THE GLOBAL ENVIRONMENT MONITORING SYSTEM

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Selected works on Integrated Monitoring

NITED NATIONS ENVIRONMENT PROGRAMME

THE GLOBAL ENVIRONMENT MONITORING SYSTEM
OF THE
UNITED NATIONS ENVIRONMENT PROGRAMME

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PREFACE

The Global Environment Monitoring System (GEMS) Programme Activity Centre of the United Nations Environment Programme (UNEP) is responsible for coordinating United Nations endeavours in environmental monitoring, particularly of pollution, climate and renewable natural resources. These three fields are fundamentally different. Therefore, in order to tackle comprehensively and globally the problems of the effects of pollutants on man, his natural resources and the climate, it is necessary to integrate concepts, methods and logistics from all three.

Integrated monitoring is now defined as the repeated measurement of a range of environmental variables in a number of environmental compartments, such as water, soil, plants and animals (see page 2 of Document 1 for definition). It is a concept which is motivating international cooperative monitoring ventures and which may prove key in understanding and controlling the effect of pollutants on the environment.

GEMS feels it is important at this stage to make a compendium of the latest thinking on integrated monitoring, in order to provide under one cover the basis for future development of the concept and its associated methodologies.

CONTENTS

INTER-AGENCY CONSULTATION ON INTEGRATED MONITORING

Nairobi 14 - 16 January 1980

REPORT OF THE MEETING

I. OPENING OF MEETING

1. The meeting was opened at 10 a.m. on 14 January 1980 by Mr. F. Sella, Director of the Global Environment Monitoring System (GEMS) Programme Activity Centre of the United Nations Environment Programme (UNEP).

II. PARTICIPATION

2. The meeting was attended by representatives of UNEP, WMO and UNESCO, which are the three main United Nations organizations so far concerned with integrated monitoring. In addition consultants were present from Canada, China, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland and the United States of America (see Annex I).

III. BACKGROUND TO INTEGRATED MONITORING

3. Early in the 1970s the WMO Executive Committee suggested that it would be more efficient if member nations expanded the use of World Weather Watch stations established in their territory for the monitoring of background air-pollution (BAPMoN 1/ stations) to include pollution monitoring in other environmental compartments such as surface water and oceans.

4. In a resolution of the twenty-sixth Session of the WMO Executive Committee in 1974, Members were officially urged, for scientific as well as economic reasons, to establish "multi-media" monitoring stations and to include in the functions of such stations the monitoring of pollution in soil and biota.

5. Such multi-media monitoring was advocated on a number of occasions in WMO by the Soviet Union, where various relevant activities had been initiated during the latter part of the 1970s. The idea was further discussed in several sessions of the WMO Executive Committee Panel of Experts on Environmental Pollution, which recommended that the scientific and technical aspects of multi-media monitoring be examined in expert meetings or seminars.

6. A meeting of experts on siting criteria for BAPMoN stations was held at Mainz in 1976. A background paper on ecological monitoring was prepared by the Monitoring Research and Assessment Centre (MARC) at the request of UNEP and WMO (See Document 2), and the possibility of monitoring biota at BAPMoN stations was discussed.

7. In 1978, the thirtieth session of the WMO Executive Committee passed a general resolution about WMO activities in the field of environmental pollution. It was emphasized that data emanating from BAPMoN stations - in particular those monitoring in several media - would be useful for studying not only problems related to climate and its changes, but also many other problems concerned with the exchange of pollutants between different compartments of the environment.

1/ UNEP/WMO Background Air Pollution Monitoring Network

8. In December, 1978, multi-media monitoring was the subject of a symposium held at Riga, Latvian SSR, which was organized by the State Committee of the USSR for Hydrometeorology and Environmental Monitoring, and sponsored by UNEP, WMO and the Latvian Academy of Sciences. A number of papers on the problem were presented, and the scientific benefits of an integrated approach to monitoring of pollution at the background level were discussed. The symposium recommended that multi-media monitoring should in future be referred to as "integrated monitoring", and, in order to develop the required methodology, pilot projects should be organized in suitable ecosystems in countries which had shown special interest in the subject, e.g. the Soviet Union and the United States of America.

9. A Workshop on Long-term Ecological Monitoring in Biosphere Reserves, held at Oak Ridge, United States in October 1978, was sponsored by the United States Man and the Biosphere (MAB) Committee. It explored in some depth the theoretical and operational aspects of both multi-discipline and integrated monitoring in relation to their application within biosphere reserves.

10. An inter-agency consultation on monitoring in biosphere reserves and integrated monitoring was held in Geneva in September 1979 (see Document 3). A programme proposal for ecological monitoring in temperate broadleafed forests, preferably in biosphere reserves was discussed in some detail, and it was noted that an ecosystem approach to monitoring and research could provide a valuable background and data base for integrated monitoring. Since the USSR delegates were unable to participate, the September meeting called for the current consultation to be held in Nairobi in January 1980 to discuss further co-ordination of existing and proposed approaches to integrated monitoring and the relationship between integrated monitoring and monitoring in biosphere reserves.

11. A glossary of selected terms is provided with this document for clarification (Annex II).

IV POINTS ARISING FROM DISCUSSION

A. Definition of integrated monitoring

12. Integrated monitoring is defined as the repeated measurement of a range of related environmental variables or indicators in the living and non-living compartments of the environment, and the investigation of the transfer of substances or energy from one environmental compartment to another.

13. Monitoring becomes truly integrated when the measurements of different variables or of the same variables in different compartments are co-ordinated in time and space to provide a comprehensive picture of the system under study. The variables might include chemical substances (e.g. pollutants), geophysical processes (e.g. wind, ocean currents), biological processes (e.g. primary productivity) or other variables as may affect man, his natural resources and the climate.

B. Objectives and uses of integrated monitoring

14. Integrated monitoring is for the general purpose of comprehensive assessment and prediction of environmental states and processes. In particular, the objectives may include:

(a) The description of present environmental conditions;
(b) The detection of variability and trends;
(c) The determination of significant changes caused by man;
(d) The modelling and prediction of future environmental states and processes.

15. It is necessary for the data obtained from individual monitoring projects to be collated and standardized so that they will be useful to environmental managers and research workers. The uses may include:

(a) Climate prediction;
(b) Resource management;
(c) Pollution control;
(d) Environmental impact assessment;
(e) Research, such as the establishment of baselines, the study of pathways, global biogeochemical cycles and dose-response relationships.

C. Special features of integrated monitoring

I. Some specific outcomes

16. Integrated monitoring may lead, among others, to the following results:

(a) A general scanning for the presence of substances produces valuable data on baselines and trends and can give early warning concerning the distribution of significant substances;

(b) A specific investigation to trace the pathways of one or more substances from sources through the environment and its compartments and, where applicable, the food chains to specific targets, can give insights for improved monitoring and control measures;

(c) Such investigations of pathways may also contribute to the knowledge of the chemical, physical and biological components of the environment, to the understanding of biogeochemical cycles and thus particularly to the modelling of climate.

2. Location of integrated monitoring

17. It is recognised that integrated monitoring is cost-effective conducted at sites which meet the requirements and offer the facilities of the UNEP/WMO regional BAPMoN stations. These sites should preferably be located in biosphere reserves.

3. Applicability of integrated monitoring

18. Integrated monitoring may be appropriately conducted in any major biome and at any site representative of a major ecosystem important to man, either aquatic and oceanic (e.g. lake, estuarine, open ocean and coastal waters) or terrestrial (e.g. tundra, forest, grassland).

4. Integrated monitorint operations

19. The operational details of an integrated monitoring project must be specified with respect to siting criteria, frequency of sampling, data types, data collection and handling, analytical methods, and quality control. Useful guidelines and lists are given by Izrael' (Document 4), Munn (Document 5), Wiersma and Brown (Document 6) for pollution monitoring, and by the report of the inter-agency consultation on monitoring in biosphere reserves and integrated monitoring (Document 3) for renewable natural resources. However, operations will have to be worked out for specific integrated monitoring projects. The references are appended and should be used as sources for further detailed planning. The operations are carried out in the field by national services supported by, or in co-operation with, international agencies.

20. Integrated monitoring may be highly complex and costly at the outset. However, it is a valuable tool for producing information for management and control, and, as correlations are found, pathways understood, variability determined and transfer coefficients estimated, attention may be focused on monitoring of a few key elements at rationally established intervals.

5. Ecosystems and integrated monitoring

21. The philosophy and approach of ecosystem monitoring as outlined during the inter-agency consultation on monitoring in biosphere reserves in September 1979 (see Document 3) are compatible with both the objectives and operations of integrated monitoring. Such ecological monitoring can provide information on likely baseline states, trends and pathways against which to judge the significance of a change in the ecosystem. However, relating pollutant levels even to qualitative effects in the ecosystem may require experimental data. The data generated by ecosystem monitoring and analysis are essential to the understanding of pathways. For example, the estimation of biomass and productivity are necessary for the mass balance calculation of a pathway analysis.

6. Effects of deleterious trace substances

22. Understanding of the effects of pollutants on climate, ecosystems and man is the subject of research (e.g. epidemiological investigations) and experiments. Identification of both the target and the consequence of the pollutant acting on it may arise from chance observations or from routine monitoring which may detect changes in levels of a certain substance at critical points. Targets and consequences may also sometimes be pinpointed or predicted through experimental research under controlled environmental conditions (e.g. in the ecostat, microcosm or phytotron). This approach is very useful for estimating transfer rates of substances between environmental compartments, determining distribution patterns and assessing or estimating effects, for example, by using high dose levels and appropriate assumptions to extrapolate down to the levels observed in the field.

V CONCLUSIONS AND RECOMMENDATIONS

23. Integrated monitoring is an important research and management tool, and should be developed for environmental managers initially in conjunction with the UNEP/WMO BAPMoN stations in pilot projects.

24. WMO and UNESCO should inform Member States through their executive bodies of the objectives and uses of integrated monitoring as defined by this meeting, and UNEP should assist in the development and co-ordination of relevant activities.

25. Taking into account the recommendations of the September consultation as appropriate, a UNEP/WMO/UNESCO international pilot project of integrated monitoring should be established, which would, ideally, have the following characteristics:

(a) It should be sited in study areas which meet the requirements of the UNEP/WMO regional background stations and which are representative of ecosystems belonging to a mixed deciduous/coniferous temperate woodland type, preferably within biosphere reserves under the MAB programme;

(b) Recognizing that the Soviet Union has offered to participate in such a pilot project and that research very closely related to integrated monitoring has been conducted for several years in the United States of America, the pilot project should take advantage of existing co-operation and be linked to more than one study area, for example, one in the European part of the USSR and one in the eastern United States. The possibility of adding an appropriate study area in a third country should be explored.

26. The meeting recommends that steps be taken by the countries concerned to call on their MAB national committees and national meteorological services to finalize the choice of appropriate study areas for the project.

27. The meeting further recommends that a small technical expert consultation be convened at WMO headquarters during 1980 to formulate the operation details of the pilot project, as referred to in paragraph 19. This consultation would specify the necessary technical inputs for the particular study areas, define the data types and monitoring sequences to be followed, consider any experimental approaches which may be necessary, and finalize logistic and institutional details for the preparation of a UNEP/WMO/UNESCO project document for a project to be initiated in January 1981.

VI CLOSURE OF THE MEETING

28. After the customary and heartfelt exchange of courtesies, Mr. Sella declared the meeting closed at 1 p.m. on 16 January, 1980.

Nairobi
25 January 1980

ANNEX I

PARTICIPANTS AT MEETING ON INTEGRATED MONITORING

NAME	ORGANIZATION
Mr. Y. Anokhin	Senior Scientist of USSR State Committee for Hydrometeorology and Environmental Monitoring (GOSCOMGIDROMET)
Mr. R.E. Munn	University of Toronto
Mr. J. Port	Department of the Environment/London
Mr. F. Rovinsky	Head of Department on Monitoring Pollution (GOSCOMGIDROMET USSR)
Ms. J. Song	Assistant Chief Engineer, Department of Science and Technology, Environmental Protection Office of the State Council, People's Republic of China
Mr. B. Wiersma	US Environmental Protection Agency, Las Vegas, Nevada, United States of America
Mr. C. Wong	Staff member of Chinese Mission to UNEP
Mr. B. von Droste	MAB/UNESCO Paris
Mr. A. Köhler	WMO/ENP Geneva
Mr. F. Sella	Director, GEMS/PAC
Mr. C.C. Wallen	GEMS/PAC UNEP Geneva
Mr. M.D. Gwynne	GEMS/PAC UNEP
Mr. H. Croze	GEMS/PAC UNEP

ANNEX II

A GLOSSARY OF SELECTED TERMS

Definitions of selected terms which appear in the report or which arose repeatedly during the Meeting are provided below.

Background

An adjective referring to the state of a compartment of the environment (q.v.) in which levels or concentrations of substances are little or not at all affected by man's activities owing to distance from pollution sources.

Biogeochemical cycle

The cyclical passage of elements through the compartments of the environment (q.v.).

Compartment (of the environment)

One of the major components of the environment - soil, air, water, plants, consumers, decomposers - between which materials, energy, and hence pollutants may pass.

Ecostat, microcosm, phytotron

Terms for experimental chambers of varying sizes, or collections of such chambers, in which biological systems or parts thereof are emulated or replicated to determine the effects on biological processes (usually in plant systems) of differing degrees of exposure to extraneous substances or of controlled changes in the chamber's environment.

Ecosystem

A functional biological unit, which includes an assemblage of interdependent animals and plants linked by nutrient and energy flows, together with the physical and chemical features in a particular geographical area.

Inventory

A survey or its immediate product which indicates the instantaneous state of a system. Examples are: the current level of heavy metals in human blood, or the number of cattle in a particular area.

Monitoring

The process of collection of a time-series of data to measure trends as well as to understand how a system works. A major aim is to establish correlations between parts of the system (both internally and with exogenous elements) in order to make recommendations to management bodies on where and how to impose the most effective control.

Contd.

ANNEX II

Transfer rate

The rate (assumed constant) at which a substance transfers from one compartment of the environment to another.

Transfer coefficient

The ratio between the steady state concentration of a substance in two environmental compartments. It is used in equations to predict the total accumulation of substances in one or more environmental compartments (q.v.).

Baseline station

An observation site within the UNEP/WMO Background Atmospheric Pollution Monitoring Network (BAPMoN) which is not influenced by local and regional man-made or natural air pollution sources, so that surface measurements represent composition throughout the depth of the troposphere and for horizontal extension of the order of 1000 km at least. Changes in land-use should not be likely to influence collection of background data for several decades. The observation programme includes gaseous constituents (CO_2, O_3,CH_3,SO_2, NO_x,N_2O), aerosols (suspended particulate matter and selected physical and chemical parameters), the chemistry of wet precipitation (acidity, conductivity, pH, Na, Ca, Cl, SO_4, NO_3, $N4_4$, K, Mg and heavy metals) as well as turbidity and sun radiation measurements. The term "global" is also used instead of "baseline". Suitable sites usually are small islands and/or high mountain peaks.

Continental station

A station within the UNEP/WMO Background Atmospheric Pollution Monitoring Network (BAPMoN) which carries out a somewhat reduced observation programme compared to a baseline station, but which meets in principle the same siting criteria. It will usually be located in land masses at higher altitudes. The representativity of observations in time and space may be slightly less than for a baseline station. Continental and baseline stations together should cover all major biomes.

Regional station

The category of station within the UNEP/WMO Background Atmospheric Pollution Monitoring Network (BAPMoN), which forms the large majority of BAPMoN stations. It will in general be located within the surface boundary layer of the troposphere at a site representative for distances from ca. 100 to 1000 km. Local influences of man-made pollution or natural surface exchange must be absent or avoidable. The reduced observation programme (compared to a baseline station q.v.) includes turbidity measurements, wet precipitation chemistry and sampling of suspended particulate matter. A main purpose of the Regional station network is to determine typical levels of air pollutants and possible long-term changes in atmospheric composition within regions significantly influenced by man. At appropriate Regional stations, measurements will also be carried out in media other than air.

Document 2

WORLD METEOROLOGICAL ORGANIZATION

REPORT OF EXPERT MEETING ON SITING CRITERIA

(MAINZ, 26-28 OCTOBER 1976)

1. OPENING OF THE SESSION

1.1 The session was convened by Mr. G. Kronebach, representing the WMO Secretariat, in the office of Dr. C. Junge at the Max-Planck Institute for Chemistry in Mainz. He commented that the siting criteria for WMO's Background Air Pollution Network had remained essentially unchanged since their adoption in 1970. The task of this group was, therefore, to review each criterion to determine if it was still valid in the light of six years of experience. He concluded his remarks by thanking UNEP for providing the funds to convene the session.

1.2 Dr. R. E. Munn (Canada) was elected Chairman of the session. He noted that, in reviewing the siting criteria, the group had also to consider the siting aspects of monitoring in other media.

1.3 All experts present (except the Chairman) had participated in an informal WMO meeting convened at the Institute the previous day to review the ECE plan for investigating the transport of pollution in Europe. A list of participants is attached (see Appendix A).

1.4 The agenda, as adopted, corresponds to the major subject headings of this report and is not reproduced separately.

2. OBJECTIVES OF THE WMO NETWORK STATIONS

2.1 Before the group could review and comment on siting criteria for the WMO Background Air Pollution Network, it was agreed that the objectives of the network had to be redefined.

2.2 After a thorough review of the objectives as documented in WMO Operations Manual for Sampling and Analysis Techniques for Chemical Constituents in Air and Precipitation (WMO No.299), the group decided that there was one basic or fundamental objective:

To obtain, on a global and regional basis, background concentration levels of atmospheric constituents, their variability and possible long-term changes, from which the influence of human activities on the composition of the atmosphere can be judged. This will permit studies of:

a) Possible effects on climate,
b) Transport and deposition of potentially toxic substances,
c) The atmospheric part of biogeochemical cycles (including exchange rates).

2.3 Having defined the objectives of the network, the group then identified the various steps which had to be carried out to make the network a viable (on-going) project. These are enumerated below under the heading "Design of the system".

Design of the System

a) Establishment of siting criteria for three types of stations: baseline; regional; and regional stations with extended programmes,
b) Identify variables to be monitored,
c) Develop methodology for monitoring,
d) Arrange for standardization and intercalibration within the network (quality control),

e) Training component,
f) Publish data,
g) Evaluate data and develop improved methodology,
h) Review network design.

3. REVIEW OF EXISTING SITING CRITERIA

3.1 Having revised the original objectives of the network and set down a plan for achieving the ultimate goal of WMO in this endeavour, the group then carefully reviewed the existing criteria. The discussion and proposals which follow are restricted to achieving WMO objectives only.

3.2 Criteria for Baseline Stations

3.2.1 These criteria have been set down in paragraph 2 of the General Introduction of WMO Manual No. 299. In their discussions the group was aware of the problems involved when criteria must be formulated which have to remain valid for a long period. Some criticism has been expressed that the existing criteria are too stringent. In this regard, it was noted that criteria a) which states that there should be no changes in land-use practices within 100 km from the station could be relaxed for mountain stations well above the surface mixed layer. The group wished to retain criteria b) and c). The remaining sub-paragraphs d), e) and f) are not siting criteria and, rather, pertain to the operation of the station. They should be placed elsewhere in the Manual.

3.2.2 To further reinforce its stand - to retain the existing criteria - the group considered the siting criteria used in the last century to site meteorological and astronomical observatories. These observatories were considered to be located far from cities. In most cases, an inspection will reveal that they have now been enveloped by urban growth.

3.2.3 Another aspect of relaxing the established criteria concerns the amount of time that "clean" air is expected to pass over a station. The experience of countries operating baseline stations has indicated that, no matter how good the site, one can expect that a fraction of the data will be contaminated from local (or "nearby") sources. It was therefore decided to incorporate the material in Part II, paragraph 2.1 into the discussion. It was also agreed that, under all circumstances, sampling sites should be chosen so that regional contamination and the local effects of vegetation or of heating, cooking, generation of electricity and transportation involving the use of fossil fuels should be downwind during a minimum of 60% of the year.

3.2.4 Changes in the wording of the General Introduction, paragraph 2 (b) were deemed necessary. The idea that islands should not be under the direct influence of sea spray was agreed, as was the elimination of the word "major" to qualify population centres and highways.

3.2.5 The final selection of a site requires a careful evaluation of the levels of significant consituents of the atmosphere actually found at the site. To ascertain this, an elaborate programme of feasibility studies was required. Details on how to conduct a feasibility study should be described in the Manual. Some views on this appear in Appendix B.

3.2.6 The desirability of locating a baseline station in a UNESCO/MAB Biosphere Reserve or national reserve was suggested. This type of site would meet the siting specifications for a baseline station and, in addition, permit monitoring in the biota (see item 4). Other types of stations which might qualify were those established in IHP hydrological basins.

3.2.7 When discussing "Variables to be monitored" (see paragraph 1.3 Part II of the Manual), the group proposed the following breakdown:

a) Pollutants with potential effects on climate (e.g., carbon dioxide, ozone, aerosols),
b) Toxic substances (e.g., pesticides, reactive trace gases, heavy metals),
c) Substances useful for determining the atmospheric part of the biogeochemical cycles (e.g., nitrates, sulphates)

3.3 Criteria for Regional Stations

3.3.1 The criteria as described in paragraph 4 of the General Introduction were discussed. Since these criteria were formulated in 1970, important new aspects have become apparent. These concern the establishment of stations for various special purposes, for example, to determine the rate of development of urbanization. It was recognized that all stations established for various national purposes might not meet the WMO siting criteria for regional stations. However, it was suggested that Members could be invited to identify those stations in a national network which would fulfill the necessary criteria.

3.3.2 The Manual (paragraph 5, Part I) says that stations should be sited as much as 60 km from a large pollution source. The group agreed that experience has shown that this could be reduced to "40 to 60 km".

3.3.3 In paragraph 9, Part I, a forest clearing is proposed as an "ideal site for measurements of most atmospheric constituents". The group considered that a forest clearing would be a good site for measurements of the minimum programme of a regional station (i.e., turbidity and precipitation), but not for stations where other constituents are included in the monitoring programme.

3.4 Criteria for Regional Stations with Extended Programmes

3.4.1 The group proposed that comments be inserted between the paragraph dealing with this category of station and regional stations to explain the philosophy or "transition" from one type of station to the other. It would also mention the possibility and desirability of monitoring additional constituents at WMO regional stations as various national or international purposes may require.

3.4.2 The purpose of a regional station with extended programme would be to provide background level measurements which would be representative of a much larger area than a regional station. In this respect, it would closely resemble a baseline station.

3.4.3 Inclusion in the programme of additional constituents would however not qualify a station to be a regional station with extended programmes. In other words a regional station which was monitoring more variables than those of the minimum programme might or might not qualify as a regional station with extended programme; the key factor would be the degree to which it met the specified siting criteria.

3.4.4 The siting criteria concerning the location "above the surface boundary layer" was changed to "remote location, preferably in a mountainous area" (see paragraph 11 (a), Part II).

3.4.5 The sense of paragraph 3.1.3 of this report, which refers to the "60% criteria", should be incorporated into paragraph 12 of Part II. In addition, the words "normally can" should be replaced with "might". Reference to the material on selection of sites should also be made for these stations.

4. SITING ASPECTS OF MONITORING IN OTHER MEDIA

4.1 The expert group noted that the WMO Executive Committee on several occasions had passed resolutions to the effect that WMO background air pollution stations should as far as possible be sited to allow for monitoring of pollutants in other media than air, i.e., oceans, fresh water and biota.

4.2 For discussion of this problem, the group considered a document prepared in London at the request of UNEP by MARC and titled: Monitoring Requirements for Biological Systems (see Appendix C) and a document submitted to the WMO Executive Committee by the U.S.S.R. (see Appendix D).

4.3 It was concluded that there was nothing in the WMO criteria for siting of baseline stations and regional stations as discussed during the earlier part of the expert meeting which would make impossible the monitoring in other media provided suitable conditions for such monitoring would exist at the sites of the stations. It was noted, however, that for biological purposes intakes for samples of atmospheric chemistry constituents should be at least ten metres above the vegetation surface with a uniform fetch of 500 metres. This would make "forest clearings" mentioned in the present version of the WMO Manual (paragraph 9, Part I) quite unsuitable for siting purposes.

4.4 It was generally agreed that criteria for siting of stations for monitoring in other media need to be developed so as to make possible a comparison with the criteria developed by WMO for monitoring in air. It was clear, however, that monitoring in biota and ecosystems would be desirable at background air pollution stations in order to allow for a better understanding of the deposition of pollutants from the atmosphere. For certain pollutants, the level of concentration in the atmosphere at the background level might not be sufficient for monitoring with present techniques while it might be possible to follow trends of the build up of pollutants in soil and biota; in fact, a whole ecosystem can often be used as an indicator for changes of the baseline for pollutants.

4.5 The group considered the suggestions for variables to be monitored in air and other media at background air pollution stations as well as criteria for selection of such variables as presented in the MARC document (Appendix C). It was agreed that arrangements should be made by WMO for pilot studies in integrated monitoring to be carried out at some regional stations on the lines proposed in that document.

4.6 It was noted that certain ecological attributes of the region may be usefully employed to support the atmospheric and other criteria during the process of preliminary survey prior to choosing a suitable site for a regional station. The prevailing regime of airborne sulphur oxides and of acid rain is known to determine the species composition of the lichen flora of the districts. Similarly, epiphytic mosses, growing naturally or placed artificially in the region, accumulate airborne trace metals in proportion to prevailing atmospheric regimes. Lichen surveys and moss analyses can help by indicating representative sites where gradients for these airborne substances are least sharp. Likewise, trace metals surveys, particularly for Pb, Zn and Cd, of the top centimetre of undisturbed soils are also useful but much less sensitive than lichens and mosses.

4.7 The group listened with great interest to the presentation by Dr. Popov of the plans for integrated monitoring to be organized at some stations in the U.S.S.R. Two stations in Kazakhstan and in Siberia are planned for such purposes and the plans for monitoring of various variables are given in Appendix D which show great similarities with some of the proposals in the MARC document.

4.8 The expert group further proposed that WMO invite some countries with a number of regional stations already in operation to arrange on a pilot basis integrated monitoring at one of their stations located in an ecosystem of special interest; details about criteria for siting, variables, etc., would be drawn from the experience in the U.S.S.R. and the suggestions made in the MARC document.

4.9 The group further suggested that, at the appropriate time, the whole problem of organising integrated monitoring be considered within the framework of GEMS. In the meantime, it was proposed that WMO contact UNESCO and FAO to discuss problems of common concern in this area and to design suitable joint pilot projects in integrated monitoring which could be carried out in biosphere reserves or at WMO background air pollution stations. It was hoped that this could be done prior to the next Panel session.

5. SITING ASPECTS OF MONITORING ADDITIONAL ENVIRONMENTAL POLLUTANTS FOR SPECIFIC PURPOSES

5.1 The WMO Executive Committee has expressed concern about the need for a better understanding of the cycling of pollutants throughout the environmental media, including the meteorological and hydrological aspects of their transformation, long-range transport and pathways.

5.2 The group recalled that the newly drafted objectives now included studies of (i) the transport and deposition of potentially toxic substances and (ii) the atmospheric part of the biogeochemical cycles.

5.3 It was also noted that the recent APOMET technical conference urged that the following variables be included in the WMO network:

a) Pesticides and PCB's,
b) Reactive gases,
c) Aerosols,
d) Halogenated hydrocarbons

Sampling and analyses procedures for the above variables were also specified.

5.4 The group considered that stations established with the siting criteria as proposed could add any of these variables to their programme.

APPENDIX A

LIST OF PARTICIPANTS

G. Goodman	(MARC, U.K.)
C. Junge	(F.R.G.)
A. A. Khalil	(Egypt)
E. Meszaros	(Hungary)
R. E. Munn (Chairman)	(Canada)
V. A. Popov	(U.S.S.R.)
R. F. Pueschel	(U.S.A.)
H. Rodhe	(Sweden)
C. C. Wallen	(UNEP)
G. Kronebach	(WMO)
A. Köhler	(WMO)

SELECTION OF SITES FOR BASELINE STATIONS AND REGIONAL STATIONS WITH EXTENDED PROGRAMMES

(Revised paragraph 1.2 of Part II of the Manual)

The criteria for baseline stations and regional stations with extended programmes discussed in the general introduction of this Manual should be considered when choosing potentially suitable locations. The final selection of sites among all potentially suitable locations requires a careful evaluation of the levels of certain significant constituents of the atmosphere actually found at the site. A review of any past data collected in the vicinity of the site is an essential starting point for this evaluation. If this review shows no serious fault in the location, an interim sampling programme (feasibility study) at the actual site must be carried out. This programme must provide records of the daily cycle under different meteorological conditions and for all seasons of the year, documenting the levels of the key constituents and the variations in these levels, along with an appropriate supporting meteorological record. The choice of suitable constituents to be included in the programme will depend on the type of location considered. For sites in an oceanic environment measurements of the concentration of Aitken nuclei may be suitable. Other variables which can be used for this purpose are: the light scattering coefficient, the voltage of the electrical field and the chemical composition of precipitation and aerosols. For sites on a high mountain carbon dioxide may also be included. It can be expected that for certain periods of the day or for certain weather situations or wind directions, the site will be influenced by local or regional anthropogenic sources. If an evaluation of these preliminary data suggests that the site can provide background information for at least 60% of the time and that all considerations lead to the conclusion that this situation will remain long enough to warrant the installation of a station, and if, furthermore the geographic location of the station contributes to the global distribution of sites, the station may be considered part of the baseline network. A continual programme for testing the validity of the record for each site is necessary (see paragraph 2.1).

WORLD METEOROLOGICAL ORGANIZATION

EXPERT MEETING ON
SITING CRITERIA

FIRST SESSION, MAINZ, 26-29 OCTOBER 1976

PXM/Doc. 5
(18.X.1976)

ITEM 4

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MONITORING AND ASSESSMENT RESEARCH CENTRE

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MONITORING REQUIREMENTS FOR BIOLOGICAL SYSTEMS

A Discussion Paper prepared for WMO

by

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1. Introduction

Establishment of the WMO global network of baseline and regional stations for the monitoring of variables related to climate provides an opportunity to review how useful these might be as sites from which monitoring information related to living organisms and soils could be collected. A subject of this complexity covers many fields where current understanding is inadequate and where controversial views abound, so that the topic deserves a much more detailed technical report than is presented here. The present discussion paper may however be regarded as a starting point for a working session in which the range of problems and possibilities for biological monitoring can be explored.

Individual plant and animal populations and their characteristic species assemblages, which together with the supporting media (air, soil and water) typify the various ecosystems, can all be more or less valuable potential resources for man. These ecosystem components may also be sensitive indicators of environmental change. They may respond to chemical pollutants by accumulating the contaminant substance in amounts proportionally related to ambient levels or supply rates. On occasions, these amounts are more easily measured from accumulating biota or soils than they are by the direct measurement of air or water concentrations. Additionally, the performance of the various species (growth, behaviour, longevity, productivity, abundance and survival) may be affected favourably or adversely by various levels of chemical dosage or by meteorological changes.

Thus, a knowledge of the levels and flux rates of physical and chemical variables in the ambient environment is useful in following ecosystem response and change. In addition, a knowledge of certain physical, chemical and performance features of soils and living organisms is useful in characterizing overall environmental change.

2. Objectives

Considered in terms of feasibility and of biological requirements, the objectives are, accordingly:

(i) to assess what atmospheric variables (especially chemical variables) need to be monitored;

(ii) to assess what can be predicted in biological terms from such knowledge;

(iii) to determine what measurements (particularly chemical) in soils, water and biota and also what biological performance measurements are needed to indicate environmental or ecosystem states and trends.

3. Types of change in ecosystems

The problems of measuring physical and chemical variables in air, water, soils and biota, although often difficult enough, are relatively straightforward compared with the problems encountered when trying to measure performance characteristics of biota and ecosystems.

For any one species, the impact of changes in ambient physical or chemical variables can be reflected by an increase or decrease in one or more of the following: biomass; embryo (or seed) production; embryo (or seed) survival; growth; longevity; animal migration; mortality; mutation. In extreme cases, population explosions or extinctions result.

It is most likely that certain genotypes in the species-population will be affected by these impacts more than others (sensitive genotypes), so that selection pressures will change the frequency composition of the gene-pool by intra-specific competition. This may well lead to differential competitive relationships between species and hence to an alteration in the species composition of the whole ecosystem. This has three important implications:

(i) a change in one species can affect the whole ecosystem;

(ii) a change at the ecosystem level cannot readily be traced to a causal change at a lower level of organization;

(iii) as the species complexity of the ecosystem increases, the ease of interpreting or predicting change falls. Precise prediction is easiest in crop (monoculture) situations, and almost impossible in complex communities such as temperate and tropical forests.

The prediction of crop growth in a varying environment is becoming increasingly precise, using deterministic simulation models (Milthorpe and Moorby, 1974; Monteith, 1975; Thornley, 1976). Such models could be extended to include the impact of atmospheric contaminants (Mukammal, 1976; Waggoner, 1975) and other pollution sources and it is to be expected that only then will pollution work attain a high predictive value. Uptake of pollutants by plant canopies can be considered as analogous to other types of transfer processes, models of which are widely used in agronomy (Lake 1972; Monteith 1973, 1975). Work with pollutants both in the field (Garland, 1975; Waggoner, 1975) and in the laboratory (Bennett and Hill, 1973) has used this approach. Simulation modelling of the movement of pollutants through ecosystems is also conceivable, and this would facilitate prediction of the responses of other parts of the ecosystem to the pollutant, but much basic research is needed.

Changes in genetic constitution, by mutation or selection, are much less easy to predict (Bradshaw, 1976), and here it would seem there is no alternative to direct monitoring.

4. Criteria for selection of air chemistry variables for monitoring

The following criteria have been used to identify a potentially harmful contaminant (Goodman 1974), criteria 1 - 4 being the most important:

"(1) toxic in larger amounts (acceptable daily intake <ca. 100 mg/kg body mass)

(2) non-essential for life-processes (N.B. all active allochemicals)

(3) accumulates with age (i.e. incompletely excreted or detoxified)

(4) environmentally persistent (poorly biodegradable; thermo-stable in air below 200^{o} C)

(5) biochemically active (e.g. modifying: enzyme activity; protein synthesis, redox states)

(6) rate of sequestration (deposition in fat or bone, etc.) similar to absorption rate (i.e. pool of active chemical in tissues and body fluids)

(7) wide variation in toxicity with age or genotype or nutritional state (i.e. susceptible groups within population)

(8) environmentally mobile (i.e. relatively low boiling-point or

melting-point; relatively high vapour pressure at s.t.p.)

(9) does not form relatively stable (inert) complexes with organic matter, clay-colloids, sediments, acid soils

(10) pronounced increase in human environment in last 2000 to 3000 years or in environment of target species ~~during its last 100~~ generations"

It is important to bear in mind that measurement of chemical substances in ecosystems can be undertaken for two purposes:

(i) to assess their potential for harm to that ecosystem;

(ii) to use the measurements as an indication of the partitioning and turnover in the whole environment of the chemicals which are being injected into the biosphere and to which it is committed through time.

Accordingly, Baseline and Regional Stations should adopt two criteria for the selection of an air chemistry variable to be monitored:

(i) If it occurs at rural sites (say, 100 km from source) at levels more than 0.1 of those shown to produce frank effects on plants or animals, it should be monitored.

(ii) If it occurs in rural sites at atmospheric levels which either cause accumulation in plants in concentrations above 0.1 of those known to harm animals or will become concentrated in food chains to levels affecting target animals, it should be monitored.

The need for backup research is illustrated by the fact that present data on harm levels are not sufficiently comprehensive or comparable to enable a rigid application of these criteria. In table 1 literature references to 'rural levels' have been applied irrespective of distance from source. The figures for distance and level are open to alteration; 0.1 has been chosen of the level known to affect organisms to allow for (a) possible increases in pollution level, and (b) uncertainty in the levels known to be biologically effective (safety factors).

5.0 Value of the existing programme at WMO Regional Stations

5.1 The present measurements

Measurements of precipitation considered at regional stations are adequate by the criteria outlined above (section 4). Atmospheric turbidity is of little use to the biologist, but direct measurement of total radiation (Szeicz, in Wadsworth 1968) is most important. At Regional Stations, the following measurements would be considered necessary: SO_2, O_3, NO_x, and particulates. Of the other variables mentioned, CO and metals do not normally fulfil the first of the two criteria and need not normally be measured. Although metals may be important after food-chain concentration in the ecosystem, they may be better monitored in other ways. SO_4 and NH_3 should be measured due to their relevance to the atmospheric chemistry of SO_2, although they do not fulfil the above criteria.

Physical measurements needed to make full use of pollutant data are radiation (total and quantum flux over the waveband 400 - 700 nm, the region of importance in photosynthesis flux), temperature, water vapour, and wind. The present regional programme covers these parameters, with the possible exception of photon flux.

5.2 Nature and presentation of the measurements

For biological purposes, intake to samplers for atmospheric chemistry constituents should be above the normal surface boundary layer, well away from vegetation which will absorb some pollutants (Martin and Barber, 1971; Bennett and Hill, 1973) and have a large (200 - 400 m) fetch over homogeneous vegetation (Biscoe et al., 1975; Lake, 1972). It is not clear if all these factors are at present considered; the suggestion of siting in 'forest clearings' (WMO, 1974) clearly does not fulfil these criteria.

The time over which measurements are integrated and thus data are presented is also of importance. Crop simulation models use measurements over 30 min - 1 h photoperiod (variable from ca. 8 - 16 h) and this is clearly an ideal to be aimed at. Both pollutants and associated physical measurements should be presented together, integrated over the same time period. Since it is not clear, for many pollutants, if plants respond to mean concentrations, peaks of concentration, or dose, if longer integration times than 1 h are used, a periodic sampling programme to determine the variability of the pollutant levels should be incorporated.

5.3 Use of the data

In order to predict the effect of a pollutant on an organism it is insufficient to establish a relationship between the level of the pollutant and growth. Not only would such a relationship rarely be sufficiently precise, it will also be restricted in use to the set of environmental conditions under which it was established, as environmental variables interact in a non-additive manner to affect growth (Milthorpe and Moorby, 1974). As suggested under 2. above, simulation modelling is the most suitable approach, for both uptake and effect of the pollutant.

Given the measurements listed above, integrated over as short a time as possible, we consider that the effects of the pollutant measured could be assessed in two ways, if backup research were available:

(i) deposition to the plant canopy;

(ii) effect on primary productivity.

Movement through the ecosystem, and effect on consumers, still need basic research, and direct monitoring must be considered here.

It is also hoped that biologists would use these figures as a standard reference in providing a perspective for their work. A facility for checking the performance of instruments used by biologists could also be usefully developed.

6.0 Supplementary air chemistry measurements

6.1 The supplementary measurements required

Using the criteria given in 4. above, ethylene (C_2H_2) is the only desirable addition to the total list suggested for regional stations. However, all of this list should be run at as many regional stations as possible.

CO_2 should be measured at all regional stations. It is a major substrate for plant growth, and even small changes in its level can appreciably affect the rate of photosynthesis and growth (Milthorpe and Moorby, 1974). To minimize local effects of vegetation on CO_2 level, intake to samplers should be well above the normal boundary layer and away from trees, etc.

Applying the second criterion given under 4. above, a large number of metals and organic compounds such as pesticides would have to be considered. Problems of atmospheric sampling and of tracing the fate of these compounds in the ecosystem indicate that they are best monitored by sampling target organisms where applicable (see 7.3 below).

6.2 Nature and use of the data

The comments under 5.2 and 5.3 above, apply.

7.0 Chemical measurements in other media

7.1 The need for chemical measurements

Chemical measurements in other media are essential in tracing the path and eventual fate of a pollutant in an ecosystem; they provide the key to the first stages in establishing causality where there are suspected changes in an ecosystem due to pollutants. Such information cannot at present be deduced from air chemistry measurements.

The media in which chemical measurements might be taken are: water in seas and oceans, water in rivers and lakes, snow and ice, soils, vegetation and animal tissues e.g. bones or livers. It seems likely that there will be at least some regional stations sited to cover all of these situations. A suggested study proposal ideally carried out jointly between MAB 14 and WMO is outlined in Annex 1 to cover measurements in other media. Projects similar to this are under discussion in UNESCO.

7.2 Variability and sampling

Whereas the fluid medium of air is able to pass over a static sensor, soils and vegetation are themselves static so that the sensor must be moved over them along transects or grids. This means that time resolution used for air variables must be replaced by spatial resolutions for soils and biota. Thus, from the viewpoint of soil characteristics, plant growth and animal performance, measurements of these media are less critical in time but much more critical in space. There is no value in reducing figures to a time interval smaller than a month or perhaps a season as only slow change is to be expected. Occasional situations may require more frequent sampling but since the work would involve extra manpower, this could presumably be provided as required by particular research projects. The siting of the regional station should attempt to minimize the spatial sampling errors but the variability is likely to depend largely on the material involved e.g. samples in snow and ice can be expected to be much more representative because of a previous history of mixing.

7.3 Useful measurements

The monitoring of pollutants in media other than air is necessarily more labour intensive and therefore less likely to be undertaken so extensively at regional sites. The need for particular measurements varies considerably, depending on the site and the material to be measured.

In each case, metals, pesticides etc. with long half-lives in ecosystems and which accumulate up food chains or in sediments etc. should be measured. Of the many possible, Pb, Cd, Hg, ΣDDT (DDT + DDD + DDE) and PCB's have been selected as particularly important. Additionally, sulphur should be measured to trace the fate of this major atmospheric pollutant. Under ~~each heading below, compounds of particular importance in~~ that environment are listed.

7.3.1 Oceans and seas

It can be envisaged that some sites will be on seashores, on islands or even on weather ships. It is outside the competence of the authors to assess the requirements for such sites critically and liaison with the programmes of international oceanographic agencies would be particularly appropriate in this field, e.g. IOC or IGOSS. There would clearly be problems in relating atmospheric measurements undertaken at a regional station to oceanic measurements because of the uncertainty of the source and transport of materials by currents.

7.3.2 Rivers and lakes

In these two systems, it is possible to envisage a regional station which could include a whole catchment area or less satisfactorily, an area known to be representative.

The required measurements would be flow rate or input into a lake, weekly measurements of pH, nitrates, nitrites, phosphates, salinity, monthly B.O.D. and temperature.

7.3.3 Snow and ice

Seasonal or yearly measurements of the following would be required: pH, nitrates and phosphates.

Evidence exists that abnormally high accumulation of certain volatile pollutants occurs in northern latitudes at sites where they have not been introduced by man. Chemicals such as ΣDDT, PCB, polynuclear aromatic hydrocarbons (PAH), organic phthalates and others may be volatilizing from hotter regions and condensing out in snowfall in colder areas. There is merit in a thorough study of the chemistry of pollutant accumulation at selected Baseline or Regional stations in polar latitudes or high snowy mountains of tropical regions. This might be carried out in collaboration with UNESCO/MAB which has included such a scheme at the planning stage of Project 14.

7.3.4 Soils

Seasonal measurements of pH, nitrates, nitrites, phosphates, K, Ca, Mg and Na.

7.3.5 Vegetation

Seasonal measurements of nitrates, phosphates K, Ca, Mg and Na. The artificial exposure of mosses, e.g. to monitor metals (Goodman and Roberts 1971, Roberts 1972) should be encouraged.

7.3.6 Animal tissues

Measurements in organs such as the bones or liver or fatty tissue of the metals and organic residues listed above from animals captured on a yearly basis. The animals should be representative of the various trophic levels of predator, herbivore, decomposer etc.

7.4 Planning for retrospective measurements

It is recognized that the extent of chemical analysis in the various materials listed in 7.3 may not be possible in a number of cases; it is therefore necessary to ensure that sites contain material which is itself a record of past pollution history. Tree rings can sometimes be used as a fairly accurate means of dating and modern microanalysis techniques allow each ring to be analysed for a variety of pollutants (Lepp, 1976). Sediments and ice-cores contain a history of past pollution. Pollen profiles can be used to give a good picture of the past vegetation of an area (Watts, 1973) and of pollution history (Lee and Tallis, 1973). Additionally there could be a programme of collection of material on a yearly basis to build up a bank which could be analysed retrospectively. Animal hair is an example; the yearly sampling of leaves from a particularly ubiquitous plant such as a moss or lichen could be another. There would have to be detailed consideration given to the particular material but the idea would appear to have much merit. It is especially difficult to assign a set of measurements that are likely to be of future use; this strategy would provide an insurance policy.

8.0 Biological measurements

8.1 The need for biological measurements

It was concluded above that air chemistry measurements cannot yet be readily used to assess:

(i) changes in complex ecosystems (2, 3, 4);

(ii) genetic changes (2.).

These therefore need to be monitored biologically. Additionally, there is the possibility that some parameters not yet appreciated are having an effect on ecosystems.

8.2 Variability and sampling

The apparent stability of a mature ecosystem and its apparent continuity with time, can conceal a rapid turnover of its component species-populations and accompanying fluctuations in their numbers and biomass. More fundamentally, in the time scale of quaternary ecology the so-called 'climax' vegetation shows continual change (Watts, 1973). Periodic introduction of new species into an established community is a major cause of perturbation and permanent change (Elton, 1957; Watts, 1973). Biological monitoring must therefore attempt to separate a possibly small pollutant effect from a noisy and drifting baseline, in the absence of any control observations. In addition, vegetation is geographically heterogeneous, in response to changing soils and climate.

Methods of ecosystem description take account of these factors, but at the expense of much time and effort in taking the measurements; nor is there any satisfactory means of ascribing causality to any changes. Detailed description of communities of populations of animals (Seber, 1971; Southwood, 1966) and plants (Dawkins, 1971; Goldsmith and Harrison, 1976) are still subject to controversy. Selection of a small number of species from an ecosystem carries the possibility that the chosen species are not representative of the whole system, and the probability that they will be subject to greater natural variability in time and space than the ecosystem as a whole. Further, genetic diversity of a population adds to the variability. Thus, dominant species often possess a wide range of tolerance to widely different physico-chemical conditions and therefore have poor diagnostic value.

It is only feasible to look for large changes in ecosystems, and monitoring at the single species level is too onerous a task. A possible exception is the use of carnivores at the top of a food chain - large predatory mammals and birds - as indicators of accumulating metals and pesticides, and other types of ecosystem disturbance.

8.3 Useful measurements

There are 5 basic types of measurement:

(i) mapping of community types

(ii) productivity

(iii) ecosystem composition (species diversity, abundance, age structures, etc.)

(iv) retrospective monitoring (see under 8.4 below)

(v) exposure of organisms for specific purposes

Aerial photography as a means of mapping can show changes in ecosystem type, particularly forest advance or retreat, and the use of infra-red photography can increase the information content of such an approach. It is a comparatively rapid method and provides a permanent and detailed record. This is a basic biological measurement that should be made at frequent (1 - 5y) intervals at Regional Stations; it would have the additional advantage of documenting changes in land use etc. around these stations. Its feasibility is being studied under the UNEP/FAO programme.

Productivity measurements need a good deal of time and personnel, are destructive (see various IBP method books) and thus could prove detrimental to the basic monitoring programme if large areas of vegetation were affected. For these reasons they are desirable only in very special instances.

Goldsmith and Harrison (1976) indicate that for long term effects of management etc. a suitable approach to option (iii) above is regular monitoring of performance and abundance in permanent quadrats. It is difficult to see how suitable sites could be selected in the present context. Dawkins (1971) details the exhaustive measurements necessary to monitor and predict forest growth. Measurements of the quality and consistency required cannot readily be made under the present programme. The identification of many species is still a major difficulty in many countries. Perhaps one or two dominant species could be measured in terms of density, age structure and performance, if suitable data could not be retrieved from aerial photographs (but see 8.2 above).

Exposure of plants and animals for purposes such as mutation rates (Aeurbach, 1976; Sutton and Harris, 1971) should be encouraged.

8.4 Planning for retrospective monitoring

The major problem with ecosystem mensuration is that specific problems require specific methods of data collection, and a programme started now may not help solve a future problem. Additionally, the time span of basic data will be short relative to natural variability if programmes start now. One solution to both of these difficulties is to preserve sites that accumulate information over many years, and which can be examined retrospectively in the future. Examples are: tree ring analysis, peat profiles and macrofossils, and plant pollen profiles. It is recommended that siting of stations includes areas suitable for such analyses.

9.0 Implications for siting criteria

9.1 Air chemistry and meteorological measurements

The prime need for biological purposes is to have a reliable set of background data against which measurements in biological systems can be compared. It is envisaged that the investigations will be subject to alteration in the face of particular requirements, but the basic measurements will retain continuity.

The air chemistry and physical measurements (detailed in sections 5 and 6 above) are regarded as being of greatest priority (that is, SO_2, CO_2, O_3, NO_x, PAN, C_2H_2 and particulates) together with radiation (total and photon flux), temperature, water vapour and wind.

The siting of regional stations must firstly conform to meteorological criteria; additionally, consideration of biological factors would lead to the following 5 criteria (and see 5.2 above):

(i) no changes in land use anticipated

(ii) no influences from local (10 Km) pollution

(iii) above the normal surface boundary layer and clear of trees etc.

(iv) site to be representative of the area

(v) a fetch of ca. 400 m over homogeneous vegetation

9.2 Measurements in other media

Measurements in other media have requirements which vary greatly, both between media and according to the complexity of the associated ecosystem. All the parameters said to be worth monitoring under sections 4 and 5 above, should be considered priority measurements.

Oceans and seas. Because of mixing, these are unlikely to present special problems. If the site is an island, criteria (i), (ii) and (iv) above must be applied.

Rivers and lakes. Those representative of a small catchment area should be selected; the catchment could then be taken as the boundary of the regional station. It will be essential to record flow rates in relation to concentration measurements.

Snow and ice. The area of the site could here be much smaller because it can be assumed that these media will have been efficiently mixed in the atmosphere; 5 km^2 is suggested as a minimum area.

Soils. It must be stressed that soils can be highly variable, and sites should be chosen to minimize this, or be of sufficient area to ensure that sufficient sampling will be possible. It should be noted that over a period of many years disturbance of the site may become serious. It is therefore proposed that a site has an area of not less than 10 km^2.

Vegetation. The site must again aim at uniformity and being representative of the vegetation type. To obtain a suitable area, it may be possible to use species/area curves (Greig Smith, 1964) and take an area containing a certain percentage of the species found in that ecosystem. The need for a minimum area because of possible damage from repeated sampling must also be considered, and a minimum area of 10 km^2 would again seem suitable. Monitoring sites should be chosen to cover examples of all the main global vegetation types.

Animals. One of the major problems in selecting a suitable area for animal studies lies in a definition of objectives. For example, are DDT or PCB's to be measured either in one or two common species, or in rare animals which may become extinct in the near future? The first alternative would be favoured as the territories of some animals are very large and opportunities to relate measurements in air, plants and animals will be decreased. It would seem a more practical proposition to select an animal common in an area, and to relate specific studies on rarer animals to this. Sites should be selected to include the whole migration range of the chosen species, to avoid external influences.

10. Conclusion

It is considered that measurements on pollution undertaken by WMO will be of immense value to biologists. It is urged that maximum integration with already existing programmes (e.g. MAB 14 and the IBP) be sought. Co-operation with already existing sites should prove useful in determining the precise areas and siting required of monitoring sites. Consideration should be given to creating an integrated site list so that wherever possible the WMO Regional Station is located inside a UNESCO/MAB Biosphere Reserve. It is also recommended that biologists be made fully aware of the opportunities which this sampling programme affords. It should become standard practice for work on pollution to include summaries of the relevant data from Regional Sites to set experimental work in proper perspective.

In preparing this report, several areas have been found where existing data are not adequate for rational decisions to be taken. It is to be hoped that a more detailed review of these areas will precede attempts at specific research projects aimed at changing this situation.

Table 1. Dispersal and air concentrations of some pollutants

pollutant	typical transport distance, km	typical rural concentration, ppb(1)	lowest air concentration with biological effect, ppb(1)
CO_2	throughout troposphere		any change
CO	no data	1000 - 3000(2)	1000 - 10,000(2)
SO_2	>100	20 - 50(8)	50(5)
O_3	>100	30 - 160(2)	50(3)
NO_x	>100	2 - 30(2)	15(3,6)
PAN	>100	0.5 - 3(2)	15(3)
particulates	ca.100(8)	20 - 50 ug m^{-3}(8)	no data(7)
metals; Pb	>100(8)	0.05 - 0.4 ug m^{-3}(8)	no data
F	>100	0.05(9)	1(10)
C_2H_2	no data	0.4 - 5(2)	10 - 1000(11)

Notes:

1 one part in 10^9
2 Eggleton in IRC (1976)
3 IRC (1976)
4 Mansfield in IRC (1976)
5 DOE (1976)
6 if SO_2 is present
7 the lack of data makes monitoring desirable in this case
8 Hey and Davies (1975)
9 Davison et al., (1973)
10 Davison and Blakemore (1976)
11 Mukammal (1976)

Where no reference is given, the judgment made on appropriate level would probably be generally accepted.

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Annex 1.

Outline proposal for a collaborative (MAB 14/WMO) Project

Pollutant dynamics and biotic response in ecosystems *

by G.T. Goodman

Introduction

1. The Project is intended to elucidate the uptake accumulation partitioning and loss relationships of selected environmental pollutants in ecosystems within the MAB biomes and WMO Baseline and Regional Stations. Ways will also be sought of characterizing any responses which the ecosystems may show as a result of pollutant impact.

2. The Project will be a collaborative effort over a fixed period of time. Any scientific group wishing to participate must be prepared to carry out a basic (minimum) programme according to procedures agreed beforehand by the Project Co-ordination Group (PCG). More elaborate programmes may be carried out which involve larger amounts of innovative research as they become more complex. This is particularly true of the highly complicated studies required to elucidate those performance features of ecosystem components (trophic levels, species etc.) which may best indicate and describe ecosystem response to various levels of pollutant impact. Any collaborating laboratory or scientific group can operate a programme at any predetermined level of complexity. The programme is hierarchical so that if a complex study is selected, all simpler studies must also be carried out according to the schedule agreed beforehand.

3. The two classes of pollutant selected for study are organochlorines and trace metals (see below).

4. Sites for study should be within the MAB biomes especially in UNESCO Biosphere Reserves or at WMO Baseline or Regional Stations where essential meteorological information is already available.

5. Collaborating Groups working at approximately similar Programme levels and with similar pollutant substances will be required to develop their programmes jointly by mutual information exchange leading to state-of-the-art reviews. These should be followed by draft designs for pilot-studies to be discussed and agreed at workshops prior to endorsement by the PCG and the start of the work itself. These must include sampling, analysis, intercalibration, data handling, and other techniques.

6. Project Components - The following are suggestions indicating how the structure of the Project may be designed. They should be regarded as a guide to thinking at the pilot-project design stage rather than as a fixed plan.

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* This proposal represents the author's views, based on his knowledge of the MAB 14 project and WMO interest in this area.

1. Pollutants

01 ΣDDT (DDT + DDE + DDD)
02 PCBs
03 Dieldrin
04 BHC
05 Heptachlor
06 et seq other O.C. cpas
11 Pb
12 Hg
13 Cd (these choices will have to be justified)
14 Ca
15 Mg
16 Na
17 Fe
18 Al
19 et seq other trace metals

NB Either 01 ΣDDT or 11 Pb is the basic pollutant. Others may be included as desired.

2. Biomes

01 Tropical Forest
02 Temperate Forest
03 Grazing lands
04 Arid zones
05 Aquatic ecosystems
06 Mountain ecosystems
07 Island ecosystems
08 Urban systems

These will need subdividing, e.g.

021 Coniferous
022 Northern deciduous
023 Sclerophyll
etc.

NB One ecosystem subdivision is the minimum programme.

3. Ecosystem components

01 Top predator (bird, mammal species etc.)
02 Soil (top1 cm & A layer mean)
03 Dominant herbivore

04 Dominant plant species

05 Litter

06 Earthworm or equivalent organism

07 Soil profile (A, B & C horizons)

08 Vegetation strata (tree, shrub, herb, moss)

09 Soil organisms

10 Sediments

11 et seq Other ecosystem components

NB1 01 Top predator and 02 Soil are minimum programme components

NB2 Each needs sub-dividing on tissue examined

e.g. for ΣDDT 011 Body fat
012 Pectoral muscle etc.

4. Pollutant processes

01 Pollutant level in ecosystem component

02 Pollutant interception by vegetation (dry and wet deposition)

03 Pollutant 'partition coefficients' between related ecosystem components on dry matter (DM), fresh weight (FW), volume (V) and per unit area (UA) bases

04 Pollutant loss rate per annum, on D.M. F.W., V. & U.A. bases

05 Pollutant degradation and/or transformation rates per annum on D.M. F.W., V. & U.A. bases.

06 Pollutant quantitative pathway dynamics study

NB 01 Pollutant level is minimum programme.

5. Sampling density

01 Low (20 samples)

02 Medium (100 samples)

03 High (100 - 500 samples)

04 Very high (>500 samples)

NB 01 low is minimum programme

6. Sampling frequency

01 Once

02 Twice

03 Full frequency as decided by PCG

04 Special studies eg Seasonal change study

NB 01 Once is minimum programme

7. Ecosystem description

01 Geographic location, aspect, Species list

02 Plant cover/abundance scales 8

03 Animal counts, historical data on site and former impact episodes

04 Ecosystem analysis using multivariate or other appropriate methods

05 Biomass study

NB 01, 02 & 03 are minimum programmes

8. Ecosystem performance

This is to be studied by basic research but should include population statistics, diversity indices, mortality, missing species, "indicator" species. Cellular, physiological, biochemical response.

NB This section may be omitted.

9. Associated meteorological variables

01 Daily minimum and maximum temperatures

02 Rainfall

03 Wind direction & strength daily

04 Percent relative humidity daily

05 Sunshine hours

06 Solar radiation receipt

NB 01 & 02 are minimum programme

10. Soil variables

01 pH

02 Percentage base saturation

03 Percent organic matter in A layer

04 Field capacity

05 Redox potential

06 Mechanical composition

07 Available NO_3^-, PO_4^{3-}, K, Ca, Mg, etc.

NB 01 and 02 are minimum programme

11. Rainfall Chemistry

01 pH

02 SO_4^{2-}

03 $NO_3^- + NH_4^+$

04 K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}

05 radionuclides

NB1 01 is minimum programme

NB2 Where an aquatic system is studied 02 is B.O.D.; 03 is suspended particulate; 04 is macronutrients

7. General Comments

7.1 It is to be hoped that as many collaborating groups as possible will carry out the programme at a level sufficient to provide data on 'partition coefficients' between ecosystem components.

7.2 Ecosystems undergoing man-induced changes (urban-industrial or agricultural impacts) would represent special cases as would those recovering from any such stresses.

7.3 Since the range of ecosystems is very wide and the specialist skills needed to examine them very diverse, it is essential that excellent communication links be established between all components of the overall investigation. This implies that a considerable effort be made to exchange information, reference samples of material, in cross-checking and, wherever possible, in the standardization of procedures.

NATIONAL PROGRAMME FOR COMPREHENSIVE MONITORING OF ENVIRONMENTAL POLLUTION IN THE U.S.S.R.

A comprehensive programme for observations and research into environmental pollution has been developed and accepted in the U.S.S.R., the practical implementation of which is due to start in June 1976. The programme is based on the recommendations of the Inter-governmental Meeting on Monitoring, held in Nairobi in 1974 (Document UNEP/GS/24), as well as the programme of observations at the network of background WMO stations. The observations relating to impact monitoring were however excluded from the UNEP programme since they did not serve the objective of global monitoring. The site of the comprehensive monitoring station considered meets the requirements made on regional WMO stations. The programme of observations includes the following measurements:

I. Air

1. Sulphur dioxide
2. Suspended particles (concentration by mass)
3. Sulphates in the suspended particles
4. Lead, mercury, arsenic and cadmium in the suspended particles
5. Turbidity of the atmosphere
6. Total ozone content.

II. Atmospheric precipitations (wet and dry)

1. DDT and other organochlorine compounds (PCBs)
2. Cadmium, mercury, lead, arsenic
3. All other anions and cations recommended for determination at background WMO stations (sulphates, nitrates, chlorides, etc.).

III. Water in lakes and reservoirs

1. Minerals and gas content, biogenic substances
2. Mercury (including methyl mercury), arsenic, lead, cadmium
3. DDT and other organochlorine hydrocarbons (PCVs)

IV. Soil

1. Mercury, lead, cadmium, arsenic
2. DDT and other organochlorine compounds (PCVs)
3. Carcinogenic substances (benzopyrine)

V. Biosphere (including cultivated crops, wild grasses, etc.)

   1. DDT and other organochlorine compounds (PCBs)
   2. Cadmium, mercury, lead, ~~arsenic~~

VI. Measurement of the set of meteorological parameters, as well as solar radiation (especially its UV component).

VII. Moreover, in the region of the station for background observations it is advisable to carry out field expeditions for measuring certain atmospheric pollutants (sulphur dioxide, suspended sulphate particles) for the purpose of studying the effect of nearby towns and industrial complexes on the selected observation point.

The next phase of background observations will broaden their programme as regards measurements in the air of a number of little-studied components, such as nitrogen oxide and dioxide, carbon monoxide, the total of reactive hydrocarbons and possibly others.

At all stages of the work a great deal of attention will be given to improving methods of determining the ultra-micro-concentrations of pollutants at various sites.

The results of all this research and these observations will be used for evaluating the state of the environment and for establishing the trends of its change and forecasting its state in the future.

16 October 1979

INTER-AGENCY CONSULTATION ON MONITORING IN BIOSPHERE RESERVES AND INTEGRATED MONITORING

Geneva, 18-20 September 1979

I. INTRODUCTION

1. The consultation was convened by UNEP to advise the participating Agencies about the monitoring activities that might be undertaken in these two areas in co-operation with UNEP as part of the GEMS programme. Five meetings were held and chaired by Mr. F. Sella (UNEP). Two consultants, Mr. R. E. Munn and Mr. C. B. Wiersma, took part in the discussions and their contribution to the debate was gratefully acknowledged by the representatives of the Agencies. The list of participants is attached as Annex I.

2. It was recalled that the two subjects of the consultation had both been discussed informally among agencies for a number of years and discussed recently at international meetings. Aspects of environmental monitoring in media other than air (within BAPMoN) had been discussed at a UNEP/WMO meeting in Mainz (Federal Republic of Germany) in October 1976. Monitoring in Biosphere Reserves had also been the subject of a meeting convened at Oak Ridge, Tenn. (USA) by the US MAB Committee in October 1978. The report of that meeting served as background material for the present consultation.

3. On integrated monitoring, an international conference sponsored by UNEP and WMO had been organized by the State Committee for Hydrometeorology and Environmental Monitoring of the Soviet Union in December 1978 at Riga (LSSR). While the proceedings of that conference were not yet available, a document entitled "Programme for the First Stage of the Conduct of Comprehensive Global Monitoring of Background Pollution of the Environment" had been prepared by Soviet scientists as a result of that conference, and was also used as background to the consultation. While the two subjects had had a separate history, a single consultation on both had been called because of the likely interactions between the two types of activities.

4. It was noted that internationally co-ordinated monitoring in Biosphere Reserves under a project that would contribute both to the MAB and to the GEMS programmes would raise a number of complex issues - ecological, methodological, political and ultimately organizational - and could therefore only be undertaken on a pilot basis, and that the paucity of the resources available at this stage suggested the initiation of a project of very limited scope. Various alternatives were discussed and the participants decided to recommend the start of a project of the type outlined in section II.A.

5. With regard to integrated monitoring, the discussion was seriously hampered by the absence of the consultant from the Soviet Union, Dr. Ryaboshapko, whom illness had prevented from attending. The participants, however, gave as much attention to the problem as the available information permitted and noted the similarities, but also some of the differences between environmental monitoring as carried out for instance in the Great Smoky Mountains National Park Biosphere Reserve in the USA on the one hand, and the activities that Soviet scientists proposed to undertake as integrated monitoring on the other. Accordingly, the participants formulated the recommendations contained in section II.A.3.

II. RECOMMENDATIONS

A. Monitoring in biosphere reserves

1. General

6. Ecological monitoring is a powerful tool for providing information useful in the management of biologically-based production systems. The operations of monitoring focus largely at the level of the ecosystem. Biosphere Reserves are conceived of as containing at least representative ecosystems from major climatic vegetation types. They may therefore alter ideal opportunities for siting ecological monitoring projects.

7. It was recommended that:

- Ecological monitoring be carried out in three to four representative areas of the world's temperate broadleaved forest ecosystems.
- These areas should be located, initially at least, in

(a) Eastern Europe, (b) Eastern North America and
(c) Temperate South America.

- This forest ecological monitoring programme be both part of the renewable natural resources monitoring programme of GEMS and an activity within the MAB-8 programme.
- The forest monitoring programme be designed in such a way that it may allow further similar projects to be added in the future.
- The forest monitoring projects be located, wherever possible, in Biosphere Reserves since some of these appear to be among the most suitable locations for such monitoring.
- The initial emphasis of the forest monitoring programme be on the monitoring of ecological processes in order to provide basic background information for other subsequent or concurrent research and monitoring activities, such as pollution monitoring that might be undertaken in the future.

2. Selection of the temperate broadleaved forest type

(a) Importance of the type

8. The argument for selecting the temperate broadleaved forest as the type most suitable for locating an initial series of monitoring projects includes the following reasons:

- Temperate broadleaved forest is a vegetation type which is frequently physically close to the world's heaviest industrial development, and there are, therefore, many examples of the type which are subjected to severe pollution.
- An understanding of the ecosystem dynamics of the type will contribute to understanding, when required, the movement and impact of pollutants.
- The type supports a number of economically important activities, viz., lumbering, paper pulping, hunting, etc.

- The type provides recreation areas for large urban populations.
- The type is a potential source of fuel wood in less industrial countries.
- The type has a high genetic and species diversity.
- Development and improvement of monitoring methodologies for the type may well be of use for future monitoring of more complex types, such as tropical forest ecosystems.
- A large amount of work has already been done on selected examples of the type, e.g., the Great Smoky Mountains National Park in the USA.

(b) Criteria for project area selection

9. The following are criteria for selection of temperate broadleaved forest areas suitable for ecological monitoring projects. The existing biosphere reserves will be examined carefully to determine if any fulfill the criteria. These criteria are not absolute conditions, but are those factors to weigh and optimise when making the decision on which area to choose. The first three criteria have been modified from the document by Soviet scientists referred to in paragraph 3.

10. The projects area:

- Should be typical of the region in terms of the following physio-geographical characteristics: relief, climatic factors, (nature of atmospheric circulation, thermal regime in the atmosphere, amount of precipitation, etc.), nature and state of the soil and plant cover and the water regime.
- Should not be subject to the direct influence of any major pollution sources (industrial centres, urban agglomerations). The impact of small local pollution sources (small human settlements, agricultural holdings, roads, air routes, etc.) should also be minimal.
- Should be located in an area of a minimum amount of economic activity, and there should be no substantial change in the nature of this activity in the coming decades.

- Should preferably have a reasonably untouched core area.
- Should be in a region that is readily accessible.
- Should have a relevant research institute nearby, or have a history of research and/or monitoring stemming from country-based institutions.
- Should have a good set of existing background data. Of particular importance is an extensive run of meteorological data (e.g. fifty years) including precipitation and temperature.

3. The monitoring programme

(a) Objectives

(i) General objectives of ecological monitoring

11. To provide information (see B) on the state, trend, variability and functioning of entire, or selected components of, production systems in order that policy makers may make the most effective decisions for the management of those systems. Such production systems may comprise both natural and altered ecosystems, while the selected components may include economically important natural resources. Management may involve the assessment and mitigation of impacts, both man-made (e.g. pollutants) and natural (e.g. pests), as well as of biological production, such as for food, recreation, timber, pulp, etc.

(ii) Specific objectives of the proposed monitoring projects

12. The following objectives were identified:
    - To contribute to the MAB Programme a tightly co-ordinated set of monitoring and research activities, possibly within MAB Biosphere Reserves, by establishing monitoring projects in three or four selected areas of temperate broadleaved forests.
    - To contribute to the development of a set of methodologies which may have future applicability to monitoring and research in other forest ecosystems, including tropical forests.
    - Where applicable, to engender co-ordination at the ecosystem level between existing monitoring and research activities in each study area.

- **To produce, as a result of basic inventories of the ecosystems involved, a baseline data set against which to measure future changes.**
- **To establish, as a result of monitoring activities, the trends and correlations leading to an understanding of ecosystem dynamics at a level sufficient to provide the basis for understanding, among other things, pollution pathways and impacts.**
- To produce from the data, statements which are of direct use to managers and policy makers concerned with the management or alternate use of temperate broadleaved forests.

(b) Outputs

(i) Technical

13. Static features:
    - Maps of non-living (e.g. geology, climate, soils, etc.) and living (e.g. vegetation) ecosystem elements.
    - Lists and tables of species, numbers and biomass, levels of certain pollutants, etc.

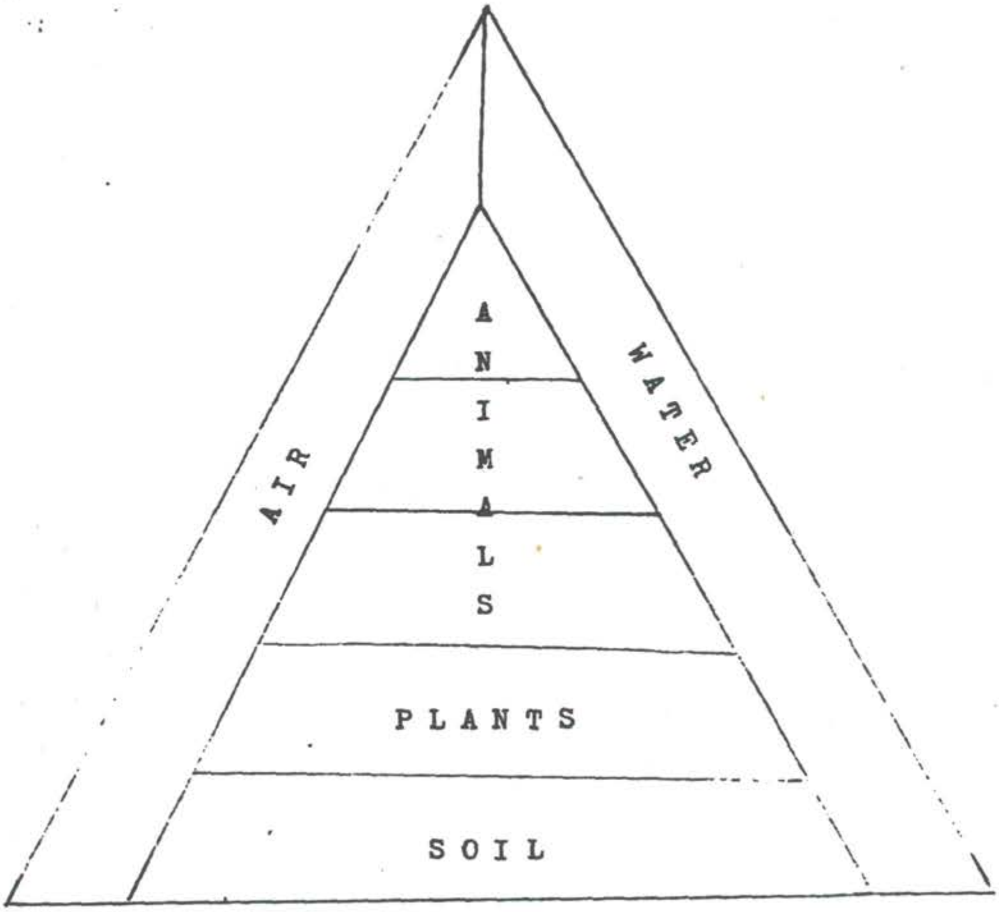
14. Dynamic features
    - Maps of seasonal production (e.g. biomass) and seasonal occupance (e.g. animal distribution).
    - Tables, etc. showing trends in production, cross correlations between ecosystem components, trace element input-output data, etc.

(ii) Executive

15. Assessment statements on:
    - Current states of key elements.
    - Current trends of key elements
    - Principal cause/effect links.
    - Sets of management plan options.

(c) Operations

16. The ecosystem is the domain of the monitoring project activities, and its compartments may be represented schematically in the following diagram:



17. There are three levels at which the ecosystem may be investigated. These levels represent increasing complexity of operations, increasing costs, and increasing information concerning ecosystem processes. They may be outlined as follows:

- <u>First level</u>: The activities occur within one or several compartments of the ecosystem. The primary activities are inventories, which produce statements concerning baseline states and spatial variability.
- <u>Second level</u>: The activities also occur within compartments, but include the time-series data collection of monitoring. The monitoring activities produce information on trends (for example, in biological yields or pollutant levels) and on temporal variability.

- Third level: At this level, the activities occur between compartments, for example, between soil and the plants, the air and the water, or along the entire nutrient cycle. Monitoring, or in some cases short time-series inventories, produce information on ecosystem functioning, cause/effect chains, pollutant pathways, etc.

18. The division into the three operational levels is useful in two situations: if funds or time are limited, valuable information may be collected by concentrating on level one or levels one and two only; if a full monitoring operation is possible, then the levels provide a logical sequence for the project operations to follow. The aims of the proposed projects could be to include all three levels.

19. A selection of the minimum requirements for key ecosystems attributes for the monitoring project is given in Table I. Easily applicable, relatively inexpensive and tested techniques already exist for collecting data on all of the listed attributes. The particular combinations and perhaps sequence of data collection will have to be devised when the study areas are selected. The system is also readily adaptable to labour intensive situations.

B. Integrated Monitoring

20. It was recommended that, to make possible a proper understanding of the details of integrated monitoring as proposed by the Soviet scientists, and of its possible relations with similar activities already under way, a further consultation be held with adequate participation of Soviet scientists. Such consultation should be held at a sufficiently early date to enable the WMO Executive Committee Panel on Environmental Pollution, which will meet in early Spring 1980, to consider the report of the consultation.

21. It is further recommended that through a general review of integrated monitoring proposals, the consultation give special attention

to (a) the methods proposed by the Soviet scientists for relating low concentrations of pollutants in the environment to the effect that they may have on the ecosystems concerned; (b) the possibilities of co-ordinating the project activities with similar ones already under way; (c) the possible relations between integrated monitoring as proposed, and monitoring in Biosphere Reserves.

TABLE I

Key attributes in the ecological monitoring of
temperate broad-leaved forests

NON-LIVING	LIVING	
	Primary Productivity	Secondary Productivity
Background inventories: - geology - climate - land form - soil types - land-use	Inventory and monitoring By major species (including lichens), layer, area, plant parts and season - numbers and biomass - stand history - cover - age structure - productivity	Inventory and monitoring: By large and small mammals, birds, fish, key invertebrate species, and season, - numbers and biomass - distribution - mortality, fertility and age structure
Monitoring: - stream dynamics (including chemistry) - erosion processes - precipitation (including snow cover; chemistry; etc.) - insolation - air temperature - wind - soil moisture		

← (NUTRIENT CYCLES) →

(litter analyses) (feeding studies)

ANNEX

Participants in the Multi-Agency Consultation on Monitoring in Biosphere Reserves and Integrated Monitoring

Geneva, 18-20 September 1979

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Russian/English

State Committee of the USSR for
Hydrometeorology and Environmental
Monitoring
123376 Moscow

No. M-357

3 May 1979

Dear Mr. Sella,

In accordance with the decision of the Riga Symposium, a working group of Soviet experts has prepared proposals for the programme for the first stage of the conduct of comprehensive global monitoring, criteria for location of stations and methods and instrumentations for use in the background monitoring system.

This material is fairly brief, but I assume that all the details and questions that may arise should be discussed at the international expert group meeting about which we talked during your stay in Moscow.

I take the opportunity to inform you that the work on the report of the Riga Symposium is proceeding in accordance with the planned time-table.

Yours sincerely,

(Signed)

Y.A. Izrael
Chairman, State Committee of the USSR
for Hydrometeorology and Environmental
Monitoring

Mr. F. Sella
Director of GEMS
UNEP

PROGRAMME FOR THE FIRST STAGE OF THE CONDUCT OF COMPREHENSIVE GLOBAL MONITORING OF BACKGROUND POLLUTION OF THE ENVIRONMENT

1. Objectives of comprehensive global monitoring of background pollution of the environment

Study of pollution of the natural environment and its ecological consequences at the global and regional background levels.

Detection of changes in the natural environment caused by the action of man-made pollutants.

Assessment of the current state of the abiotic and biotic elements of ecosystems and identification of their most vulnerable components.

Prediction of changes in the state of ecosystems through the action of pollutants on the global scale.

2. Basic principles

Comprehensive global monitoring of background pollution of the environment forms part of the Global Environmental Monitoring System (GEMS).

The monitoring is comprehensive in nature and provides for observation on the content of priority pollutants in all media, as well as study of the responses of natural systems to anthropogenic impact. Accordingly, the programme consists of two sub-programmes, one on abiotic monitoring and another on biotic monitoring.

Maximum use is made of monitoring stations and systems already established or being established under the auspices of

(1) to describe present environmental conditions and to determine trends;

(2) to study and model regional and global climate;

(3) to study and model the regional and global biogeochemical cycling of trace substances;

(4) to describe and model the movements of pollutants across national boundaries and in international waters;

(5) to study dose-response relations, e.g., with respect to acid rains and regional photochemical episodes;

(6) to parameterize some complex physical and biological processes.

The optimal network design may be different in each case.

Once the objectives have been chosen, there is need to agree upon criteria relating to the efficacy of the monitoring system. For example, if an objective is to determine trend, what precision is required in order to detect a change of X% in y years with 95% confidence? For biogeochemical models, how many significant figures need to be determined for each of the transfer coefficients? Is one of the coefficients so difficult to estimate that there is no point in striving for more than order-of-magnitude accuracy in the others? These comments imply that it would be very desirable if the models could be specified at the station design stage. This is of course difficult, and more often than not, data and model development move forward together.

3. MONITORING OF ASSOCIATED VARIABLES AND PROCESSES

In order to achieve the objectives listed above, there will often be need to monitor the behaviour of associated variables and processes. The meteorological, limnological and oceanographic elements come immediately to mind. In addition, there may be a requirement to monitor compounds that

3. Basic criteria for determining the list of pollutants to be observed in the first stage of comprehensive background monitoring

The priorities for study are:

Substances of man-made origin. It is desirable to study all sources (types of economic activity) from which they enter the environment, their cycles and migrations in the environment and their overall global balance;

Substances or transformation products having a substantial impact on human health or on the state of ecosystems and other natural systems - climate, the ozone layer, etc.;

Substances participating in natural migration processes and extending through the atmosphere or the hydrosphere to considerable distances commensurate with major regions of the earth;

Substances which are resistant to the action of natural factors (temperature variation, oxygen, micro-organisms, etc.) and which are found in any part of the world.

4. A sample list of priority pollutants and a draft of the sub-programme for monitoring of background levels of environmental pollution (abiotic monitoring) are given in Table 1.

5. Draft sub-programme for monitoring the response of biota to the action of background pollutants (biotic monitoring)1/

The basic aim of the sub-programme is to predict changes in the species composition of ecosystems and the size of the species populations as a result of predicted pollution levels.

1/ Since it is as yet untried in practice, the biotic monitoring sub-programme should in the initial stage be conducted as a pilot project in one of the biosphere reserves.

diurnal and annual cycles. These rhythms are partly obscured by small-scale fluctuations in all of the environmental signals due, for example, to micro-scale irregularities in ground cover. In the case of vegetation, for example, there is considerable difficulty in specifying species diversity and density because plants are often not randomly distributed; some species tend to occur in clumps.

These considerations should be included in the design of a MMMS, and some indication of the variability in each monitoring element should be obtained, through pilot studies for example, before making a decision about the monitoring programme. The objective is to ensure that the time and space resolutions of all components of the system are compatible. The important work of Soviet scientist L. S. Gandin (1963, 1970, etc.) should be mentioned here in connexion with the space resolution problem.

These problems are reasonably well understood in the physical sciences, and the possibility is good that the physical components of the MMMS can be reconciled. For biological monitoring, on the other hand, a number of difficulties remain. Horizontal transects of perhaps 100 m or even 1 km may be necessary although in some cases, accumulator species may be found that integrate the space-time variability in some meaningful way.

5. CRITERIA FOR SITING A MMMS STATION

The WMO has established siting criteria for regional and baseline air quality monitoring stations (WMO, 1974). A WMO Expert Meeting on Siting Criteria, meeting in Mainz in October 1976, reviewed these criteria in the light of biological applications, e.g., the impact of photochemical pollution on vegetation, and made the following suggestions for additional

6. Concomitant types of monitoring

Measurement of the background level of various substances of natural origin.

Measurements conducted in the context of climate monitoring.

Measurement of solar radiation as the main energy source for biosphere processes, including observations of direct, scattered and twilight radiation, radiation balance and albedo.

Measurement of the heat balance.

Aerological and meteorological observations.

Hydrological observations.

7. Supplementary types of monitoring

Monitoring of the past includes determination of certain priority pollutants in datable specimens (bottom samples, samples of peat, glacier material, tree rings, museum exhibits, etc.).

Monitoring of the future involves the creation of banks of samples of different objects in the environment in order to make it possible in the future, if necessary, to conduct more detailed studies of the samples using more advanced methods.

These types of monitoring serve for the deeper study of the nature of global pollution of the earth.

RECOMMENDATIONS ON CRITERIA FOR LOCATION OF COMPREHENSIVE BACKGROUND MONITORING STATIONS

The network of observation stations for comprehensive background monitoring should be based as far as possible on existing systems organized under the following international programmes:

The WMO background air pollution monitoring network;

The network of biosphere reserves under UNESCO's MAB programme;

The background monitoring network under the programme of the CMEA member countries in conjunction with GEMS.

The stations available in these networks need to be reviewed from the standpoint of suitability for carrying out comprehensive observations, i.e., their ability to conduct observations of pollution of the atmosphere, surface waters, soil and biota, as well as to study the responses of biota to background pollution.

In view of the recommendations of WMO and other international organizations, as well as of experience in the establishment of background stations in the USSR, the following criteria should be applied in selecting the regions for location of the comprehensive background monitoring stations:

(a) The natural conditions in the observation zone should be typical, on the regional scale, in terms of the following physio-geographical characteristics: relief, climatic factors (nature of atmospheric circulation, thermal regime in the atmosphere, amount of precipitation, etc), nature and state of the soil and plant cover and the water regime.

(b) The zone in which the background station is located should not be subject to the influence of any major local pollution sources (industrial centres, urban agglomerations). The impact of small local pollution sources (small human settlements, agricultural holdings, roads, air routes and sea lanes) should also be minimal.

(c) The zone in which the background station is located should be the scene of a minimum amount of economic activity, and there should be no substantial change in the nature of this activity in the coming decades: this condition is best met by biosphere reserves, reserves and protected areas.

(d) Background monitoring stations should be located at points from which the broadest range of observations of pollution of all natural media - air, natural waters, soil and biota, as well as the response of ecosystems to its impacts - can be conducted.

(e) The points selected for standing observations of pollution of the environment at the background station should meet the requirements of representativity of the data obtained at them and of uninterrupted conduct of observations for an extended period of time.

RECOMMENDATIONS ON METHODS AND INSTRUMENTATION FOR COMPREHENSIVE GLOBAL MONITORING

1. Introduction

The comprehensive global monitoring programme provides for systematic observation of the weight content of aerosols and turbidity of the atmosphere, determination of the chemical composition of precipitates and the content of priority pollutants in natural media. In the conduct of comprehensive global monitoring, maximum use must be made of the relevant international experience in the monitoring of pollutants in different media. In its observations of air pollution, the comprehensive global monitoring programme includes, as an integral part, the monitoring programme established by WMO for the global background monitoring network.

Air and wet deposition from the atmosphere will be sampled in accordance with the WMO recommendations. Surface and ground waters, bottom deposits, suspended matter, soil and biological objects will be sampled at selected representative sites, using standard sampling methods and equipment.

The conservation of samples and the permissible storage period will depend on the type of ingredients to be determined and the structure of the chemical laboratory network, i.e., on whether the analysis can be carried out on site or needs to be performed at a central national or international laboratory.

In the chemical laboratories, there must be no interference effects between different analyses, or measures must be taken to prvent them. Work on the determination of gaseous components in the air and on the processing of natural samples to determine heavy metals cannot be carried out in the same laboratory, since in the latter instance a large quantity of mineral acids is given off, causing an increased content of sulphur oxides and oxides of nitrogen in the laboratory premises.

2. Methods and instrumentation for comprehensive global monitoring

2.1 Sulphur dioxide

Method: Photocolorimetric

Equipment: Low-resolution spectral photometer for UV and the visible region of the spectrum

Sensitivity: 0.1 ug/m^3

2.2 Carbon monoxide

Method: Gas chromatography

Equipment: Gas chromatograph with flame ionization detector
Columns thermostatically controlled to 50-60°C
Carbon monoxide hydrogenation attachment

Sensitivity: 0.05 mg/m^3

2.3 Carbon dioxide

Method: IR spectrophotometry

Equipment: High-resolution infra-red spectrophotometer

Sensitivity: 0.03%

2.4 Ozone

Method: Chemiluminescent spectrophotometry

Equipment: Ozone analysers operating on the chemiluminescence principle

Sensitivity: 1 ug/m^3

2.5 3, 4-benzopyrene and other polycyclic aromatic hydrocarbons

Method: Low-temperature quasilinear luminescent spectrophotometry

Equipment: Spectrofluorimeter with a double monochromator, a xenon source and a low-temperature attachment permitting work at the temperature of liquid nitrogen. Luminescence spectrum monochromator with variable slit: resolution not inferior to 10 A/mm, aperture ratio 1:3

Sensitivity: Not inferior to 10^{-10}g.

2.6 Organochlorine compounds (pesticides)

Method: Gas chromatography

Equipment: Gas chromatograph with a two-column system, isothermic temperature control and an electron capture detector

Sensitivity: Not inferior to 10^{-10} g.

2.7 Heavy metals (Hg, Pb, Cd, As and others)

Method: Atomic absorption

Equipment: Two-beam atomic absorption spectrophotometer with automatic background correction. The monochromator should allow work in the 185-900nm range, and should have standard outlets to computer printout systems, an automatic recorder and a system of signal detectors allowing both area and peak height to be measured. The equipment must be fitted with systems for atomizing metals from solutions, by the flame method or in a graphite oven, as well as arsenic hydride and mercury vaporizers for determining arsenic and mercury effectively.

Sensitivity: 0.04 mg/l for Hg and Cd and 0.2 mg/l for Pb and As

2.8 Assessment of the response of biota to pollutants close to background levels

The response of biota is assessed by the change in the multiplication rate of large groups of individuals in appropriate (close to background) pollution conditions.

Method: Director count of number of individuals in subsequent generations

Equipment: Ecostatic vegetation chambers with a wide range of controllable environmental parameters and an automatic device for determining the number of individuals in the test group (Microvideomat and/or coulter counter attached to a computer).

3. Metrological support

In view of the need to analyse for ultramicro constituents and ensure high accuracy of the results, metrological support with the monitoring programme, standardization and intercalibration of methods and instruments are particularly important. To this end, the work of WMO, UNEP, CMEA and other international organizations on the conduct of joint studies, exchange of specimens and samples and the conduct of intercalibration exercises, seminars and symposiums should continue. Agreements should be concluded on the exchange of experts, staff training, the development of standard specimens and the development of methods and instrumentation.

In view of the participation of countries with their own scientific traditions, specific conditions of analytical practice and ranges of equipment, the work of working groups and experts on methods and instrumentation is of particular importance in order that unified standards and observation methods, and intercalibration programmes promising development and instrumental methods, etc. can be recommended.

Table 1

Medium	Pollutants and indices of the state of the medium	Frequency of observation (period)
Atmosphere	Suspended particulates, turbidity, CO_2, ozone, SO_2, NO_x, CO, hydrocarbons, benzo(a)pyrene, DDT and other organochlorine compounds, lead, mercury, cadmium, arsenic	Daily to every five days
Wet and dry deposition from the atmosphere, snow cover	Lead, mercury, cadmium, arsenic, DDT, benzo(a)pyrene, anions and cations under the WMO programme	Wet deposition: depending on the sample size required for analysis, once every ten days or monthly Dry deposition: monthly Snow cover: core sample to the full depth of the snow layer, annually before spring thaw
Surface and ground water, bottom deposits and suspended matter	Lead, mercury, methymercury, cadmium, arsenic, DDT, benzo(a)pyrene	Water: six times a year at characteristic hydrological periods (three times at flood seasons, once in the summer low-water period, once in the autumn high-water period, once in the winter low-water period) Suspended matter: same as for water Bottom deposits: once a year (in the summer low-water period)
Soil: vertical section at representative sites	Lead, mercury, cadmium, arsenic, DDT, benzo(a)pyrene	Once or twice a year
Biota	Lead, mercury, cadmium, arsenic, DDT, benzo(a)pyrene	Twice a year

Document 5

BASIC PRINCIPLES AND SITING CRITERIA FOR MULTI-MEDIA MONITORING

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OF ENVIRONMENTAL POLLUTION

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1. INTRODUCTION

In principle, the idea of a multi-media monitoring system (MMMS) is very attractive. As the term indicates, MMMS is an integrated approach to environmental monitoring, in which several elements are measured at the same place and time, but in various media: in the atmosphere, land biosphere, snow cover, soil and ground water, as well as in adjacent lakes, rivers and seas.

The main benefits of such a system are twofold:

(a) Usefulness in the development and testing of environmental models, e.g., for the biogeochemical cycling of trace substances;

(b) Cost effectiveness.

The second point needs no amplification. In the first case, it should be stated that the atmosphere is only one of several environmental compartments and that the transfer of trace substances and energy between media and along food chains is of great importance. There is no sense, for example, in measuring the chemical constituents of precipitation at one station, the chemical constituents of lake waters at another, and the effects on marine organisms at still a third site. The atmospheric scientists must work with their colleagues in related disciplines to achieve optimal environmental monitoring systems.

In this short contribution, a few criteria that should help in the design and siting of a multi-media monitoring station will be discussed.

2. OBJECTIVES OF MONITORING

The most important factor to be considered in designing a monitoring system is the objective(s). Some possibilities include:

WMO, UNEP, UNESCO, IOC, EEC, the United Nations, CMEA and other international as well as national programmes and projects, including information collection, storage and analysis centres, communications links, observation instrumentation and facilities, etc; in the first stage, monitoring is conducted by background stations in the baseline series and by WMO background stations.

The information obtained serves to provide national governmental organs, international organizations and the population with information and recommendations for protection of the health and well-being of present and future generations, as well as for rational management of the environment and natural resources.

Considerable significance is attached to global and regional problems optimizing man's activity and conserving the environment, including the earliest possible notification of substantial changes in the environment for the purpose of developing protective measures.

Assistance is to be provided to developing countries in establishing GEMS background stations and in environmental conservation in parts of their territories.

All types of monitoring are to be combined in time and space to the maximum extent possible, and comparable methods are to be used for the observations and for processing and interpreting the results. Considerable importance is attached to international co-operation in intercalibration of the methods and means of monitoring, and in the training of personnel.

affect the concentrations of the substances of principal interest. In this class are various catalysts and precursors. Sometimes, too, an estimate of the concentrations of a substance can be inferred as the remainder in a mass balance equation if all of the other terms are measured. A further interesting example is given by the heavy metals whose availability to freshwater organisms is dependent on pH. If a lake were to become more acid, the concentrations of heavy metals in fish would increase, even in the absence of additional inputs of trace metals to the lake, so that pH should be monitored. Finally, there are cases in which a surrogate substance (e.g., oceanic tritium) is preferred to a substance (e.g., oceanic CO_2) of interest. The tritium measurements show less variability than do CO_2 measurements, and thus provide better estimates of the exchange coefficients between the atmosphere, the surface mixed layer and the deep ocean. These exchange coefficients are subsequently used in models of the carbon cycle.

One of the important reasons for monitoring the associated variables and processes is to permit parameterization of complex systems. For example, latent and sensible heat transfers from the oceans are extremely difficult to measure directly but they can be estimated from shipboard observations of wind, temperature and humidity. The parameterization is through mass transfer coefficients. Similarly, there is a possibility that CO_2 fluxes could be estimated from a knowledge of CO_2 concentrations, although a few monitoring stations for CO_2 fluxes (using the eddy-correlation method, for example) would still be required.

4. ENVIRONMENTAL VARIABILITY

A characteristic of the environment is its somewhat organized variability in space and time. Not only are there spatial gradients in most of the physical and biological elements and species but also there are

Prediction is carried out by constructing a mathematical model of the succession of ecosystems under the impact of man-made pollutants.

The data required for the model on the sensitivity of biota to the action of background pollutants are obtained by:

(a) Experiments on examples of selected species in ecostats which afford a stable abiotic environment;

(b) Extrapolation of the data obtained to other types of ecosystems.

Selection of species for the ecostat experiments and extrapolation of the data to all the types of ecosystems are performed on the co-ordinates of a phylogenetic tree.

As the overall index of the response of biota to the action of background pollutants measured in experimental conditions, use is made of the multiplication rate of individuals, irrespective of population density.

The set of species to be studied in the initial stages should include autotrophic forms representative of the variety of ways in which living matter is organized. For purposes of planning and even distribution of the test objects on the co-ordinates of the phylogenetic tree, it would be desirable on technical grounds to begin the programme by testing representatives of the principle classes of lower plants (one per class).

As a result of the conduct of the abiotic and biotic monitoring sub-programmes, information will be fed into the model on (a) level of environmental pollution bu the priority pollutants, and (b) the corresponding change in the multiplication rate of species, and the model will yield information on how species may disappear, or, initially, become reduced in numbers at given levels of impact.

criteria for regional stations with expanded programmes (WMO, 1976):

(1) there should be no influence from local (within 10 km) pollution sources;

(2) sampler intakes should be above the surface boundary layer and clear of trees, etc. (a forest clearing would not be suitable);

(3) the site should be representative of the area;

(4) a fetch of about 400 m over homogeneous vegetation is desirable.

Point 3 requires special comment. Open countryside is usually quite irregular on the microscale, and the question is often asked whether a site should be chosen such that the surrounding land is unusually homogeneous (thus reducing variability in the measurements) or such that the surroundings are typically irregular. For example, Canadian weather stations in the sub-arctic are sited on relatively high ground near airports, locations that are not representative of the swamp, muskeg and spruce forests that surround them. This type of difficulty should not be swept under the rug, and an attempt should be made in the case of each proposed MMMS, to estimate:

(a) the area that contributes significantly to the behaviour of the environmental elements measured at the station;

(b) the area that the station can be said to represent.

The siting criteria should, of course, depend on the objectives for monitoring.

6. MMMS STATIONS IN CITIES

An urban area is an example of a most irregular surface. Partly for this reason, first-order synoptic weather stations are usually sited at airports or in open countryside. But as was first suggested at a WMO Symposium in Brussels ten years ago, there is a need for urban reference stations for long-term studies of the environment (WMO, 1970). These stations would be located in large urban parks and would have programmes rather like those of the Observatories that flourished in the last century. The goal would be to provide precision measurements of a large number of physical and biological elements, the data having long-term value for research and early warning purposes. One objective that might be included would be the study of biogeochemical cycles at the impact level. The core programme at each reference station would require careful specification, perhaps by a joint WHO-WMO Expert Group, and would require a clear definition of goals (as mentioned above in Section 2).

7. CONCLUSION

The idea of a MMMS is supported. However, the design of such a system needs careful specification, which cannot be undertaken by atmospheric scientists alone. Close collaboration is required with plant physiologists, soil scientists, limnologists, hydrologists and others. Happily this process has already begun in the USSR.

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RECOMMENDED POLLUTANT MONITORING SYSTEM FOR BIOSPHERE RESERVES

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ABSTRACT

Biosphere reserves have been established worldwide as part of the Man and Biosphere program of UNESCO. Part of this program is the development of a pollutant monitoring system applicable to a large number of different biosphere reserves. The system must be able to produce data that are comparable between reserves. In addition, it must be relatively inexpensive. The Environmental Monitoring Systems Laboratory of the U.S. Environmental Protection Agency, in cooperation with the U.S. Park Service, has been working on the development of such a system for the last 2 years. This paper presents some conclusions and recommendations for the design of a pollutant monitoring system. Pollutants of concern were primarily those which had a real or suspected long-term transport characteristic.

Types of samples collected on the reserves studied to date include air, water, soil, vegetation, and forest floor. Sampling design is covered, including layout of sampling blocks, subsampling, sample handling, and preservation.

Analytical procedures were chosen not only for their ability to detect suspected pollutants but also for their cost-effective nature. Multi-elemental analytical techniques were used whenever possible. Multi-organic analytical techniques were also used where available.

Mathematical models were applied to help determine the optimum monitoring system design. A brief description of the modeling technique is given and results are shown using lead as an example.

Finally, a review of current international cooperative efforts in the area of pollutant monitoring on biosphere reserves is given.

INTRODUCTION

The Environmental Monitoring Systems Laboratory is developing a multimedia, integrated pollutant monitoring system for biosphere reserves. This system, which will eventually be used as part of the Global Environmental Monitoring System (GEMS) (Wiersma et al. 1978a and 1978b), is based on the basic principle of monitoring systems design as laid down by Schuck and Morgan (1975), Morgan et al. (1979), and Munn (1973). We have used their systems approach to design a monitoring system for individual biosphere reserves.

Munn stresses the need for a systems approach to the design of a global monitoring system and expands on the need for background monitoring stations:

> "The point of view has sometimes been advanced that there is no point in monitoring insignificant concentrations of even potentially harmful substances at remote stations. This philosophy is not always valid, however, because threshold concentrations that cause biological effects are not absolutes. In many parts of the world, biological systems are in delicate equilibrium with their natural environments through the process of adaptation. Minute increases in the concentrations of particular substances may have significant effects, particularly if there are accumulating organisms in the food chains . . ..
>
> "Another justification for measuring on the global scale is in connection with trends and cycles. In the first place, there is likely to be less day-to-day variability at remote stations, so that long-term trends and seasonal cycles are easier to detect. Secondly, a network limited to a single region does not permit separation of regional from global effects. This separation is of particular importance if the trends are due to natural geochemical phenomena . . .."

Our reasons for using biosphere reserves for pollutant monitoring are:

1. They serve as locales for background reference levels of certain pollutants.

2. They provide a frame of reference against which changes in impacted areas can be measured.

3. They may reflect changes of a global nature long before such changes are obvious in more impacted areas. In other words, they can serve as an early warning system for pollutants transported over long distances.

THE GLOBAL FRAMEWORK

An understanding of both the Man and Biosphere program and the Global Environmental Monitoring System will help to establish the context within which a pollutant monitoring system will operate on the reserves.

Man and Biosphere Program

The Man and Biosphere program (MAB) was authorized at the 16th General Conference of the United Nations Educational Scientific and Cultural Organization (UNESCO) in 1970. The United States National Man and Biosphere committee was established in 1972. The MAB program has four major objectives:

1. Study the general structure and functioning of the biosphere and its ecological regions.

2. Make systematic observations of changes brought about by man on the biosphere and its resources.

3. Study the overall effect of changes upon humans.

4. Provide public information and education needed about these subjects (Risser and Cornelison, 1979).

The MAB program is divided into 14 project areas of which project area 8 (MAB 8) is the Biosphere Reserve Program. The need for biosphere reserves was outlined by an expert panel in 1973 (Programme on Man and the Biosphere 1973). The panel recommended that a set of criteria be developed for selecting and establishing a network of baseline stations in undisturbed, representative biome areas.

In May 1974, a task force set up the criteria for selecting and establishing biosphere reserves and defined the objectives:

1. to conserve for present and future human use the diversity and integrity of biotic communities of plants and animals within natural ecosystems, and to safeguard the genetic diversity of species on which their continuing evolution depends;

2. to provide areas for ecological and environmental research consistent with objective (1) above, including particularly, baseline studies, both within and adjacent to these reserves; and

3. to provide facilities for education and training (Programme on Man and the Biosphere, 1974).

To date, over 144 reserves have been established in 35 countries, including 33 in the United States.

Global Environment Monitoring System

The recognition of the need for a global monitoring system for pollutants in remote or background areas preceded the establishment of biosphere reserves by several years. Lundholm (1968) defined the need for such global stations as follows:

> "Society is to an ever-increasing degree demanding information on how production in the natural environment is and will be affected by pollution. One reason why the value of the ecologist has not been sufficiently recognized by governments is that often he did not have the basic environmental information on which he can assess changes and base recommendations for action or advance warnings on the effects of man's activities on the natural habitats.
>
> "There is an urgent need to create a kind of an early warning system based on long time series of environmental data from strategically situated stations or sampling areas. In order to follow the changing situation in the biosphere we need a network covering the globe. As the interest is focusing not on the local variations, but on the background levels and changes, the number of stations (or sampling areas) in such a network can be kept rather low . . .. The aim is to erect a global network of baseline stations (sampling areas) devoted to monitoring biotic as well as abiotic factors in the environment. The purpose is to have a means of assessing short term and long term changes caused by a selection of factors, including many forms of pollution. The erection of network is motivated mainly by the threat of pollutants . . .."

The Swedish Natural Science Research Council (Ecological Research Committee, 1970) and the United States Ad Hoc Task Force on the Global Network for Environmental Monitoring (GNEM, 1970) also called for the establishment of a global monitoring system. The administrative framework for the Global Environmental Monitoring System (GEMS) was established in Stockholm, Sweden, at the UN Conference on the Human Environment. GEMS was part of Earthwatch, an activity of the United Nations Environment Program (UNEP).

An interagency working group (Task Force II - Committee on International Environmental Affairs, 1976) was established in 1974 to list what should be monitored, including recommendations for the structure and operation of a United Nations global environment program. This working group set up Earthwatch with four integral components:

1. Monitoring (GEMS)

2. Research

3. Evaluation

4. Information exchange

This working group also established the principle that these activities were to be carried out, wherever possible, in cooperation with ongoing and planned activities: "Earthwatch reference sites would be expected to provide a coherent, integrated base of benchmark data and information on physical, chemical, and biological conditions for determining long-term trends of environmental processes. These sites should include selections from ongoing and planned activities, such as, (a) World Meteorological Organization (WMO) baseline and upper atmospheric programs; (b) hydrology stations; (c) lake biome programs; (d) Man and the Biosphere (MAB) biome programs; (e) open ocean baseline sites; (f) river outflow stations; and (g) inventory programs including those for deserts, forests, wet lands, and grazing lands."

From the above, it is obvious that the MAB program was conceived to serve an important component of Earthwatch. Martin and Sella (1976) listed the goals of GEMS:

1. Establish an expanded human health warning system.

2. Assess global atmospheric pollution and its impact on climate.

3. Assess the extent and distribution of contaminants in biological systems, particularly food chains.

4. Assess critical environmental problems related to agriculture and land and water use.

5. Assess the response of terrestrial ecosystems to pressures exerted on the environment.

6. Assess the state of ocean pollution and its impact on marine ecosystems.

7. Develop an improved international system, allowing for the monitoring of factors necessary for understanding and forecasting disasters and for implementing an efficient warning system.

The incorporation of the biosphere reserve concept (or remote areas set away in perpetuity) with the terrestrial component of GEMS was specifically called for by the International Environmental Programs Committee (1976) of the National Research Council of the United States. Franklin (1977) also listed the Biosphere Reserves as a component of GEMS. The International Coordinating Council of the Programme on Monitoring and the Biosphere (Anon, 1978) officially recognized the link between GEMS and the Biosphere Reserve system. They recommended the following:

1. that co-ordinated monitoring activities in biosphere reserves be developed in conjunction with the Global Environmental Monitoring System (GEMS) of UNEP, and with associated worldwide monitoring

activities in the fields of climatology, atmospheric pollution and environmental health sponsored by WMO and WHO; and

2. that UNEP provide support to developing countries to enable them to undertake appropriate monitoring activities in selected biosphere reserves.

Recently at a UN interagency meeting in Geneva, steps to effect these recommendations were taken. UNEP/GEMS agreed to establish three biosphere reserves as part of the terrestrial component of GEMS. These reserves were to be located respectively in the United States, the Union of Soviet Socialist Republics (USSR), and possibly in Chile as representative of a developing country. A tentative design for monitoring was established including monitoring basic ecological processes as well as pollutants.

In summary, GEMS is using the biosphere reserves as part of its terrestrial monitoring component. The program is designed to monitor pollutants and basic ecological processes.

RECOMMENDED DESIGN PRINCIPLES

This paper sets out recommended design criteria for a pollutant monitoring system for Biosphere Reserves. The specific design principles we applied are discussed below and include the following:

1. The monitoring system is multimedia.

2. A systems approach is used to relate the environmental media and aid in final design recommendations.

3. The monitoring system is pollutant oriented.

4. Every effort is made to eliminate the influences of local pollution sources on the reserve.

5. Quality assurance procedures will apply at all phases of the project.

Multimedia

A monitoring system should be able to trace a pollutant from a source to a sink or exit point. On most terrestrial remote areas the pollutant input to the reserve site is via the air route. The ultimate sources, while in most cases easily associated with man's activity in general, are currently difficult to locate. Therefore, input should be measured in the form of atmospheric concentrations, deposition and rain. Output from most biosphere reserves will be streams and rivers draining the area and the loss of pollutants via this route can be determined by sampling representative drainages. The identification of the potential sinks and pathways of movement of the pollutants requires sampling in other environmental media.

Currently, our sampling covers air, deposition phenomena, water, soil, forest litter and a variety of vegetative species. Animal specimens, terrestrial as well as aquatic, were not collected because of the difficulty of collection and of getting a representative sample. This does not mean that under more intensive monitoring programs, such samples would not be appropriate. Different species of plants are collected to determine if one or more species stand out as effective biomonitors of pollutants.

Finally, the multimedia monitoring approach sets the stage for interpreting man's impact on his environment, particularly when detailed data on ecological processes on the various sites become available.

Systems Approach

Munn (1973) states that it is essential that GEMS be designed in such a way that interactions between media can be studied, permitting delineation of the pathways of biogeochemical cycling. This requires a system approach and is as applicable to the design of a system on a reserve as it is to putting the entire GEMS system together. A promising technique for accomplishing this is the use of kinetic models. Theoretical bases of these models have been described in detail by O'Brien (1979), Miller and Buchanan (1979), and Barry (1979). Wiersma (1979) applied this approach to the analysis of the biosphere reserve monitoring project in the Great Smoky Mountains National Park.

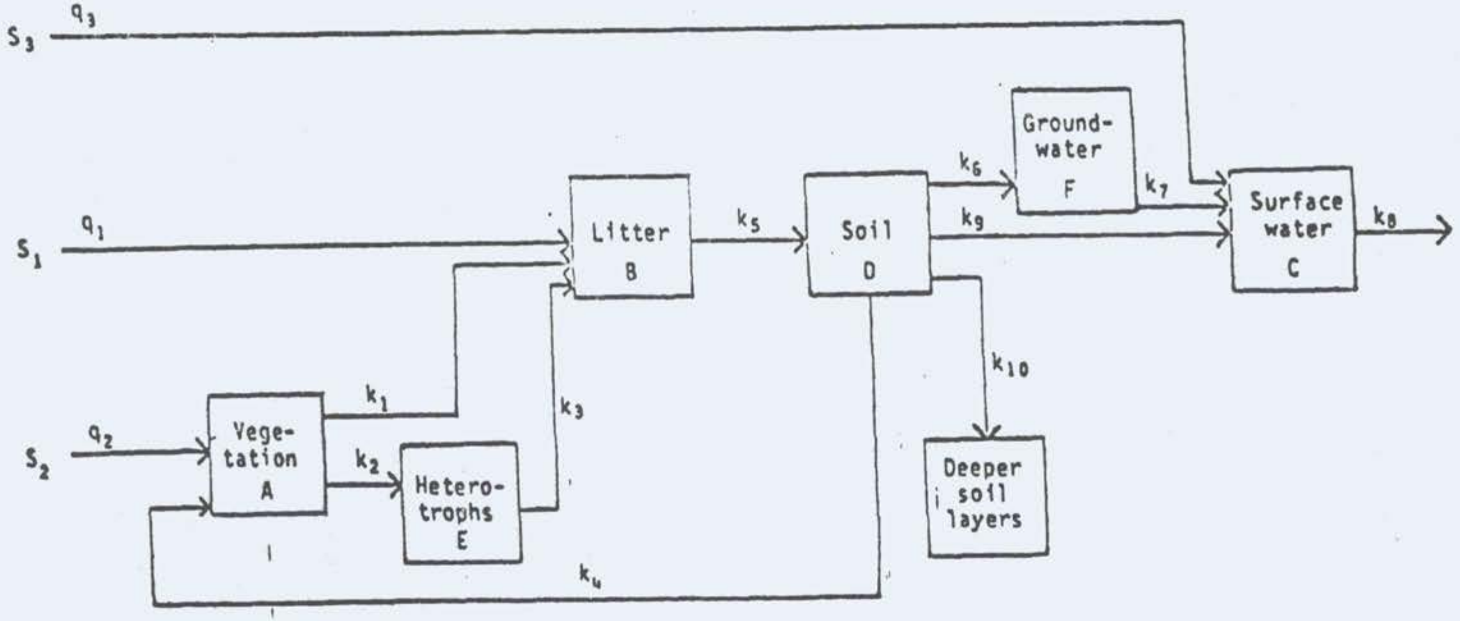
This approach starts with a schematic representation of the system to be monitored. It must be emphasized at the outset that what is intended is not a predictive model, but merely a heuristic tool to help design and evaluate the system of interest. The kinetic analysis approach does this by forcing one to consider the system as a whole at the time the monitoring program is being conceived. Doing this also sets up a procedure for carrying out the data analysis.

Figure 1 is a schematic representation of the Smoky Mountain System. It represents a cross between what is practical to monitor and an approximation of the system of interest. Once this is done the components of the environment that need to be sampled are readily apparent. Basic statistical procedures are now employed to design representative sampling in each identified compartment. The specifics of the sampling that was carried out for the various compartments identified are described by Wiersma et al. (1978b and 1979).

Once a schematic representation of the system is in hand, the equations approximating the dynamics of the system are derived. The differential equations for the Smoky Mountain Biosphere Reserve, represented in Figure 1, are given below:

$$\frac{dQ_A}{dt} = q_2 + K_4 Q_D - Q_A (K_1 + K_2) \qquad (1)$$

Figure 1.Schematic diagram of movement and distribution of lead in the Great Smoky Mountains National Park



$$\frac{dQ_B}{dt} = q_1 + K_1Q_A + K_3Q_E - K_5Q_B \tag{2}$$

$$\frac{dQ_C}{dt} = q_3 + K_7Q_F + K_9Q_D - K_8Q_C \tag{3}$$

$$\frac{dQ_D}{dt} = K_5Q_B - Q_D\ (K_4 + K_9 + K_6 + K_{10}) \tag{4}$$

$$\frac{dQ_E}{dt} = K_2Q_A - K_3Q_E \tag{5}$$

$$\frac{dQ_F}{dt} = K_6Q_D - K_7Q_F \tag{6}$$

These equations can be solved in several ways. Computer simulation techniques are applicable under both steady-state and non-steady-state conditions. Matrix algebra can also be used to solve the system of equations. If steady-state conditions are assumed, conventional algebraic techniques are applicable. The system in the Smoky Mountain Biosphere Reserve was run using lead as a test case, and assumed steady-state conditions. The steady-state equations (expressed as concentrations) are given below:

$$C^*_A = \frac{q_2\ (K_9 + K_6 + K_{10}) + K_4\ (q_1 + q_2)}{M_A\ (K_1 + K_2)\ (K_9 + K_6 + K_{10})} \tag{1}$$

$$C^*_B = \frac{(K_4 + K_9 + K_6 + K_{10})\ (q_1 + q_2)}{K_5M_B\ (K_9 + K_6 + K_{10})} \tag{2}$$

$$C^*_C = \frac{q_3\ (K_9 + K_6 + K_{10}) + (q_1 + q_2)\ (K_6 + K_9)}{K_8M_c\ (K_9 + K_6 + K_{10})} \tag{3}$$

$$C^*_D = \frac{q_1 + q_2}{M_D\ (K_9 + K_6 + K_{10})} \tag{4}$$

$$C^*_E = \frac{q_2\ K_2\ (K_9 + K_6 + K_{10}) + K_4K_2\ (q_1 + q_2)}{K_3M_E\ (K_1 + K_2)\ (K_9 + K_6 + K_{10})} \tag{5}$$

$$C^*_F = \frac{K_6\ (q_1 + q_2)}{K_7M_F\ (K_9 + K_6 + K_{10})} \tag{6}$$

Symbols used are defined as follows:

C_i^* = Steady-state concentration of lead in compartment i

M_i = Mass of compartment i

Q_i = Quantity of lead in compartment i

q_1 = Amount of lead deposited on ground surface per hectare per year

q_2 = Amount of lead deposited on overstory leaf surface per hectare per year

q_3 = Amount of lead deposited on open surface water per hectare per year

The rate constants (K_i) are estimated from literature. When unavailable from the literature, laboratory techniques such as microcosms are useful.

The equations are solved and the calculated values compared against the measured values from the monitoring program. The results of this exercise for lead are shown in Table 1. In this case there is close agreement between calculated and measured values.

TABLE 1. COMPARISON OF CALCULATED STEADY-STATE LEVELS WITH FIELD MEASUREMENTS FROM THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Component	Calculated level	Measured level
C_A^* - Vegetation	148 $\mu g g^{-1}$	34 to 40 $\mu g g^{-1}$ (Moss samples from understorey)
C_B^* - Forest litter	239 $\mu g g^{-1}$	273 $\mu g g^{-1}$
C_C^* - Surface water	0.002 $mg \ell^{-1}$	None detected by ICPES (Detection limit = 0.05 $mg \ell^{-1}$) None detected by SSMS (Detection limit = 0.001 $mg \ell^{-1}$)
C_D^* - Soil	18.5 $\mu g g^{-1}$	16 $\mu g g^{-1}$
C_E^* - Heterotrophs	Not calculated	Not measured
C_F^* - Ground water	0.0005 $mg \ell^{-1}$	None detected by ICPES (Detection limit = 0.05 $mg \ell^{-1}$) None detected by SSMS (Detection limit = 0.001 $mg \ell^{-1}$)

Certain facts stand out from this analysis concerning the final design of the monitoring system. First, if plasma emission were the analytical technique of choice for water analyses, then water sampling for lead may be discontinued because the input to the Smoky Mountain Biosphere Reserve would have to increase 25 times before the lower detection limit of the plasma emission system is exceeded. On the other hand, forest litter appears to be a good sampling medium because it appears to "concentrate" lead. Similar types of analyses would have to be run for other representative pollutants before a final monitoring program can be designed. The advantages of this systems approach are:

1. It forces the designer to consider the system as a whole rather than a series of distinct environmental components.

2. It forces an analysis and consideration of the physical, chemical and biological factors affecting pollutant transport and distribution in the system.

3. It sets up an analytical procedure for data analysis at the time the monitoring system is designed.

4. It shows the functional relationship between pollutant levels in different environmental media.

5. It identifies points where sampling design could be changed to provide for a more efficient monitoring system.

6. It identifies gaps in the current knowledge of physical, chemical and biological factors influencing transfer of pollutants and provides guidance to controlled studies addressing pollutant kinetics.

Pollutants

The selection of a limited number of pollutants to measure on background areas has been a common recommendation by many scientists concerned with monitoring systems development on background areas (Munn, 1973; Task Force II - Committee on International Environmental Affairs, 1976; and Ad Hoc Task Force on GNEM, 1970). Virtually all the pollutants suggested had a potential for long-term transport. However, advances in chemical analytical techniques allow us to reconsider this approach. For example, trace element techniques for a variety of media are now multi-elemental (Jaklevic et al. 1973, 1976; Dzubay and Stevens, 1975; and Anderson et al. 1975).

Spark source emission spectroscopy will give 26 elements per sample at one analysis. It is primarily useful for samples such as vegetation and forest litter. X-ray flourescence will measure over 20 trace elements on air filter pads at one time, and inductively coupled plasma emission spectroscopy will give 26 elements at one analysis for water samples. Spark source mass spectrometry will give estimates for virtually all elements in water samples. Neutron activation is another useful multi-elemental technique.

When using these techniques, speed of analysis is greatly increased, thereby reducing costs significantly. In addition, data analysis is simplified because the data output from these multi-elemental analytical systems can be readily placed on computer tape. However, detection limits are sometimes slightly higher than detection limits for the same element analyses by atomic absorption spectrometry. In addition, precision may be less with multi-elemental techniques. The initial purpose of measuring pollutants on reserves may allow for a decreased degree of analytical precision as well as decreased detection limits in the interest of cost.

Certain trace elements may still have to be analyzed with specialized, highly sensitive techniques. These would be elements of proven long range transport capabilities and significant toxicity to ecosystems.

Multi-residue techniques for trace organics are not as advanced as multi-elemental techniques. Also, they are more expensive than multi-elemental techniques. Multi-residue techniques are available for the major types of pesticides in most environmental samples. The techniques are routine enough that they can be recommended for use as part of a biosphere reserve monitoring program and were used in our studies.

Multi-organic residue techniques (non-pesticide) are currently available for media such as air, water and fish tissues. However, they are proably not suitable for biosphere reserve monitoring at this time because of their limited availability, the rapid development and evolution of these techniques, and their high costs ($900.00 to $1500.00 per sample).

The number of samples required is dependent on the desired confidence limits and the amount in sampling error. In our studies we arbitrarily desired a sampling error of plus or minus 10 percent at the 95 percent confidence level. For example, if witch hobble, shown in Table 2, were chosen as a sample species and strontium as the element, it would be necesary to collect approximately 23 samples. Similar estimates can be made for all species and elements. During field sampling and analysis, the number of samples used would probably be controlled by the sample/element combination with the greatest variability tempered by the resources available.

For samples that exhibit a large coefficient of variation such as the manganese in rhododendron, the number of samples required to meet precision levels as stated would be approximately 100. A decrease in precision of only 2 percent would reduce the number of samples required to 71. Our conclusion concerning the required number of vegetation samples for a biosphere reserve monitoring system is that the number required for our desired confidence level is reasonable, and a cost-effective system can be designed.

TABLE 2. COEFFICIENTS OF VARIATION FOR ELEMENTAL LEVELS IN VEGETATION SAMPLES COLLECTED IN THE GREAT SMOKY MOUNTAINS BIOSPHERE RESERVE (%)

Sample	Elements				
	Mn	Mg	Al	Sr	Ba
Rhododendron - site 11	21.4	38.5	51.4	30.4	22.3
Rhododendron - site 12	13.5	39.8	25.9	26.0	22.1
Rhododendron - site 14	15.3	50.4	22.3	37.8	17.3
Witch Hobble - site 13	20.5	30.9	22.6	23.9	11.9
Nettle - site 11	27.2	54.2	66.8	28.7	31.1
Christmas Fern - site 12	18.5	10.8	21.9	23.2	26.1
Wood Fern - site 13	10.6	64.6	20.0	34.6	12.1
Yellow Birch - site 14	34.2	45.4	30.9	24.9	26.6

Another consideration in determining the number of samples collected is the interaction of analytical error with field sampling error. All vegetation and litter samples in our studies were analyzed in triplicate and replicated nine or ten times on each sample site. With this type of design, analysis of variance techniques to determine the variability from the analytical error versus that from field sampling was accomplished (Snedecor and Cochran 1967). The estimated variance of the sample mean per determination is given by the mean square between blocks divided by the total number of determinations. This in turn can be partitioned into the various components that contribute to this variance of the individual sample mean per determination. For example, for cobalt in forest litter, 2.2 percent of the variation per determination is due to analytical error, 11.1 percent is due to subsamples from within each site, and 86.7 percent is due to variation between the sites. For lead in forest litter, the estimated variance of the sample mean per determination is broken into the following relative contributions: 1.9 percent from analytical error, 7.4 percent from variability within a site, and 90.7 percent from variability between sites, in spite of the fact that the precision limits of acceptance for lead are plus or minus 50 percent. This is an example that, as large as the analytical error may be, the field error is much greater. Therefore, to reduce field study error and to increase the reliability of estimating trace element levels, more effort should be expended on collecting samples in the field and less on reducing or improving analytical precision. Similar types of calculations were made for all elements in the forest litter; however, no deviations from the above pattern were noted.

Remote Sites

Selected sampling sites should be free of local contamination. Sampling should be at least 5 kilometers from the nearest road used by automobiles and other vehicles. Special care should be used in selecting the air monitoring sites. Suggested criteria for air sampling sites used in a previous study (Wiersma et al. 1979) were:

1. At least 8 kilometers from the nearest road that had any automobile traffic.

2. Located at as high an elevation as possible.

3. Located in a cleared area whose diameter was at least five times the height of the surrounding forest.

Quality Assurance

Field sampling must be as representative as possible. Terrain considerations sometimes preclude totally random sampling. In these cases, a grid sample is sufficient. Soil samples collected should be made up of a composite of a number of subsamples. Details on how this sampling was accomplished in the field are given by Wiersma (1979) and Wiersma et al. (1978a, 1979a).

Handling of samples should be minimized. Vegetation and forest litter samples collected for trace element analyses are processed in the following manner to avoid excessive handling. "Clean"* polyethylene bags were used to collect samples in the field. These were then placed inside another bag and sealed. They were shipped to the laboratory where immediately upon receipt the bags were opened (sample not removed) and placed in a drying oven at about 60°C for approximately 24 hours. After drying, the samples were taken into the laboratory and the vegetation broken up by hand. The technician used a new pair of surgical gloves to handle each sample. A subsample was placed in an unused 73-cubic centimeter plastic vial. Two Teflon balls were put in the vial and the vial placed in a Spex mill. The vegetation sample was ground to a powder inside the vial. The Teflon balls were removed and washed. An aliquot of the powder sample was sent to the analytical laboratory where it was analyzed directly. The remainder of the powdered sample (in the same vial) was archived.

This procedure obviously would not work for organic samples. Samples for pesticide analyses were placed in prewashed Teflon bottles but, because of the requirement for extraction, the sample handling is unavoidably increased.

Soil samples were composites of 10 subsamples. They were placed in clean bags when possible. Soil samples for pesticide analyses were placed in Teflon containers. More handling of soil samples was required because they required sieving and acid digestion. Specific details are given in Wiersma et al. (1979a).

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*supplied by "Clean Room Products"

Water samples for trace element analyses were dipped from streams and small rivers. Polyethlene bottles were used that had previously been cleaned. Samples were acidified in the field with a small amount of ultrex nitric acid. Trace organic analyses were sampled with special resin filters operated in the field or collected in 5-gallon carboys and extracted in the laboratory. The specific procedures are described by Wiersma et al. (1979a).

Air samples were primarily for trace metals. Details of this sampling are given by Wiersma et al. (1979b). To check for trace elements on air filters, three different analytical techniques were used: X-ray fluorescence, atomic absorption spectrometry, and scanning electron microscopy (SEM). Since the air sampling locations were remote, low trace element concentrations were expected. The low sample flow rates (1,000 cc/min) dictated special care in handling the sampling heads. Whenever possible, stainless steel filter holders were used. Filter holders and filters were washed and cleaned in a laboratory facility designed to have minimal trace element contaminants. They were triple-bagged in clean bags and not opened until ready to be used in the field. The sample heads were sent for AA analyses wrapped in clean plastic bags. They were not disassembled until in the laboratory. This type of handling was not necessary for samples sent for SEM analyses.

All phases of sampling are interrelated. While the extreme measures instituted above are good sampling procedure for any remote area, they were necessitated in part by the low volumes of air sampled. This was a direct result of the need to use low power consumption air pumps that were operated by batteries (Brown et al. 1979). Therefore, if flow rates could be increased or sample times lengthened, the reliability of the sample could be increased. New power sources are currently being investigated. These include remotely located solar panels and metal hydride fuel cells.

Wherever possible, quality assurance procedures were applied to samples submitted for analyses. The soil sample extracts were submitted with a minimum of 10 percent quality assurance samples. These included spiked samples, acid blanks and replicates. Vegetation and litter samples also contained up to 10 percent quality assurance samples. Samples were submitted in ascending numerical order. The contractor was required to analyze the samples in the order submitted. Every tenth sample alternated between a National Bureau of Standards (NBS) certified sample or a replicate sample. This latter sample was always taken from a large quantity of dried, powdered lettuce. The purpose of the repeated use of the same sample was to detect instrument drift. Prior to the submission of field samples, vegetative standards obtained from NBS with certified trace element levels were submitted as quality assurance samples. Based upon the results of these standards, expected precision limits were calculated for this analytical technique. The precision limits for spark source emission spectrometry are presented on the following page.

Elements	Maximum Allowable % Deviation From a Known Value or COV of Replicates
K, Ca, Mg, Cu, Mn, B, Sr, Ba, Al	20%
P, Na, Zn, Fe, Cr, Ag, Ti, V	40%
Li, Pb	50%

Minimum detection limits are:

Element	ppm	Element	ppm	Element	ppm
P	50.0	B	0.2	Sr	0.2
Na	1.0	Al	0.1	Ba	0.2
K	150.0	Si	1.0	Li	0.3
Ca	1.0	Ti	0.5	Ag	0.1
Mg	50.0	V	1.0	Sn	0.3
Zn	5.0	Co	1.5	Pb	1.0
Cu	0.2	Ni	0.5	Be	0.2
Fe	0.6	Mo	0.2	Cd	3.0
Mn	0.1	Cr	0.2		

These limits and precision values were accepted for our projects.

Similar quality assurance procedures were applied to other media. Where known value samples were difficult to obtain, two different analytical procedures were used on the same sample or on paired samples collected at the same location.

Data handling is also an essential part of quality assurance. Where possible, manual handling of data was avoided, particularly if large quantities of data were involved. For some of the analyses (trace elements in litter and vegetation), data were placed directly on magnetic tape. This included all field samples, all quality assurance samples and internal machine check samples. These were then placed on an interactive computer system. Data files could be edited and analyzed from remote terminals. This procedure eliminates several data-transcribing steps and immeasurably speeds up the analysis of data.

CONCLUSIONS

1. Monitoring pollutants in background areas (i.e. biosphere reserves) is of value for both U.S. governmental environmental agencies and international environmental agencies.

2. Pollutant monitoring on biosphere reserves can serve as an early warning of pollutant dispersal.

3. Pollutant monitoring on biosphere reserves can give background estimates of pollutants and serve as a technique for determining long term environmental trends.

4. Biosphere reserves are beginning to fulfill the terrestrial monitoring requirements of GEMS.

5. Monitoring of pollutants on biosphere reserves is practical and can be carried out in a cost-effective manner.

6. Monitoring on biosphere reserves should be multi-media.

7. A systems approach is useful in designing and analyzing a monitoring project on biosphere reserves.

~~8. Pollutant kinetics are an essential part of the systems~~ approach to monitoring.

9. Extreme care is necessary to ensure sample representativeness.

10. Extreme care should be taken to prevent sample contamination.

11. Sample variability is manageable on biosphere reserves.

12. Multi-elemental techniques are cost-effective when semi-quantitative screening of pollutants is desired.

13. Multi-residue techniques for organic compounds are suitable for routine use when pesticides are measured, but are not ready for other organic compounds.

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