6. The Atmosphere

6.1. THE PROBLEM OF CLIMATIC CHANGE

6.1.1. Introduction

Because world climate is subject to large natural oscillations, the problem of determining man's impact on climate is very difficult (SMIC, 1971). Yet even a slight shift in the positions of the main anchoring anticyclones and storm tracks can have significant effects on man, changing for example, the locations of semi-arid zones and disrupting local food production patterns, although adjoining regions may benefit in some instances while most of the world may not be affected.

The solutions to these environmental riddles may be found through atmospheric-oceanic simulation models but the modellers require data on certain trace gases and particles, which affect the atmospheric radiation balance. They also require information on a number of indicators of ground cover, such as given in Table I (SMIC, 1971, pg. 180), which affect the heat balance at the surface of the earth, and thus the heat balance of the entire atmosphere. Although the study of climatic change requires a monitoring program in several media, the recommendations have been grouped together in this Section for convenience.

6.1.2. Monitoring of the Stratosphere

Although man has not yet interfered greatly with the stratosphere, there is a need for baseline monitoring in this upper part of the atmosphere. Because there has been no international consensus on what to measure, where to sample and how frequently, no Phase I GEMS monitoring program can be recommended. However, the following pre-programming activity is proposed:

Recommendation 1: It is recommended that WMO study the feasibility of developing an operational system for periodic monitoring of stratospheric constituents, seeking advice from both IAMAP and the 1974 GARP Workshop on the Physical Basis for Climate and Climate Modelling, and making appropriate recommendations in 1976.

6.1.3. Monitoring of the Troposphere

The pollutants of most significance for climatic change are CO_2 and suspended particulates. Particulate matter in the stratosphere, e.g., from volcanoes, is of equal importance of course, but most ground-based instruments (solar radiation and turbidity sensors) integrate over the entire depth of atmosphere. The CO_2 concentrations seem to be increas-

TABLE I: Supplementary monitoring required for the investigation of climatic change (SMIC, 1971).

Factor	*Frequency of Observation*	*Space Average*
Factors describing the state of the climate:		
Polar sea-ice cover (When a suitable technique is developed, should include thickness)	(at time of yearly minimum)	Hemispheres
Mass of glaciers	10 years	Selected glaciers
Sea level	10 years	Global
Groundwater volume	10 years	Continents
Biomass of trees	10 years	Continents
Natural freshwater bodies (area and volume)	10 years	Continents
Volcanoes (now being collected)	10 years	Latitudinal zones
Factors describing man's impact:		
Irrigation area	Yearly	Continents
Artificial lakes (area and volume)	5 years	Continents
Urban area	5 years	Continents
Fuel consumption	Yearly	Continents
Forest fires	Yearly	Continents
Supplementary factors not included in original table:		
Permafrost distribution	10 years	Continents
Subarctic and major alpine tree-lines	10 years	Continents

ing at the rate of about 1 ppm per year, which is somewhat less than would be predicted from the rise in industrial releases of CO_2, indicating that some of the CO_2 is going rather quickly into the biosphere and the oceans. There is some doubt about the absolute calibrations of the non-dispersive infra-red sensors that are being used; nevertheless, the fact that a number of investigators have independently found upward secular trends in CO_2 concentrations provides convincing evidence for their existence.

There have been secular increases in suspended particulate matter over some populated regions, particularly in summer (photochemical products) but Roosen *et al.* (1973) have found no detectable trend over the last half century at 13 high-altitude sites in North and South America and Africa (based on atmospheric transmission measurements obtained for the purpose of determining the solar constant).

Climatologists have speculated for many years that changes in CO_2 and particulate concentrations might significantly affect world climate. The effect is not easy to isolate, however, because changes in atmospheric heating and cooling rates set the air in motion, thus influencing cloudiness and other meteorological elements. A long-term program of monitoring and research is therefore required.

The WMO is organizing a global network of 10 to 20 remote baseline stations, for measurements of CO_2 (continuous), turbidity (daily), and the chemical composition of precipitation (monthly). The WMO regional network of 120-150 stations provides additional coverage of turbidity and precipitation chemistry but does not include CO_2 measurements: CO_2 concentrations at most regional stations would exhibit such large diurnal and seasonal cycles that it would be almost impossible to isolate secular trends.

International agreement on methodologies has been reached, and operations manuals have been written (WMO, 1971; WMO, 1974). The United States has agreed to provide a central repository for turbidity and precipitation chemistry data. The following is therefore recommended.

Recommendation 2: It is recommended that the WMO baseline and regional networks contribute data to GEMS Phase I on turbidity, the chemical constituents of precipitation, and (baseline stations only) the concentrations of CO_2.

The WMO has received a number of requests for financial assistance to establish baseline and regional air chemistry stations. Consistent with network density considerations (evidently two stations should not be located within a few kilometres of each other, even though in different countries), these requests should be supported.

Recommendation 3: It is recommended that financial assistance for experts, fellowships, training, capital equipment and travel be provided,

to assist Member States where requested and required, for the establishment of atmospheric chemistry baseline and regional stations, consistent with overall network design.

6.1.4. Complementary Monitoring

In order to interpret the pollution data gathered in the WMO networks, rather detailed descriptions of the atmospheric and oceanic general circulations will be required. The World Weather Watch (WWW) will therefore be an essential supporting facility. In addition, the following recommendation is made.

Recommendation 4: It is recommended that the appropriate Specialized Agencies, seeking advice from COSPAR, SCOPE, SCOR, SCAR, COWAR and IAHS, develop internationally-agreed methodologies and operating procedures for monitoring the factors listed in Table 1, with the indicated frequencies of observation and space averages. As soon as inter-governmental agreement is reached on individual elements and indicators, monitoring can begin and can contribute to GEMS Phase I.

Information on ground cover, forest fire frequency, etc., is essential input to studies of climatic change, as well as to many other interdisciplinary environmental programs.

6.2. THE PROBLEM OF GLOBAL AND REGIONAL (NON-URBAN) AIR POLLUTION

6.2.1. Introduction

Some substances such as pesticides and fertilizers are released mainly in rural and forested areas. Other substances such as SO_2 and NOx are emitted from urban and industrial areas but are carried by the wind to the surrounding countryside. For example, the problem of acid rains and its effects on the forests of Scandinavia is well documented (Sweden's Case Study, 1971). Some of the source regions are several hundreds of kilometres away. There is also considerable evidence for photochemical oxidant damage to vegetation, rubber and nylon products 100 km or so downwind of large urban centres under particular meteorological conditions (strong sunlight, capping temperature inversions, etc.). Forest terpenes also participate in photochemical reactions.

Rural dust caused by ploughing, overgrazing and land erosion is at least a nuisance, while rural haze sometimes contains sulphur oxides formed from SO_2 by photochemical reactions at considerable distance from the sources. The CHESS studies (Shy and Finklea, 1973) indicate that exposure to suspended sulphates is associated with adverse health effects, more so than is exposure to SO_2 or total suspended particulate concentrations.

6.2.2. Monitoring Programs

The WMO regional network is a fundamental building block for regional air quality monitoring. The minimum programs should be expanded, however, to include substances and indicators linked to effects on human health and welfare. There should also be a related expansion of the baseline program as follows:

Recommendation 5: It is recommended that the WMO baseline minimum program be extended to include:

(a) analysis of monthly precipitation samples for mercury, lead, cadmium, DDT and PCB's;

(b) monthly monitoring for fluorcarbon II, a man-made gas that is a useful tracer for comparison with substances that have both natural and man-made sources.

Subject to implementation of Recommendation 7, monitoring can begin and can contribute to GEMS Phase I.

Member States are also encouraged to undertake local supplementary Research and Development monitoring programs at baseline stations: Aitken nuclei, SO_2, N_2O, NO, NO_2, NH_3, O_3, CO, CH_4, reactive hydrocarbons, particle size distributions, vertical distribution of particles, and total suspended particulates including sulphate and lead fractions. In a recent seminar held in Stockholm (Charlson, 1973), some precise

recommendations for tropospheric aerosol research (at both baseline and regional stations) are given, including information on feasibility of measurement.

Recommendation 6: It is recommended that the WMO *regional* minimum programs be expanded to include, where feasible,

(a) analysis of monthly precipitation samples for mercury, lead, cadmium, DDT and PCB's,
(b) continuous monitoring of oxides of nitrogen and oxidants at locations and during months when the average solar radiation is at least 400 langleys per day,
(c) collection of monthly samples of suspended particulate matter (or weekly, with subsequent combining of samples, at locations where the monthly loading is too great for the high-volume sampler to accept), with subsequent analysis for total suspended particulate and sulphate concentrations,
(d) continuous monitoring of SO_2 at locations and during seasons when there is a risk of vegetation damage.

The WMO Operations Manual Part II (WMO, 1974) includes information on some of the substances listed above. However, full implementation of Recommendations 5 and 6 will require preprogramming activities.

Recommendation 7: It is recommended that the appropriate Specialized Agencies convene an Expert Committee (with representation from IUPAC) to examine Recommendations 5 and 6, to seek inter-governmental agreement on methodologies and to prepare supplementary manuals.

Upon completion of the preprogramming activity, monitoring of the indicated substances can begin and can contribute to the GEMS Phase I program.

It will be noted that programs for monitoring heavy metals, DDT and PCB's have been largely limited to the analysis of precipitation samples. This is because the concentrations would be so variable in time and space at most regional stations that the observations would be difficult to interpret. Precipitation samples, on the other hand, tend to integrate over a rather large volume of air.

Junge and Scheich (1969) have suggested that H^+ in particulates is likely to have a direct effect on health and therefore is a much better indicator for epidemiological studies than either SO_2 or total particulate loading. Brosset (1973) has recently made a rather similar suggestion. The following recommendation is therefore made.

Recommendation 8: It is recommended that the appropriate Specialized Agencies, in cooperation with a few Member States, organize a pilot study, in which the acidity content of suspended particulates and health effects are monitored concurrently.

A number of scientists and expert committees over the last several years have noted the problem of obtaining precipitation chemistry samples on ships and on oceanic islands and coastlines, due to the interfering effect of sea spray. The following recommendation is therefore made.

Recommendation 9: It is recommended that Member States be encouraged to undertake pilot studies of the problems associated with obtaining precipitation chemistry samples on ships and on oceanic islands and coastlines.

6.2.3. Complementary Monitoring Programs

The World Weather Watch will provide useful interpretative information. In addition, data on radionuclides in the air and isotope concentrations in precipitation (See Section 12.1) wll continue to be valuable to atmospheric modellers, providing clues, for example, on inter-hemispheric transfer.

In epidemiological studies of respiratory ailments, a correlation is sometimes found with specific pollutants although the causative agent may in fact be pollen, grain dust or moulds. Because these small particles may sometimes travel thousands of kilometres, and because some of them (spores, rusts, etc.) may also cause extensive damage to crops, the following recommendation is made.

Recommendation 10: It is recommended that the appropriate Specialized Agencies organize pilot studies on aerobiology monitoring and related epidemiological networks for aeroallergin effects, noting the proposals contained in a recent Canadian Workshop Report (Environment Canada, 1973). It is also recommended that a few Member States be encouraged to host these studies.

6.3. THE PROBLEM OF URBAN AND INDUSTRIAL POLLUTION

6.3.1. Introduction

There are three broad classes of air pollutants:

a) substances occurring singly that have a direct link with health—asbestos, silica, fluorides, grain dust (asthmatics), carcinogenic hydrocarbons, etc.,

b) substances generally found together and denoted as a *reducing atmosphere*—SO_2, H_2S, smoke, CO, etc.,

c) substances generally found together and denoted as an oxidizing *atmosphere* (or photochemical brew)—O_3, NOx, hydrocarbons, PAN, CO, etc.

Chemical analysis for these pollutants, at the concentrations usually found in cities and industrial areas, usually presents no great difficulty, although some unsuspected interferences in the sensors may occur when the air stream contains several kinds of trace gases and aerosols.

The main problem associated with monitoring urban air pollution is the design of networks. There is a large space and time variability in cities, and concentrations can vary significantly at separation distances of only a hundred metres, particularly near busy traffic arteries. A substantial variation with height is also likely. There are, for example, cases of pollutants being released from fume hoods on the upwind side of a hospital and being carried around the building to re-enter through a window on the down-wind side.

The design of an urban air pollution monitoring network depends very much on the purposes to be served. If the objective is to control, the monitoring stations should be located in areas where the highest concentrations are likely to be found. If the objective is to determine trends over the decades, on the other hand, a reference site in an open park or cemetery is desirable, away from point sources and in an established land-use zone. If the purpose is to compare health effects of residents living in various parts of the city, a rather dense network is required, sufficiently dense, in fact, to permit the construction of isopleths with some confidence. Finally, if the purpose is to compare epidemological data from various cities, appropriate air pollution indicators such as weighted averages obtained from the isopleths must be found.

The use of annual mean values of air pollution concentrations will smooth away much of the variability, but the principal health or vegetation effects may be associated with daily or hourly peaks during episode conditions.

6.3.2. Monitoring Programs

The WHO has rightly decided to begin with a modest pilot program of air pollution monitoring at only three sites—"inner city-commercial", "inner city-industrial" and "surburban - residential"—in each of 16 cities. The pilot study will be limited to monitoring SO_2 (continuously) and suspended particulate matter (daily) or COH values (2-hourly). Monographs on analytic methods have been published but there is a need for further work on siting criteria. The following recommendations are therefore made.

Recommendation 11: It is recommended that an Expert Committee (with representation from SCOPE, IAMAP and IUTAM), be convened to establish criteria for siting air monitoring stations in urban areas.

Recommendation 12: It is recommended that pilot studies of urban air pollution be encouraged, with the inclusion, wherever possible, of cities for which multiple-source pollution models, emission inventories and

mesometeorological networks are available, thus permitting spatial inferences to be drawn from the initial 3-site monitoring grids. Finally, it is recommended that an operational proposal for urban air pollution monitoring be prepared in 1976.

Recommendation 13: To assist Member States, particularly in tropical and subtropical regions where there are relatively few data on urban air quality, funds should be provided for equipment, training courses, and site inspections.

The question of epidemological monitoring is equally important. However, because health effects involve all media, discussion will be postponed until Section 12.2.

6.3.3. Complementary Monitoring Programs

The interpretation of air quality data, particularly trends, requires supporting meteorological information. The WMO has traditionally emphasized the need for *representative* sites for weather observations, and few locations in cities have met their criteria. In addition, the special needs of aviation have encouraged the establishment of a great many airport observing stations. The following recommendation is therefore made.

Recommendation 14: It is recommended that the appropriate Specialized Agencies establish siting criteria for urban meteorological *reference stations* (i.e., stations in parks or other areas where land-use zoning is not likely to change over decades) and supporting mesometeorological networks for the guidance of Member States.