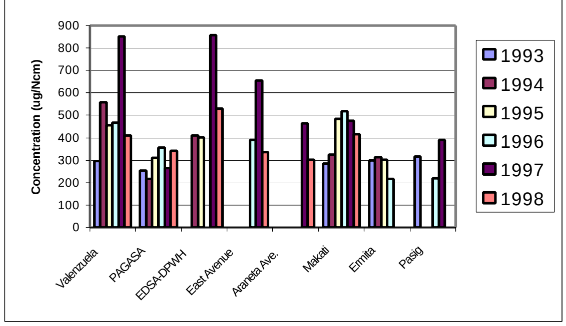
Lead emissions in Metro Manila exceed the national AQG (1.0 µg/m^3) at the start of 1993, but it dropped down to concentrations of 0.3-0.5 µg/m^3 by December 1994 (Table 4). This has resulted from the use of unleaded gasoline after February 1994.

CO, O_3, NO_x, Hydrocarbons and other compounds are not routinely measured and their concentrations remain largely unknown. Data available from automatic stations like O_3, CO, NO, and NO_2 are still in its infancy stage and measurements taken from these stations needs further validation from Japan's Environment Agency.

Figure 6.1. Yearly Averages of Total Suspended Particulate Matter Levels in Metro Manila



6.2 Maximum Yearly Averages Total Suspended Particulate Matter Levels in Metro Manila



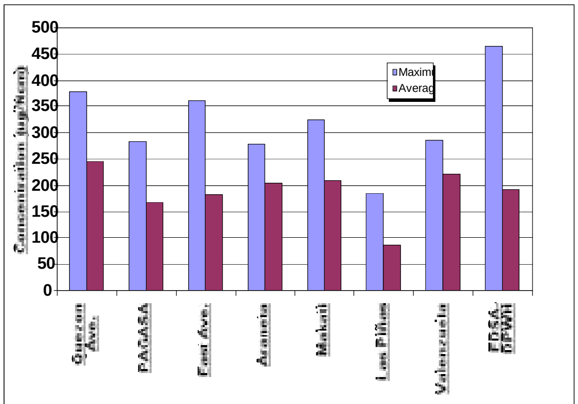


Figure 8. Maximum and Average Total Suspended (µg/Ncm) January-June 1999

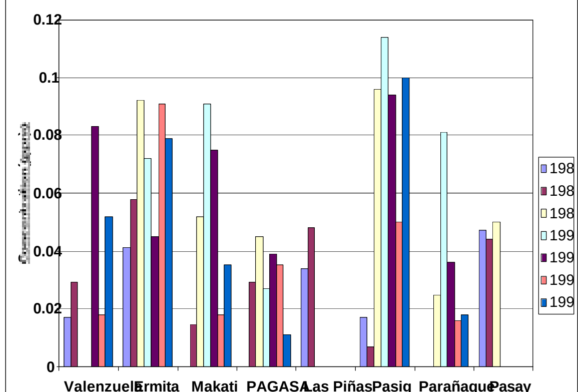


Figure 9. Yearly Average Maximum Conce (1987-1

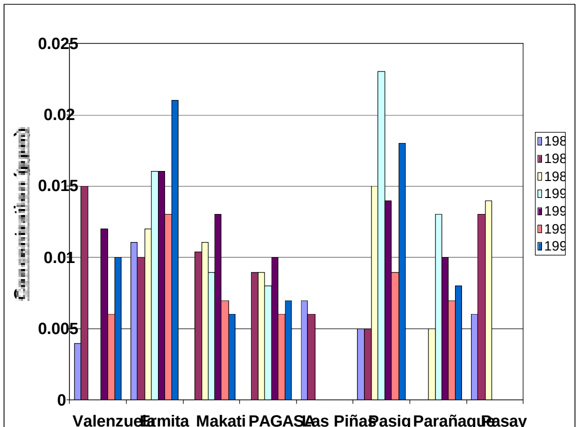


Figure 10. Yearly Average Concentration of SO_2 at Various (1987-1993)

Table 2. A Tabulated Summary of Air Quality Concentration from 8 Fixed Sampling Stations in Metro Manila

Pollutants	**Years of Record**	**Annual Average**	**Maximum Average**	**WHO/ AQG**		**DENR/ AQG**	
				Short Term	Long Term	Short Term	Long Term
TSP (µg/Ncm)	1993 – present	206	399	150-230	60-90	230	-
PM_{10} (µg/m^3)	1993 – 1994	193	269	70	-	150	-
SO_2 (ppm)	1987 – 1993 discontinue	.010	.05	.05	.02	.07	.03
Lead (µg/m^3)	1993 - 1994	.365	-	-	0.5-1.0	1.5	-

Table3. PM_{10} concentrations (µg/m^3) measured at various stations

Station	**Concentration**		Period	**No. of Observation**
	Average	**Maximum 24-hr**		
Ermita	144	258	Aug – Feb	62
ADB-EDSA	219	321	Aug – Feb	47
DENR-NCR	227	321	Oct – Feb	26
Makati	179	206	Jan – Feb	10
Monumento	198	241	Feb. '92	5

Table 4. Ambient Lead Concentration (µg/m^3), (1993 – 1994 record)

Yr/Mon	**Ermita**	Las Piñas	**Makati**	**Pasig**	**Quezon City**	**Valenzuela**
1993						
JAN		0.4				0.7
FEB	1.28			0.45		0.48
MAR	1.06		1.18	0.45		
AUG	0.58		0.27	0.28	0.28	0.23
SEP	0.26		0.27	0.31	0.23	0.48
OCT	0.33		0.59	0.38	0.37	
NOV	0.56		0.49		0.33	0.49
DEC	0.57				0.28	0.66
1994						
JAN	0.33	0.23	0.37	0.63	0.26	0.45
FEB	0.4	0.24	0.29		0.29	0.87
MAR	0.42	0.17	0.39		0.42	0.85
APR	0.21	0.14	0.29		0.18	
MAY	0.2	0.16	0.25		0.17	
JUN	0.29		0.35		0.17	
JUL	0.24		0.24		0.19	

Table 5. National Ambient Air Quality Guidelines for Criteria Pollutants

Pollutant	μg/m³	ppm	Averaging Time	μg/m³	ppm	Averaging Time
Suspended Particulate Matter TSP PM_{10}	 230(f) 150(g)					
Sulfur Dioxide (e)	180	.07	24 hours	80	.03	1 year
Nitrogen Dioxide	150	.08	24 hours	-		-
Photochemical Oxidants As Ozone	140 60	.07 .03	1 hour 8 hours	-		-
Carbon Monoxide	35 mg/m³ 10 mg/m³	30 9	1 hour 8 hours			
Lead(d)	1.5	-	3 months (d)	1.0	-	1 year

Notes:

a. Maximum limits represented by ninety eight percentile (98%) values not to be exceeded more than once a year
b. Arithmetic mean
c. Geometric mean
d. Evaluation of this guideline is carried out for 24 hour averaging time and over three moving calendar months
e. SO2 and Suspended Particulates are sampled once every six days when using manual methods. A minimum number of twelve sampling days per quarter or forty eight days each year is required for these methods. Daily sampling may b e done in the future once continuous analyzers are available.
f. Limits for Total Suspended Particulates with mass median diameter less than 25-50 μm
g. Provisional limits for Suspended Particulate with mass median diameter less than microns until sufficient monitoring data are gathered to establish proper guideline.

The applicable methods for sampling and measurement of the pollutants listed as follows:

Pollutants	Methods
Sulfur Dioxide	Gas Bubbler and Pararosaniline Method Methods or Flame Photometric Detector
Nitrogen Dioxide	Gas Bubbler Griess-Saltzman or Chemiluminescence Methods
Ozone	Neutral Buffer Potassium Iodide (NBK), or Chemiluminiscence Method
Total Suspended Particulates (PM_{10})	High volume with 10 microns particle-size inlet Gravimetric
Carbon Monoxide	Non-Dispersive Infra-red Spectrophotometry (NDIR)
Lead	High volume and atomic absorption Spectrophotometry (NDIR)

The state of air pollution and its dispersion can be influenced by the meteorological conditions over a surrounding area. Prediction of air pollution can be done using atmospheric models with meteorological and environmental parameters as inputs. For Metro Manila and adjoining environs, the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) existing network of the meteorological observing stations can be used for assessing potential air pollution dispersion in the area. A number of rainfall stations also exist in the vicinity.

Presently, Metro Manila does not have an operational system of air pollution prediction using meteorological conditions as inputs. Although existing air pollution models can be applied for assessing present environmental condition, the use is not yet fully explored. Dispersion modeling is limited to special and planned projects that are environmentally critical or located in an environmental critical area. Projects falling under this category must secure an environmental compliance certificate before undertaking actual construction and a complete Environmental Impact Assessment (EIA) be submitted. As part of the EIA, a full description of the project's effect on local air pollution must be made. More popular air population models used include the multisource Gaussian model and a number of software packages (CALINE, KILDER system) on dispersion modeling. Meteorological input to the models is represented by a joint wind speed, direction/stability matrix representing the annual frequency distribution of these parameters.

At present, air quality management in Metro Manila is constrained by limited institutional capacity of all concerned government agencies, which is attributable to inadequacies in financial and human resources, equipment and facilities. These inadequacies result in the lack of reliable and up-to-date data on emission sources and air quality, weak enforcement as a consequence of changes in various socioeconomic factors. There is no established institutional matrix between the PAGASA and the EMB on related activities which resulted to gaps between meteorological and air pollution observing systems.

The air pollution monitoring system operated by the EMB has the following shortcomings:

- 24-hour samples of TSP and SO_2, are collected infrequently (2-4 days per month)
- Pm_{10}, lead, CO, ozone, and other compounds are not measured routinely
- Many measurement sites do not clearly represent typical areas such as city background stations (commercial, industrial, residential); traffic exposed (street side) stations; or industrial hot spot stations.
- Non existence of adequate meteorological observing stations designed for air pollution monitoring and research.

With the existing planned Metro Manila Air Quality Improvement Sector Development Program, it is envisioned that it will be able to address the shortcomings and data gaps in the monitoring system of the air quality management.

The objective of the program is to promote policy reforms to improve air quality through the abatement of mobile and stationary sources of air pollution. It focuses on the Metro Manila airshed, the location of the main concentrations of air pollution. The scope consists of policy reforms and investment requirements integrated within an agreed policy matrix termed the Air Quality Action Plan.

The GAW Urban Environmental Monitoring and Meteorological Research Project (GURME) will play an important role on the identified air emission issues under the Air Quality Action Plan regarding the strengthening of ambient air quality monitoring, dispersion modeling/forecasting and capability building of the institutions involved. This will entail among others harmonization of observation program and network design for both air pollution emissions and related meteorological parameters.

6.3 Malaysia (presented by Leong Chow Peng)

Malaysia's dynamic population growth in the past decade has resulted in a total population of 22.7 million. According to the latest population census, 50.7% of this population reside in urban centres and it is estimated that by the year 2020, two-thirds of the population will live in urban areas. Currently more than half of the urban population reside in the states of Johore, Perak, Selangor and Kuala Lumpur in Peninsular Malaysia. There is a general tendency towards concentration in the large metropolitan centres, with internal migration becoming more intensified and concentrated in the highly populated Klang Valley.

One of the most obvious effects in the last three decades of industrialization and urbanization is a significant deterioration in air quality as a result of pollution from motor vehicles and industrial emissions. Recent studies indicate that the air quality in Malaysian cities is becoming increasing unhealthy for living. Children, the elderly and disabled are especially vulnerable.

In recent years, a new source of regional air pollution caused by land and forest fires burning out of control are enveloping Southeast Asian countries. It has been found that these regional haze occurrences are closely correlated with short-term climate oscillations such as El Nino-Southern Oscillation (ENSO) events which regularly create drought conditions that are conducive for outbreaks of forest fires.

Monitoring of urban air quality and trends

Anthropogenic emissions, particularly the sulphur and nitrogen species, are projected to increase dramatically into the next century as countries in Southeast Asia continue to rely on fossil fuels as the primary source of energy. In 1992, emissions of nitrogen oxides and sulphur dioxide in the Klang Valley were reported to be 54 tonnes and 36 tonnes respectively with 67% of nitrogen oxide emissions attributed to mobile sources and 86% of sulphur dioxide emissions attributed to industries. Even under normal conditions, the atmosphere of the Klang Valley and many other Malaysian cities contains a potent mix of hydrocarbons, nitrogen oxides and other pollutants, which under warm and sunny conditions could react photochemically to produce acidic aerosols.

Among the issues of concern on urban air quality are the following :

- Declining visibilities
- High concentrations of fine particulates and effects on human health
- Atmospheric acidification and the impacts of acidic deposition on the ecosystem
- Increased levels of tropospheric ozone

Most of the occurrences of dense haze episodes (September 1982, October 1991, August-October 1994 and July - October 1997) in Malaysia in recent years were transboundary in nature. The 1997 episode involved the burning of huge tracts of forest in southern Sumatra and Kalimantan which went on uncontrollably for several months leading to the most prolonged and pervasive haze event ever encountered in Southeast Asia. Satellite aerosol maps indicate that the atmosphere over the Klang Valley was strongly influenced by long-range transported aerosols from the intense fires in Sumatra while plumes from fires in Kalimantan were affecting eastern Malaysia particularly the town of Kuching. Associated with the elevated particulate concentrations, low visibilities were observed throughout the country. It was found that these particles have a high content of ammonium sulphate and other soluble ions. In humid air, they rapidly absorb water and grow to sizes where the particles will scatter light, thereby reducing visibility. Most of these particles have diameter less than 2.5 microns and because of their ability to penetrate deep into the human lung, there is much concern regarding the impacts on human health.

Elevated ozone is in general a growing problem in urban centres of Southeast Asia although current levels have may not have reached those encountered in cities in Europe and North America. However, during incidences of forest fires in Kalimantan and Sumatra, elevated ozone concentrations have been detected downwind of the fires.

The role of meteorology is evident in the strong diurnal variation for almost all the major air pollutants measured. A minima in the afternoon is likely due to dilution of the local ground emissions caused by solar heating of the surface and subsequent deep convection in the atmosphere.

Preliminary results from long-term monitoring of rainwater pH by the Malaysian Meteorological Service indicated a trend of increasing rainwater acidity particularly in the western and southern parts of Peninsular Malaysia where most of the major urban centres are located. This has motivated the department to initiate a more comprehensive study at selected locations and be involved in other regional projects on atmospheric acidification and its impacts on the ecosystem.

Collaborative Studies

Several studies which were undertaken in collaboration with international agencies/countries have yielded valuable information contributing to a better understanding on the tropical urban environment. These studies include :

- Malaysia-DANCED project on "The origin, formation and composition of aerosol haze in Malaysia" (1996 - 1997)
- Malaysia-CSIRO project on "Atmospheric Acidity and Acid Deposition at Petaling Jaya" (1993 -)
- Malaysia-Australia "Malaysian Haze Study" (1999 - 2001)

The study on acid deposition at Petaling Jaya, in particular, indicated that anthropogenic sulphur and nitrogen are both important sources of acidic species in Malaysia and the magnitude of total sulphur and nitrogen deposition flux estimated at this site is of the order of 200 - 400 meq m^{-2} y^{-1} . This is firmly in the range that in Europe and North America has resulted in adverse environmental effects upon soils and surface waters. Dry deposition is also established to be of equal importance as wet deposition.

The DANCED study provided strong evidence that the high pollution load detected in the Klang Valley during these haze episodes was not caused by a build-up of local pollution but was due to the high concentration of fine particulates transported by prevailing winds from sources of biomass burning in the vicinity and injected into the atmosphere from aloft. The investigation also revealed extremely high levels of oxalic, formic and acetic acids during the haze, the highest ever reported in ambient air.

The Malaysian Haze Study, while still in progress, further confirms some of the results of the earlier studies, in particular the important role of meteorology in haze build-up.

Future Activities

Recent developments in the country has highlighted the need for a meteorological model to forecast regional meteorology and to characterise and quantify the atmospheric transfer of air pollutants. This will facilitate informed policy-making and pave the way for formulation of effective pollution reduction strategies in the future. The Swedish Meteorological and Hydrological Institute has offered to provide and install the Mesoscale Atmospheric Transport Chemistry Model (MATCH) at the Malaysian Meteorological Service as well as provide training on the operation of the model. This activity is expected to take place in early 2000.

At the same time, efforts have been initiated to expand and upgrade the meteorological and air quality measurement programme of the department in order to support national requirements and meet future challenges. Plans for the immediate future are focused on capacity building to strengthen the knowledge base and acquisition of relevant model products to enable more accurate seasonal climate predictions as well as transport dispersion models for smoke haze. In this regard, the Malaysian Meteorological Service has adopted an integrated approach through links with other international programmes such as :

- WMO-Programme to Address ASEAN Regional Transboundary Smoke (PARTS)
- RAINS-ASIA
- WMO Air Quality Measurement Program using Passive Samplers
- East Asian Acid Deposition Monitoring Network (EANET)
- IGAC-DEBITS Composition of Asian Deposition (CAD) Programme
- NOAA Project on Capacity Building in Seasonal Climate Prediction for
- ASEAN : Regional Modelling, Application Studies and Training

Conclusion

Due to the large concentration of population in urban centres, Malaysia has placed great importance on efforts to safeguard the urban environment and ensuring sustainable development in our towns and cities. Efforts by WMO and the international community to assist developing countries in Southeast Asia to advise, alert and generally manage urban meteorological and environmental issues should be directed at improving the infrastructure and enhancing the capability and capacity for monitoring and modelling environmental disasters including long-range transport of anthropogenic pollutants. In this respect, Malaysia looks forward to the prompt implementation of the various regional programmes which are already in the pipeline.

6.4 Indonesia (presented by Hery Harjanto)

In supporting the WMO-BAPMoN Program, Indonesian Meteorological and Geophysical Agency (BMG) has been monitoring Total Suspended particles (TSP) since 1976. There were seven monitoring stations established in Jakarta, namely BMG Headquarters, Ancol, Monas, Halim, Bandengan, Glodok, and Cileduk. Starting in 1980, several other parameters have also been sampled at BMG site. These parameters are SO_2, NO_x, surface ozone, and chemical composition of rainwater.

Beside BMG, there have been two other institutions which also carry out air quality monitoring in Jakarta. These national institutions are the Jakarta Municipality office (DKI) which operates 12 monitoring stations, and the Research and Development Center of the Ministry of Health which has 2 sampling sites in Jakarta. The three agencies mainly observe TSP, SO_2, and NO_x parameters, while DKI also measures carbon monoxide at several stations.

The Outlook of Metropolitan Jakarta

Jakarta is the capital city of Indonesia, and the district of Jakarta is also called the DKI-Jakarta province. Being the capital of a developing country, Metropolitan Jakarta becomes the center of activities such as administration offices, trades and business center, industries, and residential area.

The city is situated in the northern coast of Java at 6°S latitude and 106° E longitude. It covers an area of approximately 590 km^2, or about 0.03% of the total area of Indonesia. The area is very flat, with the mean elevation of 7 m above sea level. The total population of Jakarta was estimated as much as 9.4 million in 1998, which was about 4.64% of the Indonesian population. The annual rate of its population growth was 1.23%, while the population density is about 16.1 thousand people per square km.

Due to its location, which is close to the equator and surrounded by water, Jakarta has a warm and humid climate. The day-time solar heating and night-time earth cooling may result in the local land and se breezes. The annual mean temperature of Jakarta is about 27°C, while the humidity varies from 70% to 90%. Total annual rainfall recorded in Jakarta is around 2000 mm. As the city is situated in a coastal region, the prevailing wind is greatly affected by local winds, in particular land breeze and sea breeze. In addition, the wind pattern of Jakarta is also driven by monsoon system. The local winds and monsoon will impose each other according to their directions. The prevailing wind will get stronger when they are in the same direction, and will be weakened when they are in opposite directions. The annual mean of wind speed for Jakarta ranges between 2 and 3 m/s.

Jakarta has two seasons, namely, wet or rainy season (December-March) and dry season (May-October), while the transition period is in April and November. The seasons are driven by monsoon; the northwest monsoon associated with rainy season and southeast monsoon associated with dry season.

Sources of Air Pollution in Jakarta

There are a number of air pollution sources which can be identified in Jakarta. These pollutant sources are classified into three main sources which are transportation, industry, and domestic sectors. Emission sources of the air pollutants in Jakarta are mostly from fuel combustion, in particular emission resulting from transportation and industrial sectors.

Previous study on the emission inventory of air pollution showed that the dominant pollutant sources in Jakarta was transportation. Table 6 shows the increasing number of motor vehicles in Jakarta from year to year. The annual increasing rate is estimated about 10-15%.

Table 6. Number of Motor Vehicles in Jakarta (1992-1997)

Year	Passenger Cars	Buses	Trucks	Motor Cycles	Total
1992	572,149	206,459	216,662	916,889	1,912,159
1993	617,565	226,320	228,569	991,036	2,063,490
1994	753,723	293,101	293,152	1,344,774	2,684,750
1995	849,939	310,128	320,246	1,540,825	3,021,138
1996	967,229	310,636	344,730	1,755,153	3,397,748
1997	1,095,170	311,471	380,788	2,055,332	3,842,761

Source: Central Bureau of Statistics, Jakarta, 1998

Table 7 displays the concentration level of air pollutants including dust, SO_2, NO_2, hydrocarbon, CO, and CO_2 in 1995 in comparison with the pollutants level of 1997. It is obvious from the table that for both years the emission from transportation sector was recorded far greater than the emission from industrial and/or domestic sources.

Table 7. Air Pollution Load From Mobile and constant Sources in Jakarta (Ton/Year)

1995

Parameter Sources Kind	Dust	SO_2	NO_2	HC	CO	CO_2
Transportation	48,924,272	262,325,138	65,241,827	156,516,168	3,344,774,373	68,503,918,650
Industry	116,319,284	150,921,973	150,891,973	20,780,721	98,179,940	171,189,589
Domestic	140,776	497,198	497,198	33,364	62,731	787,762,676

1997

Parameter Sources Kind	Dust	SO_2	NO_2	HC	CO	CO_2
Transportation	702,060	1,308,947	3,378,660	2,587,280	61,636,060	9,778,584
Industry	50,335	3,462	223,789	5,736	29,549	463,265,770
Domestic	2,596	65	9,961	948	2,387	29,502,778

Source: Central Bureau of Statistics, Jakarta, 1996 & 1998

It can also be seen in Table 7 that the concentration level of all listed air quality parameters were remarkably lower in 1997 than in 1995. This might result from declining business activities in 1997 due to economical crisis in Indonesia.

Sampling and Analysis Methods

The 24-hour sampling of TSP, SO_2, and NO_2 were carried out every sixth day in Jakarta. High volume air samplers (HVAS) have been operated to measure TSP loading at most of the sites in Jakarta. Midget impingers had been used to observe SO_2 and NO_x at BMG site until 1994. Starting from 1995, however, SO_2 and NO_2 were sampled at the same site using passive gas samplers. With the latter method, the air samples were collected continuously for a week on Whatman filters where special chemical reagents were applied.

For the method of analysis, gravimetric method has been used for estimating the TSP concentration of each site. In addition, NO_x samples were analyzed by Saltzman method while pararosaniline and chromatography methods were applied in determining SO_2 concentration level.

Total Suspended Particles

Table 8 presents the annual average of total suspended particles collected from 9 sampling stations in Jakarta between 1991 and 1998. Records in the table show higher concentration at Ancol, Glodok, and Bandengan sites, all of which are located in the north and west parts of Jakarta, close to the coastal area, and to the center of business and industrial activities.

Table 8. Annual Average Total Suspended Particulate (µg/m^3) in Jakarta (1991-1998)

Location Year	BMG (HQ)	Ancol	Monas	Halim	Bandengan	Glodog	Ciledug	Kayu Manis*	Pulo Gadung*
1991	182.2	261.2	205.8	156.4	458.8	648.3	276.2	159.0	270.0
1992	182.3	284.4	-	137.7	626.7	695.1	142.6	148.0	168.0
1993	237.0	-	-	111.4	472.5	531.6	170.9	176.0	200.0
1994	108.9	462.8	-	-	423.5	683.6	181.9	166.0	267.0
1995	117.8	559.3	168.9	-	466.9	716.2	124.2	166.0	209.0
1996	108.2	399.7	241.7	-	292.3	465.8	182.3	120.0	164.0
1997	206.7	389.1	-	-	161.6	506.7	205.2	-	-
1998	122.8	275.6	-	-	381.7	351.6	190.34	-	-

It can be depicted from the figure that in general, the TSP loading measured at every site has exceeded the WHO recommended level (90 µg/m^3). Thus, the impact of particles on health should be considered important. However, with an exemption of Ancol site, the mean TSP concentration of the other four sites were below the national standard (260 µg/m^3). This condition may be explained as the site is situated close to the north coast of Jakarta so that sea salt particles might give contribution to high TSP loading.

Figure 11 shows the fluctuation of TSP level measured at five sites representing different areas of Jakarta (central, east, west, and north part of the city) from 1995-1998. It is obvious in the figure that the TSP loading of two sites representing an industrial area (Pulogadung in the east) and another residential area (Kosambi in the west) are higher than of the other site areas. The highest concentrations exceeding 400 µg/m^3 occurred in September and November 1997, which might be attributed to the long drought evidence in the year. For each observation year, the trend mainly shows a notable increase of the concentration during the dry season, while the concentration tends to decrease in the wet season.

The seasonal variations of TSP for five different stations are plotted in Figure 12, where the peak concentrations for every station appeared between June and October. On the other hand, from November to February, the TSP loading for each site is likely to be low, probably due to the scavenging effect (washout) by rain.

SO_2, NO_2, and CO

Table 9 respectively displays the annual average of SO_2 and NO_2 levels in Jakarta. The samples were collected from three sites which are BMG as the office represented area, and from two other sites in east Jakarta which represent residential area (Kayumanis) and industrial area (Pulogadung).

Monthly variations of SO_2 and NO_2 shown in figures 5 and 6 where the graphs indicated that from 1995 to 1998 the concentration of both parameters were relatively low (less than 0.1 ppm). Comparing to their ambient standards of 0.1 ppm (SO_2) and 0.05 ppm (NO_2), the concentration of these two gases were still below the standard level.

Table 9. Annual Average SO_2 and NO_2 (ppm) in Jakarta (1991-1998)

Location	BMG (HQ)		Kayumanis*		Pulogadung*	
Year	SO_2	NO_2	SO_2	NO_2	SO_2	NO_2
1991	0.0020	0.0120	0.0001	0.0023	0.0001	0.0024
1992	0.0060	0.0060	0.0004	0.0050	0.0003	0.0079
1993	0.0070	0.0080	0.0003	0.0024	0.0002	0.0023
1994	0.0080	0.0240	0.0005	0.0044	0.0004	0.0031
1995	0.0030	0.0220	0.0005	0.0044	0.0009	0.0043
1996	0.0040	0.0440	-	-	-	-
1997	0.0070	0.0410	-	-	-	-
1998	0.0080	0.0350	-	-	-	-

*Ministry of Health Station

Conclusions and Recommendations

A number of air quality monitoring stations have been set up in Jakarta since 1976. The parameters observed mainly consist of Total Suspended Particles (TSP), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and carbon monoxide (CO).

Based upon the analysis results of the current study, several conclusions can be drawn as follows:

1. In general the TSP loading measured at every site in Jakarta has exceeded both the WHO standard level (90 µg/m^3) and the national standard (260 µg/m^3).
2. High concentration of TSP during the study period were recorded at Ancol, Glodok, and Bandengan sites. All of these sites are located in the north and west part of Jakarta which is close to the coastal area, or to the center of business and industrial activities.
3. Further study on the impact of dust particles on health and environment is recommended to be undertaken in the future.
4. Transportation sector (motor vehicles) produced greater emission compared to the emissions resulting from industrial and domestic sources.
5. In order to examine more about the impact of air pollutants on health and visibility, sampling for detecting fine particles level needs to be undertaken in Jakarta in the future.

In comparison with the standard levels of SO_2, NO_2, and CO (0.1 ppm, 0.05 ppm, and 20 ppm respectively), the concentration of these trace gases measured at three sites in Jakarta were still below normal.

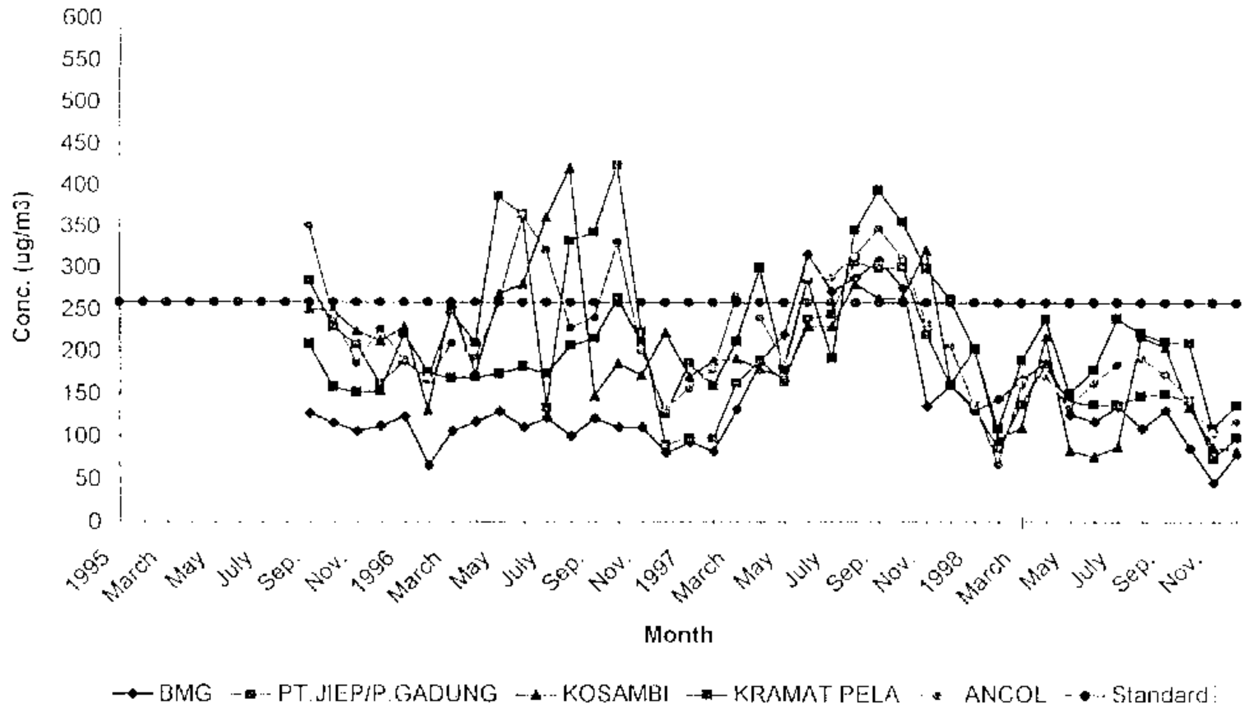


Figure 11. TSP measured at 6 locations in Jakarta.

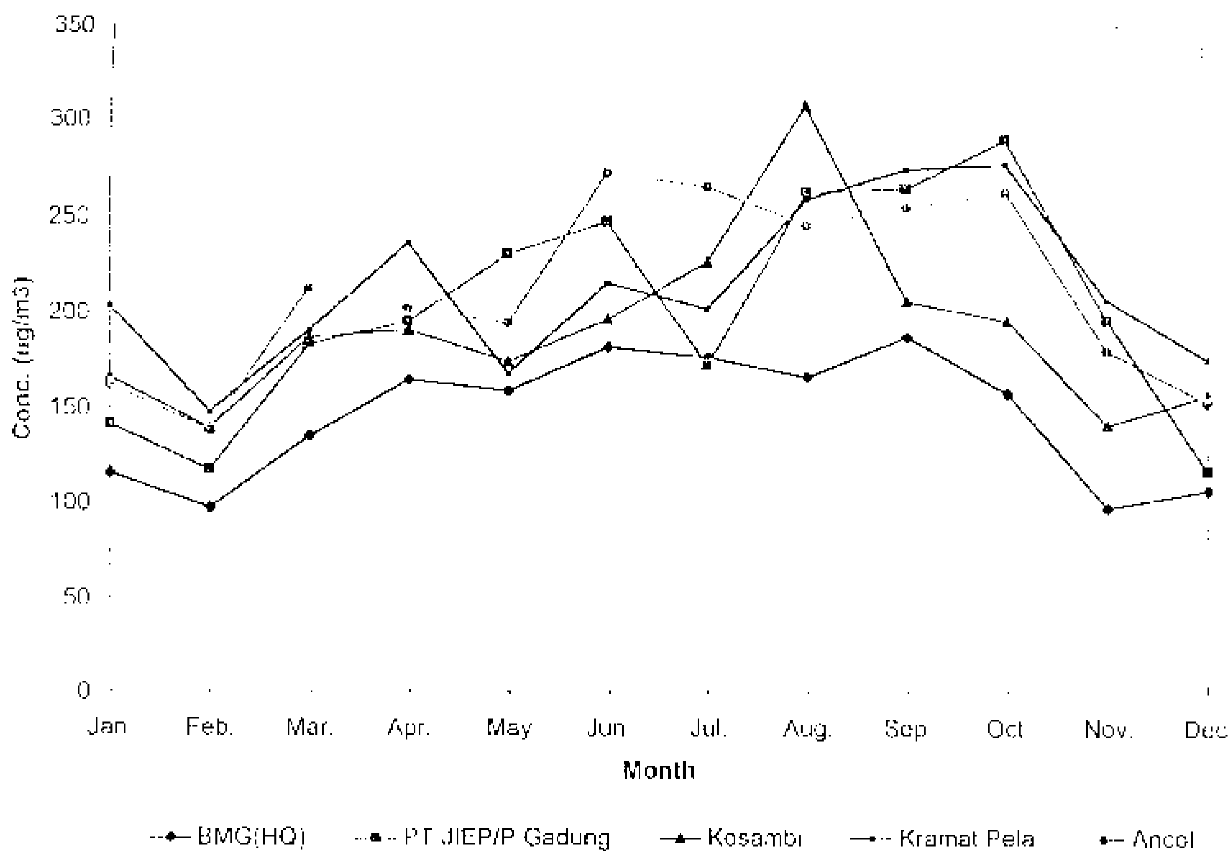


Figure 12. Typical seasonal variations in TSP in Jakarta.

6.5 Russia (presented by Emma Bezuglaya)

Over many years in MGO of Roshydromet, the information on air quality is generalized in "Annual Reports on the State of Air Pollution in Cities" which include most exhaustive information on harmful pollutants content in the major cities' air. The present paper contains the results of air quality analysis made in major cities of Russia over the 10-year period between 1988 and 1997. They are based on the data of State Network of Air Pollution Monitoring of Roshydromet..

At present a considerable part of Russian population is concentrated in highly urbanized territories. There are 34 major cities with population over 500,000 in Russian Federation, 22 of which are located in European part and 12 in Asian part. The population of these cities amounts to 22 % of the whole population and over 30 % of urban population in Russia. A lot of large industrial enterprises are located in the downtown and the uptown areas of these cities, producing negative effects on public health and ecological situations in many of the city areas. The paper presents the mean annual concentrations of TSP, SO_2, CO, NO_2 and ?aP for 1988-1997 and emissions of these pollutants into the air from industrial sources and motor transport for 1988-1997.

The experience of long-term studies and estimation of air pollution in cities shows that it is impossible to determine correctly the causes of high air pollution without using information on meteorological conditions resulting in pollution. We receive the meteorological information every year and include it in the Annual Reports. It is well-known that urban air quality is formed as a result of complex interaction of natural and anthropogenic factors. Natural topography and climatic parameters (air temperature, wind velocity, solar radiation, precipitation, frequency of surface and elevated temperature inversions, stagnation's and so on) are important conditions forming the "climate" of air quality and frequency of episodes of high air pollution level. A certain level of different pollutant concentrations form under the impact of mixing, transport, dispersion and washing out of harmful pollutants released into the atmosphere with emissions from industry and different kinds of transport. The territory of Russia is characterized by a wide variety of climatic conditions, e.g. surface inversion frequency varies almost several-fold: from 10-15 % to 50-60 %.

These meteorological parameters determine air pollution potential (APP). APP determines the transport and dispersion of pollutants coming to the air basin of a city with emissions from enterprises and motor transport. As a result of special studies made at MGO, the territory of Russia was divided into five areas with different climatic conditions of pollutant dispersion Low APP, favorable conditions for dispersion, is observed in the north-west of European part of Russia (areas I and II). Most unfavorable conditions for dispersion (very high APP) are in Eastern Siberia (area V). Mean concentrations BaP in Siberia in areas with high APP are in two tine is high then in European part of Russia Industrialization of Siberia and Ural cities, when the relation between air pollution and climatic parameters was not known yet, became one of the causes of unfavorable air quality in them. Many of major cities having considerable harmful pollutant emissions on their territories and a lot of plants are situated in unfavorable climatic zones, the so-called areas of high and very high air pollution potential with low dispensability of the atmosphere. High level of pollutant concentrations is observed most often in these conditions.The method of forecasting of high level air pollution was carried out in Russia.

At present the State Network of Air Pollution Monitoring in major cities of Russia include 230 stations, in all cities of Russia includes 649 stations. Selection of stations is made with consideration for meteorological conditions on the territory of city, the site relief, and emission sources location to fix the highest pollution levels. According to the classification of measurement site, stations are divided into the 3 categories *"city background"*, *"traffic"* (near highways), *"industrial"* (near industrial enterprises). In the cities under study there are 77 city background stations, 66 stations near highways and 87 stations near industrial enterprises In most Russian cities industrial enterprises are often located in residential districts over the whole city territory. Therefore it is difficult to distinguish "pure" residential areas. Simultaneously, with measurements of pollutant concentration at stations, the following accompanying meteorological parameters are observed: air temperature, wind speed, and direction. The data of thise observations were the basis of studying the thermal and wind regime of cities.

Modern cities' conditions form the urban climate, change radiation, thermal and wind characteristics over urban territory which effect the environment. According to investigations, the air temperature over city increase and heat is land forms. The average long-term differences in temperature between a city and the vicinity varies from 0.3 to 3 degrees.

Population health risk could be related with the air pollution level higher than maximum permissible concentrations (MPC) or higher than the values recommended by WHO. According to the techniques using API, last year's 14 major cities are included in the national priority list of most polluted cities of Russia. The high air pollution level in them is determined by concentrations of formaldehyde, nitrogen dioxide, TSP, and so on. As a result of production decrease, closing many enterprises for 1988-1996, the emissions decreased for particulate matter, SO_2 NO_2, CO by10 - 28 %. The annual mean TSP concentrations for 10 years in Russia decreased by 21 %, and NO_2 and CO increased by 10 % respectively.

There is observed a continuous growth of NO_2 annual mean concentrations (by 10%) over the ten-year period in lot of cities.. Since industrial enterprises emissions for this period decreased, this concentration growth is caused by the increase traffic intensity. (In some cities, in St. Petersburg for example, the total cars number increased 3-4 times during last 10 years.)

Until recently, the urban air pollution level was believed to be determined by the amount of emission released into the urban air basin and by local conditions of transport and dispersion of pollutants over the given territory. This special study has been made to get a more complete idea of the global meteorological effect upon pollutant's concentrations. Our Project is - "The investigation NO_2 concentrations variations in urban atmosphere under effluence meteorological factors".

Among pollutants released into the atmosphere with anthropogenic emissions from industry, power plants and motor transport, nitrogen oxides relate to the most important ones. They form basically in the process of organic fuel combustion as nitrogen oxides which are transformed to nitrogen dioxide. Usually the concentration of NO and NO_2 in the air are determined simultaneously. The reactions, with participation of nitrogen oxides in the atmosphere and photochemical processes, lead to O_3 formation.

The growth of nitrogen oxide concentrations in cities and the effect of global processes on them make us study these pollutants and NOx transformation into $NO_{2.}$ For this purpose regression analysis was to be done on the mean concentrations of NO_2 in Russian cities depending on the solar radiation intensivity. Concentrations are of nitrogen oxides ($NO+NO_2$), in ppb, and NO_2 according to the data of 132 stations in Russia. The highest concentrations are observed in many big cities with highest emissions, as well as in cities on the Pacific Ocean coast: (in Magadan and Vladivostok) , in which nitrogen emission are low. This map points to a considerable contribution of natural sources of emissions, for example, volcanoes.

We received that the nitrogen dioxide concentrations increase from north to south and is related with the differences in total solar radiation intensity as well as the differences in NOx concentrations. Within the latitudes under study, the total solar radiation changes by a factor of more than two and the mean NO_2 concentrations also increase by the same factor. On the average for a year the content of NO_2 in NOx at a given latitude can be predicted rather accurately. These values increase appreciably from the location of latitude 70^o N to 50^o N and vary slightly at smaller latitudes. The mean limiting values of NO_2 with NOx=100 ppb are equal to 25 ppb at latitudes $60\text{-}70^o$ N, and 45 ppb at latitudes $40\text{-}50^o$ N. At high latitudes the emissions of nitrogen oxides from industrial sources are usually low, therefore the limiting concentrations of NO_2 in the urban atmosphere are not observed.

In following form, the analysis of the monthly mean concentrations of nitrogen oxide and dioxide change over a wide range. Accordingly, substantial variations of NOx mean concentrations for winter months are observed. This enables consideration of the dependence of nitrogen oxides transformation over a wide range of concentrations. It is seen that for the biggest cities the relationship between NO_2 and NOx is also very close. The correlation factor was 0.917, and the regression equation $Q_{NO2} = 0.35\ Q_{NOx} + 6.4$, shows that $0.41NO_x$ transformation to NO_2 in winter.

However, the absence of any support does not allow us to progress substantially. Besides, this work should be done in collaboration with different physiographic conditions:

seaside, continental, in northern and southern latitudes. The theoretical group actively works in our department. This group has developed the main acting in Russian national normative documents for calculation of the air pollution by industrial enterprises (sources) (OND-86) and for the determination of sizes of the contamination zones under emergency releases of the toxic materials in the atmosphere. The breadth of the conducted researches and the perspectives of their development are described in the Proceedings of MGO, dedicated to 150th Anniversary of the observatory foundation. At present essential attention in the research activities is given to the development of normative methods of calculations of the long-term averaged concentrations and the features of the air pollution from the automobile sources taking into account the meteorological condition.

Under the presence of the WMO Projects on the development of the techniques of modeling and calculating of air pollution, MGO can take part in these works and render assistance to their participants.

6.6 Vietnam (presented by Nguyen Van Tue)

6.6.1 The air quality measuring network in Vietnam

The Hydometeorological Service of Vietnam (HMS) has set up and conducted an air and water quality measuring network since 1992. Together with other agencies, HMS has played an important role in monitoring the air and water quality in the whole country. The observed data from the air and water quality measuring network have well contributed to environmental impact assessment and resources management in the nation so far.

In spite of that, the network and activities relating with the network operation have revealed many imperfect matters that need to be solved. Moreover, the rapid development in socio-economic aspects of the country in recent years has required systematic accurate data on air and water quality for effectively exploiting the national air and water resources and environmental protection. Further, studies on improvement of the air and water quality measuring network is necessary for these purposes. The current status of the air quality measuring network in Vietnam is described below.

The network

At present, the air and water quality measuring network belonging to HMS includes 3 laboratories located in 3 parts of the country, 9 environmental measuring stations in reservoirs, 6 coastal environmental measuring stations, 48 river environmental measuring stations, 57 salinity intrusion stations, 22 air quality measuring stations and one regional background air quality monitoring station. The two latter kinds of stations form the air quality measuring network under the HMS.

The regional background air quality monitoring station is located at the Cuc Phuong national reserved forest. It is about 100 kilometers South from Hanoi City. The station has equipped with a meteorological station, observing meteorological parameters just like weather stations. The 22 air quality measuring stations are located at 22 other meteorological stations. Most of them are at the main cities and towns of Vietnam.

Operations of the network

Due to the lack of equipment, the regional background and other air quality measuring stations chiefly observe total monthly dustfall and collect rainfall water samples for chemical composition analysis.

The dustfall samples are collected from the first day of a month to the first day of the next month by an apparatus made of glass containing water with chloroform ($CHCl_3$) as a biocide substance. After the sample period, the samples are filtered by filter papers. Those filtered papers are called “dry samples”. The water, after filtering all samples in a month, is mixed and a sample is taken (about 500 ml). That sample is called “wet sample”. Dry samples and wet samples are brought to laboratories to determine the total monthly dustfall.

Rainfall water of each event is collected by a home-made semi-automatic apparatus. The apparatus has a cover that automatically opens to collect a sample when it rains and would be closed by hand after raining stops to prevent dry deposition during the sampling period. An amount of the collected rainwater is taken to measure "*in situ*" pH and electrical conductivity (EC) for each rainfall event. The rest of the sample is then stored in a container with toluene as a biocide substance. After a ten-day period, a sample (about 500 ml) from the water stored in the container is taken and brought to laboratories to do the analysis. The analysing parameters are: pH, EC, SO_4^{2-} , NO_3^-, Cl^-, NH_4^+, Na^+, Ca^{2+}, Mg^{2+}, K^+ and HCO_3^-.

The observations of some contaminate gases such as SO_2, CO, NOx, and total suspended particulate matters (TSP) are conducted as investigation campaigns at some stations and in some cities and towns. The data have shown that most of cities and towns are affected by pollution of dust. The concentrations of contaminate gases are low except sometimes, at some places in towns and cities, these are rather high and excess the levels that meet with the ambient air quality standard (Vietnam standard TCVN 5937 - 1995).

Studies on acid deposition have been conducted by The Water and Air Environment Research Centre, HMS and by National Environmental Agency (NEA). From the studies, some following remarks were reported:

- At most locations, rainfall water is in the neutral range and slightly alkaline.
- The values of pH are relatively high and stable in summer when there is large amount of rainfall. In winter, i.e. dry season, when there is little rainfall, the values of pH have a tendency to be low and the variation is significant.

Acid rains were reported recently in the South of Vietnam where the pH values fell to 4.0 (Ho Chi Minh City, in August, 1996 and in June, 1997). At some other stations, pH values lower than 5 (pH < 5.0) were also reported. It indicates that acid rain happened in the country. However, detailed and adequate data are not available for assessment.

Under the Acid Deposition Monitoring Network in East Asia (EANET) project, 2 acid deposition stations (at Hanoi and Hoabinh, 80kilometers southwest from Hanoi) were set up and equipped. These stations have just come into operation. Hopefully, these stations will provide meaningful data for studying the acid deposition status in Vietnam.

Some remarks

Nearly 10 years in operation, the air quality measuring network has fulfilled some its tasks. But quite a few imperfect problems remain:

- Due to the lack of equipment, only a few parameters of air quality could be observed.
- The apparatus used for observation is rather simple and backward. The same situation has been seen in the laboratories doing the sample analysis.
- The methodologies in observation and analyzing have not been standardized. There are not many documents as guidelines or technical manuals in the field of air quality monitoring.
- Compiling and evaluating the data and doing research on air quality monitoring have not been fully developed, so it is difficult to assess the effectiveness of the network operation.
- The interactions between agencies relating with air quality monitoring in the country are poor.

Improvement of the air quality measuring network

In order to improve the air quality measuring network in Vietnam, a set of problems should be defined and solved. The main tasks may be as following:

- Assessing and reviewing the existing network and its operation for reorganizing the network. There might be some steps involved:
  - Defining the purposes of monitoring: The objectives of the network should be as follows:
    - \+ to determine the concentrations in the representative areas of the country;
    - \+ to determine pollutant concentrations in polluted areas (e.g. towns, cities, industrial areas);
    - \+ to determine the air pollution trends and;
    - \+ to develop a database for future pollution control strategies.
  - Defining the parameters should be monitored: For the assessment of ambient air quality and accordance with the ambient air quality standard (Vietnam standard TCVN 5937-1995), at least 6 parameters: CO, NOx, SO_2, O_3, total suspended particulate

matters and Pb should be monitored. Besides meteorological parameters such as temperature ; relative humidity, wind speed, wind direction, barometric pressure, solar radiation and cloud should also be monitored.

- Defining the types of monitoring stations. There should be 4 kinds of stations in the network: national background stations, regional air quality stations that are representative for the 9 ecological regions of the country, urban air quality stations and rainfall sampling stations for chemical compositions analysis.
- The appropriate equipment configurations for each kind of station.
- The number and location of the stations in the whole country.

* Providing quality equipment for the network and upgrading the network to a relative modern status.
* Strengthening the capabilities in managing and operating the network.
* Developing the methodologies in observing and establishing appropriate guidelines for the network.
* Developing the training programs so that the operating of the network would be carried out at a high standard.

Air quality monitoring has been becoming an urgent problem to meet in the rapid industrialization and urbanization of the country. A great deal of effort should be made to get an effective air quality monitoring network. As a developing country, Vietnam needs close cooperation and comprehensive support from experts and international organizations in this field.

6.6.2 Air quality computations for the Red River delta, Vietnam (presented by Tran Thuc)

Air dispersion modelling is a technique for calculating pollutant concentrations at downwind receptor locations resulting from emissions from sources located upwind. A series of equations is needed to do these calculations, which are coded in a computer model and typically referred to as an air dispersion model.

An air quality model can be used as a surrogate for a monitoring network and is much cheaper. It can be used for predicting result of an air pollution mitigation strategy before that strategy is formalized by regulation. The model can also be used to give an overall picture of air quality throughout the whole area with the simple addition of other sources in the area. Effects of major accidental industrial gas release can also be simulated.

Because modelling is inexpensive compared to monitoring, several scenarios including future production, growth, and control measures can be assessed with the model to see what the expected consequences and changes will be. A site or several monitoring sites can be selected based on the scenarios modelled. If the modelled predictions are higher than the short-term standards which are designed to protect health, then preliminary policies that include future abatement strategies can be formulated and their implementation tied to actual monitoring results.

The model used for this work is the Mesopuff Model which was developed by the U.S. EPA for use in regulatory studies to assess the impact of sulfur oxides and nitrogen oxides emitted from major point and area sources over source-receptor transport distances of tens to hundreds of kilometers. The model was designed to include effects important on the mesoscale such as spatial and temporal variability in winds, dispersion, chemical transformation, wet removal, and dry deposition.

Application for the Red River delta

Data: Data used in the computation include surface and upper air meteorological data, emissions from industries and from transportation.

Meteorological data: Hourly data at 10 surface meteorological stations in 1997 are used in the computations. The stations are selected so that they are somehow uniformly distributed in the whole delta. Moreover, stations near to the main emission sources are also selected. Meteorological parameters used in the computations are: wind speed and direction, air temperature, pressure, relative humidity, cloud cover and ceiling height.

Upper air data at Ha Noi station (the only station in this area) include the vertical distribution (up to 500 mb level) of temperature, pressure, wind speed, and direction.

Emission data: Air quality parameters considered are SO_2, NO_2 and TSP. Estimated and measured pollutants emissions from major industrial areas in the region are used in the computations.

Dust emitted from transportation is calculated by applying the US EPA guideline.

Dust from road emitted due to vehicle: $E = k\left[\frac{sL}{2}\right]^{0.65}\left[\frac{W}{3}\right]^{1.5}$

Dust due to wind: $E = 1.9\left[\frac{s}{1.5}\right]\left[\frac{365-p}{235}\right]\left[\frac{f}{15}\right]$

Dust from vehicle emission: $\mathrm{T} = \mathrm{aN}$

where: k = grain size parameter for paved road, sL = silt content, W = vehicle weight, s = silt concentration, f = frequency of wind speed greater than 5.4 m/s, a = dust emitted from 1 vehicle in 1 unit road length, N = number of vehicle passing.

Emissions of NO_2 and SO_2 from transportation are calculated based on the Vietnam Standard for vehicle.

Environmental zoning:

Air Quality Index: An air quality index was used in the Red River Delta. It is calculated using the general function:

$$\text{Air Quality Index} = \frac{\text{Computed Value}}{\text{Vietnam Standard}}\,100\%$$

which gives a range of air pollution from very clean at zero, to equal the standard at 100, to very polluted at double the standard (200). The overall index for a given receptor location is the maximum of the individual pollutant indices.

Environmental Zone: An environmental zoning concept was used in the Red River Delta. Each location has an overall index, which can be interpreted, as a zone. A zone is considered Pristine (0-20% of the Standard); Clean (20-50% of the Standard), Watch (50-100% of the Standard), Polluted (100-200% of the Standard), and Very Polluted (>200% of the Standard).

Results: The model is applied to compute the distribution of some hazardous parameters such as SO_2, NO_2, and TSP in the Red River delta. Computations are make for different scenarios, i.e., (1) Present condition; (2) Scenario I: Due to industrial development, emission at all sources are increased by 1.5 times compared to the present condition; and (3) Scenario II: Thanks to industrial pollution reduction program, emission of TSP from all sources are reduced by 70% compared to the present condition.

Some remarks from Air Quality Modeling

In general, air quality in the Red River delta is still clean and not polluted by SO_2, TSP, vµ NO_2 from industries. Concentrations of these parameters are still lower than the Vietnam Standard. Although there are some industrial zones in the region that emit certain amount of SO_2, TSP, and NO_2. These sources mainly cause local pollution within an area of several kilometers in diameter.

From environmental zoning, the Red River delta area would be zoned as "*Clean*" with individual receptors ranging from "*Very clean*" at locations in the rural area and far from emission sources, to "*Polluted*" at locations near to large emission sources.

With the assumption that due to industrial development, emission from all sources will increase by 1.5 times compared to the present condition. The area zoned as "*Polluted*" will be enlarged. The region can be considered as "*Clean*" with individual locations ranging from “*Very clean*“ to “*Very Polluted*“.

If all sources are provided TSP filter that can reduce about 70% TSP emission, then the region can be rated as "*Clean*" of TSP.

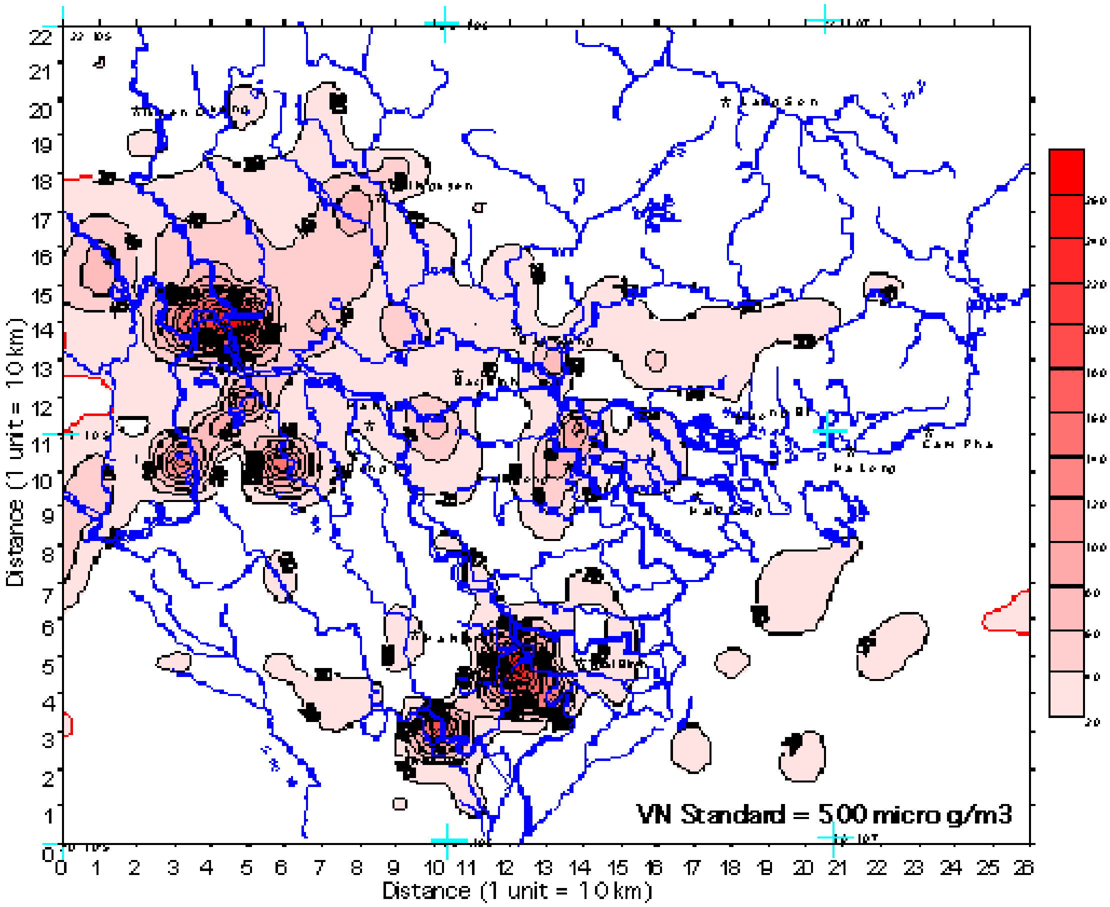
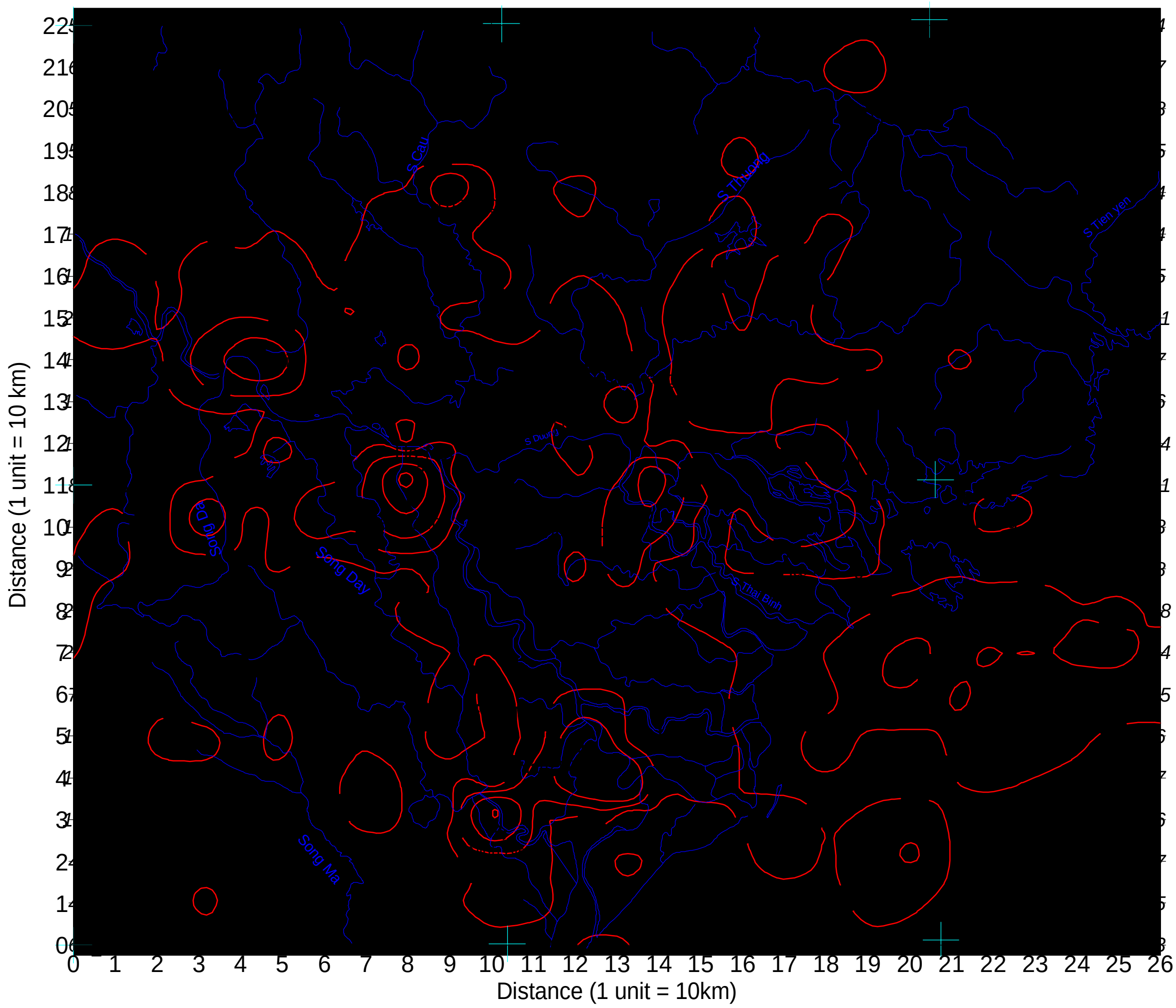


Figure 13. Distributions of Maximum 1-hour Averages NO_2 Concentration (Present Condition)



***Notes**: Pristine:* *AQ = 0-20% VN Standard* *Clean:* *AQ = 20-50% VN Standard*
Watch: *AQ = 50-100% VN Standard* *Polluted:* *AQ = 100-200% VN Standard*
Very Polluted: *AQ >200% VN Standard.*

Figure 14. Environmental Zoning for the Red River Delta (Scenario I)

6.7 South Korea (presented by Gangwoong Lee)

During July 1998, major sulfur species in both surface seawater and underlying atmosphere were measured in Masan Bay, Korea: dimethyl sulfide (DMS), sulfur dioxide, non-seasalt sulfate, methyl- sulfonic acid (MSA) in the atmosphere and dissolved DMS, dissolved β-dimethylsulfoniopropionate (DMSP) and particulate DMSP in seawater. The average concentrations of major atmospheric sulfur species were 3.7 ppbv, 112 pptv, 4.7 $\mu g/m^3$, and 8 ng/m^3 for SO_2, DMS, particulate SO_4^{2-}, and MSA, respectively. Water DMS, dissolved DMSP and particulate DMSP concentrations were extremely variable in time and location. Atmospheric DMS concentrations were higher during daytime than during nighttime. The level of atmospheric DMS in Masan Bay was primarily determined by meteorological conditions, but not much by chemistry.

When the concentrations of DMSP in dissolved and particulate form and DMS in seawater were concurrently enhanced, atmospheric DMS concentrations were also increased but not as much as those of DMS in seawater. The variation of DMS mixing ratios was closely linked with DMS concentrations in seawater. There was a clear correlation among dissolved DMSP, particulate DMSP, and dissolved DMS, which was a key factor controlling the level of atmospheric DMS.

During a short period of time, atmospheric DMS mixing ratios were comparable to those of anthropogenic SO_2. However, MSA concentrations were much lower compared to those of particulate sulfate. It is, therefore, likely that DMS was a significant source of atmospheric sulfur in highly productive Masan Bay, depending on meteorological conditions and the degree of anthropogenic influence nearby.

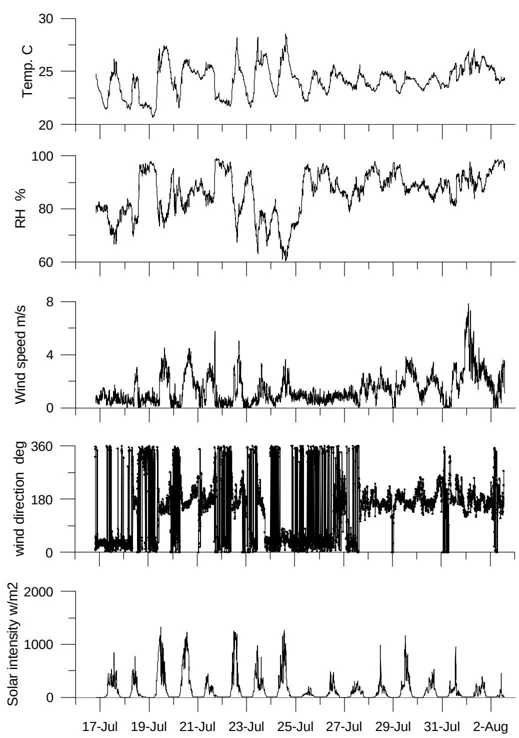
Experiment

Major sulfur species in both surface seawater and overlying atmosphere were measured in Masan Bay, Korea in July 1998: dimethyl sulfide (DMS), sulfur dioxide, non-seasalt sulfate, methylsulfonic acid (MSA) in the atmosphere and dissolved DMS, dissolved DMSP and particulate DMSP in seawater.

Together with these sulfur species, atmospheric trace gases such as O_3, SO_2, NO_x, and HNO_3, and meteorological parameters were measured. Water properties and biological factors were also observed. Experimental method used to measure each species is as follows:

Table 10.

	Species	Sampling Method	Analytical Method
Air & Seawater	DMS, DMSP	Carbosieve S III	TDU-GC-SCD-FPD
Atmospheric Trace Gases	SO_2, NO, NO_2, O_3	On Site	Thermo Environmental Instruments
	HNO_3	Nylon filter	IC
Aerosol Composition	NO_3^-, $SO4^{2-}$, NH_4^+, Na^+, MSA	Teflon filter	IC
Meteorological Parameters	WD, WS, Temp., RH, Solar Radiation	On Site	Automatic Weather Station
Seawater Properties	Salinity	Glass bottles	Salinometer
	Water Temperature, Dissolved oxygen	In situ probe	D.O. meter
Biological Parameters	Chlorophyll-a	Glass-fiber filter	Spectrophotometer
	Phytoplankton, Zoo plankton	Lugor's solution	Microscope



Results and Discussion

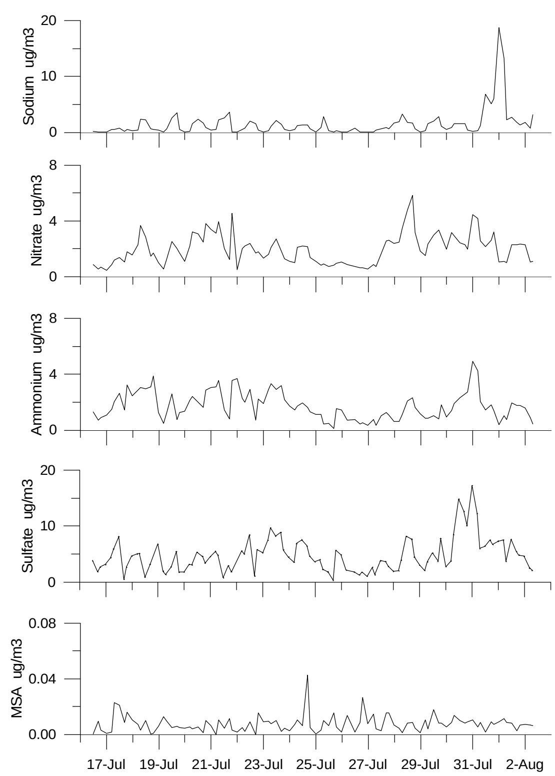
Measurement results are summarized in Table 11 below:

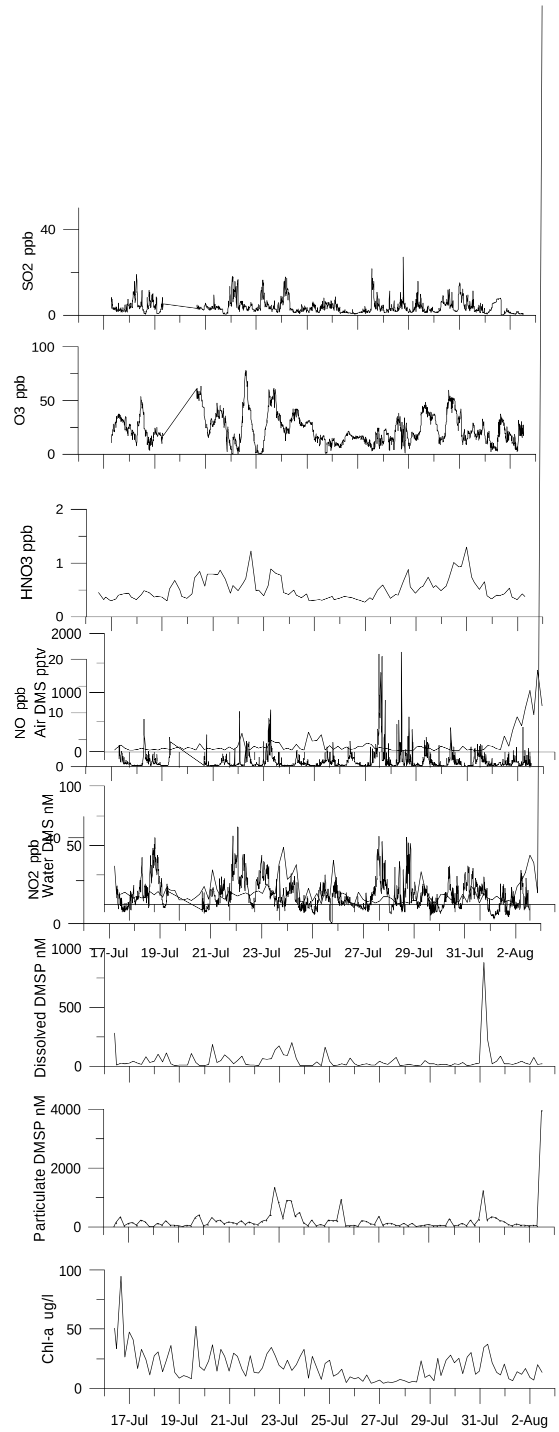
Table 11. Concentrations of Measured Species in Masan Bay in the Summer of 1998

Species	Average	Median	Standard Deviation
Air DMS (pptv)	112.2	44.2	207.6
Water DMS (nM)	16.5	7.0	74.0
Dissolved DMSP (nM)	45.7	17.5	96.1
Particulate DMSP (nM)	200.4	87.6	437.2
Particulate MSA (μg/m^3)	0.008	0.007	0.006
Particulate NO_3^- (μg/m^3)	2.0	1.9	1.1
Particulate SO_4^{2-} (μg/m^3)	4.7	4.3	3.0
Particulate Na^+ (μg/m^3)	1.4	0.7	2.4
Particulate NH_4^+(μg/m^3)	1.7	1.5	1.0
Particulate Ca^{2+} (μg/m^3)	0.1	0.1	0.1
Particulate Mg^{2+} (μg/m^3)	0.2	0.1	0.3
Gaseous HNO_3 (ppbv)	0.5	0.4	0.2
SO_2 (ppbv)	3.7	2.9	3.1
O_3 (ppbv)	23	20	14
NO (ppbv)	1.0	0.4	1.8
NO_2 (ppbv)	13.3	12.0	6.8

The following figures show the results of continuous measurements made on Dot Island during July 17– August 2.

- Meteorological Parameters
- Aerosol Composition
- Atmospheric Trace Gases
- DMS in air and DMS, DMSP in Seawater





[Water DMS concentration suddenly went up to 760 nM on August 2.]

Vertical distributions of sulfur species in seawater observed in Station A, D, and G on July 17 and August 1 are shown in the following figures.

Left Plate: Temperature (■), Chlorophyll-a ( ), Dissolved Oxygen (●)
Right Plate: Particulate DMSP (■), Dissolved DMSP ( ), DMS (●)

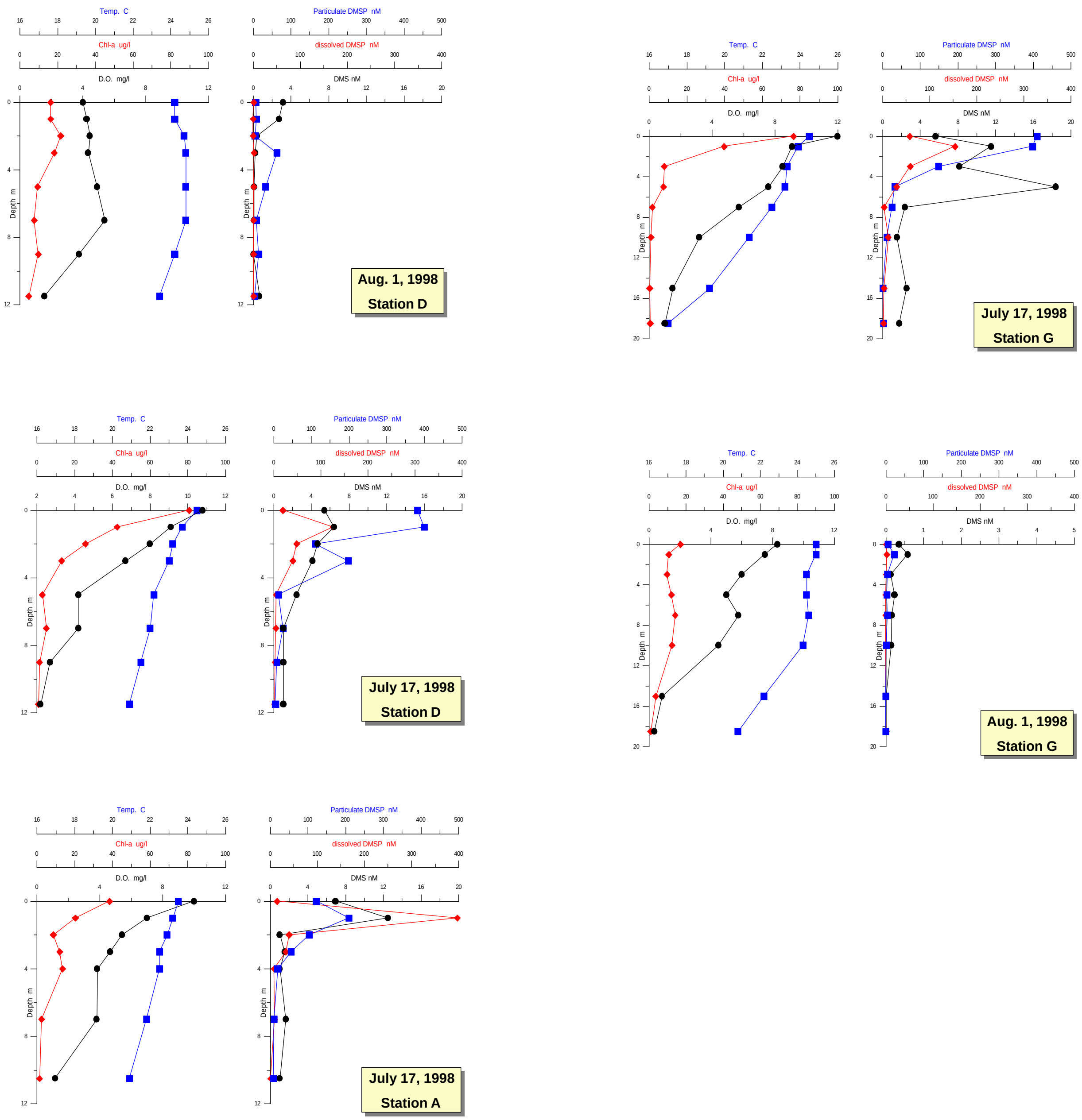


Figure 15. Observations in seawater.

The average concentrations of major atmospheric sulfur species were 3.7 ppbv, 112 pptv, 4.7 µg/m^3, and 8 ng/m^3 for SO_2, DMS, particulate SO_4^{2-}, and MSA, respectively.
Concentrations of water DMS, dissolved DMSP and particulate DMSP were highly variable both spatially and temporally.
Atmospheric DMS concentrations were higher during the day th an during the night, which is just opposite to the tendency expected from photochemical model . It implies that

meteorological conditions played more important role in regulating the level of atmospheric DMS in Masan Bay than chemical factors.
The enhanced concentrations of DMSP in dissolved and particulate form and DMS in water were concurrently observed around the July 23 and 25. The increase in atmospheric DMS concentration was also observed, but not as much clear as th at of DMS in seawater.

Conclusions

Preliminary results suggest:
DMS was a significant source of atmospheric sulfur in highly productive coastal region, Masan Bay, depending on meteorological conditions and the degree of anthropogenic influence nearby.
The variation of DMS mixing ratios was closely linked with DMS concentrations in seawater.
There was a clear correlation among dissolved DMSP, particulate DMSP and dissolved DMS, which would be a key factor controlling the level of atmospheric DMS. The detailed mechanisms will be elucidated after finishing the analysis of phytoplankton and zooplankton species.

6.8 Portugal (presented b Renato A.C. Carvalho)

Portugal is an european country integrating 3 territories: mainland, Açores and Madeira islands Figure 16. The Portuguese mainland is situated in the southwest extreme of Europe, in the Iberian west front to the Atlantic Ocean, between 37º N and 42º N; the 9 islands of Açores, situated in the middle of the Atlantic Ocean, about 1600 - 2000 Km to the west of Portugal, at the latitudes of 37º - 39º N and the 2 islands of Madeira, situated also in the eastern Atlantic Ocean, off the North Africa coast, about 1000 Km to the southwest of Portugal, at the latitude of 33º N. The population of Portugal is about 10 million people in a territory of 90.000 Km^2; the more populated areas are the littoral coasts to the north of Lisboa and of Algarve, as well as the islands of Açores and Madeira. In the more populated lands, the main urban areas are situated, namely Lisboa (700.000 inh.), Por to (300.000 inh.) and 10 more cities (50.000 – 100.000 inh.).
In Portugal the systematic study of the atmospheric sciences was initiated in the 14th, 15th, and 16th centuries when the meteorological conditions observed during the sea voyages by the portuguese navigators were regularly recorded, mainly of winds and sea currents in the Atlantic and Indian Oceans. Later, in the 17th century, meteorological observations were regularly made at the Medical School in Lisboa, from 1777 to 1785, as well as at the M adeira island, from 1747 to 1753, by Tomas Heberden, at the village of Mafra from 1783 to 1786 by D. Joaquim de Assunção Velho and at Porto, on 1792 by José Bento Lopes. was installed near the Politechnical School of Lisboa, and since 1882 daily weather ch arts were published; nowadays it remains as a urban meteorological observatory of the Meteorological Institute.
During the second half of the 19th century, about 14 meteorological stations were installed in Portugal, 2 in Açores, 1 in Madeira and 2 in Cap e Vert islands most of them in urban areas, in old towers. During the first half of the XX century, about 25 more climatological stations were installed and on the decade of 70's there was about 150 meteorological/climatological stations and about 600 udo metric stations.

Climate of Portugal

The climate in Portugal is a consequence of the mean frequencies of the air masses (Table 12) and the influence of the main synoptic centres as the Açores anticyclone and its eastern ridge , all year round, but more frequently during the semester of May to October; the thermal low pressure over Iberian peninsula, mainly since June to September; the polar front on November to March and for short periods of 1 to 3 weeks, for 3 -5 times on November to March, the western ridge of the winter anticyclone over the north or central Europe; finally, another synoptic feature relevant to the climate of Portugal is the low pressure which is formed to the southwest of Portugal, over the Atlantic ocean, mainly on the transition months (Oct., Nov., April and May).

Table 12. Mean Frequencies (%) of air masses in Portugal

Air mass	Year	Summer (June – Sept.)	Winter (Dec. – Mar.)
Tmsub	65	80	50
Tc	10	15	5
Pmw	17	5	30
Pmk	5	0	10
Pc	3	0	5

In Table 13, the main features of the climate in each territory of Portugal (mainland, Açores and Madeira) are presented.

Table 13. Climate of Portugal

	PARAMETER	Mainland (37º-42ºN)			Açores (37º-39ºN)			Madeira (33º N)		
		Year	Jan	Jul	Year	Jan	Jul	Year	Jan	Jul
Mean values	Sunshine (h)	1800-3100	50-160	220 – 380	1500-1900	75-100	200-250	1700-2240	110-140	180-300
	Global Solar Rad (Kcal/cm^2)	140 – 165	5 – 7	20-24	119-135	4 – 6	16-17	-	-	-
	Total Precipitation (mm)	400 – 3100	50-500	2 – 50	770-3600	60-420	20-130	350-3000	55-460	5 – 30
	Mean Air Temp (ºC)	7 – 18	0 – 13	15-25	14-18	11–14	17-22	9 - 20	5 - 17	14-22
	Mean Max Daily Temp (ºC)	11–23	5 – 16	19-34	17-21	13-17	21-25	12-23	8 – 20	19-25
	Mean Min Daily Temp (ºC)	4 – 14	1 – 10	9 – 20	11-15	8 –12	14-18	6 – 16	3 – 13	10-19
	Specific humidity (g / Kg)	5 – 9	4 – 7	7 – 13	8 – 12	7 - 9	9 – 15	6 – 12	5 – 10	6 – 14
	Pred. Wind direction	N-NW	N-NE-NW	NW-N	N – W	SW-N	NE-N	N-NE	N-NE-SW	N-NE-NW
Extreme values	Daily Max Temp (ºC)	46,5	25,0	46,5	32,0	22,5	32,0	39,0	27,0	39,0
	Daily Min Temp (ºC)	- 16,0	- 16,0	1,0	0,0	0,0	7,0	- 6,0	- 6,0	2,0

Typically, the climate of Portugal is temperate, but sometimes extreme weather conditions appear related with precipitation, wind speed and air temperatures as occur in subtropical and tropical climates.

In fact, 24 hours precipitation of 100 mm to 200 mm as well as 30 mm to 50 mm in one hour or short period precipitation of 20 – 30 mm/10 min and 10 – 20 mm/5 min are frequent. The wind speed show frequently values of 40 to 50 m/s, and gusts of 60 to 80 m/s and the heat waves during 3 to 6 days with maximum daily air temperatures of 37º C to 42º C, and occasionally 43º C to 45º C, occur in average once every 3 to 5 years.

Air composition observations in Portugal, GAW network

There are air composition observations in Portugal published for several years in the XIX century, made at the Observatory in Lisboa, namely for atmospheric ozone at surface in two daily periods, night and day.

Later, at the same Observatory, suspended particles in the air at surface (condensation nuclei) were measured during several years. In the late 50's, the National Meteorological Service (NMS) began to make total ozone observations during the International Geophysical Year (IGY), in 1957–58, first in S. Maria (Açores) and later, since the beginning of 60's in Lisboa; now, this total ozone series has been re-evaluated since mid 60's, and has existed more than 30 years (1967 – 1999). In 1974, the NMS decide to begin a new WMO programme in Portugal, establishing 2 BAPMoN stations with extended regional programme (Bragança and Faro); at same time the atmospheric turbidity programme was implemented at 9 stations, 8 of them using pirheliometers and 5 using sunphotometers. In 1987 two more stations (Viana do Castelo and Castelo Branco) began to operate the minimum programme and on 1992 two more stations (Angra do Heroísmo, Açores and Funchal, Madeira) began to operate, including atmospheric ozone obs ervations (surface and total with Brewer instruments); in 1984, a 4th station equipped with Brewer spectrophotometer began to operate in a mountain Observatory – Penhas Douradas, 1380 m.

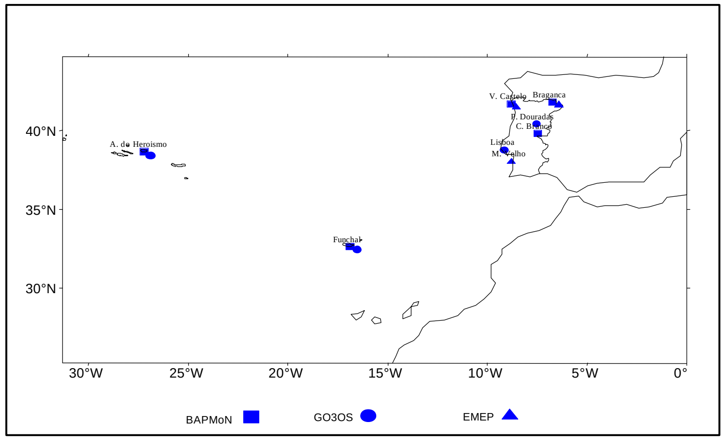


Figure 16. GAW network in Portugal

Considering the scientific importance of UV-B radiation and its influence over living organisms, an UV-B radiation (broadband) network of 5 stations will be installed along the coast of Portugal (mainland); the UV-B data will be collected in real time in Lisboa (IM headquarters) through telephone network in order to suppor t the UV-B index forecast for public information, specially during summer (May – September). Actually, 7 GAW station are being operated in Portugal (5 in mainland, 1 in Açores and 1 in Madeira island) (Figure 24).

National Automatic Meteorological Statio n Network (NAMSN) in Portugal

The Portuguese Automatic Surface Network, initially constituted by 22 Automatic Meteorogical Stations (AMS) in 1996, is now operating with 47 AMS, and will continue to grow to reach 93 AWS in mainland and islands on 2000. Th ese AMS generate SYNOP reports plus 10 minute meteorological data, for several parameters, both to be transmitted hourly to the Central System at the Meteorological Institute headquarters (Lisboa).

The main objectives of this network are:

a) to improve the spatial and time coverage of meteorological data in real time for synoptic meteorology activities;
b) to have an adequate spatial coverage (about 1000 km^2/station) for weather warnings at synoptic and mesoscale;
c) climatological studies, including solar and wind energy availability as well as the hidric availability;
d) to give support for local climate studies, including microclimate characterisation.

This network includes 9 AMS in the Açores, 6 AMS in the Madeira and 78 AMS in the mainland (Fig. 17), defining an average distance between AMS of 35 Km, which is adequate to support the use of mesoscale models for numerical weather prediction.

Portuguese Urban Automatic Meteorological Station Network (UAMSN) in Portugal

In 1997, the Portuguese Meteorological Institute decided to implement a national Urban Automatic Meteorological Stations Network. The network will be in operational mode in the year of 2000 and will consist in 19 meteorological stations, 5 regional concentrators and 1 national centre (Fig.18).

The criteria for the selected urban areas was mainly the number of inhabitants: 1 AMS per 50.000 inhabitants and 1 per 100.000 inhabitants for Lisboa (700.000) and Porto (300.000).

The meteorological stations and the concentrators (Regional and National concentrators/centre) will be installed in the following urban areas:

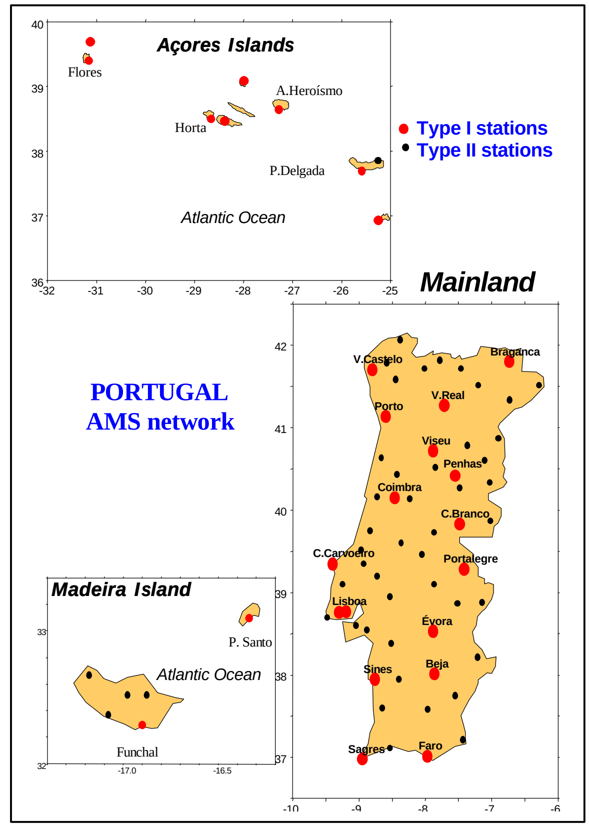
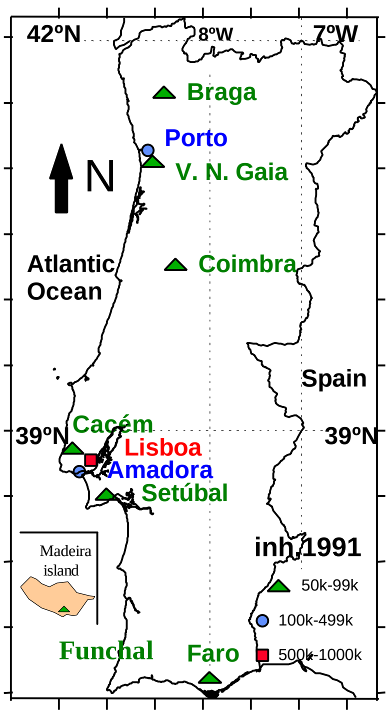


Figure 17. National automatic meteorological network in Portugal

- 1 Braga, 3 Porto, 1 V.N. Gaia and 1 Regional Center in Porto
- 1 Coimbra with 1 Regional Centre
- 6 Lisboa, 1 Setúbal, 1 Cacém, 1 Barreiro, 1 Amadora,

1 Regional Centre and 1 National Centre in Lisboa

- 1 Évora with 1 Regional Centre
- 1 Faro with 1 Regional Centre
- 1 Funchal (Madeira Island) with 1 Regional Centre



gure 18. Urban automatic eteorologica stations in rtugal

The basic meteorological data, namely the air temperature and relative humidity, dew point and wet bulb temperatures, precipitation amount, duration and intensity, global solar radiation, wind speed and direction will be organised in the regional and national concentrators in different data bases; from these data bases different kinds of visualisations will be possible. A set of meteorological data will be available for each station describing the meteorological conditions for different applications namely for urban weather watch and for civil protection warnings, air pollution meteorology urban planning and climatological studies in urban areas.

For air pollution dispersion, the data available will be wind speed and direction at height of 6m, the wind direction standard deviation, air temperature and relative humidity and global solar radiation.

In order to support the weather forecast activities especially for warnings, civil protection actions and road traffic security, all AMS may be programmed to send alarm messages (for the beginning and for the ending) as far as certain established thresholds are reached, for the following meteorological variables:

- mean wind speed in 10min: 15m/ s
- instantaneous wind speed: 23m/ s
- total precipitation in 5min: 5mm
- air temperature: 0º C and 40º C.

6.8 Mynamar (presented by Tin Ngwe)

The Union of Myanmar is located between 9° 30; to 28° 31' north latitude and 92° 10' to 101° 11' east longitude. The area is about 677,980 square kilometers. Roughly one third of Myanmar lies outside the tropics, but the configuration of the country is such that the whole may be regarded as a tropical country. The population of Myanmar was nearly 48 million in 1998. It is comprised of seven states and seven divisions.

Yangon is the capital city of Myanmar. Meteorological measurements in Yangon (Kaba - aye) represents for urban, Mingaladon for suburban and Hmawbi for rural area. In this presentation, the radiation distribution between urban and rural area of Yangon division is already analyzed. Urban meteorological stations in Myanmar are shown in Figure 19.

Background

Most cities are anthropogenic sources of heat and pollution. In addition, the downtown areas are covered by a large percentage of asphalt and concrete, which are usually dry, water proof surfaces with albedoes and heat capacities that convert and store incoming radiation as sensible heat better than the surrounding country side. Thus, the surface layer in cities is generally warmer than that of their surroundings.

The greatest temperature differences between urban and rural areas are usually observed during the night. In many cases, heat from the cities is sufficient to maintain a shallow convective mixed layer at night, even while a substantial stable boundary layer has developed over the surrounding country side. Cities with a population of about 1,000 have been observed to have maximum temperature excesses (compared to the surrounding rural area) of 2 ° to 3°C, while cities of a million or more inhabitants have been known to generate excesses of 8 ° to 12°C.

While a natural source radiation is always below safe level and no controls can be affected, man made radiation can endanger environment. These man made sources could be industrial sources either in use or waste. They could also arise from nuclear accidents such as the Chernobyl Reactor accident in Russia or Three Mile Island in USA. They could produce radiation effects across national boundaries. There is also nuclear waste which may be improperly dumped.

Data Acquisition

The following three stations are used to analyze for the comparison of meteorological conditions between urban and rural areas in this presentation.

- *Kaba-aye Station*

This station is situated at the capital city of Myanmar named Yangon and it is the headquarter of the Department of Meteorology and Hydrology. Yangon area is estimated at about 10,177 square kilometers and the population of Yangon is about 5.2 million in 1998. Kaba-aye Station is representative of the urban area in this study and the location is 16° 52' north latitude and 96° 10' east longitude.

- *Mingaladon Station*

This station is situated near the International Airport and it is the headquarter of the Aviation Meteorological Division. This station is representative of the suburban area in this study and the location is 16° 54' north latitude and 96° 11' east longitude. The straight distance from the Kaba-aye Station (urban station) is about 5 km.

- *Hmawbi Station*

This station is surrounded by the agricultural farms and the straight distance from Kaba-aye Station (urban station) is about 50 km as well as 45 km from Mingaladon Station (suburban station). This station is representative of the rural area in this study and the location is 17 ° 02' north latitude and 95° 38' east longitude.

The monthly mean data, collected during 1987 to 1996 in above mentioned three stations are used to analyze in this presentation which are

- maximum temperature
- minimum temperature
- relative humidity
- sunshine hour

Method of Analysis

(a) Air Pollution Monitoring

Using modern air-samplers, the air in Yangon has been regularly sampled and analyzed for the content of dust (air-particulate-matter or APM) and its chemical composition, specifically heavy elements. Air sampler is used to pump known volume of air through fine filters and dust particles as fine as a few micrometers are deposited. The weight of filtered dust is measured. Also using the method of x-ray fluorescence elemental analysis is carried out.

(b) Radiation Balance

For the estimation of radiation balance, only two components are taken into consideration.

(i) Shortwave Radiation

$$R_g = (1 - a)R_a(a + b\frac{n}{N})$$

where

R_g = short wave radiation in cal/sq cm
α = albedo for urban is 0.18
suburban is 0.20
rural is 0.23
R_a = extra-terrestrial radiation in cal/sq cm
a = constant for humid tropic is 0.29
b = constant for humid tropic is 0.42
n = observed sunshine hour
N = maximum possible sunshine hour

(ii) Infra-red or long wave radiation

$$R_L = \in sT^4(0.1 + 0.9\frac{n}{N})(0.56 - 0.079\sqrt{e_d})$$

where

R_L = long wave or infra-red radiation in cal/sq cm
$\in$ = emissivity
σ = Stefen Boltzman constant
T = Temperature
E_d = vapor pressure

The balance of the above two kinds of radiation are taken into account for the net radiation of the station.

Result and Discussion

The result of the air pollution monitoring in Yangon is shown in Figure 20. We find that dust content of air in Yangon has seasonal variations – higher levels in summer periods and relatively smaller levels during the rainy season. The range is 49.85 to 172.82 microgram per cubic meter of air (1 microgram is 1 millionth of 1 gram). Mass concentration in aerosols at Yangon in 1997 can be seen in Figure 21. In Yangon, we have a record of many years data on radioactivity in air and rainwater. The average values which are compared to the safety limits prescribed by International Commission on Radiological Protection (ICRP). Here we can claim clear and safe air and water as regards radiation.

From the comparison of meteorological conditions between urban and rural areas, the following can be seen:

- for the net and short wave radiation, urban area (Kaba-aye station) has the highest radiation and the rural area (Hmawbi station) has the lowest radiation. While the slight difference can be seen in the radiation at the suburban area (Mingaladon station) and the urban area (Kaba-aye station), the significant difference of rural (Hmawbi station) can be seen clearly in the Figure 22. After the withdrawal of southwest monsoon, there is more significant difference between rural station and the other stations.
- Long wave radiation in the rural area is higher than in the urban area during the cold season but significant difference can not be seen in the rest of the time of the year which are shown in Figure 23.
- In all stations, the amount of long wave radiation is small in the rainy season.

Conclusion

As recognized by the thirteenth World Meteorological Congress, WMO has a critical role to play in the study and management of urban environment. Accordingly, WMO, the Executive Council, and the Commission for Atmospheric Sciences will help to establish an urban environment meteorological research program. This has been specified as the GAW Urban Research Meteorology and Environment project (GURME).

Myanmar, National Meteorological, and Hydrological Services implemented the meteorological monitoring, forecasting, and modeling. On the other hand, Myanmar NMHSs will take part in this project activities (GURME), to handle the meteorological and air quality aspects of urban pollution, both in research and operational modes in the future.

Figure 19. Urban Meteorological Stations in Myanmar

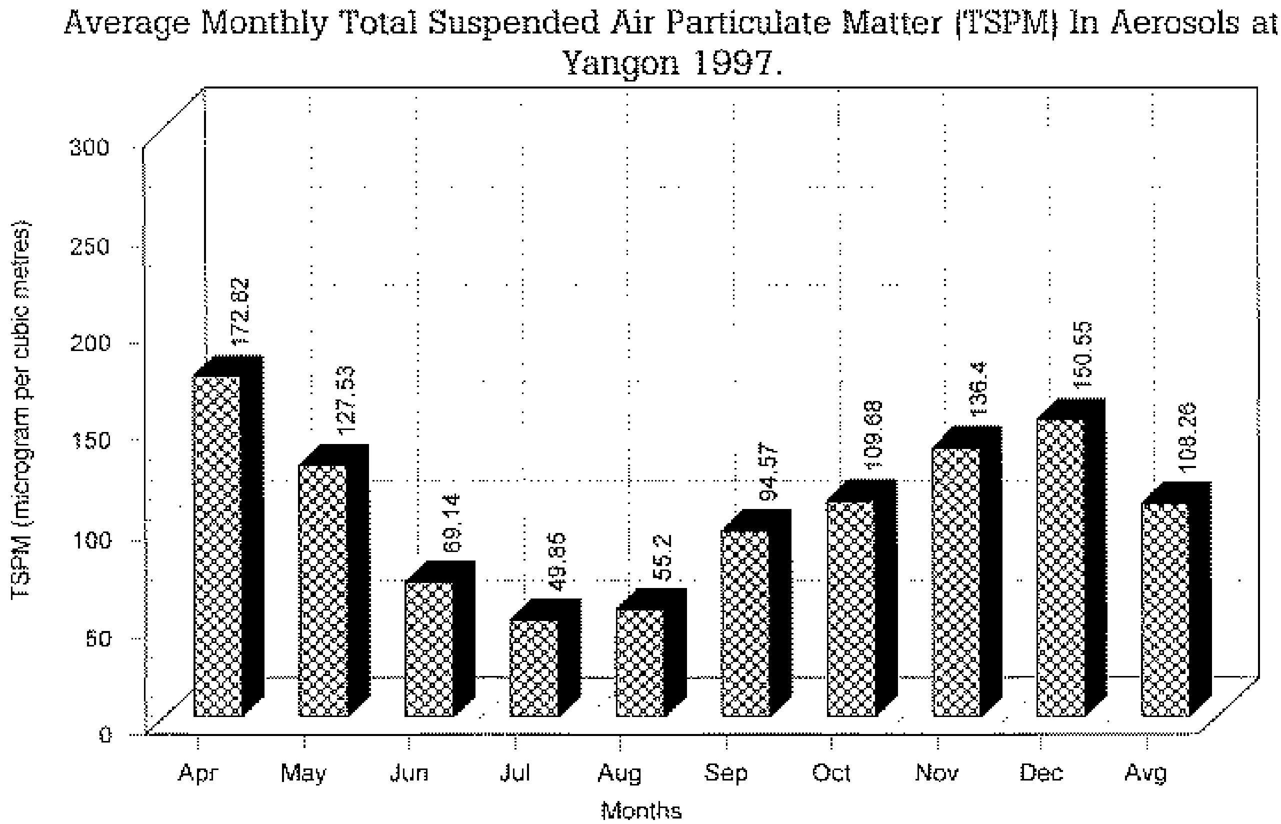


Figure 20. Average Monthly Total Suspended Air Particulate Matter (TSPM) in Aerosols at Yangon 1997

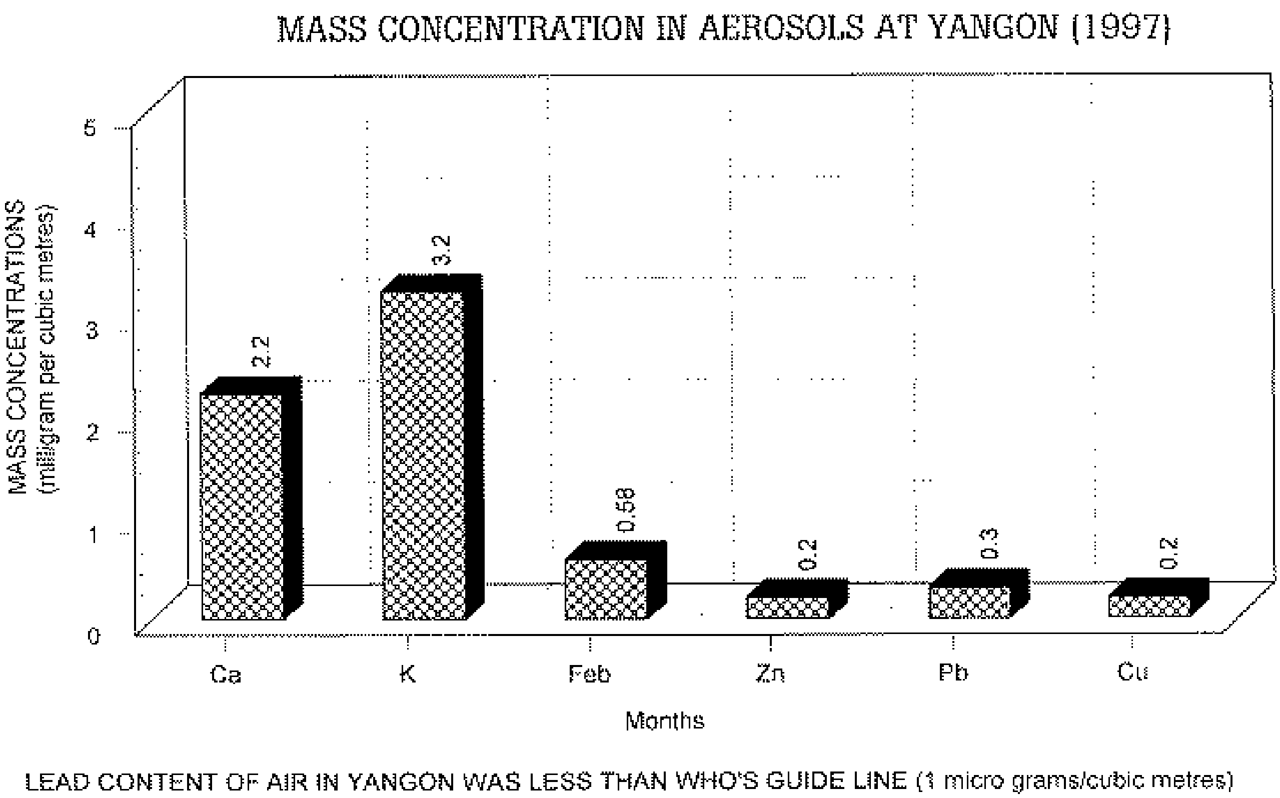


Figure 21. Mass Concentration in Aerosols at Yangon (1997)

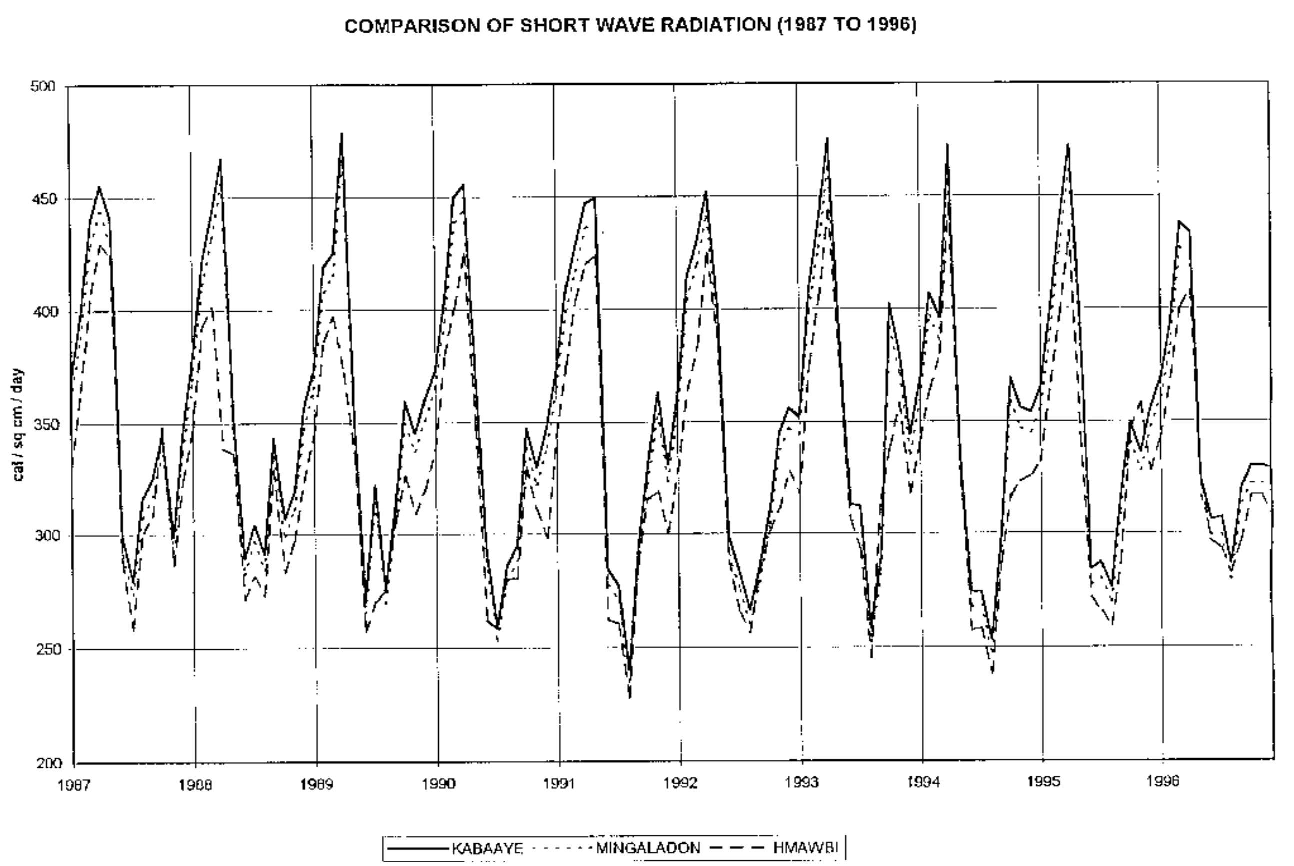


Figure 22. Comparison of Short Wave Radiation (1987 -1996)

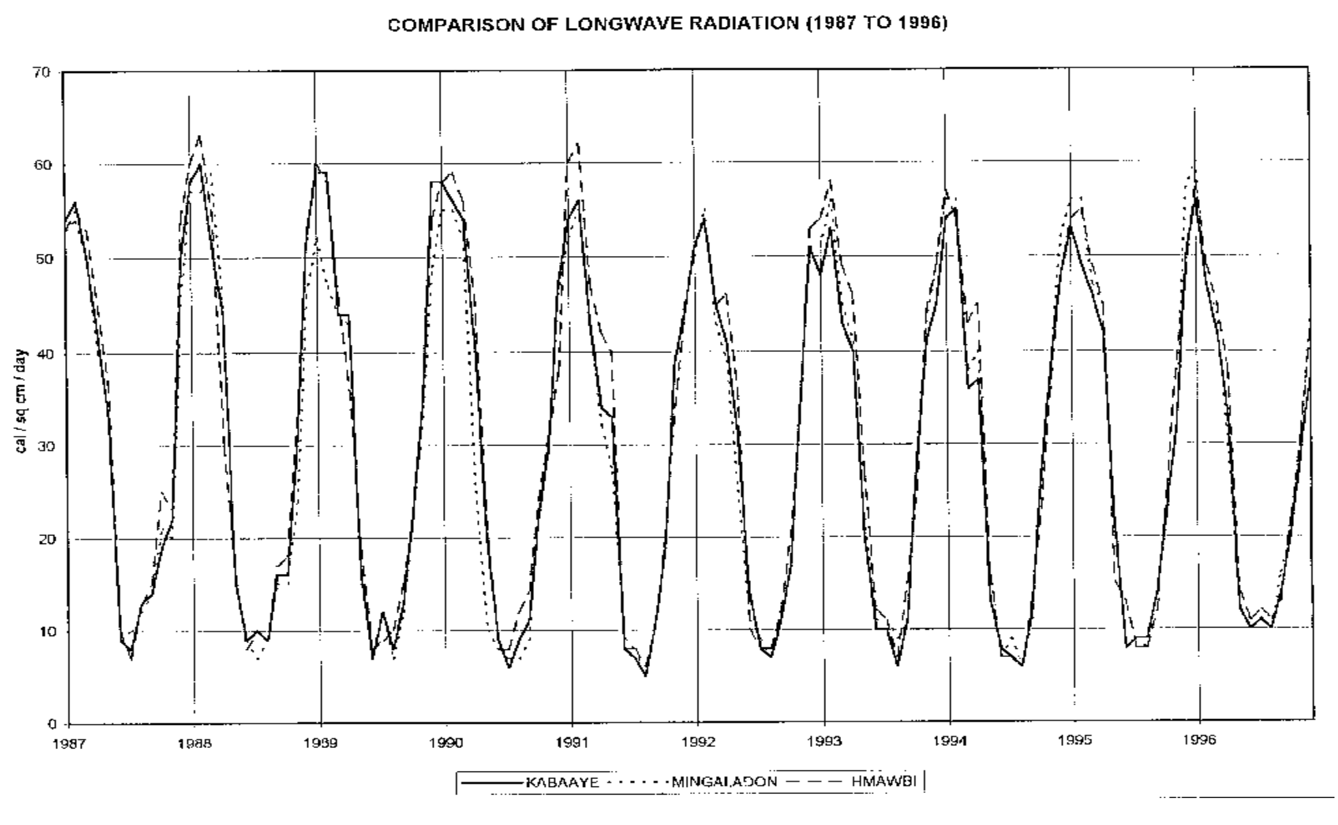


Figure 23. Comparison of Longwave Radiation (1987-1996)

6.9 Turkey (presented by Selahattin Incecik)

Urban air pollution is a major problem in developing countries of the world. In recent years, concern about urban air pollution has increased. UNEP/GEMS, (1991) reported that the number of cities with more than 4 million inhabitants will be 66 cities by the year 2000 in the world. Mega et al. (1996) explained the potential for air pollution in the cities that will experience in future unless control strategies are developed and implemented during the next several decades. Ankara, has experienced severe air pollution problems in the last 30 years. Due to the poor dispersion conditions, irregular terrain and its peculiar topography with the usage of poor quality lignite in the city caused the worst air pollution events. Mean SO2 and TSP concentrations higher than National Air Quality Standards have been detected many times in this period. It would also need to examine the conditions of the sudden increase of concentration levels on the first day of an episode. This would assist in the development of air quality improvement strategy for Ankara, which mentioned in the Ministry of Environment(1992) report. Therefore, the prediction of episode day will be greater value in policymaking decision to reduce pollution in the city for further studies.

Climate and Topography of the Region and the Pollution Sources

Ankara (39 ^{o}N; 32^{o}E) is situated in central part of Asia Minor. The mountains and hilly areas up to heights of 850 and 1200 m surround the city and strongly prevent the airflow into the city. The climate of Ankara is a typical Continental type. In winter, the cold core Siberian anticyclone causes decreasing temperature and snow. During winter, poor dispersion conditions in Ankara are associated with the development of a high-pressure system over the Asia Minor and the warm ridge aloft. Besides, maritime polar air masses affect the northern and central part of Turkey. Depression from the Mediterranean provide another source of active frontal conditions in the winter. The average daily temperature is 2.7 ^{o}C during winter, the coldest month being January (- 0.1^{o}C). The dominant wind direction is NE, N throughout the year with the average of 2.3 m s^{-1}.

SO_2 and TSP Pollution Sources

The capital city of Ankara with a three million people is one of the developing cities in Turkey. Higher levels of air pollution have been arised in Ankara in the 1970s and 80's. The major emission sources in the city are space heating, industry and the traffic. A natural gas program was initiated in 1990. According to METU Report (1993), around 750,000 tonnes of hard coal, 400 million cubic meters of natural gas and 150,000 tonnes fuel oil has been consumed in 1992 in the city. In spite of it not being an industrialized city , there are some small factories in Ankara (mainly small to medium scale factories). As much as 58.7% of the SO_2 and 63.1% of the TSP emissions come from heavy residual oil and hard coal respectively. There are nearly 700,000 houses in the city. 57% of th em take parts individual heating system and rest of central heating. Among of them, 61% of the houses use hard coal and 36% natural gas and 3% fuel oil. There are also about 400,000 registered cars and buses and trucks in the city. The estimated SO_2 and TSP emissions in a year are about 1000 and 700 tonnes respectively in the city.

Methodology

Episode Classification

High air pollution potential may be defined as a set of large-scale meteorological conditions that would lead to the occurrence of high co ncentrations of pollutants in the cities. SO_2 and TSP concentrations measured in 8 stations in Ankara province were used to select the most intense air pollution episodes in the cold period of the years 1989 -1994. 26 episodes of the total 93 days ranged from 2 to 8 days exceeding 400 μgm^{-3} for SO_2 National Ambient Air Quality Standards, at least two stations for two or more days were founded. Furthermore, 9 episodes for a total of 27 days exceeded 300 μgm^{-3} for TSP NAAQS. This gives that air pollution episodes for SO_2 have greater importance than TSP in Ankara. The average winter SO_2 and TSP levels were higher in 1989 and 1990 than the following years. This result reflects the policymaking decision on the fuel switching and other imposing on the restric tions to reduce emissions. The worst air pollution has occurred in December, January and February.

Horizontal Pressure Gradients

Usually, the presence of a high-pressure system or by a warm ridge aloft can create the weak surface pressure gradient and p oor dispersion conditions at the surface. In this study, a classification of surface horizontal pressure gradients used by the method of Kallos et al. (1993) is applied. The results of classification of surface pressure gradients using by 0200 LST reflect an analysis of for 360 days (Table1). Generally, relatively weak pressure gradients (5hPa per 500-1000km) are principally dominant in the region with 43.7%(Sahin, 1999). Thus, stagnant weather conditions are usually expected in the city.

Temperature at 850 hPa

Atmospheric stability is an important factor to take into account for air pollution studies. The temperature data at 850hPa relative to the surface can be used as a kind of stability criteria. We compared the temperatures at 850hPa level for one d ay before episode, during episode, and days after the episode as T_{e-1}, T_{e-o}, T_{e+1} respectively. A considerable temperature rise had started to occur at the 850hPa level over Ankara of the first and the second episode day. The maximum frequency is 92 for $T_{e+1} \geq T_{e-o.}$ The condition of $T_{e-o} \geq T_{e-1}$ also corresponds to 67%. This result could be related with warm air advection or subsidence conditions. In short, the temperature at 850-hPa level may be attributed as an indicator of the on set of episodes.

Inversions

Surface inversions are important atmospheric conditions as far as the dispersion of pollutants and air pollution levels are concerned. These limit vertical mixing pollutants depending upon their intensity, thickness and the base of the layer. In this study inversion base heights and their frequencies are classified with temperature differences for the episode days. As expected, surface inversion represents the episodic conditions with the heighest values (the maximum ratio is 75.8%). Nocturnal surface inversions occurred for 71% of the inversions with a 250meter depth. Elevated inversions lie mainly in 250-750 meters corresponding to 60.5% for episode days. However, the number of frequencies for exceeding 750m inversion depths is negligibly small during daytime. Besides, the most prominent intensity class is 0-2.0^oC and 2.1-4.0^oC for nighttime conditions with a total percentage frequency of 65.3. The average SO_2 concentration has been also found as 404 $\mu g/m3$ during these conditions.

Relative Vorticity

In international literature, relative vorticity has been defined as a better diagnostic tool for weather analysis (Bluestin, 1993 and also Pissimanis, 1991). In this study, relative vorticity of ξ, 850mb, 700mb and 500mb values for both nighttime a nd daytime episodes were calculated to estimate the beginning of air pollution episodes or onset of the episodes (Sahin, 1999). An examination of nocturnal relative vorticity advection on the 500, 700 and 850 -hPa levels showed 74% of the total values are negative for 0200 LST. A total of 26 episodes for both daytime and nighttime conditions had negative vorticity occurring with 71% at 850hPa level. The highest negative values are found at 850 hPa with 83% and the lowest negative values are found with 63% at 500 hPa. The percentage of relative vorticity at the first day of episodes is the highest at 850hPa level with 79% and 73% in both nighttime and daytime respectively. Thus, a direct relationship may attribute to the state of becoming negative relativ e vorticity and the onset of the episode.

Concluding Remarks

This paper describes meteorological conditions and air pollution episodes in Ankara. For this study, meteorological conditions and air quality data were investigated by considering episode criteria. High episode levels were generally associated with tending to increase the existence of weak surface pressure gradients.

General tendencies were found for the temperature of 850hPa level as follows:

1. Up to one day before the onset of episode , temperature is decreased.
2. Following the first day of episode, temperature are increased.
3. Temperature continiuty is increased at the second day of episode.

Surface inversions also have an important role on the rising air pollution levels in the city. An examination of relative vorticity to estimate the beginning of air pollution episodes or onset of the episodes was made. The results of nocturnal relative vorticity at the 500, 700 and 850hPa pressure levels showed 74% of the total relative vortici ty values were negative. The percentage of relative vorticity at the beginning of episode period is maximum at 850 -hPa level with 79% and 73% for nighttime and daytime respectively. As a summary, the state of becoming negative vorticity at 850 hPa, and 85 0hPa temperature and the inversions, tend to be an indicator in production of episodes. The worst air pollution episodes in Ankara are associated with anticyclonic conditions and warm air advection.

7. GURME ACTIVITIES

A few initial activities initiated under GURME were discussed.

7.1 Passive Samplers

Gregory Carmichael reported on a new monitoring activity including passive samplers. This activity combines component of three separate studies.

1. A pilot study funded by NOAA-US Weather Service, to use passive samplers at selected WMO-GAW stations.
2. A continuation of the use of passive samplers as part of the RAINS-Asia Phase II project funded by the Japan Trust Fund at the World Bank .
3. A pilot study demonstrating the use of passive sampler at both regional and urban scales, funded by The Swedish Consultancy Fund at the World Bank .

These 3 elements are being coordinated together and collectively comprise a network of ~50 stations and are being done in collaboration and as a component of th e IGAC-DEBITS programme.

The project aims are: 1) to repeat a previous network for sulfur dioxide(SO_2) in Asia in background air; and 2) to extend the capacity to monitor more pollutants in background as well as urban air. The network will spread out to G AW's network in South America and Africa to provide a wide,exclusive and valuable data set that can be used for variety of purposes including model evaluation and inter-comparision with other methods. Several stations from previous studies in Asia and GAW's network will be used together with some newly established sites. Sulfur dioxide(SO_2), ammonia(NH_3) and ozone(O_3) will be monitored monthly at background sites and with short sampling peroids in urban site. The precursors of ozone such as formaldehyde(HCHO) and VOCS (volatile organic components) will be monitor in urban sites. This project began in August 1999 and will run for twelve months.

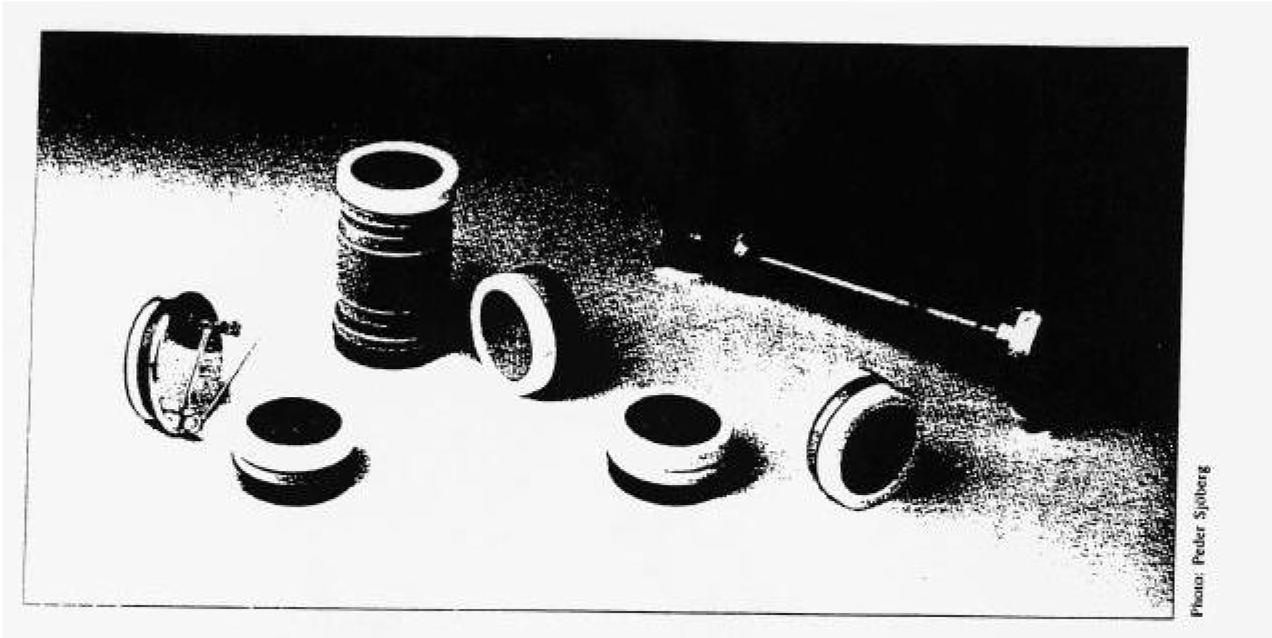


Figure 24. Passive samplers for various gases.

Background

Passive samplers are simple devices consisting of an impregnated filter or molecular sieve which preferentially sorbs the gas to be analyzed and a diffusion barrier to keep the sampling rate constant (usually an entrapped air volume). The samplers provide a time - integrated loading of gases and are ex cellent for field measurement since no electricity, pumps, or other supporting equipment are needed. The passive sampler was designed based on molecular diffusion of principles. The gas molecules diffuse into the sampler and are collected on an impregnated filter or an absorbant material specific to each pollutant measured and the sampling rate was kept constant by a diffusion barrier. To ensure that gas is transported to the filter by molecular diffusion, the inlet region of the sampler covering with a fi ne mesh (stainless steel mesh with a thread diameter of 0.08 mm and mesh aperture of 0.125 mm) that can minimize the convective transport. Therefore, the sampling rate can be calculated using Fick's first law of diffusion across the entrapped air volume fr om the perpendicular cross section area to transport direction and the distance that the gas has to diffuse.

Passive samplers have a variety of forms. For example, long and narrow samplers (e.g. diameter 10 mm and length 50 mm) provide a higher detection limit, while wider and shorter samplers (e.g. diameter of 20 mm and length of 10 mm) provide a lower detection limit. At the same ambient concentrations the latter sampler has 20 -fold increase in sampling rate.

It is crucial to impregnate the collective filter with proper chemical. It must be a solid and stable reagent that selectively and quantively chemisorbes the target species, and transforms it to another stable form in which other pollutants do not interfere is carefully selected.

The measurement of SO_2 is done using passive sampler with a sodium hydroxide (NaOH) impregnated cellulose filter. The sulphite is oxidized to sulfate during sampling and the sulfate amount is analyzed using suppressed ion chromatography.

For measurements of NO_2, a mixture of iodide,arsenite, and ethylene glycol is recommended as a sorbent. On the filter, NO_2 is converted to nitrite and then analyzed using FIA (flow injection analysis) spectrophotometry.

The measurement of NH_3 is done using a citric acid as an absorbent. Ammonia is converted to ammonium ion and then analyzed using FIA spectrophotometry.

The passive samplers have been developed for monitoring non -methane hydrocarbons (NMHCs). They are being used to measure C_6 to C_9 hydrocarbons in urban air quality monitoring networks in Europe. The sampler consists of swagelock fitting tubes with Tenax TA, a 35-60 mesh, and a porous polymer based on 2,6, diphenyl oxide adsorbent packing that can be directly analyzed by gas chromatograph. Further information can be obtained from the WMO report at http://www.cgrer.uiowa.edu/people/nthongbo/Passive/passmain.html

The new air quality measurement project

The network consists of 50 stations in twelve Asian countries (China, India, Indonesia, Japan, Korea, Malaysia, Nepal, Philippines, Singapore, Thailand, Laos and Vietnam), five African countries (Algeria, Cameroon, Ivory Coast, Niger and South Africa), five South American countries (Argentina, Brazil, Chile, Peru and French Guyana) and a European country (Turkey) will be used as background and urban stations. Two types of sites are identified: regional/global; and urban/sub-urban. At the regional/global sites passive samplers are used to obtain 1 year of data at each location using monthly exposure protocol. Ozone, SO_2 and NH_3 are measured. At many stations there is the opportunity to perform an intercomparison with active ozone measurements. At the urban/sub-urban sites additional species are measured, including VOCs. The intensive set of measurements will be conducted using shorter exposure times and will be done at selected intensive periods throughout the year. A map showing the measurement sites is presented in Figures 25 and 26.

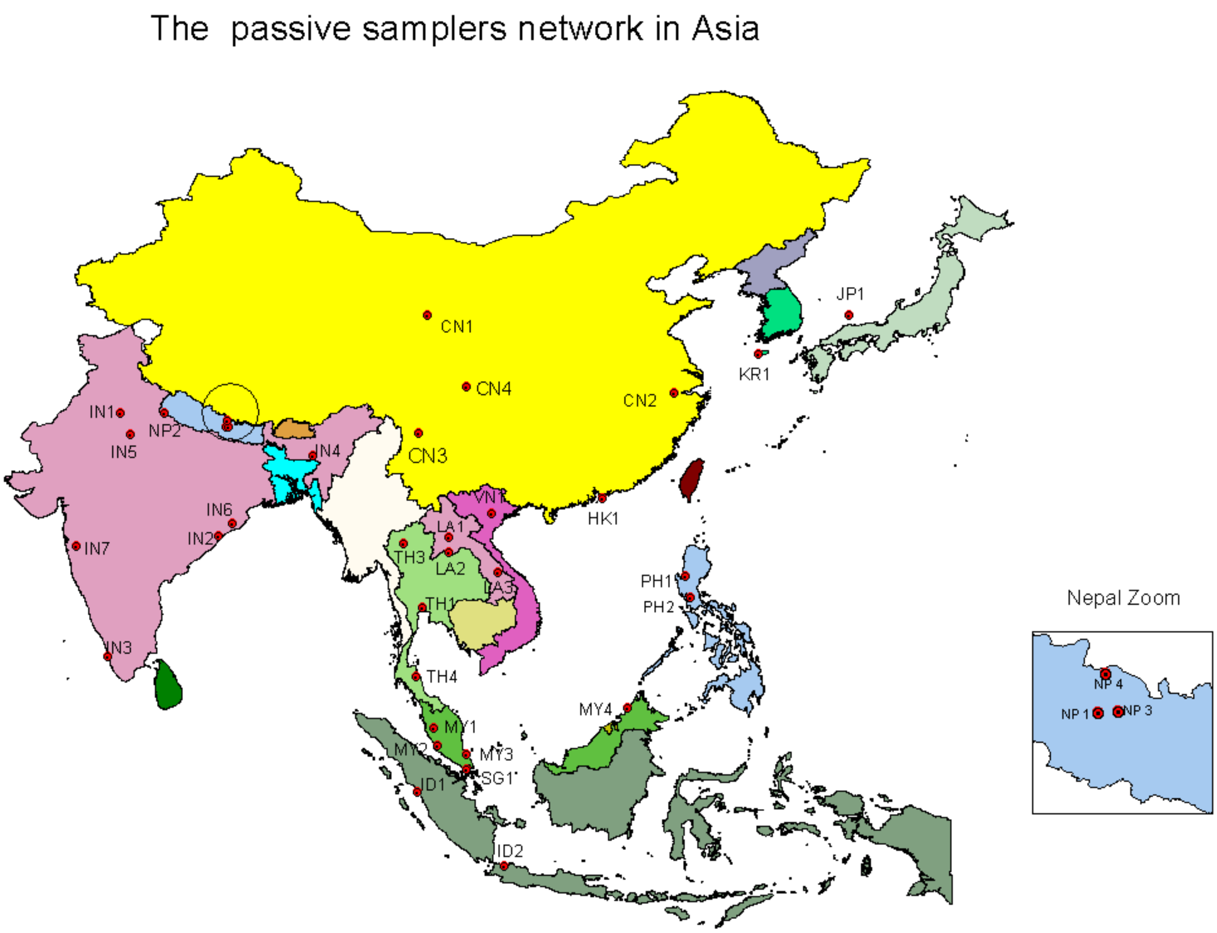


Figure 25. The Passive Samplers network in Asia.

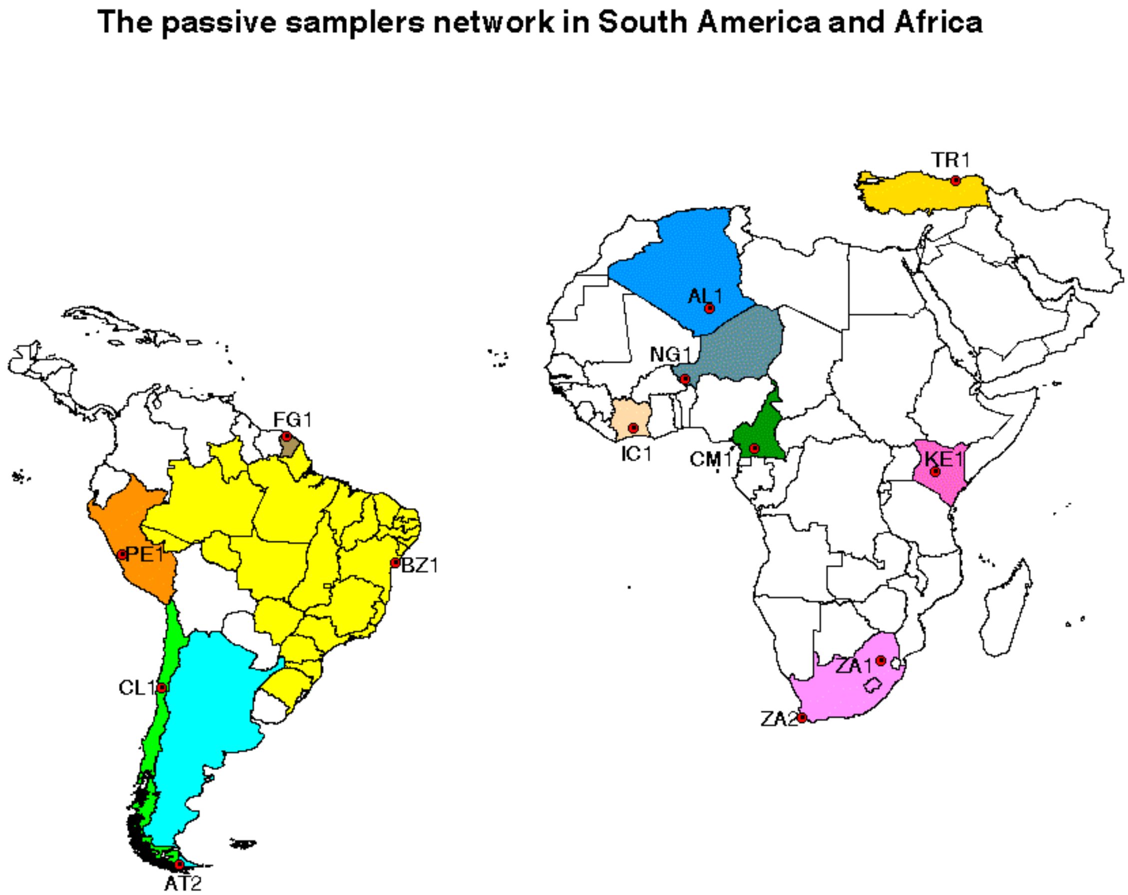


Figure26 . The passive samplers network in South America and Africa.

7.2 GURME Questionnaire

The WMO Secretariat sent out a questionnaire to all the WMO members, 185 countries and territories in all, in the summer of 1999 on the National Meteorological and Hydrological services (NMHSs) involvement in urban issues. By the time of the Beijing Workshop, 79 questionnaires had been returned, which is a very successful number. From the regions RA II and V a total of 22 questionnaires had been received.

The questionnaire requested information on the urban activities in general, on meteorological and air quality measurements, modelling, operational or research programmes/projects, and twinning/partnerships.

Of the NMHSs that had answered (in parenthesis the percentage for the RA II and V):

- 68% (91) are already involved with urban meteorology and air quality activities
- 93% (95) are interested in becoming more involved in urban issues
- 84% (91) are making meteorological measurements
- 86% (82) are interested in setting up meteorological measurements
- 57% (73) are making air quality measurements
- 80% (77) are interested in setting up air quality measurements
- 40% (36) have modelling capabilities
- 37% (45) have capabilities for air quality forecasts
- 20% (27) give out air quality forecasts on a regular basis
- 20% (41) are twinning/have a partnership with another NMHS

- 60% (55) are interested in twinning with a NMHS to receive advice
- 15% (18) have funds for the twinning activity.

A GURME contact person was identified by each NMHS in the questionnaire. This will prove very useful for the implementation of the GURME project. A report on the questionnaire will be prepared in the Secretariat.

8. BEIJING PILOT PROJECT: THE STUDY OF MECHANISM ON ATMOSPHERIC ENVIRONMENTAL POLLUTION IN CAPITAL BEIJING.

Representatives of CMA presented an urban environment research project which they have been devloping. This project titled: *The Study of Mechanism on Atmospheric Environmental Pollution in Capital Beijing* was presented as an example of the type of pilot project that GURME could help to promote. The project is summarized below:

Key scientific problems

- Environmental and geochemical cycling processes and behavior of atmospheric pollutant.
- The accumulative effect and tolerance of atmospheric pollutant in regional environments.
- The prediction theory of atmospheric environment.
- The principles of pollution control on regional scales.

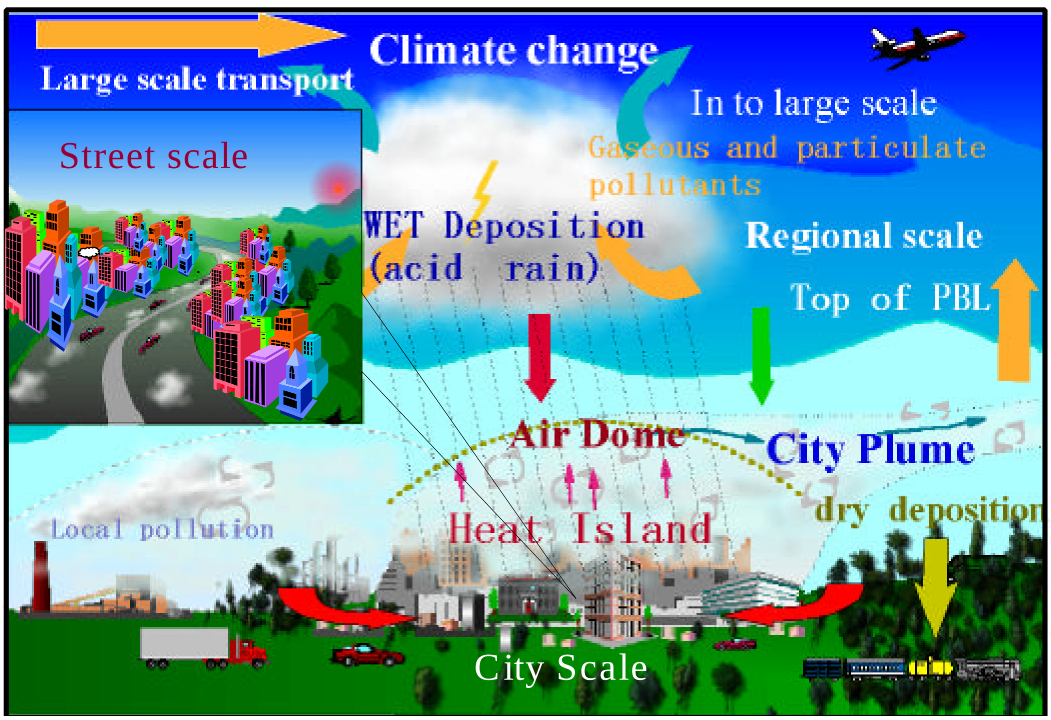


Figure 27. Air pollution macroscopic temporal and spatial d istributions and characteristics of atmospheric motion

Scientific objectives

- To reveal the forming mechanism of the regional atmospheric environment pollution and establish its prediction theory and model.
- To design the optimal scheme of monitoring and wa rning system of main pollutants.
- To foster the prevention strategies and new harnessing methods on regional environmental pollution.

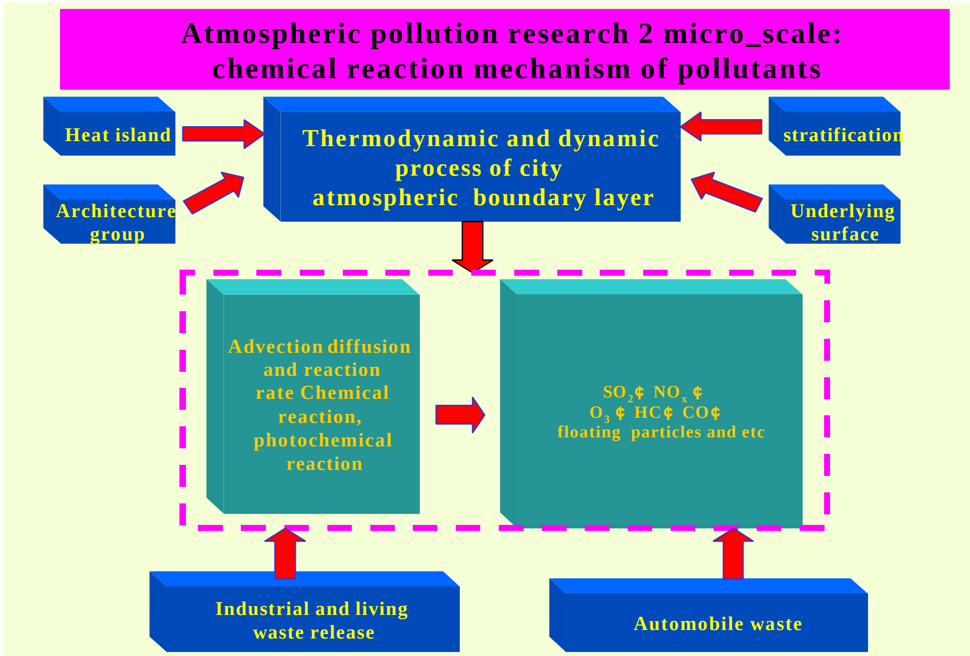


Figure 28. Chemical reaction mechanism of atmospheric pollution

Main topics

I. The mechanism of the formation of PBL pollution and its effects on the environment in Beijing

1.1 The city PBL structure feature and the dynamic and thermodynamic characteristics of pollution air dome and its formation and decaying mechanism.

1.2 The chemical process of pollutant formation for city air dome and its tempral -spatial variation mechanism.

1.3 Temporal-spatial distribution, affecting factors and variation tendency of ozone and its environmental effect.

II. The physical, chemical and ecological functi on of pollutant between atmosphere and planetary boundary layer

2.1 The chemical characteristics of dry and wet deposition, the physical and chemical features of aerosol and their transportation and transformation processes in Beijing.

2.2 Numerical simulation on the motion and transformation of main pollutants in atmosphere.

III. Formation mechanism of sand -dust and its impact on urban environment in Beijing

3.1 The temporal-spatial distribution characteristics of sand-dust, the physical and chemical characteristics of sand aerosol and its impact on urban environment, radiation and water sediment in Beijing.

3.2 The thermodynamic and dynamic conditions for the formation and development of fly ash and its forecast theory in Beijing area.

IV. Theory and method of city atmosphere environment pollution monitoring and forecasting

4.1 Scheme of optimal monitoring for atmospheric environment pollution.

4.2 Studies on high-resolution numerical prediction model for city air pollution and the scheme of its warning system.

V. Atmospheric environment pollution regulation and tackling technique in a comprehensive way

5.1 Assessment method of the impact of Beijing city planning and building on air-environment pollution.

5.2 Studies on atmospheric environment pollution tackling method and related social-economic sustainable development.

Project Framework

- The formation and its environmental effect of the urban atmospheric boundary layer pollution in Beijing.
- The mechanism of fly dust formation and its urban environmental influence in Beijing region.
- Physical, Chemical and Biological interaction and dynamical mechanism of pollutants between atmosphere and its planet boundary layer.
- Urban atmospheric environmental pollution monitoring and prediction method.
- Atmospheric environmental pollution management and comprehensive harnessing.

Approaches to the project

- Comprehensive monitoring and identification of pollutant.
- Experiment simulation and model.
- Controlling and Harnessing.

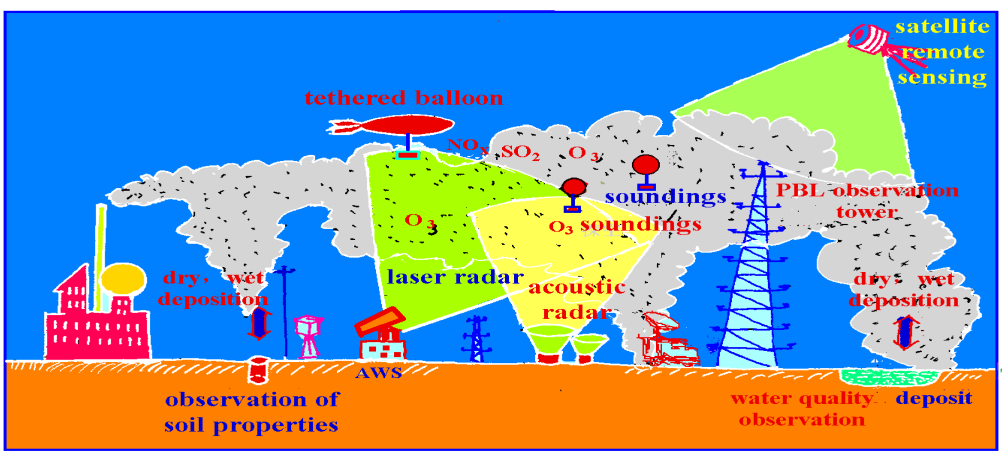


Figure 29. Urban atmospheric environmental pollution monitoring system

Figure 30. Atmosphere pollution forecast model

Creativeness and distinguishing features

- The chemical composition of pollutants, the feature of atmospheric structure of “the air dome of pollution in Beijing”,and the theory of its generation, dissipation and evolution.
- The strong non-linearity and strong heterogeneity between dynamical and physical processes in urban atmospheric boundary layer and the chemical reaction of pollutants, and their coupled theory.
- Study on pollutant dynamical migration and transformation.

9. DISCUSSION

Following the formal presentations, the workshop then focused on the task of identifying and prioritizing activities to be carried out under GURME. The workshop participants were divided into three working groups and each group was provided the same set of focus questions to discuss. The Working Group Questions were:

- *Question #1*: In what ways can GURME assist National efforts to address urban environmental issues, especially those related to forecasting (including those in support of early warning of pollution events, etc.) on shorter and longer time-scales, and research/assessment of urban environmental quality (e.g., air quality, heat/cold waves, etc.)?
- *Question #2:* What (special/additional) meteorological and air quality measurements are needed to support National efforts related to the above? In what ways (if any) does the design of measurements to support these efforts differ from that for environmental protection monitoring? What guidance should GURME provide in regards to such measurements?
- *Question #3:* What are the National modelling needs in regards to early warning and forecasting of urban environmental quality? What are the ways in which GURME can assist these efforts?
- *Question #4:* What National/Regional/International programmes are relevant to GURME? And what types of GURME linkages should be considered/pursued?

Each working group summarized their deliberations in a plenary session, which was followed by a general discussion. A compendium of the responses from each group organized by question is presented below.

Question #*1*: *In what ways can GURME assist National efforts to address urban environmental issues, especially those related to forecasting (including those in support of early warning of pollution events, etc.) on shorter and longer time-scales, and research/assessment of urban environmental quality (e.g., air quality, heat/cold waves, etc.)?*

a) GURME should focus on capacity building in the areas of problem definition, optimizing a monitoring programme based on a balance of measurements and modeling, and quantification of the economic benefits of improved air quality for all relevant compounds. GURME should identify and focus on problems with solutions, and the use of early warning as a policy tool. They should work closely with WHO in helping to quantify the economic and health benefits of improved air quality.

b) The programme needs to build awareness with stakeholders and customers, with a focus on compliance, trend analysis, industrial siting, and integration with environmental monitoring and forecasting.

c) An import role of GURME should be in the area of training and interaction with universities. One strategy is to promote training within universities, which in turn can sustain an educated workforce and encourage collaboration in environmental problem solving.

d) GURME should encourage via incentives within the responsible organizations to construct joint cross-agency activities, which bridge the meteorological services with the environmental agencies. In many countries this is not a structural problem. In other countries, a joint group, with joint management would be needed. A common data base derived from a joint activity would be a desired outcome.

e) GURME should promote the use of the Internet, to catalog all measurement and modeling techniques, with examples of successes, failures, and various degree of applications for new measurement techniques and models.

f) GURME should create a web-site for use as a forum for the exchange of information.

g) It is important to recognize that many Meteorological Services are not aware or convinced of the importance of GURME. Thus there is a need for GURME to build awareness and to advise the services of what role they can play in urban air quality monitoring and forecasts.

h) There is also a need to educate the public at the local and international levels of the role that Meteorological Services play in helping to manage air quality.

i) There is a distinct need for the development of guidelines on measurements and models.

j) There is also a need for awareness building in relation to the usefulness of air quality forecast information. The links between health and air quality on day-to-day times scales is not always appreciated.

k) GURME should consider providing guidelines to the national meteorological and hydrological services (NHMS) for the model characteristics, type and verification.

l) GURME should define the model forecasting for both short term or long term applications.

m) Research methodology should include links that integrate the development of meteorology to air quality components.

n) GURME should help undertake studies (like Country studies) to build awareness. Elements of these studies should include: capacity building, guidelines, and assessments of current situation. Major coordination effort is needed.

o) GURME should also identify new ways to demonstrate the uses of new environmental systems, measurements, and advice. This could be done through showcase opportunities like at the Olympics.

Question #2: *What (special/additional) meteorological and air quality measurements are needed to support National efforts related to the above? In what ways (if any) does the design of measurements to support these efforts differ from that for environmental protection monitoring? What guidance should GURME provide in regards to such measurements?*

a) GURME should use the internet to create a common data base and archive. Both meteorological and chemical data should be included. In addition, meteorological indicators which relate episodes could be added as a separate matrix, including information on subsidence, vorticity, temperature, pressure tendency, etc., for use in statistical model development and/or as background for dynamic model development.
b) GURME should catalogue the different needs for various countries. Some countries have specific unique air quality standards, goals, targets, which are quite different from other countries. Strategies become partly dependent on the uniqueness of the air quality objectives.
c) GURME should provide quidelines for: network design; siting; parameter and measurement procedures; method of analysis, frequency of measurements.
d) GURME should develop a PC-based analysis package (similar to CLIPS).
e) GURME should promote the use of passive samplers, in order to optimize the number and placement of monitoring sites, and to determine representativeness. Passive samplers could compliment routine monitoring activities.
f) GURME should help to harmonize measurements and indices of air quality across SE Asia.
g) GURME should develop activities related to the verification of forecasts.
h) GURME should assist the NHMSs in special air pollution measurements (such as mixing height parameter measured continuously by use of acoustic radar) and also tropospheric measurements. GURME should also assist on the calibration of these systems.
i) GURME should encourage the NHMSs to provide wind profile systems for monitoring and forecasting purposes.
j) GURME should set rules and guidance for " inter-comparison, QA, QC, chemical analysis, and inter-calibration.
k) GURME should provide broad guidance, and traditional meteorological products should not be overlooked.

Question #3*:* *What are the National modelling needs in regards to early warning and forecasting of urban environmental quality? What are the ways in which GURME can assist these efforts?*

a) GURME should utilize a website to archive information on models, including updates, uses, limitations, applications, etc. In addition, it should include information on contact persons where individuals can communicate to provide feedback to users and potential users on specific models.
b). The website should include emissions information. While GURME's role should not include the development of emissions inventory, they should play a role in making that information availiable.
c) Many countries do not have air quality capabilities within their Services, so there is a need to build that capability. Perhaps starting with statistical models that run off of National Weather Prediction output.
d) There is a need for some services to become involved in monitoring before they get involved in modeling.
e) GURME should recommend and define problem types for model users.
f) GURME should help to arrange for training and educational effort to improve model capabilities.

Question #4: *What National/Regional/International programmes are relevant to GURME? And what types of GURME linkages should be considered/pursued?*

a) GURME should look at at other WMO projects such as CLIPS as a good model for capacity building, development of software, training, WCRP for relevant modeling modeling activities; TRUCE etc.
b) There are many scientific programs focused on various aspects of urban environ ments that GURME should learn about and consider making linkages to including: UCAR/MIRAGE, IGAC, EURO-TRAC (Saturn), European Environmental Agency (dispersion tool box), TRUCE; The World Bank -- RAINS-Asia, Mega City studies; ACE-ASIA; NASA -- PEM WEST experiment, etc.
c) There is a need to formalize the relationship and demarcation between GURME and PARTS;
d) GURME should help the NHMSs establish linkages to data and meteorological centres.
e) GURME should establish links between Regional and International progra mmes such as UNEP, IGAC, WHO etc.

10. WORKSHOP CONCLUSIONS

Through presentations and working group deliberations, the following conclusions were reached:

(a) Many NMHSs have a breadth of activities related to urban environments, and these activities include a variety of meteorological and air quality measurements, and modelling and forecasting activities ranging from meteorological to chemical, and statistical to dynamic; while others are at a very early stage in developing these activities. Results from the GURME survey of NMHSs presented at the meeting indicated substantial interest in urban environmental issues within many of the Services.

(b) GURME offers significant opportunities to assist NMHSs in their pursuit of urban initiatives; but also faces important challenges. These challenges are largely related to the fact that the responsibility for urban environments often falls within several agencies. Thus there is a need to find ways to effectively co -ordinate activities with other agencies. In addition NMHS's urban activities need to be conducted in the context of National social/economic priorities. There is a clear need for capacity building in the areas of problem definition, optimising monitoring programs based on a balance of measurements and modelling, and quantifying the economic benefits of improved air quality for all relevant compounds.

(c) GURME needs to consider the regional context of urban influences in its planning. For example, the impacts of urban activities are not limited to air quality, but include such issues as water resources (through deposition). In addition, regional influences can profoundly influence urban environments (e.g., smoke in SE Asia and dust in East Asia).

(d) There is a need to assist NMHSs in providing air quality services of high quality. One aspect involves enhancing capabilities to provide meteorological and air quality forecasts of urban environments. Forecasting is an important focus since it builds upon traditional strengths of the NMHSs in terms of meteorological forecasting, and helps to define GURME programme boundaries and to concentrate efforts. This need also entails measurement efforts that support operational and verification aspects of forecasting, and performed in co-operation with appropriate agencies.

(e) Passive samplers offer a variety of valuable applications in urban environments. These include enhancing a suite of species measured, enhancing/providing spatial resolution of the measurements, and in selecting/evaluating appropriate locations for monitoring s ites.

(f) GURME offers an excellent opportunity to strengthen co -operation with important WHO activities, such as the Air Management Information System (AMIS).

11. WORKSHOP RECOMMENDATIONS

The following recommendations were forwarded:

1) GURME should assist NMHSs in providing air quality services of high quality. A spectrum of activities should be pursued. These should include activities such as: illustrating and promoting the linkages between meteorology and air quality; building awareness with end - users (customers) through applications related to compliance, trend analysis, and industrial siting; and providing opportunities for twinning and facilitating expert assistance.
2) GURME should assist NMHSs in developing urban-environmental forecasting capabilities by providing guidelines on available models, conducting inter-comparisons, and facilitating training activities. GURME should organize a workshop focused specifically on forecasting, with emphasis on presenting the spectrum of forecasting tools, ranging from meteorological to chemical, and statistical to dynamic, and an appropriate uses (including examples of model uses and limitations).
3) In the area of urban measurements GURME should focus specifically on those that support urban forecasting. This focus may require different measurements than those at present. GURME should formulate guidelines to: better define meteorological and air quality measurements (including contemporary techniques to obtain vertical structure; i.e., wind profilers, and satellite products); to help optimize the number of and placement of monitoring sites, and which measurements are needed at each site. Activities should include making available guidelines, assisting in QA/QC analysis, inter-calibrations, and extending these efforts to include key meteorological parameters.
4) GURME should promote the use of passive samplers to augment chemical measurements in urban-environments, to aid in site selection, and provide added spatial resolution in support of model evaluation.
5) GURME should fully utilise the Internet, and do so though the development of GURME Website designed to assist in its activities. These activities could include a catalogue of appropriate measurement and modelling techniques, with examples of successes, failures, and various degrees of applications for new measurement techniques and models, and as a forum to exchange information on a variety of issues is encouraged. Furthermore GURME should consider utilizing the Internet to create or link to common data bases, and data archive for those parameters of interest to GAW and WMO, and that includes both meteorological data and chemical data. Such an activity should be done carefully to avoid unnecessary duplication and should include links to other existing data bases. The GURME web site should also house archives and updated information on models, including examples of use and limitations, and contact person information for each model, where the contact person would provide feedback to users and potential users for specific model s.
6) GURME should promote a series of pilot projects to demonstrate how NMHSs can successfully undertake/expand urban environment issues. The Chinese CMA "Beijing project" presented at the workshop represents an excellent example. GURME also needs to consider other ways to promote its activities. These could include highly visible studies such as an up-date to the UNEP/WHO *Air Pollution in the MegaCities of the World*, showcasing new technologies at appropriate conferences, and developing illustrative examples .
7) GURME should pursue linkages with National/Regional/International programmes (e.g., Environmental Agencies, Municipalities, International Global Atmospheric Chemistry (IGAC) programme, etc.), in addition to other WMO programmes. The success of GURME acti vities will rest heavily on these linkages.
8) GURME should pursue efforts to enhance the already strong links between WMO and WHO. A strong co-operation will help to convey that meteorological, health and

environmental agencies can and must work together in the successful management of urban environments.

9) WMO needs to identify ways to facilitate NMHSs initiatives related to urban environments. These will include twinning relationships, facilitating the use of experts, as well as pursuing additional funding channels (e.g., such as The Asian Development Bank and The World Bank, through such programmes as their *Clean Air Initiative*)

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APPENDIX ___
GURME QUESTIONNAIRE

NMHS: ________________________

GAW Urban Research Meteorology and Environment (*GURME*) Project

This is an informal questionnaire, intended only for the WMO Secretariat use for planning the *GURME* project.

Questionnaire on existing/required activities of NMHSs
Please circle correct choice

A. General

1. Is your NMHS involved with urban meteorology and air quality activities?
   Yes No
2. Is your NMHS interested in becoming active on urban meteorology and air quality issues?
   Yes No
3. In which area would you be especially interested to cooperate in GURME?

B. Meteorological Measurements

1. Does your NMHS have meteorological measurements in urban areas?
   Yes No
2. If yes, in which cities and in how many locations per city?
3. Is your service interested in setting up meteorological measurements in urban areas?
   Yes No
4. Do you know of any other authority or institute making meteorological measurements in urban areas in your country?
   Yes No
5. If yes, specify:

C. Air Quality Measurements

1. Does your NMHS have air quality measurements (such as particles, UV, sulfur compounds) in urban areas?
   Yes No
2. If yes, in which cities and in how many locations per city?
3. Is your service interested in setting up air quality measurements in urban areas?
   Yes No
4. Do you know of any other authority or institute making air quality measurements in urban areas in your country?
   Yes No
5. If yes, specify:

D. Modelling

1. Does your NMHS have modelling capabilities for urban purposes, such as plume dispersion, 3D mesoscale, or statistical modelling?
   Yes No
2. If yes, which type?
3. Does your NMHS have capabilities for air quality forecasting?

Yes No

4. Is your NMHS giving out air quality forecasts on a regular basis?

Yes No

E. Programmes/projects

1. Are there operational or research programmes or projects on urban meteorology or air quality carried out in your NMHS?

Yes No

F. Twinning/Partnerships

I.

1. Is your government at the moment pairing or partnering with a country to give advice or assistance on setting up urban activities?

Yes No

2. Is your government at the moment pairing or partnering with a country that gives you advice or assistance on setting up urban activities?

Yes No

II.

1. Is your government interested in pairing or partnering with a country that needs advice or assistance on setting up urban activities?

Yes

2. Would you have domestic funds to support this activity?

Yes

III.

1. Is your government interested in pairing or partnering with a country that could provide you advice or assistance on setting up urban activities?

Yes

2. Would you have domestic funds to support this activity?

Yes

G. Identification

1. Name of your NMHS (country):
2. Contact person:
   Name:
   Address:
   Tel:
   Fax:
   Email:

WORKSHOP AGENDA

WMO RAII/RAV GAW Workshop on Urban Environment
Beijing, 1-4 November 1999

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