GLOBAL ENVIRONMENTAL MONITORING SYSTEM (GEMS)

SCOPE 3

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS
SCIENTIFIC COMMITTEE ON PROBLEMS OF THE ENVIRONMENT

SCOPE — 1973

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GLOBAL ENVIRONMENTAL MONITORING SYSTEM (GEMS)

Action Plan for Phase I

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SCOPE Report 3
Toronto, Canada, 1973

FOREWORD

The Scientific Committee on Problems of the Environment (SCOPE) was established by ICSU in 1969 to: a) advance knowledge of the influence of man and his activities upon his environment, as well as the effects of these alterations upon man, his health and his welfare—with particular attention to those influences and effects which are either global or shared in common by several nations; and b) serve as a non-governmental, interdisciplinary and international council of scientists and as a non-governmental source of advice for the benefit of governments and intergovernmental agencies with respect to environmental problems.

The Core Programme of SCOPE has as its immediate goal the improvement of scientific procedures for assessment over the long term of changes in environment.

This involves:

1. Defining the chief elements of environmental quality deserving assessment;
2. Specifying individual parameters which need to be monitored on the basis of provisional models of the processes in which they occur;
3. Establishing scientific requirements for collection, storage, retrieval and assessment of the data which are required;
4. Establishing procedures for accurate and balanced communication of the findings regarding changes in environmental quality to individuals and public bodies concerned with action programmes, and
5. Promoting research programmes in the biosphere which will lead to ways of analysing the environment in a more efficient and informative manner, e.g., environmental transfer processes, biotic response criteria. It is recognized that assessment should be a continuous and iterative process in which: a) existing data and findings are appraised, b) methods of sampling, observation and analysis are reviewed, c) new monitoring techniques or research activity on processes are developed to meet major needs so far as practicable, d) spatial and temporal spacing of monitoring networks for each parameter are suggested, e) the need for new parameters is examined in the light of previous observation and analysis, f) the use of the findings is appraised, and g) the effectiveness of the whole effort is assessed.

H.A.W. Southon,
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Preface

In May 1973, Dr. R.E. Munn was appointed by SCOPE, in a contractual arrangement with UNEP, as a SCOPE consultant to the Inter-Agency W/G on Monitoring. The consultant was asked to prepare a proposal for an Action Plan for Phase I of a Global Environmental Monitoring System (GEMS).

Meetings were held with UNEP Officers in Geneva on May 23, and with the Inter-Agency W/G on Monitoring on June 11, when the guidelines for a written report were discussed, noting the decision at the first session of the Governing Council of UNEP that monitoring in Phase I of GEMS should be limited to a small number of priority pollutants of broad international significance. In addition, the Inter-Agency W/G decided that the organization of the table of contents should be according to media, and that in a separate Appendix (See Appendix D), the individual priority pollutants should be discussed.

During June and early July, the consultant reviewed the relevant published literature, and discussed the principles of monitoring with a number of individual scientists. This was followed by a two-week visit to the Specialized Agencies (July 9-20) and a meeting with the Inter-Agency W/G on July 19th. In this connection, the consultant is grateful to the Agencies for their cooperation and provision of detailed documentation.

The first draft of the report was prepared between July 23 and Aug. 5 at the Laboratory of the Marine Biological Association of the United Kingdom in Plymouth, England. The consultant is indebted to the Director, Dr. J.E. Smith, for providing an office and other assistance, particularly the opportunity to discuss the principles of monitoring with a number of marine biologists.

The first draft was distributed on August 6 to UNEP, to the Specialized Agencies and IAEA, to selected members of SCOPE, and to a number of other scientists around the world. During the period Aug. 7 - Sept. 15, the consultant prepared the Appendices, and reviewed the hundreds of written comments that were received from the Specialized Agencies and IAEA, and from the scientific community. In this connection, recognition is given to the following scientists for assistance in preparing first drafts of parts of Appendix D: Dr. M.L. Phillips, Toronto, Canada; Dr. D.M. Smith, Ottawa, Canada; Dr. J.E. Smith, Plymouth, England; Dr. J. Watkins, Ottawa, Canada.

During the week of Sept. 17-21, the Royal Society in London hosted meetings of the Inter-Agency W/G on Monitoring and of a SCOPE W/G on Monitoring and Assessment. The first draft of the consultant's report (and the written comments) were reviewed at that time, and many helpful suggestions were made. Special credit must be given to Dr. G.C. Butler, Ottawa, Canada, who chaired the SCOPE Working

Party that reviewed the "First Draft" in London and who undertook to edit Appendix D (priority pollutants). A Second Draft of the entire document was submitted to the Second General Assembly of SCOPE, in Kiel in October, which decided that early publication would be desirable.

GEMS contains as components, the monitoring of the atmosphere, oceans, rivers, lakes, ground-water, soils, vegetation and forests, drinking water and foods. The scientific basis for GEMS is so multidisciplinary that no single person can be expected to be a specialist in all fields. Nevertheless, because the environment must be considered as a single entity, the consultant gladly accepted the challenge in the belief that the alternative, a report by a committee of specialists, is not the best vehicle for obtaining a balanced view of a multidisciplinary subject.

Finally, it is to be noted that the Abstract is in the form of a Table summarizing the Phase I monitoring program. Other important specific proposals are scattered throughout the report in the form of recommendations, and have not been summarized.

ABSTRACT

Recommended Phase I GEMS Monitoring Program

(Asterisks denote that programs are subject to inter-governmental approval of operating manuals specifying site selection criteria, monitoring procedures and methods of chemical or physical analysis.)

	Type	No. of Stations	Pollutants and Indicators	Suggested monitoring frequency
(1) **Atmosphere**				
(a) **Stratosphere**	No GEMS Phase I program recommended.			
(b) **Troposphere**	(1) **Baseline** (remote)	10-20	—CO_2	continuous
			—turbidity	daily
			—precipitation chemistry: (SO_4, C1, NH_4, NO_3, Ca, Mg, Na, K, pH, isotopes) (Hg, Pb, Cd, DDT, PCB's)*	monthly
			—fluorcarbon 11*	monthly
	(Atmospheric baseline stations are encouraged to undertake local supplementary R. and D. monitoring of Aitken nuclei, SO_2 N_2O, NO, NO_2, NH_3, O_3, CO, CH_4, reactive hydrocarbons, particle size distribution of particles, and total suspended particulates including sulphate and lead fractions.)			
	(2) **Regional** (intermediate)	150-200	—turbidity	daily
			—precipitation chemistry (same as at baseline stations)	monthly
			—total suspended particulates (plus sulphates and lead)	monthly
			—SO_2, NO, NO_2, O_3, oxidants, reactive hydrocarbons, CO	dependent on location and season
	(3) **Impact***	3 stations per city	—SO_2	continuous
			—total suspended particulates	daily
			or COH values	2-hourly
	(Member States are encouraged to undertake local supplementary monitoring programs, and to coordinate with epidemiological pilot studies.)			
	(4) **Selected radionuclides**	Existing UNSCEAR cooperative programs to continue (See Section 12.1.)		
(2) **Oceans and Enclosed Seas**				
(a) **Deep oceans**	No GEMS Phase I program recommended.			
(b) **Surface mixed layer**				
	(1) **Remote areas***	20	Minimum program will depend on location and season, but may include daily observations of nitrates, nitrites, phosphates, salinity; weekly observations for alkalinity, CO_2 and petroleum hydrocarbons; and twice-a-year observations of fluorcarbon 11.	

(2) **Intermediate areas***
- about 200 — As above, but excluding fluorcarbon 11 and with the following possible additions: weekly observations of chlorophyll and selected nutrients; 5-yearly determinations of Pb, Cd, Hg, DDT, PCB, nitrate and nitrite residues in selected marine life; visual observations of oil slicks and tar balls on occurrence.

(3) **Impact areas***
- to be determined — As above but frequency of observations and additional substances to be monitored will be dependent on local conditions and objectives.

(4) **Selected radionuclides** — Existing UNSCEAR cooperative programs to continue (See Section 12.1.)

(3) **Rivers and lakes**

(1) **Remote areas***	5-10 lakes 10 rivers	—pH, BOD, dissolved oxygen, chlorophyll a, phosphorus, nitrogen, coliform bacteria	seasonally
(2) **Intermediate areas***	100 sites	—as above	monthly
(3) **Impact areas**	(Member States are encouraged to undertake pilot studies)		

(4) **Ground-water** — No GEMS Phase I program recommended.

(5) **Snow and ice** — No GEMS Phase I program recommended.

(6) **Soils**

(1) **Remote areas***	10-20	—pH, salinity, nitrates, phosphates	seasonally
(2) **Intermediate areas***	100	—as above	seasonally
(3) **Impact areas areas***	local option	—as above	seasonally

(Member States are encouraged to undertake local supplementary R. and D. monitoring for Hg, Pb, Cd, DDT, PCB's, ammonia, soluble salts of the alkali metals and alkaline earth metals.)

(7) **Vegetation and forests**

(1) **Remote areas***	20	—Hg, Pb, Cd, S, DDT, PCB's in lichens, mosses, edible nuts, berries and grasses	annually
(2) **Intermediate areas**	No GEMS Phase I program recommended.		
(3) **Impact areas**	No GEMS Phase I program recommended.		

(Terrestrial biome stations are encouraged to undertake local supplementary R. and D. monitoring of the relevant priority pollutants in List 2, Section 5.)

(8) **Foods**

(1) **Remote areas**	(included in vegetation and forests program)		
(2) **Intermediate areas***	150	(Minimum program to be decided later)
(3) **Impact areas***	200	(Minimum program to be decided later)
(4) **Selected radionuclides**		Existing UNSCEAR cooperative programs to continue (See Section 12.1.)

(9) **Drinking Water**

(1) **Remote areas**	(covered in rivers and lakes program)
(2) **Intermediate areas**	No program recommended
(3) **Impact areas**	Pilot studies of urban drinking water may be undertaken.
(4) **Selected radionuclides**	Existing UNSCEAR cooperative programs to continue (See Section 12.1.)

(10) **Animals, birds and birds eggs**

No GEMS Phase I program is recommended but pilot studies by Member States and intergovernmental and other regional groups are encouraged, particularly for residues of Hg, Pb, Cd, DDT and PCB's.

Contents

1. INTRODUCTION

The idea of a world-wide linkage of national and regional environmental monitoring networks is exciting and challenging. The concept has already been accepted at Stockholm and will hereafter be referred to as GEMS (Global Environmental Monitoring System). GEMS will bring many opportunities for interdisciplinary and international cooperation.

Monitoring is defined here as the process of repetitive observing, for defined purposes, of one or more elements or indicators of the environment* according to pre-arranged schedules in space and time, and using comparable methodologies for environmental sensing and data collection. Monitoring provides factual information concerning the present state and past trends (over the period of record) in environmental behavior. As examples, monitoring could include hourly observations of trace gases, daily measurements of water-quality indicators, annual surveys of forest cover, and periodic sampling (at 5 - to 10-yr intervals) of the heavy metal concentrations in food or seaweed. The observations need not be made at fixed times or at fixed locations. The system could include, for example, a mechanism for activation of supplementary data collections whenever pre-designated criteria were met, e.g., during high pollution episodes, during natural disasters, or whenever a few cases of cholera were detected in a region. The system could also include random or cluster sampling (of biota) according to standardized procedures. An important constraint, however, is that the observations be made in a systematic way.

Assessment is defined as the process of interpretation of data obtained from monitoring networks and diverse other sources. The word *assessment* has three distinct meanings in the context of monitoring:

(a) quality control,

(b) examination of the efficiency of networks, including optimization of space and time densities of observations so that interpolations between observations can be made with the desired accuracy,

(c) examination of the state of the environment, the determination of trends, and the prediction of future states, often for use in comparisons with environmental criteria or standards.

These definitions differ from those adopted in 1971 by the Intergovernmental W/G on Monitoring or Surveillance, which defined *monitoring* as a system of continued observation, measurement and evaluation for defined purposes. It is useful, however, to make a distinction between *monitoring* and *assessment* (or *evaluation*).

At the outset it should be emphasized that the design of an interdisciplinary monitoring network is not an easy task. The environment can be observed only imperfectly, the pathways through the biosphere

* Indoor environments are excluded from GEMS, unless particularly specified.

of many substances such as PCB's are not well understood, and the knowledge of the effects of various substances on human health and other biological systems is fragmentary.* Nevertheless, there is already sufficient scientific information to make a modest start towards GEMS, recognizing that an optimum design will only be reached after several decades of monitoring and assessment.

The Action Plan developed at Stockholm is divided into three parts:

1. Earthwatch,
2. Environmental management activities,
3. Supporting measures.

Earthwatch includes not only GEMS but also environmental assessment, the International Referral Service (IRS), the development of environmental criteria (e.g., dose-response relations), and supporting activities. GEMS is to provide basic data sets for environmental assessment while *Earthwatch* is to provide the necessary information for environmental management, e.g., for the preparation of alternative strategies for decision makers.

2. TIMING

GEMS cannot become fully operational in a day or in a decade. The program must therefore be divided into several phases. At the first session of the Governing Council of UNEP, there was agreement that the program should at first be limited to monitoring of the concentrations of a small number of priority pollutants of broad international significance. Although the monitoring of other kinds of data (indicators of human health and biological effects; information on food and natural resources; emission strengths) is equally important, in many cases there is not yet sufficient international agreement on methodologies for monitoring to be feasible.

The Inter-Governmental W/G on Monitoring at its meeting in Nairobi in early 1974 may wish to recommend a modest program of monitoring priority pollutants. If the recommendations are accepted at the Second Session of the UNEP Governing Council, Member States may wish to participate in GEMS, in the knowledge that methodologies for monitoring have been accepted internationally. A complete world coverage is not likely to exist (even for a few priority pollutants) in less than a few years, however. In the case of the world meteorological networks, for example, despite continued expansion over the last century, the network is still not complete.

The Phase I Action Plan will include not only proposals for monitoring a selected list of pollutants but also pre-programming activities of three types:

* Because pollutants usually occur in combination, multiplicative (synergistic) effects may take place. Furthermore, these effects are sometimes not detectable until after several generations.

(a) Expansion of the list of priority pollutants and of the media in which they may be monitored;

(b) Examination of other kinds of relevant environmental indicators (related to effects on human health and biological systems, to food and natural resources, to emission strengths, and to socio-economic states);

(c) Development of physical, chemical, biological and sampling methodologies to improve network design in the light of assessment requirements.

In some cases, field experiments (similar in concept to GATE) and intercomparisons of instruments and reference standards will be necessary.

At the end of Phase I (1976), the Inter-Governmental W/G on Monitoring, and subsequently the UNEP Governing Council, may be asked to examine a preliminary analysis of the GEMS data collected in Phase I, as well as substantive proposals for Phase II of GEMS. Thereafter the system may continue to develop stepwise, but consideration might be given in 1976 to extending the duration of Phase II to 4 years. Special note should be made of the fact that the 1976 assessment will necessarily be very preliminary. The data banks available from the various components of GEMS will most certainly be incomplete.

3. OBJECTIVES OF MONITORING

In August 1971, the Intergovernmental W/G on Monitoring or Surveillance, convened in preparation for the Conference on the Human Environment, laid down the following objectives for a world-wide environmental monitoring system (UN, 1971):

"To provide the information necessary to ensure the present and future protection of human health and safety and the wise management of the environment and its resources by:

a) (i) increasing quantitative knowledge of natural and man-made changes in the environment and of the impact of these on man's health and welfare;

(ii) increasing understanding of the environment, and, in particular, of how dynamic balance is maintained in ecosystems, as a basis for managing resources;

b) providing early warning of significant environmental changes (including natural disasters) in order that protective measures may be considered;

c) making it possible to check the effectiveness of established regulatory mechanisms and to plan optimal technological development."

These objectives were submitted to the Conference which took them as a basis for the Action Plan.

It might be emphasized that not all human activities degrade the environment. There are many instances in the last century of environmental restoration and of useful modification (e.g., reforestation, and the reduction of soot in urban and industrial areas). One of the objectives of monitoring should therefore be to provide continuing reassurance concerning the health of the environment in certain regions or media and to determine the progress in environmental enhancement in others.

Another objective of monitoring is to provide unbiased sets of data which can be disseminated widely both for public information programs and for the use of specialists around the world. The interpretation to be placed on the data sets may, of course, vary widely. By accepting internationally agreed comparable methodologies and intercalibrations, however, Member States may avoid local criticism (quite often unfounded) of the accuracy of their published data on environmental quality.

Finally, the importance should be re-emphasized not only of detecting environmental changes in the biosphere (harmful effects in particular), but also of determining the causes, i.e., of explaining the complex linkages between cause and effect. Only then can predictive models be formulated.

4. PRINCIPLES OF MONITORING

4.1. INTRODUCTION

There are two sets of principles that must be considered in the development of GEMS. On the one hand, there are institutional principles that have already been accepted at the Conference on the Human Environment. On the other hand, there are a number of scientific guidelines that provide a framework for network design.

4.2. INSTITUTIONAL PRINCIPLES

In 1971, the Intergovernmental W/G on Monitoring or Surveillance agreed on the following principles for GEMS.

1. Intergovernmental co-operation in monitoring should build on the basis of existing national and international systems to the maximum possible extent. Within the ICES programs, for example, considerable attention has already been directed towards the question of defining sampling requirements and methods of data presentation.
2. Existing United Nations Specialized Agencies should be used to the maximum extent possible as the institutional base for co-ordinating and implementing monitoring programmes. It is essential to improve co-ordination mechanisms within the United Nations framework.
3. With regard to monitoring on an international basis, priority should be given to global and regional (multi-national) problems.
4. The exchange of information about local problems that are of wide occurrence, and about the methods used to monitor them, is of high importance.

5. Special emphasis should be given in global monitoring to the variables of most critical importance that are capable of adequate scientific measurement at the present time. Where the measurement techniques for variables of critical importance are deficient, special attention should be given to their development.*
6. Monitoring systems should be designed to meet clearly-defined objectives, and arrangements for the evaluation of the data must be an integral part of the design of the system.
7. Nations that agree to participate in a system of global or regional monitoring incur an obligation to exchange promptly appropriate data or evaluations of the data, especially in relation to the early warning of natural disasters.
8. As international monitoring implies the participation of many nations, assistance, including assistance in training, should be given where necessary, to ensure the effective involvement of appropriate countries without regard to their stage of economic development.
9. Nations should share the responsibility of implementing international monitoring systems in areas outside national jurisdiction such as oceans and space. Activities carried out on national territories will be the responsibility of the nations concerned.

These principles were subsequently accepted by the Conference on the Human Environment. They provide a useful framework for a GEMS Action Plan.

Implied in the principles, and in the objectives given in Section 3, are several points that have been brought into sharper focus since 1972. For example, in the Report of the Executive Director to the First Session of the UNEP Governing Council (UNEP/GC/5, April 1973), reference is made to the "rising levels of harmful chemicals in food causing preoccupation that the exports of developing countries may be denied admission in order to protect the consumer. Conversely there is the danger that some developing countries unwittingly admit imported food which is harmful to their citizens", and it is suggested that "an important element in any monitoring system should be the repetitive measurements of harmful contaminants in food being traded so that trends may be identified at a sufficiently early stage to allow preventive action."

GEMS must of course be built upon existing national and regional monitoring activities. In many countries at the present time, monitoring is entirely on a sectional basis; thus, national interdisciplinary coordination will be required. There are more than a few cases of published data being in unsuitable forms for scientists and managers who are interested mainly in a particular discipline but who require interface data from another discipline. For example, National Meteorological Services do not always prepare climatic publications in a meaningful form for air pollution specialists; pollution control officers, on the other

* This is a scientific rather than an institutional principle but it has been placed here to preserve the original ordering.

hand, do not always publish air quality data in a form suitable for meteorological analysis and interpretation. Thus a significant benefit flowing from GEMS will be the strengthening and unification of national monitoring activities.

Important questions to be resolved, however, are:

1. What national data are to remain within a country, being of only local or national interest?
2. What national data are to be exchanged regionally?
3. What national and regional data are to be exchanged globally (the GEMS system)?

Finally, one basis for establishing inter-governmental monitoring priorities might be the degree of reversibility of effects. Arctic and alpine biomes recover very slowly when disturbed by man while contaminated ground waters may require decades or centuries to purify themselves. In other cases, however, environmental quality can be restored in days or weeks by the simple act of controlling emissions. This principle is recommended for consideration in the setting of priorities for Phase II of GEMS.

4.3. SCIENTIFIC PRINCIPLES

4.3.1. Historical Perspective

With the invention of the telegraph, the first international monitoring network (meteorological) began to develop about the middle of the nineteenth century. It was found that synoptic observations from locations 200 km apart could be used to *predict* the behaviour of the atmosphere. This provided a justification for network expansion and for international standardization of observing and coding procedures. Continuous review was, of course, required and is still necessary in the light of advancing knowledge of weather processes. The Global Atmospheric Research Programme (GARP) is a further step in this chain. Thus atmospheric monitoring has been of value not only for predicting the weather for the next day or so, but also for improving the accuracy of the prediction (by providing data sets for testing models).

In the middle of the nineteenth century too, phenological networks were established in many countries; voluntary observers kept careful records of the dates when fruit trees blossomed, when the spring break-up of river ice occurred, and so forth. The information was of considerable scientific interest but proved to be of little value as a predictive tool. Nevertheless, the networks were maintained for decades. In the United Kingdom, for example, publication of the annual phenological reports was not terminated until the 1940's.*

* In the last decade, there has been a mild upsurge of interest in the use of phenological events as indicators (and integrators) of man-made environmental impacts. For example, the first autumn killing frost occurs later in a city than in the surrounding countryside.

The differing experience with meteorological and phenological networks illustrates one of the fundamental problems associated with the design of operational monitoring programmes. On the one hand, there is a fear that large networks operating over decades will yield "curiosity" data and that the selected indicator chemical substances or biota will not be particularly useful for describing or predicting the total global environment. On the other hand, there is a fear that if monitoring is not begun at once, valuable information on trends (and data for testing models) will be lost. In the latter case, it is argued that the cost-benefit ratio may be attractive, even if only a small fraction of the observations prove to be useful.

Two strategies are possible, both of which should be explored.

a) Let the networks expand, for components where present knowledge justifies regional and global coverage and where feasibility of measurement has been demonstrated.

b) Undertake a few intensive pilot studies (as in the case of GARP), with a time limitation on the data-gathering phases, for components where present knowledge is inadequate.

In both cases, periodic assessments of the data are essential, in the light of improved models and changing environmental concerns. In this connection too, it is important to stress that sampling requirements are likely to change over the years due to improvements both in environmental models and in sampling technologies. An ultimate desirable goal is a reduction in the number of observations but during the learning process, frequent measurements in both space and time should be encouraged.

As a footnote, it is perhaps valuable to explain why the phenological data were not useful predictors. The timing of annually recurring events depends upon a large number of environmental factors, some averaged over the previous day or so, others averaged over a few weeks or months, making the interpretation of such data difficult.

4.3.2. The recent Literature on the Scientific Principles of Monitoring

There is a growing body of knowledge on monitoring principles, some of which is referenced in the annotated bibliography given in Appendix B. Inspection of the Appendix will reveal that most of the references refer to specific media, one exception being SCOPE 1 (SCOPE, 1971), which includes important discussions of the magnitude of the problem, and provides some general scientific principles for the design of monitoring systems. Admittedly SCOPE 1 contained inadequate proposals for monitoring *biological* systems, largely because the biologists had not reached a consensus. The same was true for the monitoring of sociological and economic indicators of the health of the environment. Nevertheless, SCOPE 1 provides a useful departure point for further discussions of monitoring systems. In a recent Canadian report (Environment Canada, 1973) the recommendations of a Workshop on a small (but interdisciplinary) segment of biology, namely aerobiology, are given. Member States can make useful conceptual contributions to GEMS by organizing similar workshops on specific monitoring activities.*

4.3.3. Monitoring and Modelling

In order to predict, a conceptual model for an environmental system must be formulated and verified with experimental data. The initial model is usually crude but it suggests data gaps and becomes more refined through successive approximations. GEMS is likely to develop in this way. The data requirements will, of course, change with time. Experience may reveal, for example, that two monitoring stations are sometimes yielding duplicate information. In other cases, it may be found that several substances behave in similar ways in their travel through the biosphere, so that only one of them requires intensive monitoring.

The simplest approach often is a "box" model, in which the mass budget of a pollutant is used, requiring estimates of the input, storage and output rates from a medium such as the atmosphere. The USSR proposal for a monitoring system for pollution in the world's oceans (IOC, 1973) illustrates the principle and shows how such a model is invaluable in prescribing the general framework of the monitoring network. Several boxes may be joined together conceptually to obtain an estimate of the rates at which substances are flowing along various pathways in the biosphere. Czeplak and Junge (1974) have recently examined inter-hemispheric exchange of pollutants in the troposphere. They have found that a simple 2-box model yields predictions that are in reasonable agreement with those obtained from a more complicated diffusion equation. For very complex systems, however, the possibility of feedback mechanisms (so-called *non-linear interactions*) increases and there may be unexepcted amplification or damping of physical and biological processes. As a simple physical example, suppose that through a combination of rare events, there is an unusually cold spell in the arctic winter, causing ice to form over a part of the polar seas that is normally open. Then there will be less cloudiness (because the oceanic moisture supply is cut off), resulting in increased surface radiative heat losses, and producing a tendency for the ice to perpetuate itself and in fact to expand outward. There will, of course, be a number of factors that will ultimately prevent a runaway situation but nevertheless, the positive feedback mechanism may be of at least temporary significance. In some other examples, environment changes may be virtually irreversible (e.g., cutting a forest-clearing in temperate latitudes, producing a frost pocket and thus preventing regeneration).

Feedback mechanisms in ecological systems have not been studied extensively as yet. Glover *et al.* (1972) have emphasized, however,

* Recommendations for monitoring tropospheric aerosols have been made at a recent Seminar held at the University of Stockholm (Charlson, 1973).

that sublethal concentrations of pollutants in the sea "may give rise to subtle effects in natural eco-systems which are exposed to them over long periods of time. Moreover, pollution at a sublethal level may interact with 'normal' natural stresses and so create effects which are out of all proportion to the component risks". "In dramatic pollution incidents as well as the long-term accumulation of 'trace-pollutants', there is a possibility that populations and communities which are not themselves exposed to pollution may be affected by disturbance of the ecosystem".

A perceptive contribution to the principles of monitoring is contained in an IAEA document (IAEA,1965) concerning marine radioactivity. A distinction is drawn there between the monitoring approaches required to meet two different objectives:

a) to define the state of the environment, and thus to provide a basis for predicting its future state,

b) to determine whether there is a present risk to man's health and welfare.

The network designs may be quite different in the two cases. This may be illustrated by considering urban air pollution monitoring. If the objective is to ensure that standards are met, the samplers should be located where concentrations are likely to be highest (subject, of course, to the criterion that receptors spend a significant number of hours per day in the vicinity of these sites). If the objective is to predict future trends over the entire city, using multiple-source simulation models, the network design must take account of the main topographic and meteorological features. For regional land-use planning, particularly with respect to siting new industry, a network designed to monitor only the highest concentrations will be of little value.

A related topic concerns monitoring of a few substances that have no impact on man's health and welfare but have one of the following properties:

a) They are useful tracers of pathways through the biosphere.

b) They are almost entirely produced by man and therefore are useful indicators. A prime candidate for consideration is fluorcarbon 11 (CCL_3F), which is released from aerosol dispensers, fire extinguishers, refrigerant fluids and anaesthetics (Lovelock et al., 1973). Monitoring of fluorcarbon 11 cannot be justified in terms of toxicity because the substance has no known effects at concentrations six orders of magnitude greater than the present level 10^{-10} by volume).* Yet routine monitoring would be invaluable because most of the priority pollutants have very large naturally occurring global sources, making it difficult to isolate and follow the man-made components (except near populated areas, where the latter predominate).

* Because the gas is an intense infrared absorber in the 8-13 nanometer region, a future rise in concentrations to above 10^{-9} by volume might be of concern in discussions of climatic change.

Finally, the point should be made that an interdisciplinary environmental monitoring system must meet the needs of all possible sectorial users. In addition, it must not be tied too closely to a particular model of the biosphere. An existing model may not require that certain elements or indicators be monitored with more than order-of-magnitude accuracy. A problem will almost invariably arise later, in that the data sets may be used for entirely different purposes than was intended initially. Thus the need for high-quality observations cannot be stressed too strongly. The meteorological and oceanographic communities have a long tradition in quality control and storage of physical data; the biologists have only recently realized the importance of preserving their observations in data banks (in comparable form) for the use of investigators several decades later. In this connection, the view is still expressed occasionally that there is no need for organized data-collection systems, that the results are available in the scientific literature. This overlooks the recent publication explosion, which makes it difficult for even a specialist to locate critical data, or to evaluate their accuracy. The International Referral Service will assist substantially but the scientific community still has a clear need for certain types of data banks and regular data publications.

4.3.4. Classification of Monitoring Sites According to the Degree of Human Impact

It is valuable to designate monitoring sites or areas as *remote, intermediate* and *impact* (SCOPE, 1971; WMO, 1971). In the *remote* category, the WMO criteria for a *baseline* air chemistry station (WMO, 1971) are as follows:

1. The station should be located in an area where no significant changes in land-use practices are anticipated for at least 50 years within 100 km in all directions from the station.
2. It should be located away from major population centres, major highways and air routes, preferably on small isolated islands or on mountains above the tree line.
3. The site should experience only infrequent effects from local natural phenomena such as volcanic activity, forest fires, dust and sand storms.
4. The observing staff should be small in order to minimize the contamination of the local environment by their presence and their living requirements.
5. All requirements for heating, cooking, etc., should be met by electrical power generated away from the site.
6. Access to the station should be limited to those whose presence is necessary to the operation of the station. Surface transportation should be by electrically powered vehicle, if at all possible.

Ideally, although this is hardly possible yet, baseline stations should be fully automatic with remote interrogation.

The suggestion has been made that before selecting a baeline location pilot studies should be undertaken at two adjacent sites (about a kilometre apart). If the measured values at the two sites are highly correlated, then the area may indeed be suitable for baseline measurements. This is not to suggest that the values will not vary from day to day or month to month; the important criterion is that the time sequences at the two sites are in phase, demonstrating that the cycles or trends are on the large scale. It should be noted, however, that this is a *necessary* but not a *sufficient* condition for a baseline location. For example, two adjacent sites downwind of a large swamp could certainly not be used to estimate the world background levels of methane, although concentrations measured at the two stations might be highly correlated.

The discussion in the previous paragraph introduces a question of some importance. Is the objective of baseline monitoring to determine background levels of various environmental substances and indicators, or merely to determine secular trends? In the latter case, the siting criteria need not always be so restrictive. As an example, the pH of lakes varies widely from lake to lake, even in remote areas. However, measurements in one or two adjacent lakes may yield valuable information of regional secular trends in acidity.

The WMO baseline program was designed for studies of climatic change. The sites may therefore not always be suitable for biological or resource monitoring, and other stations will undoubtedly be required. UNESCO (IHD and MAB) can play a useful role here in the selection of stations. In fact, the possibility of using a few of the IBP *ecological reserves* and/or IHD benchmark basins and decade glacier stations should not be overlooked. A guiding principle in the formulation of criteria for siting biological baseline stations is that the WMO criteria should be accepted, if at all possible, with additional restrictions as appropriate.

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. Acid rains provide essential nutrients to lakes and forests in many areas; in podsol regions where the soils and lakes are naturally acidic, however, precipitation scavenging of small amounts of industrial pollutants may seriously disturb the natural equilibrium. In this connection, the point should be made that many so-called *pollutants* are plant foods when found in moderation. In some parts of the world, natural deficiencies in these substances (e.g., nitrogen compounds in the arctic) may be growth-limiting. A case may therefore be made for monitoring what might be called *negative pollution* at remote stations. Cowling *et al.* (1973), for example, have found that when ryegrass is grown in sulfur-deficient soil in laboratory cabinets, the yield is increased when the airflow contains a modest amount of SO_2 (0.05 ppm by volume in this particular experiment).

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. If, for example, it can be demonstrated that an environmental trend in the North Atlantic Ocean is the same as in the North Pacific, the search for causes will turn to the global scale. Useful additional information will be provided by a knowledge of conditions in the Southern Hemisphere. For example, if an annual cycle in the incidence of certain health effects in the Northern Hemisphere is supposed to be related to the annual climatic cycle, a critical test of the theory could be made by gathering similar data in the Southern Hemisphere (where the cycle should be reversed if the hypothesis is correct).

The criteria for a WMO *regional* station are not so stringent as those listed above. The regional site "should be located sufficiently far away from built-up areas so as not to be dominated by fluctuations in pollution from local sources. The minimum distance of a site from the nearest pollution sources depends on the intensity of the sources. For large sources like fossil-fueled power stations, this distance might need to be as much as 60 km; for smaller sources, the distance can be less". Regional stations will normally be sited at agricultural or forestry research stations, or in some cases in IHD representatives and benchmark basins and IBP ecological reserves. In any event, the site should permit *representative* measurements to be made of elements or indicators, i.e., representative of the regional scale, with some assurance that there will be no major changes in land use during the next 50 years. The selection of sites will of course be difficult, often requiring pilot studies.

Finally, there are the *impact* stations, located in cities, polluted lakes and estuaries, for example. Monitoring at these places has the primary objective of measuring the amounts of pollutants to which receptors are exposed, for the purposes of (a), research investigations of effects or (b), pollution control. The sampling problem is most difficult here because of the great variability in space and time, and because of gaps in ecotoxicological knowledge, due in part to the presence of synergistic effects and biological adaptation. For most impact situations, the siting criteria have not yet been adequately defined, and there is a need for expert committees and pilot studies (see Section 4.3.7).

Certain monitoring activities may not fit within the WMO framework of baseline and regional stations. As a first example, concentrations of some potentially toxic substances may sometimes be higher in rural settings than in cities. The quality of drinking water and food supplies may be more uncertain in the countryside, while concentrations of pesticides and fertilizers in all media may be relatively high.

A second difficulty arises because certain kinds of monitoring data are collected as broad space and/or time averages. Examples include epiedemiological statistics (averaged over the life history of the respondants, and therefore representing exposures in various settings—home and work environments, countryside, etc.), indicators of species diversity, and observations obtained from remote sensors, which have only finite space resolutions. For lichen sampling, a 50-km transit may sometimes be necessary to obtain a representative value, depending on the spatial variability and on the purposes of monitoring.

A third difficulty is institutional in character. Some of the Specialized Agencies have already defined particular words in particular ways: to change the terminology would undoubtedly lead to confusion amongst Member States. For example, UNESCO-IHD has identified five types of hydrologic monitoring areas or stations:

a) *Representative basins* are basins which are selected as representative of a hydrological region, climate or environment. They are used for intensive investigations of specific problems of the hydrologic cycle (or parts thereof) under relatively stable, natural conditions. Data collected on these basins can be extrapolated and put to practical use in other regions of similar types, for which little hydrologic data are available. Because the research objectives of most representative basin studies involve the measurement of hydrological processes in relatively undisturbed environments, such basins present an excellent opportunity for monitoring the hydrological response to natural environmental changes.

b) *Experimental basins* are basins which are relatively homogeneous in soil and vegetation and which have uniform physical characteristics. On such basins, the natural conditions, i.e., one or more of the basin characteristics, are deliberately modified and the effects ot these modifications on the hydrologic characteristics are studied. This general objective makes it imperative that the research organization has the right to manipulate the land at will. Because more detailed studies are required on experimental basins than on representative basins, and also because of the necessity of owning or leasing experimental basins, these basins are normally restricted in size to a maximum of about 4 km^2.

c) *Benchmark basins* are representative basins which are still in their natural state and which have soil and vegetation conditions which are not expected to change for a long time. They provide data on hydrologic parameters for places representing various environments protected from the effects of man's activities.

d) *Vigil basins* are located where observations can be made over long periods of time to record changes in landscape features. Sites are selected to represent typical environments that will be affected by nearby cultural influences. Vigil stations differ from benchmark stations in that the latter are located in areas protected from man's influences. Types of data collected at Vigil stations vary and the same observations are not necessarily made or recorded at every site. In effect, each Vigil station could be the site for different specialized investigations.

e) *A Decade Glacier station* is a specialized form of hydrologic benchmark, which has been selected to provide data on ice and water balances, combined heat, and glacier fluctuations as related to meteorological processes on local, regional and global scales.

As another example of a special use of terms, marine scientists employ the word *baseline* to mean a pilot study, an initial survey of a polluted estuary or enclosed sea, to determine the extent of human impact on water quality and marine biota.

In view of these very real difficulties in terminology, the following rather general phrases are adopted in this report:

Remote stations and areas—to be interpreted in the sense of the WMO *baseline* stations;

Intermediate stations and areas—to be interpreted in the sense of a rural or forest environment; (Note that a specific location may be suitable for studies of climatic change but not for monitoring the effects of pesticides and herbicides.)

Impact stations and areas—to be associated primarily with toxicological studies.

Special note is to be taken of the fact that there will not always be a one-to-one relation between GEMS siting criteria and those developed for other purposes. For example, there will be a need for careful examination of all types of UNESCO-IHD hydrologic basins to determine the ones that are suitable for monitoring water quality, noting the fact the original IHD siting criteria were developed for investigations of the hydrologic cycle.

4.3.5. Time and Space Network Resolution

A factor of importance in predicting environmental changes is the time and space resolution of monitoring networks. In studying effects on living organisms, an averaging time of a year or longer for pollutant concentrations may sometimes be desirable. Particularly in impact situations, however, the most appropriate averaging times may be as small as a few days to a few minutes. Human respiratory ailments may worsen after a few hours of exposure to an air pollution episode while plant injury may occur almost instantaneously if concentrations are sufficiently high.

These considerations are important in physical as well as biological systems. For example, mean values of the meteorological elements averaged over the globe and over a year are not very useful predictors of climatic change; much of the essential information has been lost in the averaging process, the relevant time scale for simulation models being six hours. Finally, an example from the field of food monitoring will illustrate a related point. Chemical analysis of bulk samples of the total diet of a human population will provide information on secular trends in the uptake of various substances and will yield useful data for epidemiological analysis; however, because diets change over decades, and food distribution is related to world trade patterns, which also change over decades, trends in the chemical composition of total diets will be difficult to interpret. In the latter case, it would be preferable to monitor individual foods separately.

To summarize, the choice of an averaging time or of a network density immediately prescribes to a certain extent the resolution of the effects that can be usefully examined. In this connection, it should be noted that many data publications are merely summaries (containing mean values and perhaps also frequency distributions) that have been designed to meet the needs of particular users. For multidisciplinary assessments, however, the original observations must be readily retrievable upon request from data banks.

4.3.6. Complementary Monitoring Activities

In order to interpret cause-effect relations and to predict, a number of associated elements and indicators must be monitored. For example, there have been changes in fish populations and perhaps also in water quality in the Gulf of St. Lawrence over the last several decades. It seems, however, that a major contributing factor has been the increasing control of the tributaries flowing into the St. Lawrence River, through hydro-electric power generation. This has been reducing the range of the annual cycle of freshwater outflow into the Gulf. Because the freshwater outflow induces an underlying salt-water inflow, the physical and biological properties of the Gulf have changed. A simple analysis of fish population indicators versus water quality would therefore be misleading.

Many similar examples will come to mind but suffice it to say here that the relevant environmental indicators should be monitored. In an unpublished document (FAO, 1971), the point is rightly made that "monitoring on specific aspects of the environment such as soil degradation, water pollution, etc., carried out by random spot checking may prove difficult to interpret and lead to false conclusions unless the findings can be reviewed in the light of the nature, distribution and inter-relationship of natural resources and environmental factors obtained from basic monitoring, surveys and research".

4.3.7. Expert Committees and Pilot Studies

Expert Committees are very useful in recommending methodologies and procedures to be adopted inter-governmentally, in assigning priorities, and in bringing scientific problems into focus. However, Expert Committees rarely solve problems. There is often a need, therefore, for pilot studies, some of which can be undertaken in an individual laboratory but others requiring large field programs and international cooperation.

The scientific literature on monitoring is consistent in its philosophy that pilot studies must precede routine monitoring. The space and time variabilities of environmental indicators must be determined as a prerequisite for rational network design. In this connection, a number of pilot studies are in progress or are planned; in the marine environment, for example, there are the experimental studies of the Baltic, the Mediterranean and the Gulf of Mexico. In the field of community health, the CHESS studies in the United States are another example.

There are a number of ways in which GEMS and the Specialized Agencies can help in the promotion of pilot studies, through coordination, the provision of technical experts, training, funding for equipment, etc. However, the role that Member States can play should not be overlooked, and they should be invited to undertake pilot studies in areas of their own special competence.

4.4. OPERATIONAL PRINCIPLES

Mention should be made of a number of operational principles whose relevance is so obvious that little comment is required.

a) Comparable sampling techniques should be agreed upon internationally. The recommended methods, siting criteria, units of measurement, etc., should be published in manuals.

b) Periodic inter-calibrations are required, and reference standards or samples will be necessary in some cases.

c) Data banks should be compatible but there is no need for a single world environmental data centre. There are many mechanisms for storing observations, and each Specialized Agency will have it own preferred mode of operation. The important consideration is that a detailed and up-to-date inventory of data banks be maintained by GEMS, or its delegated authority.

d) There is an evident requirement for quality control. Even in the most competent research laboratories, arithmetic mistakes may occur when measurements are made repetitively.

e) Deadlines for submission of data should be recommended, and reporting forms should be standardized.

f) Physiogeographic descriptions (and photographs) of each monitoring site should be prepared and regularly updated.

g) Station log-books should be maintained, including complete documentation on instruments, calibrations, dates of power failures, occurrences of unusual natural or man-made phenomena, etc.

h) Because of the increasing mobility of man (with aeroplanes, snowmobiles, etc.), remote sites are becoming more and more accessible.

Attempts should therefore be made to develop indicators of temporary breaks in the fidelity of the observations because of campfires, snowmobiles or other compromising conditions. In the case of the WMO baseline stations, Aitken nuclei counters might be useful detectors of human intrusions.

i) Over decades, there will be changes and improvements in monitoring techniques. The need is obvious for at least one year of overlapping records whenever a new type of instrument is introduced.

j) The initial data obtained at each site should be analysed statistically to determine the variability of the signal, the objective being to optimize sampling frequencies. At the outset, therefore, a continuous signal should be recorded if at all feasible. Similarly, data from groups of stations should be analyzed statistically to determine spatial variability. The calculation of spatial correlation coefficients will be useful here in optimizing network densities and in the discovery of local anomalies.

4.5. THE SYSTEMS APPROACH TO MONITORING AND ASSESSMENT

The biosphere is often subdivided for convenience into components such as the atmosphere, the oceans and the continents. Ultimately, however, models of each medium must be coupled in order to undertake simulations of the total system. In this connection, an important distinction should be drawn between those media (e.g., oceans and atmosphere) that diffuse and dilute, and those media (e.g., food chains) that concentrate. Because the characteristic time scales are quite different, the linkages between the two types of media are difficult to specify in any practical way.

Simulation models are required to meet one of the objectives of Earthwatch—the development of alternate environmental management strategies. To replace an air pollution problem by a water pollution problem is no solution.

Multidisciplinary simulations are also essential tools in many scientific investigations: the problem of climatic change, for example, requires models of the linkages between the atmosphere and the biosphere, the oceans and the ice-covered regions of the world.

In view of the above, it is evident that GEMS should be designed in such a way that interactions between media can be studied, permitting delineation of the pathways of biogeochemical cycling. Here the approach developed by UNSCEAR (e.g., UNSCEAR, 1972) for ionizing radiation is commendable.

The Sections to follow are organized according to media rather than substance, at the suggestion of the Inter-Agency W/G on Monitoring. In Appendix D, however, each of the priority pollutants is discussed separately, and some indication of pathways through the biosphere is given.

The action Plan takes note, in a qualitative sense at least, of the need to design a total system. Some gaps are unavoidable, however, for at least two reasons:

a) Physical understanding of global biosphere processes is limited by a lack of suitable data. GEMS should include a feedback capability to adapt its network design in response to the data it generates. Charlson (1973) has suggested that 'institutionalized measurement programs often result in a freezing of methodologies" and he implies that this may ultimately lead to a network that is not in tune with current knowledge of the biosphere. Such a tendency should be resisted in the case of GEMS.

b) The feasibility of monitoring interface flux rates has not yet been demonstrated in many instances. The transfer of pollutants across the air-sea boundary is an example. It is therefore not yet possible to design a global monitoring system that includes the data required for even existing models of the biosphere.

5. The Priority Pollutants and Environmental Stress Indicators

An Inter-Agency W/G on Monitoring (UNEP, UNESCO, IOC, WHO, WMO, IAEA, FAO, IMCO, UNSCEAR) met frequently in 1973 and selected a tentative list of priority pollutants that should be examined for feasibility and significance in the context of GEMS. The list was reviewed in September 1973 by a Working Party of SCOPE: Dr. G.C. Butler (chairman), Dr. R.E. Munn, Dr. F.N. Frenkiel, Dr. I. Nisbet, Dr. D.A. Rennie, Dr. R.E. Waller, Dr. G.F. Humphrey, Dr. F. Webster and Mr. R. Citron (Rapporteur). The Working Party agreed on four lists of substances and environmental stress indicators:

1. Priority substances that should be examined for feasibility of measurement;
2. Selected substances drawn from list 1 that should be measured in GEMS Phase I;
3. Selected substances drawn from list 1 that could be monitored locally or regionally wherever there are special local problems;
4. Substances in list 1 not recommended for routine monitoring (mainly because feasibility has not yet been demonstrated).

List I: Substances and environmental stress indicators that are potentially important with respect to their direct and indirect effects on man and the biosphere:

1. Airborne sulphur dioxide and sulphates.
2. Suspended particulate matter.
3. Carbon monoxide.
4. Carbon dioxide and other trace gases that affect the radiative properties of the atmosphere.
5. Airborne oxides of nitrogen.
6. Ozone, photochemical oxidants and reactive hydrocarbons.
7. Polycyclic aromatic hydrocarbons.
8. Toxic metals, especially mercury, lead, and cadmium.
9. Halogenated organic compounds, especially DDT and its metabolites, PCB, PCT, Dieldrin and short-chain halogenated aliphatic compounds.
10. Asbestos.
11. Petroleum hydrocarbons.
12. Toxins of biological origin (from algae, fungi, and bacteria).
13. Nitrates, nitrites, and nitrosamines.
14. Ammonia
15. Selected indicators of water quality: biological oxygen demand (BOD), dissolved oxygen (DO), pH, coliform bacteria.
16. Selected radionuclides.
17. Airborne allergens.

18. Eutrophicators (e.g.,nitrates and phosphates).
19. Soluble salts of the alkali metals and the alkaline earth metals.
20. Other substances that have caused significant local environmental problems in the past such as arsenic, boron, elemental phosphorus, selenium, and fluoride.
21. Noise.
22. Waste heat.

After evaluating the substances and indicators included in List I, the following were selected as having high priority and also as being technically feasible for monitoring in GEMS Phase I. Many of these are already being monitored in existing national, regional and/or global programs.

List 2: Substances and environmental stress indicators recommended for monitoring in GEMS Phase I:

Substance or Indicator	*Media*
1. Airborne sulphur dioxide and sulphates	air
2. Suspended particular matter	air water
3. Carbon monoxide	air
4. Carbon dioxide	air, oceans
5. Airborne oxides of nitrogen	air
6. Ozone, photochemical oxidants and reactive hydrocarbons	air
7. Toxic metals	
a. mercury	man soil food biota water
b. lead	man soil food biota water air
c. cadmium	man food biota water
8. Halogenated organic compounds, especially DDT and its metabolites, PCB's and Dieldrin	man soil food biota
9. Petroleum hydrocarbons in water	water

10. Selected indicators of water quality	water
a. biological oxygen demand (BOD)	water
b. dissolved oxygen (DO)	water
c. pH	water
d. E.coli	water
e. ammonia	water
11. Nitrates, nitrites, and nitrosamines	water food soil
13. Specific radionuclides (Cadmium 137, Strontium 90)	all media

List 3: Substances that could be monitored locally or regionally wherever there are special local problems:

1. Soluble salts of the alkali metals and alkaline earth metals	groundwater soil
2. Eutrophicators (e.g., nitrates and phosphates)	water soil
3. Other substances that have caused significant local environmental problems in the past such as arsenic, boron, elemental phosphorus, selenium, fluoride, and selected heavy metals	soil water food
4. Noise	air
5. Waste heat	air water
6. Ammonia	soil

List 4: Substances not recommended for GEMS Phase I (mainly because the feasibility of systematic monitoring has not yet been demonstrated):

1. Polycyclic aromatic hydrocarbons
2. Asbestos
3. Allergens
4. Selected microbial contaminants
5. Myco-toxins

The SCOPE Working Party also considered the operational question of the frequency of observations and the density of networks. Some guidelines are included in the Abstract (to be found at the beginning of this report).

For comparison, Appendix C contains the lists of priority pollutants contained in the Convention on Ocean Dumping, the text of which was approved in London in November 1972: Annex I of that Convention contains a list of substances to be prohibited completely while Annex II gives substances requiring a special permit.

6. The Atmosphere

6.1. THE PROBLEM OF CLIMATIC CHANGE

6.1.1. Introduction

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

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

6.1.2. Monitoring of the Stratosphere

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

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

6.1.3. Monitoring of the Troposphere

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

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

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

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

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

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

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

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

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

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

Recommendation 3: It is recommended that financial assistance for experts, fellowships, training, capital equipment and travel be provided, to assist Member States where requested and required, for the establishment of atmospheric chemistry baseline and regional stations, consistent with overall network design.

6.1.4. Complementary Monitoring

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

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

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

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

6.2.1. Introduction

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

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

6.2.2. Monitoring Programs

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

Recommendation 5: It is recommended that the WMO baseline minimum program be extended to include:
(a) analysis of monthly precipitation samples for mercury, lead, cadmium, DDT and PCB's;
(b) monthly monitoring for fluorcarbon II, a man-made gas that is a useful tracer for comparison with substances that have both natural and man-made sources.

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

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

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

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

(b) continuous monitoring of oxides of nitrogen and oxidants at locations and during months when the average solar radiation is at least 400 langleys per day,

(c) collection of monthly samples of suspended particulate matter (or weekly, with subsequent combining of samples, at locations where the monthly loading is too great for the high-volume sampler to accept), with subsequent analysis for total suspended particulate and sulphate concentrations,

(d) continuous monitoring of SO_2 at locations and during seasons when there is a risk of vegetation damage.

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

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

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

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

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

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

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

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

6.2.3. Complementary Monitoring Programs

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

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

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

6.3. THE PROBLEM OF URBAN AND INDUSTRIAL POLLUTION

6.3.1. Introduction

There are three broad classes of air pollutants:

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

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

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

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

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

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

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

6.3.2. Monitoring Programs

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

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

Recommendation 12: It is recommended that pilot studies of urban air pollution be encouraged, with the inclusion, wherever possible, of cities for which multiple-source pollution models, emission inventories and mesometeorological networks are available, thus permitting spatial inferences to be drawn from the initial 3-site monitoring grids. Finally, it is recommended that an operational proposal for urban air pollution monitoring be prepared in 1976.

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

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

6.3.3. Complementary Monitoring Programs

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

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

The Oceans and Enclosed Seas

7.1. INTRODUCTION

Many specialized Agencies, regional organizations and scientific committees have an interest in monitoring the sea. There are world-wide observing networks in physical oceanography, including measurements of salinity; the ICES Data Centre in Copenhagen has in fact been in existence since 1902. Studies of the chemical and biological composition of the oceans on the other hand, have been undertaken regionally for the most part, the growing number of such programs being an indication of international interest. A basic principle, therefore, is that the GEMS oceanic components should be built around: (a), existing regional chemical and biological studies; and (b), the global physical oceanographic programs. The third scale of monitoring, in impact areas, will be most difficult to implement because the space and time variability is usually largest here, and the selection of sampling sites and water-quality indicators will not be an easy task.

Because ocean weather ships are stationed in remote areas, they could be used to commence a modest baseline program. The weather ships were originally established to provide meteorological observations, navigational assistance and rescue services in support of trans-oceanic aviation but this primary justification is now diminishing. The ships could direct their attention to chemical and biological monitoring. In this case, however, consideration should be given to some relocation because the present stations are not necessarily best suited for the purposes of GEMS, particularly in terms of the main features of ocean circulations. It should be noted that if changes are made, however, the ongoing series of atmospheric and oceanic data, which are of value in establishing physical baselines, may be broken. Thus, careful attention must be paid to the possible conflict between the need for unbroken atmospheric and oceanic series versus the desirability of improving monitoring effectiveness through station relocations.

Isolated islands have been suggested as an alternative to ocean weather ships but local effects (convergences, etc.) will often make their shorelines non-representative of conditions over the open oceans. In spite of this, island stations can play a role in monitoring relative levels of pollutant fluctuations and in serving as sites for early detection of pollutant increases. The concentrating effects of islands may in fact sometimes enhance their effectiveness in the latter role. An example of useful island-station monitoring is the program of sampling and analysis of petroleum tar balls on beaches and over the open ocean being carried out by investigators at the Bermuda Biological Station. Another possible use of an island is as a telemetry terminal for signals received from buoys located several kilometres offshore.

Ships of opportunity, fishing vessels and oceanographic research ships have also been suggested for monitoring the seas but there are several related problems.

a) Commercial ships are not prepared to stop to take deep-water samples. (Several research laboratories are presently attempting to develop deep-water sensors that can be used with moving ships.)

b) Commercial shipping has preferred navigation routes while fishing fleets follow the fish stocks. Hence, not only would the spatial distribution of observations be biased but also there would be the possibility that samples would be contaminated by other ships in the vicinity.

c) Observations from moving vessels confound space and time variations. Until pilot studies demonstrate that horizontal gradients in an area are insignificant and that time variations are slow, observations from a stationary platform are preferred. In many instances, the upper mixed layer of the sea, which responds rather rapidly to atmospheric changes (particularly wind), is characterized by significant chemical and biological variability.

d) In the case of oceanographic research vessels, programs are determined by particular interests of the Institutes, and these interests often change from cruise to cruise. To add a commitment for repetitive measurements of specific elements and indicators would degrade the research programs of the Institutes. Nevertheless, these vessels have a fundamental role to play in pilot studies.

Despite the above-noted comments, there are some exceptions, the plankton monitoring program in the North Atlantic (by the Edinburgh Oceanographic Laboratory of the Institute of Marine Environmental Sciences (UK), and formerly of the Scottish Marine Biological Association) being one notable example. The first regular observations were in 1931, and by 1968, thirty-three merchant ships and weather-ships were participating in the program. The Continuous Plankton Recorder, towed at a depth of 10m, provides information on abundances and species of plankton, integrated over 16-km intervals (Oceanographic Laboratory Edinburgh, 1973).

There have also been a number of programs for routine sampling of commercial catches of fish. In this connection, the migratory behaviour of marine life should be noted. Birds and salmon, for example, travel great distances, while seaweed has a rather narrow environmental sphere. Without adequate information about the life cycles in the former case, the interpretation of observations on populations, chemical contents, etc., will be difficult.

Because the oceans are the final sinks for many pollutants, the importance of monitoring cannot be over-emphasized, if for no other reason than to provide continuing reassurance that the very large (but not infinite) assimilative capacity of the seas is not being over-burdened. In impact areas, of course, this state may already have been reached in some cases. A useful ecotoxicological review of harmful substances in the marine environment has recently been published (GESAMP, 1973).

7.2. MONITORING AS A BASIS FOR REGULATORY SURVEILLANCE

One of the stated objectives of GEMS is to make it possible to check the effectiveness of established regulatory mechanisms. Article IX of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters provides: "The Contracting Parties shall promote, through collaboration within the Organization and other international bodies, support for those Parties which request it for *inter alia* the supply of necessary equipment and facilities for research and monitoring"—"Preferably within the countries concerned, so furthering the aims and purposes of this Convention". In this connection, the view has been expressed that GEMS should be designed to operate on a real-time basis to detect oil spills and other marine dumping. There are a number of reasons why a negative reply must be given, at least for the next ten years.

a) The required density of ship or buoy stations would be so large as to make the cost exhorbitant.

b) The supporting telecommunication facilities and regional analysis centres could be linked to the World Weather Watch, but the system would require expansion.

c) Remote sensing by satellites or aircraft might be feasible for detecting oil slicks (See Section 12.6) but not deep-water dumping.

Parties to the Convention and regional authorities may of course proceed to develop early-warning systems but they should not be considered to be a part of GEMS, nor should UNEP funds be used for this purpose.

In a more positive vein, GEMS can play an important role in determining average regional values, particularly in impact areas, to determine whether there are long-term upward or downward trends in water quality and marine life, thus checking the effectiveness (over periods of years) of established regulatory mechanisms. A note of caution should be added, however. Because the geophysical environment is characterized by long-term secular fluctuations, the interpretation of trends in water quality or fish populations within a region may be difficult.

There is one other way in which GEMS can assist in checking the effectiveness of established regulatory mechanisms, as follows:

Recommendation 15: It is recommended that the appropriate Specialized Agencies include in their oceanic monitoring programs, a provision for increasing the frequency of observations made at regular stations, and for temporary activation of supplementary stations, as quickly as possible after a marine episode of international significance is reported.

The London Convention of 1972 on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter designated IAEA as the competent body to define high-level radioactive matter which should not be dumped at sea, and also called upon the Parties to take full account of the Agency's recommendations in issuing permits for dumping other radioactive matter.

The IAEA has been taking the necessary steps to meet such responsibilities.

Recommendation 16: It is recommended that the IAEA keep under periodic review the recommendations called for under the London Convention of 1972 with respect to ocean dumping of radioactive wastes in order to ensure that the principles involved remain valid with the development of techniques and the provision of new data.

7.3. MONITORING PROGRAMS

7.3.1. Monitoring in Remote Areas

The use of weather ships is recommended for an initial program. Because the present monitoring activities vary from ship to ship, there is need for agreement, amongst the participating countries, on a minimum comparable program. At weather ship P in the Pacific, for example, measurements are made daily for salinity, silicate, phosphate and nitrate, and weekly for alkalinity, total CO_2 and atmospheric CO_2. In the eastern Atlantic, on the other hand, the chemical constituents are monitored only intermittently, usually to meet the needs of specific research investigators, and the results may or may not be published in the scientific literature.

Recommendation 17: It is recommended that UNEP use its good offices to promote the development of a minimum program of monitoring for selected priority pollutants at ocean weather ships, both in the atmosphere and the sea. When inter-governmental agreement is reached, the program may contribute data to GEMS Phase I.

7.3.2. Regional Monitoring

IOC has proposed a pilot project for monitoring marine pollution. The first phase will begin with the analysis of surface oil residues and dissolved petroleum hydrocarbons in samples of sea-water. This should be supported.

Recommendation 18: It is recommended that the pilot project for monitoring of petroleum residues and dissolved hydrocarbons in samples of sea-water be supported, including the costs of technical conferences, preparation of manuals, training, regional workshops and equipment for laboratories and commerical ships registered with developing countries. Based on the results of this pilot study, a proposal should be prepared in 1976 for an operational program and/or for additional pilot studies, noting the substances contained in Annexes I and II of the Convention on Ocean Dumping (See Appendix C of this report.).

The hydrocarbon content of marine waters is only one of many indicators of the health of the oceans. However, the pilot project is a useful first step, and it has the support of IOC, including the research and technical groups of experts within IGOSS. Extension of the project to other pollutants should be considered at a later date, and in the light of the scientific advice of GIPME.

Additionally, there is a need to examine the sources and sinks of marine pollution. The question of monitoring river outflows is considered in the next subsection. Another important term in the mass budget of oceans is the transfer across the air-sea interface. Part of the marine input comes directly from precipitation. (See Recommendation 9.) Part of the oceanic loss occurs with evaporating sea spray. However, a significant transfer takes place across the interface during fine weather, due to evaporation (gain to the air) and absorption (gain to the sea). Measurements of a substance in the sea and at shipboard level in the air indicate the direction of transfer but not the magnitude. There is a boundary-layer resistance at the interface, and the mass-transfer rates are complicated functions of the turbulent structures of both the atmosphere and the sea. This problem has been recognized for a number of years by various groups of experts, and a joint SCOR-IAMAP-ACMRR W/G has recently been organized. The following recommendation is therefore made.

Recommendation 19: It is recommended that the work of the SCOR-IAMAP-ACMRR W/G on tropospheric transports of pollutants to and from the sea (Stockholm Recommendation 89) be encouraged, and that IUTAM be invited to join the W/G. It is further recommended that Member States be encouraged to undertake supporting pilot studies.

Finally, there is need for additional pilot studies on marine biota in regions away from main sources of pollution. The principal objective should be the search for meaningful measurable indicators of the health of the marine environment. The following recommendation is therefore made.

Recommendation 20: It is recommended that the appropriate scientific committees and associations jointly be given support to organize amongst marine biological laboratories, pilot studies on monitoring of marine biota in regions away from main sources of pollution, the objective being to search for meaningful measurable indicators of ecosystem behaviour. Priority should be given to such variables as sunlight, timing of seasonal turnover of the surface layer, chlorophyll content, species diversity and nutrients.

In this connection, mention should be made of the important survey paper prepared by SCOR-ACMRR-UNESCO-IBP/PM, "Monitoring Life in the Ocean" (1973), which provides and excellent basis for the development of pilot studies.

7.3.3. Impact Monitoring

Impact monitoring, although most important in terms of effects, and presenting the fewest chemical-analysis problems, is nevertheless the most difficult to realize because of space and time variability. In some cases, a plume of pollution may not mix quickly with the surrounding sea water but may meander offshore in almost laminar layers. Sampling at 10-m depths may miss the peak concentrations within the plume.

Sampling of the mass transport of pollutants at river mouths presents similar difficulties, and an internationally-agreed methodology has not yet been developed. In addition, much of the pollution draining into the sea comes from small streams and rivulets which are not normally monitored, even within national programs. Mention should be made here of the UNESCO RIOS program, within which the monitoring activities at existing IHD river stations will be expanded to include chemical sampling. The following recommendation is therefore made.

Recommendation 21: It is recommended that the appropriate Specialized Agencies in collaboration with SCOR, IAHS and IUTAM be encouraged to develop internationally-agreed methodologists for monitoring the mass flow of pollutants from the continents to the seas, noting the contribution already being made within the UNESCO RIOS program. It is further recommended that Member States be encouraged to host pilot studies. Finally it is recommended that a proposal be prepared in 1976, for an operational program and/or for additional pilot studies.

As mentioned previously, a number of pilot studies of polluted bodies of water are in progress. It seeems important that the investigators should maintain contact with one another, exchanging information on methodologies and results, and attempting to reach agreement on monitoring techniques. The following recommendation is therefore made.

Recommendation 22: It is recommended that SCOR be invited to organize a workshop on existing pilot studies of the marine environment in impact areas, with a view to seeking a consensus on monitoring procedures, particularly the space and time optimizations of sampling networks.

Finally, because fish is part of the human diet, a monitoring program is desirable. In this connection, it should be noted that the relation between pollution concentrations in seawater and in marine life varies from species to species and depends (even in the case of an individual species) upon a whole chain of environmental circumstances. The uptake rates cannot therefore be predicted universally from a knowledge of the concentrations (or anticipated changes in concentrations) in sea-water.

There have been a number of recent studies of pollution concentrations in marine life. Preston (1973) has determined the heavy metal concentrations in seawater, seaweed and the muscles of fish collected in the coastal waters surrounding the British Isles. For pesticides, Butler (1966) has recommended the oyster as an indicator species, because it is particularly effective in storing residues and in subsequent flushing from its tissues if sea-water concentrations of pesticides diminish. Butler has described a network of 170 stations that is operating in the coastal waters of the United States. A number of other studies have been reported in other countries. Holden and Marsden (1967), for example, have examined the pesticide residues in seals and porpoises in Scotland and Canada. The following recommendation is therefore made.

Recommendation 23: It is recommended that inter-governmental agreement be sought on methodologies for monitoring fish, seaweed and other foods derived from the sea, for the relevant priority pollutants contained in list 2 in Section 5. The resulting programs should be coordinated with other food-monitoring activities described in Section 11.

When inter-governmental agreement is reached, such monitoring may contribute data to GEMS Phase I.

7.3.4. Complementary Monitoring Programs

The World Weather Watch and the various physical oceanographic monitoring programs will provide essential support to the GEMS marine components. In addition, data on radionuclides (See Section 12.1) will continue to be of value to marine modellers. Finally, solar radiation, which is not included within WWW, is an important quantity in the interpretation of phytoplankton blooming, and should be monitored in GEMS Phase II.

8. Rivers, Lakes, Ground Water, Snow and Ice

8.1. INTRODUCTION

Man deliberately uses rivers for waste disposal, disturbing the biota and creating downstream pollution problems. Sometimes chemical substances, such as fertilizers and pesticides, inadvertently find their way into rivers by run-off, erosion and leaching, or into ground-water by percolation.

Not all river pollution is man-made, of course. Berner (1971), for example, has estimated that about 28% of the world river sulphur resulted from human activities, the remainder coming from sedimentary rock weathering, volcanic emanations and hot springs, and sulfur carried inland from the oceans and subsequently falling in rain. Rock weathering is of course accelerated by human activities such as highway construction, which may release significant amounts of trace substances (including heavy metals) into the environment.

Many watersheds are shared by several countries. In addition, the continental water systems ultimately drain into the oceans. The problem of river pollution is therefore of both international and global significance..

One of the particularly difficult problems associated with obtaining a mass budget of river pollution (or of transfer rates into lakes and oceans) concerns sedimentation. There is often no clear demarcation between the river and the river floor. Furthermore, because pollution often enters the human food chain through minute biological organisms living in this "grey zone", the need to study sediments and their transports cannot be too strongly emphasized. Of importance is the fact that the smallest particles absorb relatively the most pollution and are transported the farthest, other things (currents, etc.) being equal. Mention should be made here of the UNESCO-IHD program on river sediments. During the first phase of the project, a survey of existing data was carried out by UNESCO with the cooperation of IAHS. Data on total erosion in 100 major rivers of more than 20 countries are now available for the computation of the gross sediment transport to the oceans. On the other hand, data on the annual specific erosion and annual turbidity collected from more than 100 rivers give an idea of the importance of erosion in the different climatic and ecological zones of the globe. Both these surveys are being updated.

One of the difficulties encountered in the execution of this program has been the lack of standard methods for measuring sediment transport.

To overcome this, the UNESCO Secretariat, in co-operation with IAHS, is preparing guidance material on modern methods of measuring sediment transport, including radiosotope techniques, with the co-operation of other international organizations. The execution of this project is being co-ordinated by the IAHS through its Commission on Erosion and Sedimentation.

Turning next to lakes, their physical and biochemical characteristics are rather different from those of the sea. Even in very large lakes, there are trapped fauna, slow hydrologic turnovers, seiches, etc. The design of a monitoring network for one of the Great Lakes is therefore likely to be quite different from that in the North Sea, for example.

Ground-water, which is estimated to contain more than 95% of the world's fresh water, is an important long-term sink for pollution. Paradoxically, the scientific community has given little attention to the problem of preserving the quality of this natural resource, which does enjoy a measure of short-term protection from environmental degradation. However, gradual contamination by petroleum hydrocarbons is in fact an almost irreversible process. Of equal or in some cases greater significance is the depletion of ground-waters by man in many parts of the world. This in turn may cause local harmful secondary effects through land subsidence and (along sea-coasts) salt water intrusions. Although recognizing the importance of monitoring both the quality and quantity of ground-water, the sampling problems are very considerable, due in part to the natural and man-induced variabilities occurring even within small areas.

Finally, the snow and ice surfaces of the globe must also be included in discussion concerning GEMS. In the first place, indications of past trends (sometimes over centuries) in pollution concentrations can be obtained from chemical analyses of snow and ice cores. Secondly, the secular trends in world snow and ice distributions are important in the context of climatic change. (See Recommendation 4). Here the important contribution of the International Commission of Snow and Ice of IAHS should be mentioned.

8.2. MONITORING PROGRAMS

UNESCO-WMO have a very extensive IHD network of stations in rivers, lakes* and watersheds. Extensive documentation is available, e.g., UNESCO (1969), and technical manuals have been written. Because the main emphasis within the IHD program has been on water quantity rather than on water quality, however, the station locations may not be entirely suitable for GEMS. Nevertheless, river flow rates are certainly required to interpret pollution transfer rates. In addition, the detailed physical picture that has been obtained of a number of small watersheds is a prerequisite for the design of pollution monitoring networks.

In the context of GEMS, the following classification of rivers, lakes and ground-water is proposed:

a) *remote areas*—hydrological basins where there are no upstream man-made emissions of pollutants arising from agricultural, industrial or urban activities;

*The IHD lakes are at least 100 km^2 in area or 10 km^3 in volume.

b) *intermediate areas*—hydrological basins where there are no up-stream emissions from industrial or urban sources, although there may be agricultural fertilizers and insecticides entering the water system through runoff.

c) *impact areas*—hydrological basins into which industrial and/or urban wastes are being released.

Using this terminology, the following recommendations are made.

Recommendation 24: It is recommended that the appropriate Specialized Agencies develop, and seek intergovernmental agreement on, a minimum river and lake water-quality monitoring program at remote and intermediate stations (but not at impact locations) using, for example, pH, BOD, dissolved oxygen, chlorophyll *a*, phosphorus, nitrogen and coliform bacteria as indicators, sampling at least once a month in intermediate areas, and once a season in remote areas. As soon as methodologies and site criteria have been incorporated into technical manuals, the program may contribute data to GEMS Phase I.

Recommendation 25: It is recommended that the appropriate Specialized Agencies examine the IHD river and lake networks in the light of requirements for inland water quality monitoring and that Member States be encouraged to offer to host pilot studies. In this connection, the possibility should be examined of designating 5 to 10 small lakes at isolated locations (in the arctic, for example) as remote monitoring areas. Finally it is recommended that in 1976, a proposal for expanded pilot and/or operational programs for monitoring inland water quality be prepared.

Recommendation 26: It is recommended that an expert committee be appointed to assess the present state of the world's major aquifers and to make recommendations on the feasibility of world-wide monitoring of ground-water, both for quantity and quality.

Recommendation 27: It is recommended that SCOPE be encouraged to propose long-term research programs for monitoring methodologies for inland water quality and for related biological indicators and accumulators.

Recommendation 28: Noting that a number of national and international river authorities are engaged in research and modelling of the chemical and biological qualities of water in impact areas, it is recommended that they be invited to submit program outlines through the appropriate Specialized Agencies to UNEP, for consideration as GEMS pilot projects. For the developing countries, financial support from UNEP might be required.

8.3. COMPLEMENTARY MONITORING ACTIVITIES

As already indicated, the IHD water quantity network, and the associated research investigations of IHD basins, will provide essential information in the design and implementation of the inland water quality component of GEMS.

9. Soils

9.1. INTRODUCTION

In arid and semi-arid regions of the world, the more serious environmental problems include salinization and alkalization of soils, and the leakage of certain plant nutrients, in particular nitrate-nitrogen, below the rooting zone. Salinization has reduced dramatically the area of productive land in irrigated regions of such countries as India and Pakistan. Recent studies have suggested that in the Great Plains region of North America also, there is reason for concern, with an increase of up to tenfold over the last fifty years, in the acreage of saline soils within areas of productive farm land. In Scandinavia, on the other hand, the problem is that of acidification of soils, reducing agricultural and forest yields (Sweden's Case Study, 1971). In the Laurentian Shield of North America, there is increasing concern that acidification may be occurring there also (e.g., Beamish and Harvey, 1972).

The rising popularity of disposing of urban and livestock wastes in agricultural soils has added a further dimension to environmental problems, in particular in semi-arid and arid regions of the world.

Improper or unwise land-use, leading to erosion, to accelerated leaching of nitrate-nitrogen, or to salinization of productive soils, has only recently been recognized as a serious environmental problem in semi-arid regions. An example is the high frequency of summer fallowing, typical of much of the Great Plains region of North America, the Middle East and many other regions of the world; summer fallowing was initially introduced as a means of conserving moisture, for weed control, and to regenerate soil fertility, particularly nitrogen. However, Rennie (1973) has suggested that the summer fallow tillage operations facilitate accelerated rates of decay of organic matter, are directly responsible for significant leakage of nitrate-nitrogen below the rooting zone, and indirectly have resulted in a comparatively rapid spread in soil salinity. These studies carried out in Western Canada, together with those reported from North Dakota, Nebraska, and also Israel led a joint FAO-IAEA panel of experts to conclude, "that studies involving the acquisition of more analytical data on nitrogen residues and their trends in soil and water are needed. These studies should be made in relation to soil environment, hydrological status, local agricultural practice, population density, waste disposal, etc. Priority should be given to arid or semi-arid zone agriculture where needs for intensive animal and plant production are associated with limited and precious water supplies."

Soil microbes are important sources or sinks for air pollutants. Grey and Jensen (1972) have found that bacteriogenic sulfur released by anaerobes in mud flats near Salt Lake City is a significant fraction of the total regional sulfur emissions while other investigators have shown that soil microbes are significant sinks for trace gases such as CO, ethylene and NO_2. A useful set of papers on the effects of pollutants on microbial activity and the resulting soil degradation is to be found in the proceedings of a recent conference (Rosswall, 1973, pp. 457-479).

Soil is not a renewable resource in the same sense as air and water. There are, in fact, critical input limits (not yet well defined) for pollutants which, if exceeded, cause almost irreversible damage. There are also a number of land uses, some of which are listed above, that degrade the soil.

Because of the importance of maintaining or increasing world food production, and because of the almost irreversible processes involved in land degradation, soil monitoring and assessment must be given high priority. In the arid zones, a trained land-use officer can give a reproducible qualitative estimate of the degree of salinization of the soils. Quantitative field sampling and analytical assessment techniques for monitoring salt movements in soils have been used under field conditions in Western Canada and elsewhere; however, some modifications in methodology are required to meet specific physiographic and soil conditions in other regions prior to initiating a soil monitoring program

9.2. MONITORING PROGRAMS

Only a small GEMS Phase I program for soils is recommended, despite the evident importance of the medium.

Recommendation 29: It is recommended that intergovernmental agreement be sought on methodologies for monitoring pH, salinity, nitrates and phosphates of soils at remote stations (not under cultivation), intermediate stations (under cultivation) and impact stations (receptors of urban and animal wastes). When operational manuals have been written and approved, the program may contribute data to GEMS Phase I.
Member States are encouraged to undertake local supplementary Research and Development monitoring for mercury, lead, cadmium, DDT, PCB's, ammonia and soluble salts of the alkaline earth metals.

Recommendation 30: It is recommended that appropriate Specialized Agencies in cooperation with SCOPE be invited to propose long-term research programs into the methodologies of soil monitoring, particularly in impact areas.

9.3. COMPLEMENTARY MONITORING ACTIVITIES

Soil monitoring should be coordinated with atmospheric and vegetation or forest monitoring, so that pathways, sources and sinks of trace substances may be examined in an integrated way. In particular, productivity measurements should be made at the soil monitoring stations.

10. Vegetation and Forests

10.1. INTRODUCTION

Vegetation and forests are useful integrators of the state of the environment. They are also important renewable sources, providing food and shelter, as well as having substantial economic impacts. Vegetation monitoring is not an easy task. A central problem is the variability in space and time. At an atmospheric or oceanic remote station, a sample of air or of seawater is likely to be representative of a reasonably large volume, if proper precautions are taken. Vegetation, on the other hand, is likely to show important microscale variations, due to differences in shade, soil characteristics, and the differing responses of different species to the same environmental stimuli. To overcome this problem in some community air pollution studies in the United States, sensitive plants are grown indoors in uniform exposures and in similar soils that are regularly fertilized and watered according to pre-arranged schedules. Species are chosen which yield symptoms characteristic of specific pollutants, and in some cases laboratory bioassays are subsequently performed.

A question that is difficult to answer is what are the indicators of the productivity and the health of a vegetated plot. Likely parameters include species populations and diversities, net photosynthetic rates, dry-weight productivity, pollution uptake rates, visible leaf damage, and evaporation rates. To understand the effects of air and soil pollution on these indicators, measurements must be made at remote, intermediate and impact locations or areas. The question then arises as to whether the other environmental factors should be kept as constant as possible—by using special plantations with identical soils (initially), or whether it would be preferable only to monitor at sites not under cultivation or forest management. These are questions to be investigated by UNESCO-MAB and the scientific community. At the present time there are as yet no internationally agreed methodologies. Furthermore, although there may now be a consensus that individual biome studies are relevant on the global scale, there is certainly no universal acceptance of the principle. This latter point of view overlooks the fact that the biosphere was spatially coherent prior to human intervention. The main vegetation and forest belts of the world were well defined, having become adapted to local and regional climatic and soil conditions, and having in fact modified these conditions to optimize their own survival rates. Human activities have disturbed these natural processes, and it is important to quantify both the baseline and disturbed states.

As a supplementary reason for monitoring the net photosynthesis of vegetation, the atmospheric global models of CO_2 and CO require estimates of uptake rates by vegetation. At present, there is little information on the magnitudes of these rates, as related to season, latitude and vegetation type.

Finally, the point should be made that vegetative covers (even under baseline conditions) are vital living entities, never quite in equilibrium with their environments over decades. The process of *succession* is often supposed to lead slowly to a steady-state *climax* condition, but this overlooks the effects of long-term climatic trends. Lakes too have a life history, man's influence being merely to accelerate the process of eutrophication. The long-term data obtained from baseline biome stations must be interpreted in this light.

In summary, there are two important reasons for monitoring vegetation and forests:

a) to obtain information on productivity,
b) to obtain information on the health of the biosphere. A poor site, for example, may support a slow-growing crop which remains healthy.

10.2. EXISTING BIOLOGICAL PILOT STUDIES

A number of biome pilot studies are in progress, many of them initiated through IBP. A subarctic environmental monitoring station has already been established in Finland, for example. Laamanen (1972) has expressed the view that the program should be coordinated as much as possible with those at other similar stations around the world. The initial monitoring at the Finnish site is limited to sampling for a few chemical substances in air, soil and an adjacent lake.

The IBP has sponsored a number of international biome studies. The tundra program, for example, links field investigations in the USSR, Austria, Canada, Finland, Ireland, Norway, Sweden, UK, and the USA (Welgolaski and Rosswall, 1972). The grassland theme includes field sites in many countries, the Matador site in the Canadian prairies being a typical example. In North and Latin America, the Institute of Ecology (TIE) has organized a network of field stations under a consortium of Canadian, U.S. and Latin American universities and institutions.

The main purpose of most existing terrestrial biome studies is to establish the inter-relations existing in plant communities under baseline conditions, with special attention being paid to productivity and stability of various species. This type of investigation is an essential preprogramming activity for GEMS Phase II and should be encouraged.

10.3. MONITORING PROGRAMS

Only a very modest Phase I GEMS program of monitoring can be proposed. However, a number of pre-programming activities for Phase II are recommended. Here, UNESCO-MAB has an important role to play.

Recommendation 31: It is recommended that the appropriate Specialized Agencies develop operation manuals for annual collection (where present) of samples of suitable species of lichen, mosses, edible nuts, berries and grasses at WMO baseline and other designated remote stations, and for subsequent analysis for mercury, lead, cadmium, sulphur, DDT and PCB's When intergovernmental agreement is reached, the program can provide data for GEMS Phase I.

The justification for this recommendation are three-fold: (a) many of these plants are in the food chains for Eskimos and other native peoples; (b), some of the plants are accumulators of pollution and are useful indicators of global pollution trends; (c), lichens in particular are very sensitive to certain types of air pollution, providing early warning of harmful biological effects.

Recommendation 32: It is recommended that the appropriate Specialized Agencies, with the assistance of SCOPE, be encouraged to develop methodologies and siting criteria for remote, intermediate and impact biological monitoring stations or areas, noting the siting criteria already established for hydrologic basins and atmospheric chemistry stations. It is also recommended that a proposal for an operational program for monitoring be prepared in 1976 by the appropriate Specialized Agencies.

Recommendation 33: It is recommended that during the period 1974-76, local supplementary Research and Development monitoring programs be encouraged at existing biome stations, to include monitoring of the relevant priority pollutants given in List 2, Section 5, in appropriate biological samples.

Finally, the FAO World Forest Inventory program should be supported.

Recommendation 34: It is recommended that the FAO World Forest Inventory program be encouraged, noting the need to develop more quantitative indicators of forest cover.

10. 4. COMPLEMENTARY MONITORING ACTIVITIES

Meteorological and precipitation chemistry measurements should of course be taken at all pilot stations or areas for biome studies. In some cases, detailed micro-meteorological observations within and above the canopies will be required.

11. Food and Drinking Water

11.1. INTRODUCTION

11.1.1. Food

Food contamination arises in two ways. In the first place, and directly related to GEMS, is the inadvertent introduction of environmental pollutants into food chains, especially in accumulator species. Of equal or of more importance to mankind is food spoilage particularly in tropical countries, due to rodents, insects and bacteria.*

The concept of remote, intermediate and impact areas is quite suitable for food monitoring.

a) Remote areas: an initial program is proposed in Section 10.3 under Recommendation 31.

b) Intermediate areas: yearly collection of unprocessed staple foods produced locally—root crops, fruits, meats, fish, etc.

c) Impact areas: periodic collection of processed foods in high-exposure areas, with special emphasis on the diets of critical groups such as children.

A special problem related to the interpretation of food monitoring data concerns the enormous variations in diets (kinds and amounts of food), even within a small sample population, whereas the quantities of air and water consumed are relatively constant. There are related difficulties in that citizens of a small community may eat food that is locally contaminated and that is not representative of regional conditions.

11.1.2. Drinking Water

The pattern for monitoring of drinking water is as follows. Samples of city water supplies could provide impact measurements (using the word *impact* in the sense that the greatest numbers of people would be affected by contamination). In rural areas in many countries, however no GEMS Phase I can be proposed because the variability in sources and quality of drinking water presents insurmountable difficulties in obtaining representative samples. Finally, for remote areas, the proposed baseline program for lake and river water quality monitoring described in Section 8.2 is sufficient. (See Recommendation 24).

11.2. FOOD MONITORING PROGRAMS

By way of introduction, recognition should be given to the progress already made by FAO and WHO on the development of methodologies

* In the USA, the annual loss of agricultural products during storage, marketing and processing is estimated to be 2800 million dollars (FAO-WHO, 1972).

for food monitoring. This work is undertaken through consultants, expert committees and panels. In addition to this information service, a more formal mechanism exists for achieving international agreement on levels of contaminants to be tolerated in foods. This is through the Codex Alimentarius Commission, composed of representatives of governments: its Committee on Pesticide Residues has recently (1972) accepted a set of methods for analysing residues of 12 types of pesticides in foods moving in international trade.

The ongoing work of the Commission and its Committees such as those on Pesticide Residues, Food Additives and Methods of Analysis and Sampling can contribute and, in turn, will also rely to some extent on the results of the food monitoring program.

Food monitoring should for comparison purposes, be coordinated with monitoring in other media, in order to reveal enrichment in the food chains of man. Examples of concentrating substances are mercury, cadmium, lead, organochlorine compounds, nitrate and nitrite. In addition, of direct harm to man, and for which analyses should be made, are mycotoxins, nitrosamines and selected microbial components.

Recommendation 35: It is recommended that intergovernmental agreement be sought on statistical sampling and collection techniques for food monitoring appropriate to the substances selected, and noting the desirability of having separate programs for intermediate and impact areas. When agreement is reached, the program my contribute data to GEMS Phase I.

The sampling program should include the following:
a) The appropriate staple foods based on the consumption in the country concerned, but also some common staple foods used in many countries,
b) Indicator foods that provide early warning of potential food contamination problems,
c) Selected microbial analysis in specific foods liable to contamination.

Recommendation 36: It is recommended that intergovernmental agreement be sought after consultation with IUPAC, on methods of analysis for trace substances suitable for use in food monitoring. These should include methods for DDT, mercury, lead, cadmium, mycotoxins, nitrates, nitrites, nitrosamines and selected microbial components in the appropriate foods.

Since "total diet" analyses are required for epidemiological studies, and since these analyses are already done in several countries, the following recommendation is made.

Recommendation 37: It is recommended that intergovernmental agreement be sought on methodologies to be used in total diet analyses, and that in 1976, a proposal be prepared for a Phase II GEMS program.

The development of operational food monitoring programs in the developing countries will require training, manuals and other facilities. The following recommendation is therefore made.

Recommendation 38: It is recommended that funds be provided for consultants, training, laboratory equipment, development of data collection systems, and preparation of operational manuals in food monitoring.

11.3. DRINKING WATER MONITORING

There is at present no international program of data publication on drinking water quality, althought there are a number of national and local reports. Municipal water-treatment plants normally take measurements and keep records of water quality, but they do not always use comparable methods. In this connection, a recent publication "International Standards for Drinking Water" (WHO, 1971a) provides valuable guidelines.

The need for an international monitoring program is linked to the fact that the interpretation of epidemiological studies requires supporting information on all environmental parameters including the quality of drinking water. Nevertheless, it is not possible at this time to propose a GEMS Phase I component. Instead, the following recommendation is made.

Recommendation 39: It is recommended that the appropriate Specialized Agencies examine the desirability and feasibility of organizing an international public health monitoring program for urban drinking water quality, commencing with a pilot study in a small group of cities, taking into account actual ingestion of water and water-containing foods, and in coordination with total-diet investigations and the urban air pollution pilot study (see Section 6.3.2.). Finally it is recommended that a proposal be made in 1976, for pilot studies and/or an operational program.

No intermediate-area activities in water quality monitoring within GEMS are suggested, for the reason given in Section 11.1.2. Nevertheless, programs of technical assistance to developing countries in the field of rural water quality should be strengthened.

For remote areas, the proposed baseline program for monitoring the water quality of lakes and rivers should be sufficient. (See Recommendation 24.)

12. All-Media Recommendations

12.1. MONITORING OF SELECTED RADIONUCLIDES

UNSCEAR, in cooperation with WHO, FAO, IAEA, WMO and national laboratories publishes regular reports on ionizing radiation (e.g., UNSCEAR, 1972). In addition, many countries publish national summaries; The Canadian report (e.g., DasGupta, 1972), for example, contains information on gross beta radioactivity in surface air and precipitation at 24 monitoring sites, concentrations of stable elements and selected radionuclides in whole milk samples obtained from 16 cities, as well as other special results.

Inspection of these reports indicates a tendency to publish summarized data (e.g., mean values and monthly extremes) rather than the original values. Presumably there are few requests, if any at all, for the basic data sets.

The UNSCEAR program is commendable and meets its stated objectives. For the purposes of GEMS, a selection from amongst the many radionuclides needs to be made, however. As indicated in list 2 in Section 5, Cesium 137 and Strontium 90 have been chosen, because of their relatively long half-lives, their ubiquity, and their consequent importance as tracers of biogeochemical pathways.

There is a related world program of monitoring isotype concentrations in precipitation. The data are published by IAEA, in cooperation with WMO and participating national laboratories (e.g., IAEA, 1973). The information is valuable to atmospheric modellers, providing clues, for example, on inter-hemispheric transfers. The following recommendation is therefore made.

Recommendation 40: It is recommended that the UNSCEAR cooperative program contribute data on levels of Cesium 137 and Strontium 90 in various media to GEMS Phase I. It is further recommended that the IAEA cooperative program on monitoring isotope concentrations in precipitation also contribute data to GEMS Phase I.

12.2. EPIDEMIOLOGICAL MONITORING

The health of human populations is already "monitored" in many ways, using indices such as infant mortality or general death rates, growth rates in terms of weight and height, and statistics of hospital admissions, sickness-absence or consultation rates with physicians. Variations in these indices with time and place are related to a whole range of medical and socio-economic factors, and it is in general difficult to isolate direct effects of environmental agents. The most clearly defined relationships are seen in the case of acute effects, whenever in a particular locality, a sudden increase in morbidity or mortality follows a sharp change in some environmental factor. Quite simple indices, such as daily or weekly totals of new cases of a particular disease, may sometimes be sufficient to implicate a local environmental factor, but in general it is necessary to monitor morbidity and mortality in considerable detail for this purpose.

The role of environmental factors in the gradual development of chronic disease is more difficult to determine, and it usually requires special enquiries among carefully defined population groups. Useful indicators of the possible influence of environmental factors can, however, be obtained from routinely collected statistics of morbidity or mortality. Much work has been done relating death rates from selected diseases in different cities, or in different parts of the same city, to the quality of air, water or food, but the populations often differ in many respects other than the quality of their physical environments. The use of occupational groups helps to reduce the variations in general socio-economic factors, but there may then be complications due to selection for fitness for the job. Data on the health of children can be valuable, but again there is a need to control for extraneous variables. Studies of the prevalence of chronic disease and of death rates among migrant groups are of special interest, since they give some idea of the relative importance of environmental conditions and ethnic origins.

An Expert Committee of WHO (WHO, 1971b) has included on a list of desirable properties for an epidemiological index, ready availability of the data (i.e., without the need for special investigations) and completeness of coverage (relating to whole populations rather than small samples); the most widely available statistics are those based on death certificates or hospital admissions. There is international agreement on the classification of causes of death, but the reliability of diagnoses varies widely. To make the maximum use of routinely collected data, there is a need to ensure uniformity in reporting procedures, and it would be helpful in studies of long-term effects, if separate sources of data on individuals could be linked in some way.

The following recommendation is therefore made.

Recommendation 41: It is recommended that the appropriate Specialized Agency examine various simple indices of morbidity and mortality, and of growth rates in terms of weight and height, noting their usefulness in studies of both short- and long-term effects of environmental stresses. Upon selection of a few priority indices, intergovernmental approval should be sought for their universal adoption.

Despite a number of difficulties (the diagnosis may be incomplete or wrong), intergovernmental standardization of reporting procedures would be a major step forward.

The suggestion has been made that selected indoor environments of study groups should be monitored. This may be feasible for selected populations, e.g., miners, but there is the additional problem of obtaining representative measurements of the indoor environment. Air quality in mines, for example, varies with depth and local ventilation rates. Nevertheless, the following recommendation is made.

Recommendation 42: It is recommended that the appropriate Specialized Agency appoint an expert committee to consider the usefulness and feasibility of monitoring selected indoor environments in order to obtain quantitative data on cause-effect relations with pollutants.

The possibility of remote, intermediate and impact epidemiological monitoring is attractive. Prior (1971), for example, has examined the health of selected groups in New Zealand, Rarotonga in the Cook Islands (representative of a transition zone between a simple existence and a European-style life) and Pukapuka and the Tokelan Islands, where life, work and dietary habits have changed little in the past century. This approach is recommended as a model for further studies.

Recommendation 43: It is recommended that the appropriate Specialized Agency develop pilot epidemiological studies for remote, intermediate and impact situations.

The question of epidemic forecasting should also be mentioned. WHO already has some programs in this field (WHO, 1972a) but the reporting of outbreaks by Member States is on a purely voluntary basis. With the recent increase in international travel, and with the current interest in monitoring, this seems an appropriate time to review existing programs and procedures.

Recommendation 44: It is recommended that an expert committee be appointed to review existing programs and procedures for epidemic forecasting.

The recommendations listed above should be undertaken in parallel with basic studies on the toxicities of various substances. A recent survey of environmental health effects is given in the WHO publication, "Health Hazards of the Human Environment" (WHO, 1972b).

12.3. MONITORING OF ANIMALS AND BIRDS

12.3.1. Introduction

Many pilot studies have been made of wild animal and bird populations, migratory behaviours and trace-substance uptakes. A number of regional networks manned by amateur observers also exist. In this connection, the sampling uncertainties associated with monitoring the numbers of endangered species are not always recognized. This is the classical "extreme-value" problem in statistics, for which the random sampling errors are likely to be large and the statistical confidence limits very wide.

An example of a well-formulated pilot study is that described by Holden (1970), a cooperative examination of organochlorine pestiside residues in terestrial and acquatic wildlife. Laboratories in the following countries participated: Canada, Finland, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States. In the first part of the program, an intercalibration of analytical methods was undertaken, through exchange of samples of cod liver oil, chicken egg, sprat homogenate and a solution of standard chemicals. In the second stage, starling, pike, marine mussel and dogfish were caught in areas believed to be free of local pesticide usage, and analyzed. It was found that the range of variation of residues among individuals of a natural population was much larger than that due to analytical errors or to differences between laboratories.

No Phase I GEMS component can be proposed. However, two important recommendations are made, one dealing with the *chemical* analysis of animal and bird specimens, the other dealing with the *effects* of environmental stresses on species and mixed populations.

12.3.2. Chemical Analysis of Wildlife Specimens

A number of pilot studies have already indicated the feasibility of monitoring for specific residues in wildlife. The following recommendation is therefore made.

Recommendation 45: It is recommended that the appropriate Specialized Agencies develop and seek intergovernmental agreement on a program for monitoring for some of the relevant priority pollutants in a few designated species of birds and animals, in remote, intermediate and impact areas. It is further recommended that an operational program be proposed in 1976 for GEMS Phase II.

During the period 1974-76, Member States are encouraged to undertake additional pilot studies, with emphasis on residues of mercury, lead, cadmium, DDT and PCB's.

12.3.3. Monitoring of Effects

When multi-species populations of birds or animals are placed under environmental stress, they respond in various complex ways. Partly because the interactions are not yet well understood in many cases, simple indices are often used to measure biological effects:

(a) Indices of species diversity or of equitability
(a measure of relative abundance),

(b) Age structures of populations,

(c) Reproductive rates,

(d) Presence or absence of sensitive indicator species.

(e) Thickness of bird eggshells (believed to be related to pesticide concentrations).

A number of individual and regional pilot studies have been undertaken. (See Jenkins, 1971, for a review, and for some recommendations concerning monitoring programs.) These pilot studies should be encouraged and expanded. In addition, there is need for national and international workshops to achieve a consensus within the scientific community on monitoring methodologies. The following recommendation is therefore made.

Recommendation 46: It is recommended that SCOPE-IUCN be invited to organize workshops on methodologies for monitoring communities of animals and birds, including endangered species, and that recommendations be made to the appropriate Specialized Agencies in 1976.

During the period 1974-76, Member States are of course encouraged to organize workshops and related pilot studies.

12.4. EMISSION MONITORING

In order to undertake a mass budget of pollutants, information on source strengths (e.g., emission rates of various industrial pollutants from chimneys and water pipes) is required. In some cases, regional source strengths can be inferred from economic data but the latter information is not always in a suitable or readily available form. Based on a SCOPE study, a consultancy report has been prepared by A. Hollaender on a proposed international registry of potentially toxic chemicals, for the UN Advisory Committee on the Application of Science and Technology to Development. There will be a number of difficulties in implementing such a scheme. In addition, there is a genuine need within the scientific community for better estimates of the strengths of the *natural* sources of the priority pollutants, as well as for man-made heat releases. The following recommendation is therefore made.

Recommendation 47: It is recommended that over the next two years, the appropriate Specialized Agencies examine the feasibility of monitoring source strengths on the regional scale. It is also recommended that SCOPE be invited to explore in greater detail than presently available, the scientific requirements for source-strength data, both man-made and natural, and for both point and diffuse area sources.

12.5. SOCIOLOGICAL AND ECONOMIC MONITORING

The health of the environment depends to a certain extent on sociological and economic factors. In the interpretation of epidemiological data, for example, information is required on the following variables: diet, education, working conditions, housing, transportation, employment, clothing, recreation and social insurance coverage (WHO, 1971b). Nevertheless, there has not yet been inter-disciplinary consensus on the most relevant sociological and economic indicators for international environmental monitoring. The following recommendation is therefore made.

Recommendation 48: It is recommended that UNEP stimulate research programs into the development of sociological and economic indicators of the state of the environment.

12.6. REMOTE SENSING

COSPAR W/G VI has prepared a report on remote sensing of climatic indicators (COSPAR W/G VI, 1972) while NASA published an earlier document on remote sensing of pollution (NASA, 1971). The most exciting remote-sensing applications for air pollution monitoring will probably not come until the 1980's, when it may be possible to obtain precise estimates of the total atmospheric burden of various trace gases.

In the immediate future, remote sensing will be most useful in determining surface properties (see Recommendation 4, Section 6.1.4.), including the presence of oil slicks and chlorophyll (an indicator of phytoplankton activity), and thermal pollution of water bodies. The following recommendation is therefore made.

Recommendation 49: It is recommended that COSPAR convene a meeting of specialists to determine the present state of the art in remote sensing, to recommend a GEMS Phase II component, and to prepare long-term proposals for research programs and pilot studies.

12.7. RARE EVENTS

The need for supplementary short-term monitoring has already been mentioned in Recommendations 15 and 43, which dealt with marine oil spills and epidemics. Other examples could be cited, e.g., massive bird kills due to inadvertent releases of toxic substances into the environment. It is noted here that the Smithsonian Institution has had considerable experience in reporting rare environmental events. The following general recommendation is therefore made.

Recommendation 50: It is recommended that UNEP appoint an Expert Committee, with representation from the Smithsonian Institution, to examine the question of emergency monitoring and to make recommendations.

12.8. PRESERVATION OF SAMPLES

Substances and processes of most concern today may be replaced by others in fifty years. Not only will knowledge of cause-effect relations increase but also the ability to measure will improve. The conceptual framework for understanding the environment is always based on what can be perceived at a particular moment in time. There is merit, therefore, in considering the storage of samples for analysis in the distant future. Appropriate material might include human teeth and hair.

WHO already has a program for storing human serum at its Serum Reference Bank in Tokyo (WHO, 1970). WHO has emphasized that in order to ensure adequate supplies for posterity, procedures for withdrawal of samples from such Banks must be established at the outset. In addition, the storage techniques must be examined carefully. There is, of course, the related problem of short-term storage and shipment of samples from GEMS remote stations to central laboratories. Robertson (1968), for example, has commented that many of the discrepancies in the reported concentrations of trace elements in the oceans are due to contamination of the samples, either during collection and storage or subsequent analysis. The following recommendation is therefore made.

Recommendation 51: It is recommended that SCOPE be invited to convene a group of experts to examine the desirability and feasibility of long-term storage of samples of physical and biological material. It is also recommended that SCOPE include in its study, the problem of short-term storage and shipment of samples obtained from remote stations and transported to central laboratories. Finally, it is recommended that the Inter-Agency W/G on Monitoring examine the SCOPE report and make appropriate recommendations to UNEP in 1976.

12.9. HISTORICAL MONITORING

SCOPE (1971) recommended in 1971 that efforts be made to extend environmental time series backward in time, e.g., by using museum specimens, varves and glaciers. Even if the information were fragmentary, it would be of value provided that the measurements were reliable. The following recommendation is therefore made.

Recommendation 52: It is recommended that a group of experts be convened to explore the general area of historical monitoring, and to prepare guidelines for deciding whether various types of historical data should be included in the GEMS system.

13. General Recommendations

13.1. TRAINING AND REGIONAL LABORATORIES

Many Agencies rightly stress the need for training programs and the establishment of regional laboratories. In the field of marine training and education, SCOR and IOC already have a comprehensive series of activities, including designated depository libraries. In the interests of efficiency, Inter-Agency coordination and multiple use of the same facilities is desirable. Complete integration will not be possible because of the differing structures and operating procedures of the Agencies. In some cases too, there are scientific reasons for not considering total integration.

Training seminars and workshops should also be coordinated whereever possible. A practical solution might consist of general seminars on the GEMS program, organized by the Inter-Agency W/G on Monitoring, and followed by specialized seminars, arranged by individual agencies.

The following recommendations are made.

Recommendation 53: It is recommended that the Inter-Agency W/G on Monitoring engage a consultant to examine Agency programs for training workshops and regional laboratories, and to recommend ways and means of obtaining maximum coordination.

Recommendation 54: It is recommended that a specific reference centre be designated in each region of the developing world, for books, reports, manuals and journals related to environmental monitoring and assessment. It is further recommended that funding and coordination be provided by UNEP. Finally, it is recommended that SCOPE be invited to provide annually to UNEP a list of relevant publications to be requisitioned by UNEP for all such reference centres.

Because of the very broad nature of GEMS and of Earthwatch, and because of the high priority of the programs, research on environmental monitoring and assessment must be stimulated at a multi-disciplinary level. The following recommendation is therefore made.

Recommendation 55: It is recommended that one or a few Member States be encouraged to give long-term support to institutions on monitoring and assessment, with associated training facilities for scientists from the developing countries. The institutes should be located at universities and should have the endorsement of the Member State and of its appropriate Academy of Science.

13.2. DATA PROCESSING AND PUBLICATION SYSTEMS

Although there is no requirement for a world data bank, the Agency data systems must be compatible. The following recommendation is therefore made.

Recommendation 56: It is recommended that the Inter-Agency W/G on Monitoring engage a consultant to examine Agency environmental data systems, to ensure compatibility and to make appropriate recommendations.

13.3 INTERNATIONAL REFERRAL SERVICE

There must be a close connection between IRS and GEMS. The following specific recommendations are made, in addition to that contained in Recommendation 54.

Recommendation 57: It is recommended that IRS should maintain complete documentation on GEMS components, including physio-geographical descriptions of monitoring sites and areas, with annual revisions.

Recommendation 58: It is recommended that UNEP support the work of the Smithsonian Institution in providing periodic surveys of national and regional environmental monitoring activities, to assist Member States and the Governing Council in their deliberations concerning GEMS programs.

13.4. MANAGEMENT OF GEMS

GEMS is envisaged as developing slowly into a very large system, with many major components. The need for careful coordination and management is therefore evident. Many of the Agencies, as well as UNEP itself, will require a full-time staff officer for GEMS within the next two years. In addition, there must be periodic reviews of the scientific credibility of the programs as well as assessments of the state of the environment. The following general recommendations are made.

Recommendation 59: It is recommended that the Inter-Agency W/G on Monitoring be retained as an essential coordinating body for GEMS. In order that the W/G can meet its objectives, it is recommended that UNEP employ a full-time staff officer for GEMS and that sympathetic consideration be given to Agency proposals for similar positions.

Recommendation 60: It is recommended that the Inter-Agency W/G on Monitoring prepare in 1976, a preliminary *assessment* of the health of the international and global environments, based on GEMS and other data. In that preliminary report, attention should be given to the examination of appropriate methodologies for assessment.

Recommendation 61: It is recommended that SCOPE and SCOR be invited to provide to the Inter-Agency W/G on Monitoring, continuing scientific advice on GEMS and on methodologies for environmental assessment.

The development of suitable methodologies for environmental assessment will not be an easy task. At a meeting in London in September 1973, a SCOPE W/G on Monitoring and Assessment proposed a series of workshops on methodology, one for each medium, followed by a further synthesizing workshop for all media. This concept was accepted by the SCOPE Second General Assembly, as a viable mechanism for providing methodologies for predicting the future, and permitting the development of environmental options for the "global village."

Environmental assessment will of course, require reliable data. Thus the greatest importance must be placed on quality control, and on the absolute necessity for inter-governmental agreement on comparable sampling and analytical procedures for monitoring each pollutant and indicator.

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Stockholm tropospheric aerosol seminar Rep. A.P.-14, Inst. of Meteorol., U. of Stockholm, 72 pp.

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Report of Sixth Session, FAO, Rome pp 24-25 and Appendix IX

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Monitoring and surveillance of the human environments: FAO policy and future plans. Unpub. document, FAO, Rome, 12 pp.

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Revised review of harmful substances Annex IV, GESAMP V/10, IOC, Paris, 38 pp.

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Modern methods in the study of microbial activity. *Bull. No. 17*, Ecol. Res. Com., Swedish Nat. Sci. Res. Council, Stockholm, 511 pp.

SCOPE
Global environmental monitoring. SCOPE 1, 67 pp. (Available from SCOPE, c/o Royal Society, London, England).

SCOR-ACMRR-UNESCO-IBP/PM (1973)
Monitoring life in the ocean. SCOR, London, England. 71 pp.

Shy, C.M. and Finklea, J.F. (1973)
Air pollution affects community health *Env. Sci and Techn., 7*, 204-208.

SMIC (1971)
Inadvertent Climate Modification. MIT Press, Cambridge, Mass., 308 pp.

Sweden's Case Study (1971)
Air pollution across national boundaries. The impact on the environment of sulphur in air and precipitation. Royal Ministry for Foreign Affairs, Royal Ministry of Agriculture, Stockholm, 96 pp.

UN (1971)
Report of the First Session of the Intergovernmental Working Group on Monitoring or Surveillance. A/CONF. 48/IWGM, 1/3, UN, Geneva, 31 pp.

UNEP (1973)
Action plan for the human environment. Programme development and priorities. Report of the Executive Director, UNEP/GC/5, Geneva, 41 pp.

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List of International Hydrological Decade stations of the world. UNESCO, Paris, 148 pp.

UNSCEAR (1972) Ionizing radiation: levels and effects. United Nations, New York, 2 volumes, 440 pp.

Welgolaski, F.E. and Rosswall, Th. (Ed) (1972)
Tundra biome. Proc. 4th Int. Meeting, IBP, 320 pp.

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Multipurpose serological surveys and WHO serum reference banks, WHO Tech. Rep. 454, WHO, Geneva 95 pp.

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Guidelines for baseline and regional stations with expanded programmes. WMO, Geneva, 100 pp.

APPENDIX A: GLOSSARY

PART I: Terms

Assessment: the process of interpretation of data obtained from monitoring networks and other sources.

Baseline station or area: a monitoring station or area in a remote area far from civilization.

Earthwatch: the UNEP programme of environmental monitoring, environmental assessment, the International Referral Service, the development of environmental criteria and supporting activities.

Environment: ambient conditions, normally out-of-doors.

Global pollutants: ubiquitous pollutants that spread around the world.

Impact station or area: a monitoring station or area for measuring the concentrations of pollutants to which receptors are exposed. Such stations or areas could be located in cities, polluted rivers or estuaries, where dosages are suspected of causing harmful effects.

International pollutants: pollutants found in sufficiently high concentration at a number of individual locations around the world that they may cause local harmful effects; and alternatively, pollutants that cross international boundaries.

Langley: unit of energy transfer—one gram-calorie per square centimetre.

Monitoring: the process of repetitive observing for defined purposes of one or more elements or indicators of the environment according to pre-arranged schedules in space and time, and using comparable methodologies for environmental sensing and data collection.

Pollution: a resource out of place.

Regional station or area: a monitoring station or area in a rural or forested area, or in the ocean or lake, at sufficient distance from urban and industrial pollution sources to permit considerable initial dilution of the pollution.

APPENDIX A: GLOSSARY Part II: Abbreviations

ACMRR	Advisory Committee on Marine Research
BOD	Biological Oxygen Demand
CHESS	Community Health and Environmental Surveillance System
COWAR	Committee on Water Research
COSPAR	Committee on Space Research
FAO	Food and Agriculture Organization
GARP	Global Atmospheric Research Programme
GATE	GARP Atlantic Tropical Experiment
GIPME	Global Investigation of Pollution in the Marine Environment
IAEA	International Atomic Energy Agency
IAHS	International Association of Hydrological Sciences
IAMAP	International Association of Meteorology and Atmospheric Physics
IAPSO	International Association of the Physical Sciences of the Ocean
IBP	International Biological Programme
ICES	International Council for the Exploration of the Sea
ICSU	International Council of Scientific Unions
IFYGL	International Field Year on the Great Lakes
IGOSS	Integrated Global Ocean Station System
IHD	International Hydrological Decade
IMCO	Intergovernmental Maritime Consultative Organization
IOC	Intergovernmental Oceanographic Commission
IRS	International Referral Service
IUCN	International Union for the Conservation of Nature
IUPAC	International Union of Pure and Applied Chemistry
IUTAM	International Union of Theoretical and Applied Mechanics
MAB	Man and Biosphere Programme
NASA	National Aeronautics and Space Administration
PCB	Polychlorinated biphenyl
RIOS	River Inputs to the Ocean Systems
SCAR	Scientific Committee on Antarctic Research
SCOPE	Scientific Committee on Problems of the Environment
SCOR	Scientific Committee on Oceanic Research
SMIC	Study of Man's Impact on Climate
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organization
WMO	World Meteorological Organization
WWW	World Weather Watch

APPENDIX B: ANNOTATED BIBLIOGRAPHY

Foreword: The papers are catalogued, using the following classifications:

1. General principles of monitoring
2. Monitoring in remote areas
3. Regional monitoring
4. Impact monitoring
5. Remote sensing
6. Stratosphere
7. Troposphere
8. Urban air pollution
9. Oceans and enclosed seas
10. Rivers, lakes, ground water, snow and ice
11. Soils
12. Biological monitoring
13. Food and drinking water
14. Epidemiological monitoring
15. Sociological and economic monitoring
16. Source strength monitoring

Under each classification, the year of publication is given, followed by an indicator number. For example, reference 3.71.2 implies that this is paper no. 2 published in 1971 under the classification, "regional monitoring".

1. GENERAL PRINCIPLES OF MONITORING

1.64.1. "Environmental measurements: valid data and logical interpretation," J.S. Nader and E.C. Tsivoglou (Eds.), US Dpt. of Health, Education and Welfare, Rbt. A. Taft, Sanitary Eng. Center, Cincinnati, Ohio, USA, 1964, 327 pp.

These Proceedings of a symposium contain useful papers on monitoring the air and water environments.

1.70.1. "Meteorological observations and instrumentation," S. Teweles and J. Giraytys (Eds.), *Meteorol. Monog.* 11, (33), 1970, 455 pp.

These symposium proceedings contain many usful insights into the principles and practical operational considerations associated with network design.

1.70.2. "SCEP: Man's Impact on the Global Environment," MIT Press, Cambridge, Mass., USA, 1970, 319 pp.

Chapter 3 (pp. 167-222) is a detailed discussion of the scientific requirements for international environmental monitoring. A number of specific recommendations are made.

1-70-3 "MABNET: the establishment of a global network of eco-stations for the MAB program," R. Citron, Smithsonian Institution, Cambridge, Mass., USA, 1970, 31 pp.

The problem of monitoring the biosphere is discussed, and a general framework for biological monitoring is presented. The report also includes a compilation of parameters suggested by numerous experts for monitoring on a global scale.

1.70.4. "Biometeorological Methods," R.E. Munn, Academic Press, New York, 1970, 336 pp.

Chapters 2 and 3 include discussions of time and space considerations in the design of monitoring networks.

1.70.5. "National and international environmental monitoring activities: a directory," Smithsonian Institution Center for Short-Lived Phenomena, Cambridge, Mass., USA, 1970, 292 pp.

A description is given of operating and planned international and national environmental monitoring activities.

1.70.6. "A global network for environmental monitoring," U.S. Nat. Comm. for IBP, Washington, D.C., 1970, 50 pp.

A proposal for a global monitoring program is given.

1.71.1. "Global environmental monitoring," SCOPE 1, 1971, 67 pp. (available from SCOPE, c/o Royal Society, London, England).

This wide-ranging interdisciplinary examination of the problems of international environmental monitoring is recommended reading.

1.71.2. "Surveillance of environmental contamination," G.C. Butler and J.J. Barry. In: Radioecology applied to the protection of man and his environment. Rome (1971), EVR 4800, pp. 723-733.

Some monitoring principles are enunciated, based on the needs for data to determine biological harm commitments of various pollutants.

1.71.3. "Report of the First Session of the Intergovernmental Working Group on Monitoring or Surveillance," A/CONF. 48 IWGM. 1/3, UN, Geneva, 1971, 31 pp.

This document is a basic reference on international environmental monitoring.

1.71.4. "The establishment of an international environmental monitoring program," R. Citron, Smithsonian Institution, Cambridge, Mass., USA, 1971, 70 pp.

This report contains an action plan for global environmental monitoring, a listing of existing (1971) programs, and a useful bibliography.

1.71.5. "International surveillance and monitoring of the environment," basic paper by the United Kingdom prepared for the Stockholm Conference, 1971, 7 pp.

The principles of monitoring are discussed in relation to objectives.

1.72.1. "Assessment and control of environmental contamination: experience with artificial radioactivity," G.C. Butler, I.L. Karol, B.G. Lindell, D.J. Stevens and V. Zeleny. *Biol. Conservation 4* (1972), 177-184.

The basic principles used for monitoring, assessing and controlling radioactive contamination of the environment are described.

1.72.2. "Ionizing radiation: levels and effects: Vol. 1: levels," UNSCEAR, UN, New York, 1972, 197 pp.

Present levels of ionizing radiation in various media around the world are given.

1.73.1. "The statistical analysis of the results of sampling an environment for a contaminant when most samples contain an undetectable level," G. Berry and N.E. Day, *Am. J. Epidem. 97* (1973), 160-166.

An example is given of aflatoxin levels in diets, in which 2432 samples were taken, with all but 124 at an undetectable level. A statistical analysis of these data is made using the gamma distribution.

See also: 9.65.1., 12.71.2.

2. MONITORING IN REMOTE AREAS

2.68.1. "Role of contamination in trace element analysis of sea water," D.E. Robertson, *Anal. Chem. 40* (1968), 1067-1072.

The contamination of sea-water samples during laboratory analysis for trace elements is discussed.

2.68.2. "The absorption of trace elements in sea water on various container surfaces," D.E. Robertson, *Anal. Chem. Acta 42*, 533-536.

The loss of trace elements by absorption onto the walls of containers (used for storing seawater samples) is invesigated.

2.69.1. "Atmospheric dust content as a factor affecting glaciation and climate change, "F.F. Davitaya, *Annals Assoc. Amer. Geog. 59* (1969), 552-560.

The author includes information on secular trends in solar radiation at 4 stations in the USSR, as well as trends in the dust contents of glacier firn samples, dating back to 1800, taken from the Maili Plateau, Kazbek, USSR.

2.70.1. "Atmospheric aerosol: does a background level exist?" W.M. Porch, R.J. Charlson and L.F. Radke, *Science 170* (1970), 315-317.

Measurements of light-scattering made with an integrating nephalometer at Point Barrow, Alaska and Mount Olympus, Washington, USA, suggest that a background level of aerosol exists and that the concept of a background is applicable.

2.70.2. "Is carbon dioxide from fossil fuel changing man's environment?" C.D. Keeling, *Proc. Am. Philosoph. Soc 114* (1970), 10-17.

This paper includes data on CO_2 baseline trends at Mauna Loa and the South Pole.

2.72.1. "Sources of atmospheric particulate matter on Hawaii," R.F. Pueschel and B.G. Mendonca, *Tellus 24* (1972), 139-149.

An evaluation is presented of the baseline qualities of the Mauna Loa site for particulate sampling.

2.72.2. "Plankton in the North Atlantic—an example of the problems of analysing variability in the environment," R.S. Glover, G.A. Robinson and J.M. Colebrook. "Marine Pollution and Sea Life," Fishing News (Books) Ltd., West Byfleet, Surrey, England, 1972, 1-7.

The problem of attempting to interpret secular trends (years 1948-1970) in the abundance of plankton in the North Atlantic is discussed. Several monitoring principles are mentioned.

2.73.1. "Worldwide variations in atmospheric transmission: 1. baseline results from Smithsonian observations," R.G. Roosen, R.J. Angione and C.H. Klemcke, *Bull. Am. Meteorol. Soc. 54* (1973), 307-316.

A monitoring program at high-altitude observatories in North and South America and Africa is described. Daily determinations of the solar constant over 50 years can be used to search for trends in atmospheric transmission of sunlight.

2.73.2. "Vertical and seasonal variability of fish eggs and larvae at ocean weather station India," R. Williams and P.J.B. Hart.

In "Proc. Symp. on Young Fish," IABO SCOR (1973) (in press).

The seasonal cycle of zooplankton abundance at a baseline station is described.

2.73.3. "Primary production at ocean weather station India in the North Atlantic," R. Williams and G.A. Robinson, *Bull. Mar. Ecol. 8* (1973) (in press).

The seasonal cycle of phytoplankton productivity at a baseline location is described, using chlorophyll *a* and total cell volume as indicators.

2.73.4. "Functions, progress and prospects for an environmental subarctic base level station," A. Laamenen, *Work Env. Health 9* (1973), 17-25.

A baseline station in the subarctic part of Finland is described.

2.73.5. "Halogenated hydrocarbons in and over the Atlantic," J.E. Lovelock, R.J. Maggs and R.J. Wade, *Nature 241*, 194-196.

Measurements of fluorcarbons in air and the water during the voyage of the RRS Shackleton from the United Kingdom to Antarctica, are reported.

2.73.6. "Oceanic aerosol levels deduced from measurements of the electrical conductivity of the atmosphere," W. E. Cobb, *J. App. Meteorol. 12*, 101-106.

Electrical conductivity values are reported from Mauna Loa and from ocean research vessels.

2.73.7. "The background level of the summer tropospheric aerosol over Greenland and the North Atlantic Ocean," H. Flyger, K. Hansen, W.J. Megaw and L.C. Cox, *J. App. Meteorol. 12*, 161-174.

Aitken nuclei concentrations are reported for the North Atlantic Ocean and Greenland.

2.74.1. "Guidelines for baseline and regional stations with expanded programs," WMO, Geneva, 1974, 100 pp.

This manual contains recommended analysis procedures for a number of trace gases.

See also: 1.72.2, 3.72.1, 7.74.3, 7.74.4, 9.73.1, 12.70.1, 12.72.1, 14.71.2.

3. REGIONAL MONITORING

3.70.1. "Study of the regime of atmospheric transparency," Z.I. Pivovarova, WMO Tech. Note No. 104, 1970, pp. 181-185.

The trends in solar radiation are presented for 6 stations in the USSR, dating back 40 years in most cases and to 1895 at Voikovo.

3.71.1. "WMO operations manual for sampling and analysis techniques for chemical constituents in air and precipitation,"

No. 299, WMO, Geneva, 1971, 23 pp.
This manual contains siting criteria for baseline and regional stations, as well as operating procedures.

3.72.1. "Organochlorine residues from plankton," R. Williams and A.V. Holden, *Mar. Poll. Bull.* D (1973), pp. 109-111.
Concentrations of PCB's, DDT and dieldrin in plankton are measured at a number of stations from the Firth of Clyde in Scotland to Ocean Weather Station India. There is a gradient of concentrations from the polluted estuary to the Weather Station baseline location.

3.73.1. "Pesticides other than DDT," Z.A. Patrick, Pub. EF-8, Inst. of Env. Sci. and Eng., U. of Toronto, Toronto, Canada, 1973, 6 pp.
In this non-specialist report, the author recommends regular monitoring for agricultural and forest pests so that spraying can be planned more effectively.

See also: 1-72-2, 7-70-1, 7-72-1, 7-72-3, 7-72-5, 7-73-7, 7-74-1, 7-74-2, 7-74-3, 7-74-4, 8-70-1, 9-66-1, 9-69-1, 9-72-1, 9-72-2, 9-73-1, 9-73-2, 9-73-3, 10-72-2, 11-72-2, 12-70-1, 12-70-2, 12-71-1, 12-73-1, 14-71-2.

4. IMPACT MONITORING

See: 1.72.2, 5.70.1, 5.71.2, 5.71.4, 5.73.2, 5.73.3, 5.73.4, 7.74.4, 9.72.1, 9.72.2, 9.73.2, 9.73.3, 11.72.2, 12.73.1, 12.73.2, 13.71.1, 13.72.1, 14.71.2, 14.73.4.

5. REMOTE SENSING

5.70.1 "Study to evaluate the utility of aerial surveillance methods in water quality monitoring," Pub. No. 41, California State Water Resources Control Board, California, USA, 1970, 100 pp.
It is concluded that the following useful quantities can be monitored with remote-sensing devices: oil spills, thermal anomalies in surface water, algae blooms, turbidity, coloured discharges and shoreline erosion or development.

5.70.2. "Spectra of backscattered light from the sea obtained from aircraft as a measure of chlorophyll concentration," G.L. Clarke, G.C. Ewing and C.J. Lorenzen, *Science 167*, 1119-1121.
Based on measurements made from a low-flying aircraft over the Atlantic off Cape Cod, the possibility of monitoring chlorophyll concentrations by remote sensing is discussed.

5.71.1. "Meteorological aspects of atmospheric pollution and possibilities of observation from space," K.Y. Kondratyev and

Kh. Yu. Niylisk, NASA Tech. Transl. F-14080, 1971, 32 pp. (available from Nat. Tech. Inf. Service, Springfield, Va., USA).

The possibility is discussed of using satellites to monitor atmospheric pollution and industrial thermal anomalies.

5.71.2. "Remote sensing of pollution", N72, 18324, NASA, Washington, USA, 1971, 253 pp.

This report of a NASA Working Group is a state-of-the-art review of remote sensing of both air and water pollutants.

5.71.3. "Global surveillance of air pollution," E.R. Bartle, M. Griggs and C.B. Ludwig. *In* Proc. Sec. Int. Clean Air Congress (H.M. Englund and W.T. Beery, Eds.,) Academic Press, N.Y. 1971, 1102-1107.

A feasibility study on monitoring air pollution from satellites is reported.

5.71.4. "Satellite remote sensing of large-scale local atmospheric pollution," A. McLellan, *In* Proc. Sec. Int. Clear Air Congress (H.M. Englund and W.T. Beery, Eds.), Academic Press, N.Y., 1971, pp. 570-575.

In a case study, satellite data have confirmed ground-based observations of turbidity in the Los Angeles area.

5.72.1. "Application of space techniques to some environmental problems," COSPAR W/G VI, 1972, 87 pp. (available from Dr. M. Tepper, NOAA, Washington, USA).

This report was prepared by a group of 25 experts and discusses preliminary design considerations for monitoring (by remote sensing) a number of climatic parameters, including atmospheric particles and trace gases.

5.73.1. "The principles of remote sensing," E. Dyring, *Ambio 2* (1973), 57-69.

The principles of remote sensing are discussed, and the available techniques are described.

5.73.2. "Remote sensing of oil slicks," S. Axelsson and E. Ohlsson, *Ambio 2* (1973), 70-76.

The technical problems associated with remote sensing of oil slicks are discussed.

5.73.3. "Monitoring of dumping by means of satellite remote sensing," C.T. Wezernak and F.J. Thomson, *Ambio 2*, (1973) 84-86.

An ERTS photograph on Aug. 16, 1972 of the New York Bight demonstrates the potential of remote sensing of ocean dumping.

5.73.4. "Water temperature surveys in the vicinity of power stations with special reference to infra-red techniques." D.J. Moore and K.W. James, *Water Res.* 7, 807-820.

Remote sensing of thermal pollution downstream from a power station is described.

5.73.5. "Techniques for air pollution observation from space," G. Ohring, J. Otterman and J. Joseph, *Water, Air and Soil Poll. 2* (1973), 191-217.

A survey is given of the techniques available for remote sensing of air pollution.

See also: 7-74-4

6. STRATOSPHERE

6.73.1. "Atmospheric monitoring and experiments: a summary of ongoing projects," S.C. Coroniti and A.J. Broderick, *In* Proc. Sec. Conf. on the Climatic Impact Assessment Program," (A.J. Broderick, Ed.), DOT-TSC-OST-73-4, US Dpt. of Transportation, Washington, D.C., 19973, pp. 13-21.

A summary is given of United States observing programs for detection of stratospheric constituents. These activities are part of the Climatic Impact Assessment Program.

6.73.2. "Measurements of some hydrogen1oxygen-nitrogen compounds in the stratosphere, from Concorde 002," J. E. Harris and N.W.B. Stone. *In* "Proc. Sec. Conf. on Climatic Impact Assessment Program," DOT-TSC-OST-73-4, (A.J. Broderick, Ed.), US Dpt of Transportation, pp. 78-85.

Measurements of the far-infrared emission spectrum of the stratosphere were made from Concorde 002 during its tour of the Far East in 1972. The spectra have been analyzed to obtain concentrations of H_2O, O_3, HNO_3, N_2O, and NO_2.

6.73.3. "Contribution of volcanic sulphur compounds to the stratospheric aerosol layer," A. W. Castleman, H.R. Munkelwitz and B. Manowitz, *Nature 244* (1973), 345-346.

Stratospheric sulphate concentrations obtained in the Southern Hemisphere in the years 1962-1971 are analyzed for trends. The authors suggest that volcanic emissions are an important stratospheric source for sulphate particles.

6.73.4. "The University of Wyoming Global Monitoring Program," T.J. Pepin, J.M. Rosen, D.J. Hofmann, J.S. Kroening, University of Wyoming, Laramie, Wyoming, USA, Preprint: AIAA/AMS International Conference on the Environmental Impact of Aerospace Operations in the High Atmosphere, Denver, Colorado, 1973, 5 pp.

In 1971 a program was begun to make bimonthly balloon soundings to determine the vertical profile of submicron dust in two size ranges, the ozone, water vapor, and temperature from eight different stations distributed in both the northern and southern hemispheres. Additional soundings are made from both poles each winter.

6.73.5. "Measurement of high-altitude air quality using aircraft," R.A. Rudey, P.J. Perkins, NASA/Lewis Research Center, Cleveland, USA. Preprint: AIAA/AMS International Conference on the Environmental Impact of Aerospace Operations in the High Atmosphere, Denver, Colorado, 1973, 10 pp.

The minor atmospheric constituents associated with and affected by aircraft exhaust emissions at altitudes from 6 to 20 km will be monitored in flight programs presently being implemented. A Global Atmospheric Sampling Program using Boeing 747 airlines is found to be feasible in studies conducted by airlines and airframe companies. Worldwide monitoring in the troposphere and the lower stratosphere is planned .

7. TROPOSPHERE

7.68.1. "Pesticides: transatlantic movements in the Northeast Trades," R.W. Risebrough, R.J. Huggett, J.J. Griffin and E.D. Goldberg, *Science 159,* 1234-1236.

Concentrations of pesticides in airborne samples over the Barbados have been determined.

7.70.1. "The importance of investigating global background pollution," E. Eriksson, WMO Tech. Note No. 196 (1970), pp. 31-54.

Trends are presented over the years 1955 to 1968 in the chemical constituents of precipitation at regional stations in Western Europe.

7.71.1. "Global air pollution-meteorological aspects," R.E. Munn and B. Bolin, *Atm. Env. 5* (1971), 363-402.

The question of international monitoring of air quality is discussed in Section 7, pp. 390-395.

7.72.1. "Estimation of the background contamination of the atmosphere from the chemical composition of precipitation," E.S. Selezneva, *Tellus 24* (1972), 122-127.

The precipitation chemistry monitoring network in the USSR is described, and some results are presented.

7.72.2. "Emissions, concentrations and fate of gaseous atmospheric pollutants," E. Robinson and R.C. Robbins. *In* "Air Poll. Control, Part II," (W. Strauss, Ed.), John Wiley and Sons Inc., New York, 1972, pp. 1-93.

Global budgets are presented for sulphur compounds, CO_2, CO, nitrogen compounds and hydrocarbons. Secular trends are given in some cases.

7.72.3. "Contribution to the planning of the station network for measuring the chemical composition of precipitation," I.L. Karol and L.T. Myatch, *Tellus 24* (1972), 421-427.

Using data on the chemical composition of precipitation obtained from 28 stations in the USSR from 1958 to 1965, space correlation coefficients are calculated, yielding information on methods of optimizing network densities. A number of important earlier papers (in Russian) by L.S. Gandin and associates, on the principles of optimizing network densities of meteorological fields, are referenced.

7.72.4. "Distribution of precipitation in mountainous areas," WMO No. 326, 2 Volumes, 1972, WMO, Geneva, Vol. 1, 587 pp., Vol. 2 in press.

These Proceedings of a Symposium held in Norway contain a survey paper (Vol. 1) on network design by H.L. Ferguson, and a group of related papers (Vol. 2) by D.R. Davis, C.C. Kisiel and L. Duckstein; C. V. Cole, G.A. Kulkarni and G.D. Khatavkar; D.M. Herschfield, G.H. Comer and B. Levy; and P. Hutchinson.

7.72.5. "Visibility changes in Ohio, Kentucky and Tennessee from 1962 ot 1969," M.E. Miller, N.L. Canfield, T.A. Ritter and C.R. Weaver, *Mon. Wea. Rev. 100* (1972), 67-71.

An increase in daytime summer haziness from 1962 to 1969 is reported from the airports at Akron, Ohio, Lexington, Ky., and Memphis, Tenn.

7.73.1. "Aerobiological monitoring recommendations," Atmospheric Environment Service, Environment Canada, Toronto, 1973, 11 pp.

This report contains the recommendations for aerobiological monitoring and research, agreed upon by a group of 25 experts at a workshop held in Toronto in April, 1973.

7.73.2. "Aerobiology and its modern applications," U.S. Component of IBP, Rep. No. 1973, 18 pp. (available from W.S. Benninghoff, Botany Dpt., U. of Michigan, Ann Arbor, Mich., USA.)

The US and international aerobiology programs of IBP are described. A useful bibliography is included.

7.73.3. "Report on the special observing systems for the first GARP study," Special Rep. No. 10, 1973, WMO, Geneva, 33 pp.

The present state of development of the World Weather Watch is described. The required supplementary systems are discussed.

7.73.4. "Environmental isotope data No. 4: world survey of isotope concentration in precipitation (1968-1969)." Tech. Rep. No. 147, IAEA, Vienna, 1973, 334 pp.

Isotope concentrations in precipitation from a world network are given for the years 1968-69.

7.73.5. "Airborne pests and the atmospheric environment," R.C. Rainey, *Weather 28* (1973), pp. 224-239.

The meteorological influences on the migrations of airborne pests, particularly desert locusts and African armyworms, are described.

7.73.6. "Scandinavian aerobiology," S. Nilsson (Ed.), Bull. No. 18, Ecol. Res. Comm., Swedish Natural Science Res. Council, Stockholm, 1973, 222 pp.

Aerobiology pilot studies in the Nordic countries are described.

7.73.7. "Stockholm tropospheric aerosol seminar," R.J. Charlson (Ed.), Rep. AP-14, Inst. of Meteorol., U. of Stockholm, 72 pp.

Specific recommendations are given for research and monitoring of tropospheric aerosols.

7.74.1. "Secular increases in summer haziness in the Atlantic provinces," R.E. Munn, *Atmosphere* (1974) (in press).

Since 1953, the number of hours of haze, smoke and dust has decreased in winter in all the major Canadian cities. The most marked summer effect is a substantial increase in haziness in the Atlantic Provinces and Eastern Quebec. It is speculated that this is due to an increase in photochemical activity.

7.74.2. "Large-scale transport of air pollutants," J. Nordo, A. Eliassen, and J. Saltbones. In Proc. IUTAM-IUGG Symp. on Turbulent Diffusion in Env. Pollution (F. N. Frenkiel and R.E. Munn, Eds.), *Adv. Geophysics* (1974) (in press).

Some preliminary results are given from the OECD West European long-range sulphur transport study.

7.74.3. "Symposium on trace gases," C. Junge, Ed., Int. Comm. on Atm. Chem. and Global Pollution, *Tellus* (1974) (in press).

This important symposium contains a number of significant papers on atmospheric trace gases, including new estimates of source and sink strengths.

7.74.4. "Tech. Conf. on the observation and measurement of atmospheric pollution (TECOMAP)," WMO, WHO, Geneva (1974) (in press).

The proceedings of this conference contain a large number of important references on air pollution.

7.74.5. "Global monitoring and surveillance of air pollutants," R.D. Cadle, *in* "Air Pollution," (A. Stern, Ed.), 3rd edition (in press).

A description is given of rationale and existing programs for monitoring global air pollution.

See also: 1-72-2, 2-69-1, 2-70-1, 2-70-2, 2-72-1, 2-73-1, 2-73-5, 2-74-1, 3-70-1, 3-71-1, 5-71-1, 5-71-2, 5-71-3, 5-71-4.

8. URBAN AIR POLLUTION

8.70.1. "Trends in urban air quality," J. H. Ludwig, G. P. Morgan and T. B. McMullen, *Trans. Am. Geophys. Un. 51* (1970), 468-475.

Trends in urban air quality in the USA over the period 1958-1968 are discussed. Some data on rural trends are also included.

8.70.2. "Current practices in siting and physical design of continuous air monitoring stations," V.M. Yamada, *J. Air Poll. Control Assoc. 20* (1970), 209-213.

A questionnaire was sent to local, county, state and regional air pollution control agencies in the USA, seeking information on siting and physical design of air monitoring stations. This paper is an analysis of the replies.

8.71.1. "Air quality surveillance," G.B. Morgan and G. Ozolins. *In* "Introduction to the Scientific Study of Atmospheric Pollution," (B.M. McCormac, Ed.), D. Reidel Publ. Co., Dordrecht-Holland, 1971, pp. 152-163.

The design of urban air quality networks is discussed.

8.71.2. "Air pollution in urban areas in the United Kingdom. Present position and recent national and regional trends," S.R. Craxford, M.-L. P.M. Weatherley and B.D. Gooriah. *In* Proc. Sec. Int. Clean Air Congress (H.M. Englund and W.T. Beery, Eds.), Academic Press, N.Y., 1971, 107-115.

Air pollution trends over the period 1951-1968 in the United Kingdom are described and discussed.

8.72.1. "Carbon monoxide concentration trends in urban atmospheres," M. Eisenbud and L.R. Ehrlich, *Science 176* (1972), 193-194.

Measurement of CO in New York streets in 1922, 1932, 1966, and 1967 are compared.

8.73.1. "Do air monitoring station data represent the surrounding community exposure?" N.M. Perkins, *Int. J. Biometeorol. 17* (1973), 23-28.

The CO concentrations at a monitoring station are compared with those at surrounding points in Los Angeles County.

8.73.2. "The question of the selection of the number of sampling stations and the frequency of observations of air pollution," B.B. Goroshko. In "Air pollution and atmospheric diffusion," (M.E. Berlyand, Ed.) English transl. by Israel Program for Sc. Transl., John Wiley and Sons, 1973, pp. 147-159.

The question of designing urban air pollution monitoring networks is considered. The author emphasizes that design considerations in a city containing multiple low-level emissions are different from those in a city containing one or a few tall chimneys.

8.73.3. "A methodology for monitoring and optimizing station location in a two-parameterized monthly sampling network," B.J. Rhoades, Preprint 73-159, Air Poll. Control Assoc. Annual Meeting, 1973, 22 pp.

The problem of optimizing dustfall and sulfation networks in St. Louis, Mo. is discussed.

8.73.4. "Considerations for siting air quality monitors in urban areas," P.R. Harrison, Preprint 73-161, Air Poll. Control Assoc. Annual Meeting: 1973, 16 pp.

Using Chicago as an example, the problems associated with siting urban air quality stations are discussed.

8.73.5. "Comparison of high-volume air filter samples at varying distances from Los Angeles freeways," R.J. Bryan, R.J. Gordon H. Menck, Preprint 73-158, Air Poll. Control Assoc. Annual Meeting, 1973, 24 pp.

The small-scale urban variations in concentrations of total suspended particulates, as well as the fractions of lead, benzene-soluble organics and polycyclic aromatic hydrocarbons, are described. The implications for epidemiological studies are discussed.

See also: 7.72.2., 7.74.4., 14.73.2., 14.73.4.

9. OCEANS AND ENCLOSED SEAS

9.65.1. "Methods of surveying and monitoring marine radio-activity," Safety Series No. 11, IAEA, Vienna, 1965, 95 pp.

The principles and methodologies for oceanic monitoring are included in this monograph.

9.66.1. "Pesticides in the marine environment," P.A. Butler, *J. Appl. Ecol. 3* (1966), 253-259.

This paper includes a brief description of a monitoring program for pesticides in oysters in the coastal waters of the USA.

9.69.1. "The sub-lethal effects of pesticide pollution," P.A. Butler, *In* The biological impact of pesticides in the environment. (J.W. Gillett, Ed.), Env. Health Series No. 1, 1969, pp. 87-89.

A monitoring program for pesticide residues in oysters was begun in 1965. As of 1969, there were 170 permanent sampling stations in the coastal waters of the USA. Monthly samples are analyzed.

9.72.1. "On some trace metals in the Baltic," R.S. Gupta, *Ambio 1* (1972), 226-230.

First results are reported from a pilot study of the Baltic. The concentrations of some trace metals are given, based on measurements obtained from an international network of stations.

9.72.2. "British Isles coastal waters: the concentrations of selected heavy metals in sea water, suspended matter and biological indicators—a pilot survey," A. Preston, D.F. Jefferies, J.W.R. Dutton, B.R. Harvey and A.K. Steele, *Env. Poll. 3* (1972), 69-82.

For the coastal waters of Britain, concentrations of heavy metals in samples of sea water, suspended matter, seaweed, porphyra and limpets are given. Seaweed concentrations show little change over a 10-yr period.

9.73.1. "Continuous plankton records: a plankton atlas of the North Atlantic and the North Sea," The Oceanography Laboratory, Edinburgh, Scotland, *Bull. Mar. Ecol.* 7 (1973), 1-174.

A plankton atlas for the North Atlantic is presented, based on measurements made with the Continuous Plankton Recorder, developed in 1931 and now towed by a number of merchant and weather ships.

9.73.2. "Preliminary report on GIPME and IGOSS marine pollution monitoring programs," IOC-WMO/ITECH-1/13, Mar. 28, 1973, 22 pp.

IOC consultant Dr. D. Eisma has summarized and evaluated the responses received from member states to the IOC/WMO questionaire on national and regional marine pollution monitoring programs, and to the IOC questionaire on monitoring of riverborne pollutants and marine pollution pilot studies. Dr. Eisma also makes some suggestions for a practical international marine pollution monitoring program.

9.73.3. "Heavy metals in British waters," A. Preston, *Nature 342* (1973), 95-97.

The heavy metal contents in samples of seawater, seaweed, and the muscles of fish in British coastal waters are presented. The results are mainly for the year 1971 but in the case of seaweed, a comparison is given for the years 1961 and 1970.

9.73.4. "USSR proposal for a program of global investigation of pollution in the world's oceans," GIPME, IOC, Paris, 1973, 12 pp.

A box model for oceanic pollution is used as a basis for designing a monitoring network.

9.73.5. "Monitoring life in the ocean," SCOR-ACMRR-UNESCO-IBP/PM, SCOR, London, England, 1973, 71 pp.

A program for biological monitoring of the oceans is proposed.

See also: 2.68.1., 2.72.2., 2.73.2., 2.73.3., 2.73.5., 5.73.2., 5.73.3.

10. RIVERS, LAKES, GROUND WATER, SNOW AND ICE

10.69.1. "List of International Hydrological Decade stations of the world," UNESCO, Paris, 1969, 148 pp.

A listing is given of the world network of IHD stations.

10.72.1. "DDT and PCB in south Swedish streams," A. Soedergren, Bj. Svensson, and S. Ulfstrand, *Env. Poll. 3* (1972), 25-36.

A pilot study is reported of pesticide residues in south Swedish streams, using Gammarus pulex as an indicator organism.

10.72.2. "Acidification of the La Cloche mountain lakes, Ontario and resulting fish mortalities," R. J. Beamish and H. H. Harvey, *J. Fish, Res. Bd. Canada 29,* 1131-1143.

Low pH values are reported from some lakes in Northern Ontario.

See also: 1.64.1., 9.73.2., 11.72.1.

11. SOILS

11.72.1. "The extent and effects of atmospheric pollution on soils," S. Odén, *In* "Effects of Intensive Fertilizer Use on the Human Environment," Soils Bull. No. 16, 1972, FAO, Rome, pp. 179-189.

A description is given of the Scandinavian network for the chemistry of lakes and river water, the Swedish networks for pesticides, heavy metals and the chemistry of natural soils, and the European network for precipitation chemistry. Some results are given.

11.72.2. "Consequences of trace-element contamination of soils," D. Purves, *Env. Poll. 3* (1972), 17-24.

A marked difference is found in the trace-element concentrations of urban and rural soils in Scotland.

12. BIOLOGICAL MONITORING

12.67.1. "Organochlorine pesticides in seals and porpoises," AV. Holden and K. Marsden, *Nature 216,* 1967, 1274-1276.

Pesticide concentrations were measured in seals and porpoises in Scotland and Canada far from source regions.

12.70.1. "210Pb-atmospheric deposition in lichen-carpets in northern Sweden during 1961-1969," B.R. Persson, *Tellus 22,* 1970, 564-571.

A trend analysis is presented of 210Pb in lichens in northern Sweden over the period 1961-1969. A comparison is made with other published results from the Northern Hemisphere.

12.70.2. "International cooperative study of organochlorine pesticide residues in terrestrial and aquatic wildlife, 1967/1968," A.V. Holden, *Pest. Mon. J. 4,* 1970, 117-135.

A collaborative study is described in which organochlorine residues in wildlife were monitored in 17 laboratories in 11 countries.

12.71.1. "Moss analysis—a method for surveying heavy metal deposition. G. Tyler. *In* Proc. Sec. Int. Clean Air Congress (H. M. Englund and W. T. Beery, Eds.), Academic Press, N.Y., 1971, 107-115.

Regional surveys of moss are reported from Sweden. Chemical analysis for heavy metals has shown the effects of industrial and urban sources as far as 50-60 km away.

12.71.2. "Biological monitoring of the global chemical environment," D.W. Jenkins, Smithsonian Institute, Washington, D.C. 54 pp.

A proposal is described for biological monitoring of the global chemical environment. A rationale is provided.

12.72.1. "Tundra biome," F.E. Welgolaski and Th. Rosswall, eds., Proc. 4th Int. Meeting, IBP, 1972, 320 pp.

Tundra biome studies in the USSR, Austria, Canada, Finland, Ireland, Norway, Sweden, UK and USA are described.

12.72.2. "Theoretical models for large-scale vegetation survey," J.M. Lambert. *In* "Mathematical Models in Ecology," (J.N.R. Jeffers, Ed.) Blackwell, Oxford, England, 1972, pp. 87-109.

The most critical phases in the planning and execution of vegetation surveys lies in the selection of suitable sampling methods and of appropriate analytical techniques. Various theoretical models concerned with these problems are discussed in terms of type of information required, economy of effort, and efficiency of operation.

12.73.1. "Using lichens as physiological indicators of sulfurous pollutants," K.R. Sundstroem and J.E. Haellgren, *Ambio 2* (1973), 13-21.

Compared to higher plants, lichens are extremely sensitive to sulfurous pollution. The authors make specific recommendations concerning a methodology for monitoring lichens.

12.73.2. "Mosses: sensitive indicators of airborne mercury pollution," J.W. Huckabee, *Atm. Env. 7* (1973), 749-754.

Experiments with radioactive mercury-tagged flyash show that mosses take up and retain mercury to a greater extent than grasses do.

See also: 1.70.3., 1.70.6., 1.71.1., 7.73.1., 7.73.2., 7.73.5., 7.73.6, 10.72.2.

13. FOOD AND DRINKING WATER

13.71.1. "Pesticide residues in the total diet in Canada," D.C. Smith, *Pest. Sci. 2*, 1971, 92-95.

Based on a composite Canadian diet, the daily intake of pesticides is determined.

13.72.1. "The heavy metal content of a typical Canadian diet," J.C. Meranger and D.C. Smith, *Can. J. Pub. Health, 63*, 1972, 53-57.

Based on a composite Canadian diet, the intake of 7 heavy metals is determined.

See also: 1.72.2.

14. EPIDEMIOLOGICAL MONITORING

14.70.1. "Multipurpose serological surveys and WHO serum reference banks,", WHO Tech. Rep. 454, WHO, Geneva, 1970, 95 pp.

The WHO serum reference bank program is described.

14.71.1. "Statistical indicators for the planning and evaluation of public health programmes," WHO Tech. Rep. No. 472, WHO, Geneva, 1971, 40 pp.

The principles of epidemiological monitoring are discussed.

14.71.2. "The price of civilization," I.A.M. Prior, *Nutrition Today* (1971) (July-August), 2-11.

Nutritional studies of populations in New Zealand and in some remote Pacific islands are described.

14.72.1. "Deseasonalization of mortality in the world," M. Momiyama and Katayama, *Int. J. Biometeorol. 16* (1972), 329-342.

Using data from the UN Demography Yearbook, 1967, the seasonal variations of total mortality in the 1920's and the 1960's in 18 countries are compared.

14.73.1. Contemporary population densities and human health," R.M. Factor and I. Waldron, *Nature 243* (1973), 381-384.

Using data from 10 districts in Chicago, and other data from 14 countries, the effect of population density on a number of health indicators is examined.

14.73.2. "A comparative analysis of the stimulus-response relationship between mortality and air pollution-weather," M.D. Lebowitz, *Env. Res. 6* (1973), 106-118.

For three cities in the USA, relationships are sought between mortality and air pollution and weather.

14.73.3. "Asthma and air pollution in two inner city areas in New York City," I.F. Goldstein and G. Block, Preprint 73-91, Air Poll. Control Assoc. Annual Meeting, 1973, 25 pp.

An epidemiological study of asthma diagnoses in the emergency wards of 3 New York hospitals is described. The records are for the years 1969-1971.

14.73.4. "Air pollution affects community health," C.M. Shy and J.F. Finklea, *Env. Sci. and Tech. 7* (1973), 204-208.

The CHESS epidimiological studies in the USA are discussed.

15. SOCIOLOGICAL AND ECONOMIC MONITORING

15.73.1. "Measurement of annoyance due to exposure to environmental factors," T. Lindvall and E.P. Radford, (Eds.), *Env. Res. 6* 1973), pp. 1-36.

A report is given of a Symposium on human annoyance as related to environmental health. Some of the topics include odors, airborne irritants, noise, urban crowding, food and water pollutants, aesthetic factors and housing conditions.

See also: 14.73.1.

16. SOURCE STRENGTH MONITORING

16.71.1. "The changing patterns of fossil fuel emissions in the United States," G.W. Land. *In* Proc. Sec. Int. Clean Air Congress (H.M. Englund and W.T. Beery, Eds.), Academic Press, N.Y., 1971, 50-55.

The fuel energy use in the USA over the period 1920-1970 is discussed.

16.73.1. "Industrial production of CO_2 from fossil fuels and limestone," C. Keeling, *Tellus 25* (1973), 174-198.

Estimates are presented of the world industrial production of CO_2 over the last 40 years.

16.72.2. "Feasibility evaluation of an international registry of potentially toxic chemicals," A. Hollaender, UN Adv. Comm. on Application of Sci. and Techn. to Development, UN, New York, 29 pp.

A proposal to establish an international registry of potentially toxic chemicals is described.

16.73.1. "The effect of growth in stratospheric flight operations," B.E. Jocelyn, J.F. Leach and P. Wardman, *Water, Air and Soil Poll. 2* (1973), 141-153.

Predictions are made to the year 1990 of the emissions of oxides of nitrogen from aircraft flying in the stratosphere.

16.73.2. "Desert aerosols transported by Khamsinic depressions and their climatic effects," J.H. Joseph, A. Manes, and D. Ashbel, *J. Appl. Metereol. 12* (1973), 792-797.

The mass of natural aerosol injected into the atmosphere by desert wind systems of the Khamsinic type has been estimated, and used to infer the global dust input into the atmosphere due to deserts to be about 128 million metric tons per year.

See also: 1.70.2. (pp. 257-306), 7.72.2.

APPENDIX C

ANNEXES TO THE CONVENTION ON OCEAN DUMPING

Annex I: Substances to be prohibited completely:

1. Organohalogen compounds.
2. Mercury and mercury compounds.
3. Cadmium and cadmium compounds.
4. Persistent plastics and other persistent synthetic materials, for example, netting and ropes, which may float or may remain in suspension in the sea in such a manner as to interfere materially with fishing, navigation or other legitimate uses of the sea.
5. Crude oil, fuel oil, heavy diesel oil, and lubricating oils, hydraulic fluids, and any mixtures containing any of these, taken on board for the purpose of dumping.
6. High-level radioactive wastes or other high-level radioactive matter, defined on public health, biological or other grounds, by the competent international body in this field, at present the International Energy Agency, as unsuitable for dumping at sea.
7. Materials in whatever form (e.g., solids, liquids, semi-liquids, gases or in a living state) produced for biological and chemical warfare.
8. The preceding paragraphs of this Annex do not apply to substances which are rapidly rendered harmless by physical, chemical or biological processes in the sea provided they do not:
   (i) make edible marine organisms unpalatable, or
   (ii) endanger human health or that of domestic animals.
   The consultative procedure provided for under Article XIV should be followed by a Party if there is doubt about the harmlessness of the substance.
9. This Annex does not apply to wastes or other materials (e.g. sewage sludges and dredged spoils) containing the matters referred to in paragraphs 1-5 above as trace contaminants. Such wastes shall be subject to the provisions of Annexes II and III as appropriate.

ANNEX II:

Substances requiring a prior special permit:

A. Wastes containing significant amounts of the matters listed below:

   arsenic, lead, copper, zinc } and their compounds
   organosilicon compounds
   cyanides
   fluorides
   pesticides and their by-products not covered in Annex I.

B. In the issue of permits for the dumping of large quantites of acids and alkalis, consideration shall be given to the possible presence in such wastes of the substance listed in paragraph A and to the following additional substances:

beryllium chromium nickel vanadium	and their compounds

C. Containers, scrap metal and other bulky wastes liable to sink to the sea bottom which may present a serious obstacle to fishing or navigation.

D. Radioactive wastes or other radioactive matter not included in Annex I. In the issue of permits for the dumping of this matter, the Contracting Parties should take full account of the recommendation of the competent international body in this field, at present the International Atomic Energy Agency.

APPENDIX D

The Priority Pollutants and Indicators

Prepared by the Environmental Secretariat, National Research Council of Canada.

1. Airborne sulphur dioxide and sulphates
2. Suspended particulate matter
3. Carbon monoxide
4. Carbon dioxide
5. Airborne oxides of nitrogen
6. Ozone, photochemical oxidants atnd reactive hydrocarbons
7. Toxic metals:
   a) Mercury
   b) Lead
   c) Cadmium
8. Halogenated organic compounds
9. Petroleum hydrocarbons in water
10. Selected indicators of water quality
    a) BOD
    b) DO
    c) pH
    d) Coliform bacteria
    e) Ammonia
11. Nitrates, nitrites and nitrosamines
12. Environmental radioactivity

(Wherever the units ppm and ppb are mentioned, the phrase "by volume" is understood.)

D.I. AIRBORNE SULPHUR DIOXIDE AND SULPHATES

a) *Sources, environmental distribution, and sinks*

Robinson and Robbins (1972) have estimated the world sulphur cycle in 10^6 metric tons/year).

Sources	
Industry, space heating and transportation	
(mainly in the form of SO_2 and H_2S)	70
Fertilizer applications to soils (sulphates)	11
Rock weathering (sulphates)	14
Biological decay: Continents	68
Oceans	30
(H_2S and organic sulphur compounds including dimethyl sulphide)	
Sea spray (sulphates)	44
Volcanoes (SO_2, H_2S, sulphates)	small

Sinks

Precipitation and dry deposition:	Continents	90
	Oceans	71
Vegetation intake		26
Gaseous absorption by the oceans		25

The sinks listed above are mostly temporary, with considerable recycling through the biosphere and geosphere. The final sink, the deep ocean, is estimated to have a strength of 95×10^6 tons/year.

The gas SO_2 is associated mainly with human activities, and concentrations are highest in towns and near smelters and oil refineries (SO_2 values are sometimes greater than 0.05 ppm/yr, 0.20 ppm/day, 1 ppm/hr). Background levels (about 0.2 ppb) at remote sites are near or beyond the threshold of chemical detection.

The residence time of SO_2 varies widely, ranging from tens of minutes in a very polluted atmosphere to several days in a clean environment. On this account the mere measurement of SO_2 concentration alone gives no indication of the flux of sulphate pollutants. The gas oxidizes, particularly in the presence of sunlight or fog, to form sulphate aerosols and weak sulphuric acid droplets. The sulphate aerosols are removed from the atmosphere mainly by precipitation, so that the residence time is dependent on meteorological conditions. Within an anticyclone that remains stationary over an industrialized area for a few days, the assimilative capacity of the atmosphere can become impaired, and episode conditions may develop.

b) *Effects of SO_2*

Because SO_2 usually occurs concomitantly with other trace gases and particulates, and because atmospheric relative humidity is an additional relevant consideration, the effects of SO_2 are difficult to isolate. For example, the corrosion of metals is much more rapid in a humid than in a dry climate for the same concentrations of SO_2.

1. *Effects on materials*

Except in a very dry atmosphere, corrosion of metals becomes significant at SO_2 concentrations of about 0.03 ppm/yr. SO_2 also damages building materials such as limestone and marble, causes fading of fabric, dyes and paints, and reduces the life of textiles and leather (NATO, 1971).

2. *Effects on vegetation*

Linzon (1973) has examined the available literature on SO_2 damage to forests and epiphytic lichens. He concludes that there is ample evidence for effects at the following concentrations:

0.02 ppm/yr

0.35 ppm/4 hrs
0.10 ppm/4 hrs combined with 0.10 ppm/4 hrs of NO_2 or O_3
0.55 ppm/2 hrs

3. *Effects on animals*

Animals exhibit a higher resistance to SO_2 than does man. Animal toxicity is therefore not a limiting factor in deriving SO_2 criteria or standards (EPA, 1969).

4. *Effects on humans*

Epidemiological studies are not specific for SO_2. However, the following effects have occurred with the indicated concentrations of SO_2 and particulates.

Accentuation of symptoms in patients with chronic lung disease:
0.23 ppm/day of SO_2 and 300 ug/m³ of smoke,
Rise in illness rates among elderly bronchitics:
0.27 ppm/day of SO_2 and 150 ug/m³ of particulates,
Increased mortality (due to bronchitis and lung cancer):
0.04 ppm/yr of SO_2 and 160 ug/m³ of particulates.

These values are representative of a large number of results summarized in EPA (1969) and NATO (1971).

5. *Effects on biota*

SO_2 is ultimately converted to H_2SO_4 and is removed from the atmosphere in precipitation. These "acid rains" cause acidification of lakes and rivers, leaching of cations from poorly buffered soils (podsols) and the disruption of soil and water ecosystems (Sweden's Case Study, 1971).

c) *Effects of Sulphates*

There is growing evidence to suggest that a number of sulphates may have a significant health effect (Junge and Scheich, 1969; Shy and Finklea, 1973; Brosset, 1973). Whereas SO_2 is largely absorbed in the nose and the upper respiratory tract, sulphate particles (which are mainly less than 0.5 u in diameter) may be inhaled into the lower respiratory tract and may be absorbed to form a weak solution of sulphuric acid.

d) *Feasibility of measurement*

Recommended methods for measuring SO_2 and sulphates are contained in WMO (1974). There are in fact many procedures for measuring SO_2; spectroscopy and flame photometry are probably the best for continuous and remote sensing. Those chemical methods depending on the reducing power of SO_2 may be adequate in the absence of interfering chemicals.

The sulphates, which are always found in the particulate phase, may be measured by titration, if they are acids, or by precipitation as barium sulphate, after collection by high-volume filters.

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D. 2. SUSPENDED PARTICULATE MATTER

a) *Introduction*

Suspended solids in water and particulate matter in the atmosphere both refer to the same physical phenomena, very small pieces of material supported against the forces of gravity in the medium, air or water, for lengthy periods of time by turbulent or molecular motions.

b) *Sources and Sinks of Suspended Solids in Water*

The natural erosion of soils and rocks by surface waters produces most of the suspended solids in water. Organic matter in the process of decomposition also comprises a significant fraction. Industrial and municipal waste waters often contain large quantities of suspended solids. Deposition, either temporarily in river beds and estuaries, or more permanently in the bottoms of eutrophying lakes and in the sea-bed constitute sinks. Normal levels of suspended solids in surface waters are a few milligrams per liter (mg/liter); in some turbulent rivers or highly polluted areas, suspended solids may reach 500 mg/liter.

c) *Biological Effects of Suspended Solids in Water*

The deposition of suspended solids on the bottom of rivers or lakes may blanket the habitat of bottom-dwelling form of life. In some cases, the pumping rate of oysters is reduced, the gills of fish are plugged, or the normal penetration of light into the water is prevented and aquatic photosynthesis is reduced. Of more importance, however, is the decomposition of excess organic material, such as the wood fibres from paper mills. This decomposition requires oxygen; in extreme conditions the oxygen content of the water may be reduced below that necessary to support aquatic life. Some suspended solids contain chemicals that are toxic to certain species, or else that can accumulate in edible species and thus represent a potential hazard to man.

Current ecological evidence indicates that inert, non-toxic suspended solids below 25 mg/liter are not harmful to fisheries, and levels in the range 80 to 400 mg/liter are unlikely to support good fisheries.

d) *Feasibility of Measurement in Water*

The analysis of the suspended solids concentration in water can be done easily by filtration, although characterization by size distribution or by chemical nature requires more elaborate equipment.

e) *Sources and Sinks of Airborne Particulates*

Particles in the air vary in size from 6×10^{-4} to 20 micrometers. Natural processes account for over 90% of the particulate matter in the atmosphere. Of most importance are sea spray, pollens and microorganisms, aerosols formed in the oxidation of naturally-produced chemicals such as hydrogen sulphide, sulphur dioxide and nitrogen oxides, and wind-blown dust. Man-made sources of most importance are combustion and industrial effluents, aerosols formed by oxidation of the gaseous effluents, sulphur dioxide, nitrogen oxides, hydrogen sulphides and ammonia, and hydrocarbon vapors. Precipitation and diffusion to the Earth's surface are the main sinks. Residence time varies from a few minutes for fly ash and large particles, to days and months for the smallest. Background levels are about 10 micrograms per cubic meter (ug/m^3); in some polluted areas, particulate daily averages reach 1000/ug/m^3.

f) *Effects of Airborne Particulates*

1. *Climatic Effects*

Theoretical considerations suggest that the presence of particulates in the atmosphere lowers the quantity of solar radiation reaching the earth.

Studies of volcanic activity and global temperature indicate atmospheric cooling sometimes occurs for a year or so following intense volcanic eruptions. Direct sunlight is reduced noticeably, particularly in winter, at particulate concentrations averaging 100 to 150 ug/m³.

2. *Effects on Materials*

Corrosion of metals occurs at an accelerated rate of particulate concentrations of 60 to 180 ug/m³ in the presence of sulphur dioxide. In urban areas, rapid soiling rates from particulate deposition are a problem, often resulting in economic loss.

3. *Effects on Vegetation*

Excessive dust may block light needed for photosynthesis and plug stomates, interfering with oxygen and carbon dioxide exchange with the atmosphere. Ingestion of particles containing toxic material such as arsenic deposited on plants can subsequently be harmful to animal health.

4. *Effects on Humans*

Atmospheric particulate matter attenuates solar radiation, particularly in the ultraviolet. This may have a small effect on human health in populated areas, although no convincing epidemiological evidence has yet been presented.

Atmospheric particulates are correlated with the frequencies and severity of respiratory ailments. The size distributions of the particles as well as the total loading are important. A large proportion of particles having diameters from a few microns upwards is removed in the upper respiratory tract, and it is mainly those in the sub-micron range that can reach and be retained in the pulmonary air spaces (NATO, 1971). Unfortunately, monitoring of size distributions is laborious and relatively expensive. Most air quality networks include only observations of 24-hr. total suspended particulates or indirect indicators such as soiling index (which is sensitive to colour as well as to weight of particulates) or a measure of turbidity or solar radiation attenuation.

There is evidence from epidemiological studies that effects on health can be related to the available indices of suspended particulate matter, but equally they can be related to the concentrations of other pollutants that are present at the same time. Acute effects have been demonstrated in atmospheres containing coal smoke, together with other suspended and gaseous pollutants when the 24-hr. average concentration of parparticulates, inferred from a soiling index, has exceeded 250 ug/m³, and the accompanying sulphur dioxide concentration has exceeded 500 ug/m³ (Lawther *et al.*, 1970). Increased prevalence of respiratory illnesses has, however, been associated with extended exposures to lower concentrations than this. Because of the lack of specificity in these studies, results obtained in localities with one particular type of pollution cannot be applied to situations where the mixture is of a different character.

e) *Feasibiilty of measurement*

1. Atmospheric Turbidity

The sun photometer is a recommended instrument for the WMO air chemistry network (WMO, 1971). Recent US-Canada intercomparisons have revealed calibration drifts in the reference standards at the 0.38u wavelength although the 0.5u wavelength measurements seem to be satisfactory.

Alternatively, the pyrheliometer may be used, but as emphasized (WMO, 1974): "Experience suggests that under very clear conditions, use of pyrheliometers requires considerable detailed knowledge of the characteristics of the instrument (filter transmission factors, etc.) as well as precise information of other attenuating factors such as total ozone and water vapour."

2. Particle size distributions

WMO (1974) has published an authoritative account of methodologies for obtaining particle size distributions. No available method covers the full spectrum of atmospheric particle size.

3. Particulate concentrations

The high-volume sampler is a widely-used instrument in urban air-quality surveys, yielding a 24-hr. weight measurement. The volume of air sampled is determined from readings of a flow indicator and the mass is weighed, permitting calculation of the concentration. There is a risk with this instrument that particles well beyond the respirable size range will be collected.

Other measurements are made by drawing air at relatively low rates through filter paper, and estimating the amount of particulate matter from the reflectance or transmittance of the filter paper.

Further details of these and other methods are given in WHO (1974) and WMO 1974).

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D.3. CARBON MONOXIDE

(a) *Sources, environmental distribution, and sinks*

The world emissions of CO as follows: (in 10^6 tons/year)

Natural Sources	
Oxidation of methane and formaldehyde	3000
Decay and synthesis of cholorophyll	90
Photochemical oxidation of terenes	54
Oceans	220
Total	3364
Anthropogenic Sources (estimated for year 1970)	
Transportation	250
Coal and light	1
Other fuels (oil, gas, kerosene)	1
Industrial processes	41
Incineration (solid waste)	23
Miscellaneous (agricultural burning, etc.)	41
Total	360

The atmospheric residence time and the sink strengths for CO are not well established, and in fact, there has been mild controversy since the discovery in the late 1960's that the tropical oceans are often supersaturated with CO, indicating the presence of a marine biological source. Present estimates of the CO residence times range from 0.2 to 1-3 years.

Robinson and Robbins suggest that there are no proven significant oxidation reactions for CO in the troposphere. Possible sinks include upward diffusion into the stratosphere (believed to be very slow), absorption by the oceans (not proven), precipitation scavenging (Swinnerton *et al.* 1971), and biological uptake (proven but magnitude uncertain). CO as well as CO_2 are used by plants during photosynthesis, the former gas being largely overlooked in field experiments because it is such a small fraction of the latter. The other process that is now believed to be of significance is uptake by soil fungi.

Concentrations of CO as high as 50 ppm occur occasionally on busy urban expressways. Background concentrations are estimated to be 0.14 ppm in the Northern Hemisphere and 0.06 ppm in the Southern Hemisphere.

(b) *Biological Effects*

The affinity of haemoglobin for carbon monoxide is over two hundred times that for oxygen. The absorption of carbon monoxide is associated with a reduction in the oxygen-carrying capacity of blood due to the formation of carboxyhaemoglobin. Normal blood concentration of carboxyhaemoglobin in non-smokers is 0.5%, in smokers 5%. An exposure of eight or more hours to 10 ppm carbon monoxide will raise this level in non-smokers to over 2%. Impaired time-interval discrimination, visual acuity and brightness threshold are observed at levels above 2%.

Cardiovascular changes occur at carboxyhaemoglobin levels over 5%, reached by exposure for eight hours to 30 ppm carbon monoxide. Epidemiological studies indicate that mortality from heart failure may be increased by exposure to average weekly concentrations of about 10 ppm. Due to the time lag between exposure to carbon monoxide and the formation of carboxyhaemoglobin in the blood, short-term exposures to higher carbon monoxide levels are not considered to be as hazardous as long-term exposures to low levels.

Concentrations of carbon monoxide, needed to affect plant growth and microbial activity, are much higher than normally encountered in ambient air. Detrimental effects have not been detected at levels less than 100 ppm for durations of one to three weeks.

(c) *Monitoring of Carbon Monoxide*

In view of its high urban levels and low threshold for physiological effects, the continuous measurement of carbon monoxide in urban areas is advisable. This may be accomplished with infrared analyzers, which are sensitive to carbon monoxide in the range 1 to 25 ppm. Non-urban data, requiring more sensitive detectors, may be acquired by gas chromatography or with a mercury vapor analyzer.

It is important that the significance of the oxidation of methane as a source of carbon monoxide be established.

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D.4. CARBON DIOXIDE

(a) *Sources, environmental distribution, and sinks*

Natural emissions of CO_2 include respiration by living matter and releases during decay of organic materials.

Man releases CO_2 into the atmosphere by burning organic fuels and by kilning of limestone. The emissions have been increasing steadily in recent years; Keeling (1973), for example, estimates an output rising from 1.2×10^9 metric tons in 1929 to 3.8×10^9 metric tons in 1968.

The average atmospheric CO_2 concentration around the world is about 330 ppm at the present time and it seems to be rising at the rate of about 1 ppm per year. The residence time in the atmosphere is about 2.5 years (Robinson and Robbins, 1972).

The principal sinks for CO_2 are the biosphere and the oceans. In the latter case, there is a strong dependence on sea temperature and on the pH of the surface mixed layer.

(b) *Biological effects*

At normal environmental concentrations, CO_2 has no harmful effects on biological systems. The gas is, in fact, essential for the growth of most plants.

(c) *Climatic effects*

Atmospheric CO_2 is one of many elements affecting world climate. Because CO_2 absorbs long-wave terrestrial radiation (in selected wavebands), consideration of the radiative transfer properties of the atmosphere must always include examination of the effects of a change in CO_2 concentrations, which could influence the vertical distributions of heat and temperature.

(d) *Feasibility of measurement*

1. *Atmosphere*

For biome studies, an instrumental sensitivity of 2 ppm is quite sufficient (the diurnal and annual ranges in CO_2 concentrations over vegetation are of the order of 10 to 30 ppm). This sensitivity is easily achieved with a number of commercially available instruments.

For climatic studies, a sensitivity of 0.2 ppm is required, and reference standards must maintain their stability over decades. Infra-red non-dispersive sensors are recommended (WMO, 1974), although there is still some doubt about their absolute calibrations.

(2) *Fresh and salt water*

Gas chromatography is recommended. Samples must be sealed, and analysis should be done immediately. If samples are stored, they must be maintained at the temperature of the water at the time of collection, to minimize loss of the gas to the atmosphere (Henry's Law).

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D.5. ATMOSPHERIC OXIDES OF NITROGEN

(a) *Sources, environmental distribution and sinks*

Nitrogen, which comprises almost 80% of the atmosphere, is a relatively inert gas not particularly soluble in water. Nitrogen *fixation* is the process by which nitrogen is incorporated into living tissues. This occurs through a variety of biochemical pathways.

Three oxides of nitrogen are of importance in environmental studies:

N_2O - nitrous oxide
NO - nitric oxide
NO_2 - nitrogen dioxide

Another nitrogen compound of significance is ammonia (NH_3), which is discussed in Section D. 10.e.

The major global sources for the nitrogen oxides are as follows (in 10^6tons per year, where the values have been converted to NO_2 equivalent) (Robinson and Robbins, 1972).

N_2O (bacterial action)		592
NO_2 (forest fires)		0.8
NO_2 (industrial)		
Burning of coal	26.9	
Burning of petroleum	22.3	
Burning of natural gas	2.1	
Incineration	0.5	
Burning of wood	0.3	
Total	52.1	

Lightning is not believed to contribute significantly to the fixation of nitrogen on the world scale. Hahn (1974) has recently suggested that the North Atlantic is super-saturated with N_2O and therefore must be an additional source.

NOx emissions are associated chiefly with combustion processes. occurring whenever the temperature exceeds 1000° C. and whenever the combustion gases are quenched so rapidly that dissociation back to nitrogen and oxygen is prevented. The major oxide in combustion emissions is NO but a small fraction is converted to NO_2 by reaction with oxygen during the exhaust dilution process.

NO and NO_2 are active photochemically, contributing to the production of oxidants (See Section D.6). NO may be oxidized to NO_2 during such periods. The resulting particulate biproducts are then scavenged, usually in a few days, by precipitation.

The other oxide, N_2O, has a very large natural cycle. Small fractions are lost to the stratosphere but the major portion is used by vegetation, and is, in fact, an important nutrient.

Global background concentrations of the 3 oxides are as follows:

N_2O	0.25 ppm
NO	6 ppb or less
NO_2	6 ppb or less

The residence times are 3-4 years for N_2O and about 4 days for NO and NO_2.

(b) EFFECTS

(1) *Effects on Humans*

At normal atmospheric concentrations, nitrous oxide has no known adverse effects.

Due to the rapid conversion of nitric oxide to nitrogen dioxide, the two are often combined as NOx when discussing their effects. Acute exposure to NOx causes nasal and eye irritation at 12 ppm, pulmonary discomfort at 50 ppm, bronchiolitis at 50 to 100 ppm, bronchiolitis fibrosa at 150 to 200 ppm, and bronchopneumonia at 500 ppm. Chronic expósures at NOx levels of 10-40 ppm cause lung damage, leading to fibrosis, reduced breathing capacity and increased respiratory resistance. An epidemiological study showed that people living in an atmosphere with annual average NOx concentrations of 0.08 ppm exhibited reduced respiratory performance and a larger frequency of acute respiratory illnesses, compared with controls elsewhere in the same city.

2. *Effects on Vegetation*

Chronic exposures to 0.15 ppm NOx and acute exposures to 2.5 ppm cause obvious damage to tomato plants. Many other species of commercial value are similarly affected.

3. *Effects on Climate*

An increase in tropospheric N_2O could cause an increase in stratospheric NOx, which in turn would affect the radiation balance of the atmosphere,

c) *Feasibility of measurement*

1. N_2O: A gas chromatography method is recommended (WMO, 1974).
2. NO, NO_2, and NOx: A recommended procedure has been given by WMO (1974), using the principle of the chemiluminescent reaction of ozone with NO. To monitor NOx, the NO_2 is converted to NO before the gas stream reaches the sensor. The concentration of NO_2 is then obtained by subtraction. A laser florescent technique has also been proposed (Birnbaum *et al.*, 1974). For baseline observations, Nash (1974) has used a modified Saltzman reagent and subsequent colorimetric determination, with a sensitivity of about 0.2 ppb.

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D. 6. OZONE, PHOTOCHEMICAL OXIDANTS AND REACTIVE HYDROCARBONS

a) *Sources, environmental distribution, and sinks*

Oxidants are highly-reactive gases formed photochemically, usually in the presence of NOx and hydrocarbons. One of the well-known oxidants is ozone (O_3), which is also generated during lightning, and in the stratosphere due to photolysis of O_2 to atomic oxygen with subsequent conversion to O_3.

The hydrocarbons may be of natural origin, e.g., forest terpenes, or may be released by man into the atmosphere. Hydrocarbons are classified according to their molecular structure; acyclic, alicyclic and aromatic. The third type is believed to have the most direct link with human health but it cannot be monitored operationally as yet. There is, of course, a wide range of hydrocarbons, many of which are volatile and occur as gases in the atmosphere.

Sunlight has no appreciable effect on hydrocarbons alone. In the presence of NOx, however, intermediate and secondary products are formed, some of which do have detrimental effects on materials, vegetation and man. The reactivity of hydrocarbons varies greatly, methane being the least reactive although the most ubiquitous—with large natural sources due to bacterial decomposition processes in swamps and marshes.

Robinson and Robbins (1972) have made the following estimates of global total and reactive hydrocarbons.

Sources	Total hydrocarbons 10^6 tons yr	Reactive hydrocarbons 10^4 tons yr
Burning coal	2.9	40.8
Burning oil	40.6	1594
Evaporation losses from oil	7.8	156
Evaporation of solvents	10	150
Incinerators	25	750
Wood burning	0.7	10.5
Forest fires	1.2	25
Terpene-type releases from vegetation	170	?
Methane from swamps	310	small

The photochemical products of present interest are:

1. ozone (O_3),
2. nitrogen dioxide (NO_2), formed primarily by the photo-oxidation of nitric oxide (NO),
3. aldehydes, particularly formaldehyde,
4. peroxyacyl nitrates, particularly peroxyacetyl nitrate (PAN).

No doubt, related substances will become important when detection methods improve and when the photochemical processes are better understood. The term *total oxidants* usually means the gases O_3, NO_2, and the peroxyacyl nitrates.

Global background concentrations of methane (CH_4) are about 1-2 ppm. The residence time is about 1 to 4 years, in contrast to the residence times of a few hours to a few days for the reactive species. Total hydrocarbons in urban areas have yearly average concentrations of from 5 to 15 ppm (as carbon). The reactive components are generally in the ppb range.

Total oxidants in forests, resulting from terpene photochemical reactions, may reach 0.06 ppm, as compared with global background values of about 0.01 ppm. In Los Angeles during smoggy days, concentrations can exceed 0.50 ppm. In this connection, note should be made of the fact that because the photochemical process requires several hours to complete, the highest concentrations of oxidants and of other products may occur downwind of a city, rather than in the Central Business District.

b) *Effects*

1. *Effects on Humans and Animals*

a) *Ozone*. Nasal irritation occurs at ozone levels of 0.05 ppm, headaches are experienced at 1 ppm for exposures over 30 minutes, changes in several visual parameters have been observed at 0.2 to 0.5 ppm, pulmonary congestion and changes in respiratory efficiency occur at 1 ppm. At levels of 0.25 ppm, increases in attacks among asthmatic patients were observed. Lung tumor incidence doubled in mice exposed to 1 ppm ozone daily for 15 months.

b) *PAN*. Peroxyacetyl nitrate induces an increase in uptake of oxygen at 0.3 ppm, eye irritation is detected at 0.5 ppm.

c) *Reactive Hydrocarbons*. Throat and eye irritation at 0.5 ppm is reported. Brief exposures of guinea pigs at 1 ppm formaldehyde caused temporary changes in respiratory efficiency.

2. *Effects on Vegetation*

a) *Ozone*. Tobacco is injured by exposure to 0.05 ppm ozone for four hours; 0.1 ppm for two hours damages spinach, corn and beans. Synergistic effects with sulphur dioxide reduce the threshold for injury to some plants.

b) *PAN*. PAN is the primary phytotoxicant generated in photochemical smog. A four-hour exposure to 15 ppb of PAN causes injury to tomato and lettuce plants.

c) *Reactive Hydrocarbons*. Ethylene concentrations of 1 ppm are sufficient to injure sunflower, tomato and potato plants.

c) *Feasibility of Measurement*

The chemiluminescent reactions of ozone with ethylene or nitric oxide may be used to measure ozone very accurately, without interferences. Colormetric and coulometric techniques are available for the determination of total oxidant concentrations. Gas chromatography is suitable for monitoring hydrocarbons and PAN levels; flame photometric detectors are most suitable for the former, electron capture detectors for the latter. The aldehydes can be measured with colorimetric techniques using a bisulphite reagent, but the method is only moderately sensitive.

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D. 7. TOXIC METALS

a) *Mercury*

The chemical and toxicological properties of inorganic mercury ions, elemental mercury and organic mercury derivatives are so different that they must be discussed separately.

Elemental Mercury

Mercury vapour is present in air due to degassing of the earth and industrial contamination. Past exposures in industrial workplaces indicate that 0.1 to 1 mg Hg/m^3 air is toxic. Mercury values in San Francisco were a few nanogram/m^3. One gram of liquid mercury can be taken by mouth with no observable effect.

Inorganic Mercury

Mercury is a normal constituent of many rocks and soils and thus of plants used as food. About 1 g of mercuric chloride will produce severe acute poisoning in humans. About 50 mg/kg is needed continuously in the diet to produce chronic toxic symptons in rats.

Methyl mercury

General: Methyl mercury is completely absorbed from the gastro-intestinal tract into the blood. About two months after ingestion starts in humans, neurological symptoms of toxicity appear. The first symptom is paresthesia-numbness of the extremities. Later symptoms are ataxia (loss of control of limbs) and constriction of vision. Severe cases are fatal. After ingestion ceases, there is often slight improvement but the brain damage is largely irreversible, even though the methyl mercury content of the body falls back no normal.

Methyl mercury is excreted largely via the faeces. The concentration in the blood is a good indication of total body burden. The half-life varies greatly with species, being about two weeks in the rat, 70 days in humans, and several hundred days in some species of fish. From the half-life and blood concentration, the daily intake needed to produce a given body burden can be calculated.

Release of Synthetic Mercury to the Environment:

A derivative of methyl mercury is used as a fungicide on cereal grains to be used as seed. Birds that eat the grain accumulate excessive methyl mercury. There have been many tragedies where treated grain has been unknowingly ingested by humans. In the latest of these in Iraq, the death toll has been estimated at several hundred.

In two locations in Japan, methyl mercury was discharged in factory effluents into the sea. Fish can concentrate methyl mercury several thousand fold from the surrounding water. The contaminated and dead fish were eaten by local fishermen and their families. Many deaths and disabilities resulted. The methyl mercury blood concentration and total body burden were measured on survivors of these tragedies. The body burden for the mildest symptoms (paresthesia) is estimated to be 30 mg for an adult and the daily intake needed to produce this burden is 1% of the burden or 300 ug/day. Blood levels were about 200 ng/m*l* for the mildest cases and several thousand ng/m*l* for severe ones.

People who do not eat fish have total blood mercury values of 2-5 ng m*l* and "normal" fish eaters about 10 ng/m*l*.

Biosynthesis of Methyl Mercury in the Environment:

In streams and lakes, where large amounts of inorganic mercury have been dumped into the sediments, the fish have concentrations of methyl mercury in the flesh, of a few ug/g and as high as 25 ug/g, The mercuric ion is methylated by bacterial action and the methyl mercury accumulated by the fish in some way. Many areas have been closed to fishing as a result. As the mercury is strongly absorbed by the sediments and the sediments are often only slowly moved or covered up, the situation can be expected to last many years.

There are as yet no human poisonings from "biosynthetic" methyl mercury but a few individuals in Sweden and Canada who continuously eat fish from contaminated areas have blood mercury levels near the expected toxic value without showing any symptoms.

Mercury in Food

Total mercury in food comprises both inorganic and methyl mercury and might average 10 ug/person/day. An approximation which is not strictly true is that all mercury in fish is methyl mercury and in other foods inorganic mercury. The mercury values in most foods are so low that the analysis for methyl mercury becomes difficult. Fish with more than 0.5 ug/g of total mercury are not sold in North America. Most fish in commerce are much below this and an average might be 0.1 ug/g.

Analysis of Mercury in the Environment

Mercury in the air is so low as to be of no concern. Mercury in soil is bound, is a natural constituent and again is of no concern. Total mercury in waters is of the order of 1 ug/litre and is easily measured. Few separate measurements of the more important methyl mercury have been made. Because of the great concentration of methyl mercury by fish and because they probably represent the largest source of methyl mercury in food, monitoring of fish probably represents the easiest way to monitor mercury in the environment.

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D.7. (b). LEAD

a) *Sources, environmental distribution and sinks*

Lead is a natural constituent of all soils and plants. The concentration in plants varies, depending on the plant species, time of year, soil properties, and concentrations in the soil. Lead concentration in soil is generally highest in the surface few centimetres.

Significant sources of lead in the environment include that emitted in engine exhausts as a result of the combustion of tetraethyl lead in gasoline, liquid and airborne particulate wastes from coal burning and metal smelting and lead arsenate pesticides.

The particles from gasoline combustion are emitted in two size ranges. The smaller ones are about 0.2 um in diameter, formed by direct condensation as the combustion gases cool. This size of particle remains suspended in the atmosphere by air movements and thus may be transported long distances. Lead has been found in Greenland glacier cores. The particles are removed only by precipitation or by agglomeration into larger particles. Moreover, these particles are in the size range most likely to be deposited in the alveoli of the lungs. The larger particles emitted, which are approximately 5 um in diameter, are formed when lead deposited on the inside of the exhaust system flakes off due to mechanical vibration. These particles are dense and only travel short distances (typically up to 200 m from the point of emission). If inhaled, they are deposited in the upper respiratory tract and swept upwards by ciliary action and subsequently swallowed. The lead in one cubic metre of air is 5 - 25 ug at busy city intersections 2 m above the curb, 0.5 - 3 ug in suburban gardens and 0.1 to 0.5 ug in rural areas away from roads. Particle size-distribution measurements are rarely performed. Concentrations in buildings when the windows are closed are about half of those outside.

Lead in the dustfall from air is retained in the surface soil and accumulates together with that derived from decaying vegetation. High lead contents (up to 1 g/kg or more) have been found in soils near industrial sources and in roadside dust in the vicinity of heavy traffic. In water, lead is partially absorbed by sediments and transported with them. Lead concentrations in natural waters are about 10 ug/litre.

b) *Effects of Lead*

Plants: Lead is not toxic to plants at any concentration normally found in soils.

Domestic Animals: The most sensitive domestic animals are young horses. The estimated lethal dietary level is 100 mg lead/kg dry weight of feed or 2 mg lead/kg live weight of animal per day, when fed at this level over many weeks. Some deaths of colts have been reported near lead smelters.

Aquatic Animals: The toxicity of lead to aquatic animals varies with the temperature, pH and hardness of the water, in particular. The most sensitive species (e.g., salmon and trout) die after 4 days exposure to 0.14 - 1.0 mg lead/litre in soft water.

Man: Adults—The often-heard statement that "lead is a cumulative poison" is only true for intakes above normal. For most people, the lead absorbed from the alimentary tract and lungs (the uptake) is balanced by excretion via hair, sweat, gastro-intestinal tract and by way of the urine. If lead uptake rises, the rate of excretion follows this trend, but it may require many months or years to achieve a new equilibrium. The excess uptake, if limited, will be stored in the bones where it is largely inert and does not produce the symptoms of lead intoxication (95% of total body burden is located in the bones). Only if the excess rate of lead uptake exceeds the rate at which the element can be laid down in the bones will the soft tissue concentration rise to give the typical symptoms of lead poisoning. This is a reversible process and most adults who suffer from lead poisoning recover without permanent harm when excess uptake terminates. The half-life of lead in adult bones is estimated to be several years. Clinical symptoms of poisoning do not occur in the adult until the blood lead values rises to at least 80 ug/100 g whole blood. Clinical effects include anemia, basophil stippling of red blood cells, kidney damage with aminoaciduria, tiredness, gastro-intestinal distress with constipation or diarrhoea, and nausea. Permanent neurological consequences may occur in 25% of those cases of acute lead encephalopathy occurring in children.

Criteria are required to relate the uptake (the total amount of lead absorbed by the body) to the above stages. The uptake is not measured directly, but calculated from the intake and adjusted using an absorption factor.

Most lead uptake is derived from food in which the lead content varies greatly. Older estimates in North America and present estimates in Britain suggest that the average person ingests about 300 ug/day with great variation from day to day according to the food selected. More recent estimates from diet studies in Canadian cities and on convicts in New York prisons, together with faecal analyses of American women, indicate the intake to be 120 - 140 ug/day. Most authors agree that only about 10% of the lead in the diet is "digested", so that uptake from food will be from 12 to 30 ug/day.

Drinking water has an average lead concentration of approximately 10 ug/litre. With an intake of 2 *l*/day, the intake from water would be 2 ug lead/day.

The calculation of lead uptake from air for an urban dweller is more difficult to estimate. First, the concentration of lead in air varies according to location, from bedroom to city street to office. Second, the deposition of lead in the lungs has never been measured in a normal urban atmosphere. Instead, the figure of 36%, measured by Kehoe on lead sesquioxide particles at a concentration of 150 ug/m^3, is assumed to be a reasonable estimate. Recent electron micrographs of urban air particulates by Lawther *et al.* seem to show very small, dense particles aggregated on less dense carbon particles. The behaviour of these aggregates in the lung is unknown and may well be very different from the action of lead sesquioxide. Lead particles, once deposited in the alveoli, are assumed to be completely absorbed since *post mortem* analyses of lungs have shown the same lead concentration as that found in other soft tissues. Daily lead uptake from lungs may be roughly estimated by multiplying the following factors:

> 15 m^3 of air inhaled/day; 1 ug lead/m^3 air averaged for 24 hours; 36% deposition inhaled lead in alveoli; 100% absorption of deposited lead for a total of 5 ug day.

The total normal lead uptake from all sources is then in the range of 19 to 37 ug day.

Epidemiological surveys in the United States show no correlation between the blood lead values of suburban women (mean about 16 ug/100 g) and exposure to air lead concentrations in the range 1 to 3.5 ug m^3 (annual means). Kehoe showed that a subject whose total lead ingestion was 600 ug/day (60 ug uptake) was still in equilibrium. Ingestion of 3000 ug day (300 ug uptake) resulted in a net accumulation, although the experiment was not carried for a sufficient time to determine if a new equilibrium could be established before toxicity symptoms ensued. Present-day industrial hygiene standards (299 ug lead/m^3 of air for an 8-hour day) suggest that an uptake of roughly 600 ug day may be sustained without producing clinical symptoms, but causing blood lead values to rise to about 80 ug/100 g blood.

Children—Comparable figures for lead metabolism in children are not known. Extrapolations on the basis of body weight corrections are likely to be unreliable and the capacity for storage in bone is most certainly very different. The symptoms of lead poisoning in children differ from those of adults. Those who survive a severe case of encephalopathy may be permanently impaired. The fact that some cases have blood lead values slightly above 40 ug/100 g is sometimes stated as evidence that children are more susceptible to lead poisoning than adults. This may be so, but the uptake of lead per kg body weight required to produce these blood levels is unknown. It should be borne in mind that blood only acts as a carrier of lead and is not necessarily closely related to lead concentration in the brain.

Lead poisoning is most often induced in children by eating old lead paint (a habit called pica) or in the general population by drinking soft waters that have passed through lead pipes or by consuming contaminated, illegally-distilled whiskey. None of these causes would seem to have a place in environmental monitoring. Lead in the air is not as yet contributing to ill-health.

c) *Feasibility of Measurement*

Lead in air is easily assayed using filters and high-volume samplers. Particle sizing is more difficult. The lead in biological samples (as small as a drop of blood) can be measured fairly easily by atomic absorption or anodic stripping voltemetry, although reproducibility may suffer by using such small samples. The total amount of lead released to air in any area can be calculated from gasoline consumption figures and, as gasoline is the main source, large changes in air concentrations will only follow changes in gasoline consumption or its lead content.

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D. 7. (c) CADMIUM

1. *Sources*

Cadmium is universally distributed in the natural environment at low levels. Local concentrations are found in association with zinc, and most cadmium production is a by-product of zinc smelting. Major uses include electro-plating, pigments and electrical uses.

Some rivers carry substantial quantities of cadmium: it is not yet clear whether this 'is derived primarily from natural sources or from leaching or mine tailings. Effluents from electroplating industries can also contain cadmium.

Smelters can release cadmium into the air but air transport of the particles is usually short-range and significant contamination only occurs within a few kilometres of the source.

Cadmium is taken up from soils by plants and from water by aquatic plants and animals. Highest concentration factors (10^3 - 10^5) have been reported for plankton and shellfish. Cadmium levels do not appear to increase in passage up food chains, but relatively high levels have been reported in some long-lived marine birds and mammals. Among animals used for human food, highest concentrations are found in shell fish (often 1 ppm and up to 20-50 ppm in some polluted areas).

Effects

Some adverse biological effects have been reported in highly polluted areas near smelters, but these cannot be uniquely associated with cadmium in the presence of other pollutants. Adverse effects on reproduction of fish have been reported in the laboratory at levels (1-10 ug/litre) similar to those found in many natural fresh waters. However, no unequivocal adverse effects on natural populations have been demonstrated.

An outbreak of cadmium poisoning occurred in Japan in the 1940's and was called "itai-itai" disease. It was restricted to women over 40 who had borne several children and lived in one polluted area. Obviously other factors than cadium were involved and the complete explanation is now unlikely to be known as new cases no longer arise.

Cadmium is potentially one of the most dangerous toxic elements as it is truly accumulated in the human body. Estimations of the half-life of cadmium in humans are imprecise, but are around 20-30 years. The greater part of the total body burden is stored in the liver and kidney cortex which is the most sensitive organ. When cadmium concentration reaches 200 mg/kg in the kidney cortex, symptoms of kidney damage (protein in the urine) appear. Cadmium in the body rises to a maximum at about age 50. Cadmium in the kidney cortex of normal populations is about 25-50 mg/kg. It has also been suggested that higher exposures to cadmium are statistically associated with renal ischaemic hypertension and elevated death rates. Although this is not universally accepted, the safety margin is small and concern should be expressed for high exposure groups such as habitual shellfish eaters.

Estimates of human intake from all sources (mainly from food) range from 15 to 70 ug/day. Locally significant intakes may occur from drinking water. Absorption from the gut is low, about 5%, but absorption through the lungs is much more efficient and there is some evidence that cigarette smokers ingest significantly larger quantities (up to 3 times larger) than non-smokers. It can be calculated that an intake of 62 ug/day will produce a kidney cortex concentration of 50 mg/kg by age 50.

The relative proportion of the present cadmium intake derived from "natural" cadmium always present in the environment compared with "pollutant" cadmium released by man's activities is unknown.

Monitoring

A number of methods are available for estimating cadmium levels in environmental samples. Although these have given good results when carefully calibrated, interlaboratory comparisons have often shown poor agreement. Efforts to improve standardization of techniques are needed before a large-scale monitoring scheme can be set up. Food, especially shellfish from polluted areas, should be the main concern.

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D. 8. HALOGENATED ORGANIC COMPOUNDS

Residues of chlorinated hydrocarbons, particularly DDT, its metabolite, DDE, polychlorinated biphenyls (PCB's) and dieldrin, have been identified in man and wildlife from even isolated regions of the world. Chemists initially developed halogenated organic chemicals for their inherent stability against physical and biological degradation. They have been used widely in a number of industrial applications. Some are biologically active and used extensively as persistent pesticides. Generally, compounds identified as having significant environmental effects contain chlorine.

There is strong evidence that DDT and its metabolite DDE, dieldrin and polychlorinated biphenyls (PCB's) have significantly contributed, singularly or in combination with other pollutants, to population declines in a number of fish and fish eating birds.

DDT and its metabolites, dieldrin and PCB's are concentrated from water into the fatty tissues of fish and other aquatic organisms by up to one hundred thousand times. Thus, the exposure of aquatic organisms to seemingly insignificant levels of these pollutants can result in levels which are of biological significance. Chlorinated hydrocarbons tend to accumulate in large lakes and oceans which act as sinks. It is thus not surprising that high residues and populations demonstrated to be affected by chlorinated hydrocarbons are associated with fish and fish-eating birds.

The deleterious effects of dieldrin and other chlorinated hydrocarbons have also been linked to population declines in terrestrial organisms exposed through the application of these insecticides in agricultural and forest pest control programs.

Is man affected by chlorinated hydrocarbons?

Generally, chlorinated hydrocarbons are not particularly toxic to mammals. At the present levels found in the environment, dieldrin, PCB's or DDT are not expected to produce significant effects in the general population. Of course the diet of the general population does not include large quatntities of food such as fish, containing the higher levels of chlorinated hydrocarbons. However, breast-fed infants do receive relatively high exposure to chlorinated hydrocarbons including PCB's, dieldrin and DDT and its metabolites. Levels of aldrin and dieldrin in human milk (locally exceeding 0.1 ppm) approach levels which affect laboratory animals.

An outbreak of mass human poisoning through consumption of rice oil containing PCB's was reported in Japan. The lowest exposure causing effects is estimated to be about 200 ug/kg/day. It is likely that the observable effects were related to extremely toxic contaminants, chlorinated dibenzofurans (CDBF's) found in some commercial mixtures of PCB's.

What are the demonstrated effects of PCB's dieldrin, DDT and DDE?

The reproductive success of both mammals and birds can be severely decreased upon continued exposure of laboratory animals to these compounds. Some of the effects which lead to a decerased reproductive success include decreased hatchibility, increased egg production, delayed increased susceptibility to disease, decreased egg production, delayed breeding, the production of thin-shelled eggs and decreased litter size. Both aquatic invertebrates and vertebrates are affected at low levels of these chlorinated hydrocarbons in the water. Dieldrin is more toxic than either DDT or PCB's upon a short exposure. Some of the other effects include induction of microsomol enzymes, porphyria, immunosuppression and decreased resistance to stress. Combined effects of the chlorinated hydrocarbons have been observed and total residues of chlorinated hydrocarbons at the higher trophic levels do exceed those which can produce effects in laboratory animals.

What are the effects of the declining production of DDT, PCB's and dieldrin?

Models indicate that the atmospheric cycling of these persistent pollutants throughout the world is accompanied by a significant lag before the ocean sink will reflect this decline or other changes in the use patterns of persistent chlorinated hydrocarbons.

Methods of Measurement:

DDT, PCB's and dieldrin can be measured qualitatively in environmental samples by means of gas-liquid chromatography with electron-captive detection. Because of the large number of organochlorine and other interfering substances, periodic confirmation of identification with mass spectrometry is necessary. Techniques are relatively standardized and some international agreement on methods has already been reached. The Codex Alimentarius (1972) recommends monitoring methods for biological materials and water. However, the required equipment is relatively sophisticated, analyses are slow and time-consuming and considerable efforts in training and standardization would be needed before a large-scale monitoring system can be set up. Thus, it will be necessary to choose indicator species with extreme care if a meaningful and economically-realistic program is to be developed. Since fish or mollusks concentrate chlorinated hydrocarbons, they can serve as better monitors than direct sampling of drinking water. For most of the other chlorinated hydrocarbons, adequate analytical methods are at present in the development stage.

The monitoring program must contain provisions for the periodic review and inclusion of other chlorinated hydrocarbons which may be recognized in the future as having deleterious environmental effects. Particularly, the program should consider the inclusion of chlorinated dibenzofurans and chlorinated dibenzo-p-dioxins in the future. These compounds have been identified as extremely toxic contaminants in mixtures of PCB's and derivatives of chlorophenols. Analytical techniques are not presently capable of detecting these compounds in environmental samples at the lowest levels where toxic effects are expected to occur. They are powerful mutagens or teratogens and the most common effect of human exposure is chloracne.

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D. 9. PETROLEUM HYDROCARBONS IN WATER

a) *Sources, environmental distribution, and sinks*

Crude oils are developed in nature by the decomposition of animals and plants in sediments laid down mainly under estuarine and marine conditions of rapid sedimentation. They are usually found in Tertiary formations and collect in geological reservoirs from which they are abstracted by drilling.

Oils vary greatly in their composition and physical properties. The principal component hydrocarbons are straight and branched chain paraffins, naphthenes and aromatics. Impurities are mainly sulphur compounds, nickel and vanadium, usually in low concentrations. The quantities spilled during the production, transport or handling of oils either by accident or design have been estimated to be well in excess of 10^6 tons per year. Almost all oil spills occur at sea, the greatest quantities resulting from tanker accidents, of which the 'Torrey Canyon' spill of 1967 of more than 100,000 tons is the largest so far recorded. Blow outs from exploratory and production wells account for a smaller proportion but include the Santa Barbara Californian spill of 10-20,000 tons. Smaller but more persistent seepages are common from pipe lines at production platforms and at terminals.

Petroleum hydrocarbons are not particularly biodegradable, although microbial activity is believed to be effective in some instances and is the subject of continuing study at the present time.

b) *Effects*

The hazards caused by escaping oils are in part due to their viscous nature when on the surface of the sea. Numerous and well authenticated reports record the deaths of birds (sometimes in thousands) alighting or diving through the surface of oil slicks, and of mammals (whales, porpoises, seals, etc.) which break the surface periodically, and are in part due to the toxicity of some oils.

There is substantial evidence that hydrocarbons of low carbon number are more toxic than those of high carbon number and that the order of toxicity of hydrocarbons of like carbon number is in descending order of aromatic hydrocarbons, napthenes and paraffins. Most oils are toxic on first release through the solution and emulsification of the lighter fractions, but dependent upon water temperature and wind conditions, the greater part of the lighter fractions are lost rather quickly to the air by evaporation. Weathered oil of 2 or more days in the sea is remarkably non-lethal to marine organisms.

The main hazards of oil pollution to marine organisms are probably due to long-term, low concentrations, but there is a need for continuing and more intensive research on the sublethal effects of oils, expressed as lowered viability to other environmental stresses, and in lowered growth rates and reproductive capacity.

The oceans have a rather large assimilative capacity, of course. In estuaries, inland lakes and marshes, on the other hand, oil can accumulate in bottom sediments, resulting ultimately in the death of microorganisms and the impoverishment of bottom fauna. Bengtsson and Berggren (1972) have described a lake near Stockholm that is in this condition, while Ehrhardt (1972) has found petroleum hydrocarbons, including aromatics, in oysters in Galveston Bay, Texas.

c) *Feasibility of measurement*

Oil presence in the oceans can be monitored as visible sheens, by infrared photography, by gas chromatography analyses (Ehrhardt and Blumer, 1972) and by the abundance of tar balls and residues which are relatively resistent to evaporation and biodegradation. The measurement of Total Organic Carbon (TOC) may be convenient for use on the global scale. Also, it must be emphasized the hydrocarbon-type effluents exert an oxygen demand (on receiving waters) that is mostly of the *chemical* rather than the *biochemical* type; for this reason, measurement of *Chemical Oxygen Demand* will give more meaningful information than Biochemical Oxygen Demand (BOD).

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D. 10. SELECTED INDICATORS OF WATER QUALITY

a) *Biochemical oxygen demand (BOD):*

This is a test that measures the amount of oxygen (in milligrams per liter) required for the biological degradation of organic matter in water. It is a relatively simple test to perform, and is usually done on a 5-day basis during which the sample is incubated at 20°C, with results expressed as a "BOD_5" value. As such, the test is also a measurement of the rate of oxygen requirement in a 5-day period, and this information is important because too high an oxygen demand can deplete the dissolved oxygen concentration in receiving waters (as discussed in the next section). However, it must be understood that the BOD test is not a measurement of the *total* oxygen demand; instead, it provides an estimate of the short-term oxygen demand. Recent research indicates that BOD_5 tests should be supplemented by measurements of concomitant Chemical Oxygen Demand (COD), which is a much more rapid test that provides a measurement of the oxygen demand arising from strictly chemical (i.e., non-biological) reactions. BOD_5 measurements are of particular significance in grossly polluted waters; otherwise, the BOD_5 values will usually be below 5 milligrams per liter, and below 2 milligrams per liter in relatively uncontaminated waters. Another method for potential oxygen demand is coming into use: this is a measurement of Total Organic Carbon (TOC) which is even more rapid to perform than the COD test; however, TOC measurements require special instrumentation and, therefore, may not be as convenient.

b) *Dissolved oxygen (DO):*

This is undoubtedly one of the most important indicators of water quality, in terms of ecological evaluation. Just as human beings are dependent on the oxygen present in the air they breathe, so fish and other aquatic life are dependent on the dissolved oxygen content of the water. The saturation-point of oxygen in water is temperature-dependent: at 20°C, the solubility of oxygen in water is 9.1 milligrams per liter; at 25°C, it is 7.5 milligrams per liter. When large quantities of waste-materials are discarded into waterways, they can require more oxygen (for their decomposition) than can be supplied by the receiving waters; this can be a long-term process, especially when some wastes settle and accumulate on the bottom where they undergo gradual decomposition. The consequence of this can be a reduction, and even depletion, of the water's dissolved oxygen. Not only does this impose a stress on aquatic life, but it can eventually eliminate many species that are valuable to man. Furthermore, the depletion of dissolved oxygen can mean that the accumulated wastes will then undergo decomposition by anaerobic (i.e., non-oxidative) processes, with concomitant production of malodorous gases such as hydrogen sulfide. The end-result can be a stagnant, putrid body of water. As a mere illustration of extremes, a dissolved oxygen concentration of greater than 7 milligrams per liter can be termed desirable, but concentrations below 2 milligrams per liter are viewed as undesirable. In so saying, it must be remembered that, in large bodies of water such as lakes, the "natural" distribution of dissolved oxygen will vary according to depth; in comparison, a turbulent stream will have a more uniformly-mixed distribution of oxygen. Dissolved oxygen is easily measured by titration or continuous recorders.

c) *pH:*

The term "pH" refers to the negative logarithm of the free hydrogen ions present in water. Accordingly, this means that a low pH refers to high acidity, whereas a high pH is indicative of high alkalinity. The discharge of wastes that are either highly acid or highly alkaline can have a severe impact, particularly in receiving waters that have a low mineral content (and thus, will have low "buffering capacity"), because there are not enough chemicals in the water to permit "neutralization" of the acids or alkalis. If the pH of the receiving waters becomes too low or too high, the water can have a corrosive quality and can adversely affect aquatic life. For instance, extreme pH values such as a low pH of 3 or a high pH of 11 can kill all fish species within a few hours, whereas there is fairly general agreement that a desirable pH range is within 6.5 to 8.5. Variations above or below this optimum range can, if sustained, impose severe stress on some species of aquatic life. It is also important to mention that some toxic substances that may be released in water can have enhanced toxic properties in certain regions of the pH scale; with metallic pollutants, this is because of their generally greater solubility in acidic waters (i.e., low pH). The pH of water can be easily measured by inexpensive field methods as well as continuously-recording apparatus.

d) *Coliform bacteria:*

The measurements of these organisms in water are extremely important from the point of view of safeguarding human health. They arise from contamination of water by fecal wastes, and can contaminate shellfish or other forms of aquatic life used by man as a food-source, in addition to contaminating drinking water and bathing areas. This type of organism is measured by means of a bacteriological test, and can be done using a rapid filter-membrane technique. In Canada, the Province of Ontario has set a "Recommended" level which must not exceed 100 *total* coliforms, nor exceed 10 *fecal* coliforms, nor exceed 1 fecal streptococcus (all values given in "Most Probable Numbers per 100 milliliters of water", as derived from actual counting of cultures grown on bacteriological plates).

e) *Ammonia:*

This substance can be very toxic to aquatic life, especially when present in the "free ammonia" (i.e., NH_3) form. The proportion of total ammonia that exists in water as "free ammonia" depends on pH and water temperature, with higher pH and/or temperature resulting in a greater proportion of "free ammonia" in water. For long-term conditions, "free ammonia" concentrations greater than 0.025 milligrams per liter can adversely affect aquatic life-forms. Ammonia measurements can be done easily by means of classic laboratory techniques.

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D. 11. NITRATES, NITRITES AND NITROSAMINES

The consumption of food and water containing nitrite or nitrate can lead to impairment of oxygen transport in the blood (methemoglobinemia or "blue baby disease"). There have been indications of an interaction between nitrate and hypertension patterns in man, including increased heart rate, decreased blood pressure and circulatory collapse. Nitrite may react with amines to form nitrosamines which are known to have carcinogenic, mutagenic and teratogenic effects in experimental animals, often at very low exposure levels. Animals have become ill or died after consuming feed or water containing large amounts of nitrate or nitrite, especially in drought-affected areas. Animals receiving nitrate or nitrite over long periods of time may suffer abnormalities leading to reduced productivity. Such chronic toxicity is most likely to be seen in the very young, the old, the sick and the poorly-fed animal and most frequently in cold weather. In very cold environments, nitrate can function as an antithyroid substance by "washing out" iodine. High nitrate or nitrite levels in feed and water may lead to Vitamin A deficiencies by destroying carotene or interfering with the utilization of Vitamin A. In addition, reproduction and lactation in animals, as well as digestibility of feed are adversely affected.

Vegetables such as beets, spinach, broccoli, celery, lettuce, radishes, kale, mustard greens and collards may accumulate large quantities of nitrate. Factors leading to such accumulation include the level of applied fertilizer, nutrient deficiencies, low light intensity, drought and insect damage. Nitrite accumulates in plants as the result of bruising or processes involving bacterial fermentation, such as ensilage. Concern is rising over the accumulation of nitrate in some surface water, groundwater and well-water; where concentrations are beyond recommended levels, removal from drinking water may become necessary.

Some recent studies have linked esophageal cancer in humans to dimethylnitrosamine derived from natural sources. While mixtures of nitrate and nitrite used to preserve and cure meat and fish are usually subject to legal tolerances, nitrosamines, which can be toxic to man and animals, are found to occur most frequently in such processed foods. Monitoring is required to estimate the hazard this poses to man and to establish whether nitrosamines are found in soil or natural bodies of water which contain appreciable amounts of nitrate or nitrite.

Although nitrogen is abundant and essential for all living things, supplies of the forms available to plants and needed for crop production are inadequate in many parts of the world. Man has compensated for this by using animal and human manure, by cultivating legumes and by applying chemical fertilizers. This expanded use of nitrogen, together with releases from feedlots, municipal and industrial wastes, refuse dumps and emissions from internal combustion engines, has tended to enrich the supply of available nitrogen in water bodies. Although phosphorous has received particular attention in efforts to maintain water quality by limiting growth of weeds and algae, it is nitrogen that controls algal growth and eutrophication in coastal waters and estuaries. The measurement of nitrate and nitrite in various media presents no particular difficulty from the viewpoint of methods of chemical analysis. However, present methods utilizing colorimetry, thin-layer chromatography, gas chromatography, and mass spectrometry are inadequate for monitoring the occurrence and quantity of nitrosamines in foods. Thus, there is a critical need for an accurate and reliable method to fill vital gaps in this area of growing concern.

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D. 12. ENVIRONMENTAL RADIOACTIVITY

Radioactive materials are present in the environment both as a result of natural processes and man's activities. These radioactive materials emit ionizing radiations which are a potential hazard to those exposed to them. The numerical estimates of the risks of damage from such exposures constitute the criteria on which safety standards may be based.

The release of man-made radioactivity to the environment has in the past resulted mainly from nuclear weapon testing and, to a lesser extent, from the operation of nuclear power plants. The radioactive materials are either released to the atmosphere or to waterways and, from there, can be transported to the food chain of man. Some radioactive material in the atmosphere will be absorbed directly by inhalation. The ingestion of contaminated food and the inhalation of contaminated air results in internal exposure of the population to radioactivity. Furthermore, man can be exposed directly to ionizing radiation emitted by radioactive materials in the atmosphere or on the earth; this is termed external exposure. The redionuclide that presents the greatest hazard soon after an environmental release is radioactive iodine and those that give the greatest exposure at later times are radioactive strontium and caesium. Radioactive materials and ionizing radiation can be measured down to lower levels than any other environmental contaminants. In order to assess adequately the dose commitment to human populations from environmental radioactivity, air, water, and foodstuffs (for different types of diets) should be surveyed at least four times a year.

The harmful effects of ionizing radiation are divided into two main categories: genetic and somatic. Genetic effects of ionizing radiation are those which are transmitted to future generations by the exposed individuals. Such hazards result from radiation-induced changes in the cells involved in reproduction. Genetic risks have been evaluated but the estimates cover a wide range. Somatic effects of ionizing radiation are those which are expressed in the exposed individuals themselves. The main somatic hazard from low levels of radiation are the development of leukaemia and of cancers. Present risk estimates indicate that if all members of a population of one million received a dose of one rad, there would result a lifetime risk among the exposed persons of approximately:

40 fatalities from leukaemia
100 fatalities from cancer
40 cases of thyroid cancer (usually non-fatal)

plus 300-6000 genetic defects in the next generation. Since the numerical estimates of risk are based on grossly incomplete knowledge, the greatest caution is needed in drawing quantitative conclusions, especially where protection of human health and life is involved.

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