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ABSTRACT

The Commission on Monitoring of the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU) has submitted this report to the United Nations Conference on the Human Environment. It reviews: (1) the origin, objectives, and membership of SCOPE and the Monitoring Committee; (2) basic considerations for a global monitoring system; (3) environmental problems of critical importance; (4) environmental variables appropriate for monitoring; (5) the design of global environmental monitoring; and (6) operational and institutional arrangements. Eighteen recommendations for a global environmental monitoring system are presented based on the findings of the Monitoring Committee. They provide criteria for environmental management in developed countries as well as enabling developing countries avoid environmental disamenities and establish a rational system of natural resource management. The Committee has determined that such a global system can best be created through national efforts and by inter-governmental cooperation at the level of the United Nations, combined with strong supportive and advisory activities within the international scientific community. (BL)

GL BAL ENVIRONMENTAL MONITORING

SCOPE 1

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

GLOBAL ENVIRONMENTAL MONITORING

A Report submitted to the
United Nations Conference on the Human Environment,
Stockholm 1972

by the

Commission on Monitoring of the
Scientific Committee on Problems of the Environment (SCOPE) of the
International Council of Scientific Unions (ICSU)

International Council of Scientific Unions
Scientific Committee on Problems of the Environment
Stockholm 1971

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2. Recommendations

We have examined the present state of the human environment and the most important environmental problems. We have found that the basic problems result from adverse side-effects of advancing technologies and from the increasing rate of exploitation and unwise use of natural resources. Of special importance are the side-effects that have or may have a deleterious impact on human health and well-being. We have also found that the present machinery for environmental management and resource exploitation is based on insufficient knowledge. It is not possible at present to provide the information we need to define and understand the large-scale processes going on in the biosphere, partly influenced by man's activities. We are convinced, however, that better definition and understanding can be brought about by appropriate research and monitoring. This will not only provide criteria for environmental management in developed countries but will also enable developing countries to avoid environmental disamenities and to establish a rational system of natural resource management.

We have determined that a global environmental monitoring system is desirable, timely and feasible. We have also determined that such a global system can best be created through national efforts and by inter-governmental co-operation at the level of the United Nations, combined with strong supportive and advisory activities within the international scientific community.

In the light of our findings we, the Monitoring Commission of SCOPE, submit the following recommendations.

RECOMMENDATION 1

We *recommend* that the United Nations take immediate steps to foster and co-ordinate among the nations of the world a permanent global environmental monitoring system.

RECOMMENDATION 2

We *recommend* that, in view of the existence within the United Nations system and non-governmental organizations of both ongoing and planned monitoring activities for different media and the need for inter-media integration, the most efficient ways or means for co-ordinating these activities into a global environmental monitoring system be studied and particularly the need for establishing a Central Monitoring Co-ordinating Unit.

RECOMMENDATION 3

We *recommend* that the United Nations request the International Council of Scientific Unions to establish permanent institutional arrangements to provide scientific assistance in (a) the evolution and design of the global environmental monitoring system and (b) the analysis and interpretation of data pertinent to global environmental changes and the effects of such changes.

RECOMMENDATION 4

We have carefully analysed the possible ways by which a global environmental monitoring system could be created. We have found that it can best be brought about through inter-governmental co-operation based on national efforts. We therefore *recommend* that the United Nations invite each government and each inter-governmental and non-governmental organization actively involved in monitoring to designate an appropriate Monitoring Office for participation in the global environmental monitoring system. We *further recommend* that these Offices be so designed that close co-operation can be achieved between international, regional and national activities. We *also recommend* that, whenever practicable, the programmes of each nation or organization be evolved to obtain maximum integration between monitoring activities in the different media.

RECOMMENDATION 5

We *recommend* that an international integrated network of reference stations (low exposure or "baseline" and medium exposure or "regional" areas, transects or sites) based on national activities be established for the collection of data pertinent to global environmental monitoring.

We *further recommend* that an establishment period be initiated immediately which includes a minimum priority monitoring programme and pilot research programmes, followed by a development period that emphasizes the establishment of additional stations and the inclusion of additional variables into the monitoring system.

RECOMMENDATION 6

We *recommend* that within the network of reference stations at least ten terrestrial (including freshwater) baseline stations be established immediately and that at least one be located in each of the following regions: (1) northern tundra, (2) northern coniferous forest, (3) northern hemisphere temperate grassland, (4) arctic or antarctic, (5) high mountain, (6) tropical forests, (7) desert or semi-desert, (8) tropical savanna or grassland, (9) oceanic island, (10) temperate deciduous forest.

Baseline stations in the marine environment should be established after pilot studies (Recommendation 15).

We *further recommend* that nations be invited to nominate sites for immediate establishment as baseline stations or for inclusion at a later stage.

RECOMMENDATION 7

We *recommend* that the following first priority physical and chemical data be collected as a minimum programme at the baseline stations and in all relevant media of air, water, soils and biota from the beginning of the establishment period.

a) For assessing secular changes of the global climate:
   1. Atmospheric turbidity (aerosol content)
   2. Atmospheric carbon dioxide
   3. Solar radiation
      a) broad-band direct, and diffuse radiation
      b) narrow-band direct radiation
      c) net (incident minus reflected) all-wave radiation
   4. Standard meteorological data
b) For assessing the degree of pollution in all media:
   5. Mercury
   6. Lead
   7. Cadmium
   8. DDT, its metabolites and degradation products
   9. Polychlorinated biphenyls

We *further recommend* that the following variables be seriously considered for addition to the baseline station programme during the development period and if necessary after pilot studies.

a) For assessing secular changes of the global climate.
   1. Vertical distribution of aerosols
   2. Size distribution of aerosols
   3. Rawindsonde data
   4. Surface vertical fluxes of carbon dioxide
   5. Ozone, water vapour and trace gases in the stratosphere (in association with the reference station programme)
   6. Global albedo by satellites (in association with the reference station programme)
b) For assessing the degree of pollution of the biosphere:
   7. Petroleum products
   8. Persistent organochlorine compounds other than DDT
   9. Chlorinated aliphatic hydrocarbons
   10. Chlorinated phenoxy acetic acid derivatives
   11. Relevant compounds in the cycles of S, N, P and C
   12. Certain metals (As, V, Zn, Se, Cr, Cu, Be, Ni, Mn)
   13. Organophosphorus compounds
   14. Oxygen in water

We *also recommend*

1. That other potentially harmful substances be continuously reviewed for possible inclusion in the routine programme (for example antibiotics, hormones, carcinogens, teratogens, mutagens).

2. That the possibilities of using biological accumulators and indicators be investigated by pilot studies.
3. That all the measurements be standardized and co-ordinated in space and time so that the resulting data together with appropriate information about sources and flux rates in the environment can be used to construct global dynamic budgets of pertinent substances.

RECOMMENDATION 8

We *recommend* that a number of regional stations be established and included in the network of reference stations and that nations be invited to nominate one or more sites for that purpose.

RECOMMENDATION 9

We *recommend* that the programme of the regional stations should be correlated with that of the baseline stations especially to allow global budgeting. For the establishment period we *recommend* the following variables to be measured:

1. Atmospheric turbidity (aerosol content)
2. Solar radiation
   a) broad-band direct and diffuse radiation
   b) net (incident minus reflected) all-wave radiation
3. Standard meteorological data
4. Mercury
5. Lead
6. Cadmium
7. DDT, its metabolites and degradation products
8. Polychlorinated biphenyls

We *further recommend* that the variables to be included at the baseline stations during the development period also be examined for possible inclusion at the regional stations.

RECOMMENDATION 10

We *recommend* that the different nations be invited to establish high exposure areas to investigate the correlation between high levels of contaminants (single and in combination) and possible effects on human health and the performance of biological systems and that the results from these studies be made available.

RECOMMENDATION 11

We *recommend* that a coherent programme, broadly along the lines indicated below, be developed to monitor those aspects of human health known or suspected to be environmentally induced. Accordingly, we *recommend* that the geographical distribution of the following be periodically surveyed wherever data can be obtained: actuarial data on life-expectancy, age-structure of populations and excess crude mortality and growth rate in terms of body weight and height.

We *further recommend* that the frequency of certain age-linked and other relevant diseases and disorders, known or suspected to be induced by the long-term ingestion of trace amounts of environmental contaminants, be periodically surveyed wherever data can be obtained (special attention should be given to diseases of the blood and cardiovascular system and certain forms of cancer). As far as is possible, these disease-surveys should be carried out in populations carefully selected to represent various age-groups and degrees of exposure to urban, industrial and intensively-agricultural conditions. In association with carefully selected sample populations from these surveys, analyses of human tissue (blood, soft tissue and bone), human food, drinking water and air, should be carried out for heavy metals and organochlorine compounds. Pb, Hg, Cd, DDT and PCB are suggested for the initial programme.

RECOMMENDATION 12

We *recommend* that at least two International Research Reference Stations be established, of which at least one should be in a tropical area. They should be internationally staffed and funded. In addition to the objectives of the ordinary reference baseline stations, these research stations should have the major function of determining other variables to be measured at all stations and of developing standard methods for accomplishing such measurements. These stations, which should be fully counselled by the international scientific community, should also serve as a training centre for national scientists and technicians who will participate in reference station programmes.

We *further recommend* that nations be invited to propose areas for these stations.

RECOMMENDATION 13

We *recommend* that biome studies be started immediately in association with the reference stations. These biome studies should be designed to provide information on the structure and functioning of representative ecosystems pertinent to the rational management of their resources and to obtain methods for monitoring the effects on biota of environmental change (See also Recommendation 15, item 2). We further *recommend* that monitoring for the following be implemented immediately.

1. Vanishing or endangered ecosystems
2. Vanishing or endangered vertebrates

3. Population size and distribution of birds
4. Short-lived biological phenomena

RECOMMENDATION 14

We *recommend* that pilot programmes be designed for the following monitoring activities, that cannot be confined to the networks of stations.

1. Repetitive surveys of gross vegetation pattern and land use of earth's surface (if possible with a satellite sensing system).
2. Repetitive surveys of erosion and soil cover of the continents (if possible with a satellite sensing system).
3. Monitoring of abundance and distribution of vanishing or endangered species, particularly mammals and birds, and endangered ecosystems or biocoenoses.
4. Monitoring changes in abundance and distribution of birds (a system of numerous sample plots for whole communities and special systems for selected groups of species, namely birds of prey, certain oceanic species and waterfowl).
5. Monitoring selected significant aspects of abundance, composition or activity of soil organisms in suitable areas.

RECOMMENDATION 15

We *recommend* that proper action be taken immediately to implement research activities and pilot studies to define and, if necessary, develop efficient monitoring programmes in the following areas:

1. The design of a programme for monitoring physical and chemical variables in the marine environment including the selection and establishment of reference networks. High priority should be given to those variables given high priority at the terrestrial reference stations and to petroleum products.
2. The isolation and development of biological parameters pertinent to the monitoring of specific and integrative effects on biota of environmental changes, namely relevant population characteristics (for example life-expectancy, age-structure and fecundity), community characteristics (for example species diversity), data on indicator species and processes (for example sensitive plant species or physiological processes) and incidence of congenital malformations and genetical changes.
3. The development of a programme for continuous registration of short-lived phenomena as early indicators of potential future global problems.
4. The design of a system for preserving samples from air, water, soils and biota in order to make future re-examinations of past environmental conditions possible (environmental archives).

5. Analyse the needs and possibilities of aerobiology as a method for global environmental monitoring.

RECOMMENDATION 16

We *recommend* that operations-manuals be prepared, describing in detail the basic methods of measurement and observation for the networks of reference stations and other monitoring programmes. Periodic revisions of the manuals will be necessary as existing techniques are improved and new items are added to the agreed list of parameters within the global environmental monitoring system.

RECOMMENDATION 17

We *recommend* that the United Nations invite its agencies and other relevant organizations, in collaboration with the Central Monitoring Co-ordinating Unit, (Recommendation 2), to institute discussions to formulate, define and assign responsibility for individual contributions to a practicable and unitary monitoring programme.

We *further recommend* that these discussions recognize the value of the very wide range of environmental monitoring which is proposed and planned and of the competent ongoing programmes which have been in existence for some time. These include (a) territorial monitoring activities which are the sole concern of each national government, (b) regional programmes where a sharged resource or region is collaboratively monitored by those governments directly affected and (c), the UN agency and other intergovernmental or non-governmental programmes for climatic change, human health and toxicology, marine conditions, radioactivity, education and training.

RECOMMENDATION 18

We recognize that the global environmental monitoring system is an integrated part of a much more comprehensive framework for policies, research and actions in the field of environmental affairs in general, and that monitoring cannot operate with maximum efficiency without close connection to these other environmental activities. We also recognize that no organization presently exists with the responsibility of co-ordinating all global environmental activities.

We therefore *recommend* that serious considerations be given to identifying or establishing within the United Nations system an appropriate unit to carry out this function.

3. Terms of reference

3.1. SCIENTIFIC COMMITTEE ON PROBLEMS OF THE ENVIRONMENT (SCOPE)

3.1.1. Origin

The 12 th General Assembly of the International Council of Scientific Unions (ICSU) meeting in Paris 1968, resolved that the International Union of Biological Sciences (IUBS), the International Union of Geodesy and Geophysics (IUGG), in consultation with the Special Committee for the International Biological Programme (SCIBP), should set up an "ad hoc Committee on Problems of the Human Environment". The ad hoc Committee recommended the creation of a Scientific Committe on Problems of the Environment (SCOPE). The proposed Committee was set up by the Executive of ICSU (Erevan 1969) and originally comprised eleven members together with representatives from the nine ICSU Unions that wished to participate. SCOPE first met in Madrid in September 1970 and decided to initiate four working groups, one of which was a Commission to Monitor the Environment. The establishment of SCOPE was confirmed at the 13th General Assembly of ICSU (Madrid 1970) and extended to include one representative each from India, South-East Asia and Africa.

3.1.2. Objectives

SCOPE was established for the following purposes: (a) To 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) To serve as a non-governmental, inter-diciplinary and international council of scientists and as a non-governmental source of advice for the benefit of governments and inter-governmental agencies with respect to environmental problems.

Toward these ends, the functions of SCOPE shall include: (a) Advancing studies of fundamental environmental processes, particularly those necessary to achieve a better understanding of the interactions between man and his environment, (b) Devising techniques for environmental measurements with international comparability of data, and exercising scientific leadership in the design of a plan for co-operative environmental monitoring, (c) Gathering, analyzing and evaluating information concerning global and regional environmental phenomena and trends, and the effects of environment on man, (d) Developing collaborative programmes among the Scientific Unions, National Members and Committees of ICSU and other appropriate organizations including those concerned with the social sciences, in order to promote the above mentioned activities, (e) Projecting current environmental trends into the future on the basis of alternative hypotheses of future human activity, population, use of natural resources and energy requirements, (f) Identifying or devising measures to minimize the adverse effects of the interaction of man and his environment, (g) Acting, on behalf of ICSU, in serving as a means of communication with other organizations, such as United Nations agencies, on environmental questions of broader purview than those of individual Unions and Committees of ICSU and (h) Promoting education in, and understanding of, environmental problems.

SCOPE originally selected four tasks for study, namely (i) Materials which may significantly alter the biosphere and the environment – their determination and biological assessment, (ii) A case study of the toxicology of chlorinated aromatic compounds, (iii) The scientific basis for the creation and management of artificial ecosystems and (iv) The planning of a global monitoring system.

The development of SCOPE is envisaged to broadly follow the lines of the Scientific Committee for Antarctic Research (SCAR) or the Scientific Committee for Oceanic Research (SCOR).

With its purposes and functions as described above SCOPE is most anxious to co-operate fully with other non-governmental organizations and with inter-governmental organizations and agencies.

All SCOPE activities have to be based on national participation and accordingly the President of ICSU invited national members of ICSU to designate an appropriate national committee for liaison with SCOPE.

3.1.3. Membership

(Union affiliation within parentheses)

Dr J.E. Smith, Plymouth Marine Laboratory, PLYMOUTH, U.K. (Chairman)

Professor F.di Castri, Institute of Ecology, Universidad Austral de Chile, VALDIVIA, Chile. (Vice Chairman)

Dr T.F. Malone, Graduate School, University of Connecticut, STORRS, U.S.A. (IUGG) (Secretary)

Professor F. Bourlière, Faculté de Médicine, PARIS, France.

Professor D.S. Farner, Department of Zoology, University of Washington, SEATTLE, U.S.A. (IUBS)

Professor F.J. Fenner, John Curtin School of Medical Research, Australian National University, CANBERRA, Australia

Dr F.N. Frenkiel, Naval Ship Research and Development Center, WASHINGTON D.C., U.S.A. (IUTAM)

Dr J.C. Frye, Illinois State Geological Survey, URBANA, U.S.A. (IGU)

Dr W. Gallay, The E.B. Eddy Co., HULL, Canada (IUPAC)

Professor K. Grasshoff, Institut für Meereskunde, KIEL, Federal Republic of Germany

Dr R.W.J. Keay, The Royal Society, LONDON, U.K.

Professor T. Kira, Department of Biology, Osaka City University, OSAKA, Japan

Professor S. Krishnaswamy, Department of Biological Sciences, Madurai University, MADURAI, India

Professor V.N. Kunin, Academy of Sciences, MOSCOW, USSR

Professor A. Lara, Centro de Investigaciones Fisicas, Consejaro Nacional de Educacion, MADRID, Spain. (IUPAP)

Professor C.Levinthal, Department of Biological Sciences, Columbia University, NEW YORK, U.S.A. (IUPAB)

Dr B. Lundholm, Ecological Reserach Committee, STOCKHOLM, Sweden.

Dr R.E. Munn, Meteorological Service of Canada, TORONTO, Canada.

Professor Otto Seomarwoto, National Biological Institut of Indonesia, BOGOR, Indonsia.

Professor F.A. Stafleu, International Bureau for Plant Taxonomy, UTRECHT, The Netherlands. (ICSU)

Professor F.J. Stare, Laboratory of Nutrition, Harvard School of Public Health, CAMBRIDGE, U.S.A. (IUNS)

Professor P.F. Straub, Institute of Biochemistry, Hungarian Academy of Sciences, BUDAPEST, Hungary. (IUB)

Professor T. Tashev, Institute de Nutrition, Academie Bulgare des Sciences, SOFIA, Bulgaria.

Professor R. Truhaut, Faculté de Pharmacie, PARIS, France.

Professor David Wasawo, Department of Zoology, University College of Nairobi, NAIROBI, Kenya.

Professor J.S. Weiner, London School of Hygiene and Tropical Medicine, LONDON, U.K. (IUPS)

Professor G.F. White, Institute of Behavioral Science, University of Colorado, BOULDER, U.S.A. (IGU)

3.2. SCOPE COMMISSION ON MONITORING

3.2.1. Origin

The third General Assembly of the International Biological Programme (Varna, April 1968) appointed an ad hoc committee to investigate and report on the need for environmental monitoring. This Report with three technical annexures, was presented to SCIBP at the fourth General Assembly of IBP (Rome, October 1970) where it was agreed that SCIBP should transfer to SCOPE its responsibility for the consideration of matters relating to global environmental monitoring. SCOPE had already set up a Commission on Monitoring at its first meeting in Madrid, September 1970.

3.2.2. Function

The functions of the Commission on Monitoring are as follows:

a) To initiate investigations into the methodology of monitoring, including the selection of suitable parameters, to ensure comparability of methods and co-ordination of monitoring systems;

b) to design an integrated, appropriate broad-based monitoring system for air, water, soils and biota, including man, taking into consideration already existing activities;

c) to set priorities on parameters to be initially measured commensurate with the urgency of the environmental problems to which they pertain;

d) to investigate the usefulness of studying past changes in selected parameters in order to establish baseline values and to investigate the possibilities of establishing environmental archives;

e) a prime component of the system should be a network of background (baseline) stations, far from population centers, and designed to monitor integrated values of global importance. However, the problems of cities and other areas of major development should not be neglected, and the Commission should consider the development of impact stations and other methods of monitoring those situations where human impact is critical;

f) the potential for future development of special monitoring techniques, such as those of remote sensing, should be carefully considered.

3.2.3. Membership

Dr. Bengt Lundholm, (chairman) Swedish Natural
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3.3. REQUEST TO SCOPE FROM THE UN CONFERENCE ON THE HUMAN ENVIRONMENT, STOCKHOLM 1972.

In December 1970 the Secretary–General of the UN Conference on the Human Environment (Stockholm 1972) requested that the SCOPE Commission on Monitoring "prepare a report recommending the design, the parameters and technical organization needed for a coherent global environmental monitoring system making maximum use of available capabilities of existing and planned national, regional and international networks, together with such data collection and processing centres as may be required".

3.4. SCOPE'S ACCEPTANCE OF THE UN REQUEST.

This request was accepted by SCOPE at its second meeting (London, January 1971) and the following recommendation adopted:

"The Committee, having considered the possibilities of designing a coherent global monitoring system which would include existing and planned international, regional and national networks, and convinced that such an integrated system is feasible, desirable and deserving of the strong support of the science community, asks the Commission on Global Monitoring to take the necessary action, in consultation with the international, regional and national bodies concerned, to prepare a design for such a system, including the principles for the list of variables to be studied, including the location of baseline and background stations and the needs for data collection and analysis centres. *Recommends* that the Secretary take the necessary steps to obtain financial and other support to enable the Commission to complete this design prior to the third meeting of SCOPE, so that it may, with the approval of SCOPE, be submitted to the Secretary-General of the UN Conference on the Human Environment."

4. Monitoring – basic considerations

A total system for environmental control includes three basic types of activity. The first involves measurements and observations directed towards a description of the state of the environment and its changes. The second activity is the evaluation and analysis of environmental data to determine possible trends and to develop a warning system related to pre-set criteria. This specifically includes functions such as predictions of the environmental consequences of planned actions, descriptions of the budget of contaminants and the analysis of ecosystems, determination of environmental criteria for specific pollutants, and the formulation of recommendations for actions. The third and final activity in the total system is that of action, designed to avoid environmental deterioration but in the overall context of achieving environmental management in the most beneficial way.

Global environmental monitoring or "monitoring" is used in this Report to describe activities of the first type listed above. Accordingly, monitoring is defined as, "a scientifically designed system of continuing measurements and observations." However, references throughout this Report to a global environmental monitoring system additionally include the evaluation procedures listed above as the second activity. There are no proposals included in this Report concerning the third, or action, phase of the total system.

Concern with environmental monitoring stems from man's preoccupation with his health and well-being, traditionally centred around his attempts to obtain shelter and food from crops, livestock and other biota, and to avoid disease and such natural phenomena as earthquake, fire, flood and hurricane. Man has always intended to improve his environment by increasing his control of it. However, an environmental modification orginally designed to improve the standard of living (e.g., land-drainage or deforestation for agriculture) has often generated unanticipated side effects which sometimes are harmful and occasionally irreversible or costly to correct (e.g., loss of soil fertility or topsoil and the extension of arid zones).

Traditional agents of modification such as fire, grazing animals and direct human labour have lately been enormously reinforced by modern technology. Mechanical power, explosives and chemical agents such as drugs and biocides have revolutionized the impact of man and increased his ability to modify the environment. In addition to the direct effects already evident, there remains the possibility that harmful environmental side effects, as yet unrecognizable, may appear in the future, triggered off by current human activities.

Four principle categories of environmental phenomena that affect man are: natural disasters; disease epidemics; agricultural and other biological resource productivity (forestry, fisheries, etc.); and undesirable side effects resulting from modern urban/industrial technology. The effects of floods, giant seawaves, earthquakes, hurricanes and other natural disasters requires constant attention. Many countries have traditionally operated information gathering and warning systems, and more recently, predictive networks for weather changes, geological and oceanographic phenomena have been extended and refined. Likewise, public health authorities have been set up all over the world to investigate, evaluate and control disease and other human health problems. Survey, advisory and remedial services for agriculture, soils, forestry and fisheries have been operated for many years by nearly every government. Many of these national activities are co-ordinated internationally by organizations such as WMO, WHO, and FAO.

The concept of monitoring and early warning is thus not a new one. A great deal of excellent work has already been carried out, and continual efforts are being made to improve and co-ordinate the existing national and international systems.

However, the efforts to deal with man-induced phenomena on a world-wide scale are uneven and unco-ordinated. This is because most aspects of this field are relatively new or have become of serious concern only during the last century, particularly within the last thirty years. National concern with these problems seems to depend among other things on population density, degree of industrialization, consumption of products by urban societies, intensity of agriculture and on standards of living, public education and environmental awareness. However, as contaminants from the industrialized countries spread around the globe and as more areas become developed, more and more nations must face these problems.

Since all the components of the environment – air, water, soils and living things – interact through physical, chemical and biological cycles to form an interlocking unitary environment, a disturbance or modification in one of these components may have repercussions in all. In many cases man does not know the magnitude or nature of the repercussions, because he does not completely understand the interplay between these cycles.

There are many well known examples of clearcut effects of man's impact over the globe. Human disease vectors as well as crop and livestock pests have been transported by human agency into new territories, causing loss of life and biological productivity. Dust-bowl conditions and arid regions have been generated in different continents by defective agricultural practices. Local climates have been developed in large cities by waste heat.

Many chemical substances released in large quantities into air and water or spread on farmland become widely distributed. These substances can now be found in places where they have never been applied by man, even in remote wilderness regions and in the open seas. Many are known to be highly toxic in larger amounts, but their long-term effects on man and other living things in trace amounts have not yet been determined. We know, however, that man and many animal and plant species suffer from the effects of toxic substances in terms of population decreases or increased frequency of diseases. Once released, many of these poisonous substances persist for decades in the bio-environment because they either are not degradable or are broken down only with great difficulty. Lead, cadmium, mercury, radionuclides, organochlorine compounds like DDT and polychlorinated biphenyls are in this category. We do not know if their present world distribution-patterns are equilibrium situations or whether, even if all urban-industrial and agricultural emissions ceased at once, some of these substances would still continue to circulate in the biosphere by transfer processes which are still inadequately understood.

Effects of other activities can only be theoretically surmized. The rise in the temperature of the earth's surface, expected from increased concentrations of atmospheric carbon dioxide due to the combustion of fossil fuels, could possibly thaw polar ice, raising sea-levels and flooding coasts. Dust particles, on the other hand, may lower the surface temperature of the earth by screening it from incoming solar radiation. So far, however, it is not clear to what extent man's activities have affected or are affecting the global climate.

The Report will emphasize the need for a global environmental monitoring system to include co-ordinated measurements of physical, chemical and biological parameters in the atmosphere, the hydrosphere, the pedosphere and in biota. Thus the budget, or pathways of a substance through the environment from start to finish, can be determined. Wellorganized, judicious surveys and monitoring of the substance at selected points throughout these pathways can aid in understanding its effects and in determining optimum control strategies.

The imperfectly understood cause and effect relations and environmental budgets of many substances have given rise to important questions about the complex interactions between man and the bio-environment. A programme must be initiated to obtain a picture of how all these processes occur, the rates at which they take place, the timing and nature of equilibrium situations, their effects on man and the life-support systems of air, water, soils, climate and biota. We also need to develop mathematical simulation models of environmental interactions that can predict the results expected from varying types and degrees of remedial action. The capability of advance-warning before an adverse situation becomes irreversible is absolutely essential.

The proposed system will have two basic functions: 1) It will establish existing, natural baseline values of the bio-environmental state against which contaminated states can be compared in relation to effect-levels on biota and man. 2) It will provide the basic information for the early detection and global extent of bio-environmental changes and their causes. The system visualized will be basically a service oriented function which gathers, collates, analyzes and interprets information from many sources, and presents this information to national and international agencies charged with the responsibility for managing the bio-environmental system. In addition to this primary function, the system must be supported by, and in turn, be supportive to, a continuing research programme directed to the causes and effects of bio-environmental change. This research need not necessarily be performed entirely within the monitoring system. However, the system should be responsible for mounting adequate and co-ordinated research programmes and for incorporating the results within and between the monitoring programme and for giving advice to governmental agencies.

Four considerations relevant to the basic system must be stressed initially:

a) The system which is finally evolved will be costly and time consuming and occupy the full attention of a large amount of scientific and technical manpower. For this reason the functioning of the monitoring system must be kept under careful and continuous review. This will also assist it to develop a rapid and flexible response to any new environmental situation which appears to merit investigation.

b) The most optimistic results that can be obtained from the monitoring process is that nothing significantly harmful is happening to the human environment, although beneficial trends may be recognized. Thus the justification for the system, as in law enforcement or any other "watchdog" activity, is a negative one.

c) The system will evolve from the initial fact-finding state to a state where models can be formulated and used to predict environmental trends. The development of this predictive capability will take time but will eventually provide governments with forecasts of the most likely consequences of any action programme with potential environmental impact.

d) The system itself will not have any executive authority, i.e., it will not render decisions on courses of action which are within the realm of political jurisdiction by national governments.

5. Environmental problems

5.1. INTRODUCTION

An environmental problem arises whenever there is a change in the quality or quantity of any environmental factor which directly or indirectly affects the health and well-being of man in an adverse manner. Environmental problems can be studied from two different viewpoints. One is simply to look for adverse effects without regard to their origin in order to detect trends that call for further investigation; the other is to try to understand the cause and effect relationships, which make better prediction and proper management possible.

Some of the environmental problems which are critical at the present time are fairly widely known because of the growing awareness of all levels of society, including governments, general public and the scientific community. However, our present information on the structure and function of the biosphere is not sufficient to allow an accurate evaluation of the total situation, expect to indicate some broad problem areas. There may be serious potential problems of which we are as yet unaware; other known problems may be less serious than we think.

The Commission has made an extensive survey and analysis of those problems which are currently regarded as being of critial importance. The following criteria were used in an attempt to assess the critical nature of the problems to be solved in the near future:

a) Number of people and nations involved

b) Geographical distribution of the problem

c) Temporal distribution of the problem (temporary or long-term effects)

d) Degree of irreversibility of the effects

e) Degree of impact on health, standard of living, social structure and economy

f) Degree of international significance of the problem

Although these criteria overlap and may not be exhaustive, they form a useful basis for judgement.

The consensus of the Commission's survey was that a fairly restricted number of problems were found to recur time and again. The major critical problem may be summarized as, "the adverse effects of a changed environment on human health and well-being"; i.e., the possibility that a changing environment may lead to increased mortality, increased frequency of diseases, lowered nutritional status via decreased agricultural productivity, or lowered psychological value of the environment. Concern has been widely expressed that these possible effects on man may be caused by direct input of toxic substances into the environment or improper land use. Climatic changes as a result of human activity may also adversely affect the standard of living through, for example reduced crop productivity, and increased energy consumption, etc.

Those problems considered most relevant for early implementation by a global environmental monitoring system are:

1. Potentially adverse climatic change resulting from human activities
2. Potentially adverse changes in biota and man from contamination by toxic substances including radionuclides
3. Potentially adverse changes in biological productivity caused by improper land use (reduced soil fertility, soil erosion, extension of arid zones etc.)

A second category includes problems that, although of great importance, are not suitable for early global monitoring either because of their nature or because further study is necessary to determine whether they should be included in a global environmental monitoring system. These problems are:

4. Potentially adverse changes in the growth, structure and distribution of the human population
5. Changes in the subjective human perception of the environment
6. Eutrophication of waters
7. Decreasing freshwater resources
8. Natural disasters

5.2. DISCUSSION OF CRITIAL ENVIRONMENTAL PROBLEMS

5.2.1. Potentially Adverse Climatic Change Resulting from Human Activity

Large-scale climatic changes could be caused by alterations in the earth-athmosphere system through changes in: the atmospheric content of carbon dioxide; atmospheric turbidity (aerosol content); mean global cloudiness; the earth's surface; the composition of the stratosphere; and the amount of heat generated by man's activities.

The concentration of atmospheric carbon dioxide is increasing at an average annual rate of nearly 0,3 percent. This increase, which is due to the burning of fossil fuels, is expected to accelerate in the future accompanying global economic development. Atmospheric carbon dioxide can influence climate through the "green-house effect", i.e. it is transparent to incoming solar radiation but partially absorbs the outgoing longer wavelength energy emitted by the earth. The best current estimates suggest that by 2000 A.D. the effect of increased CO_2 alone will be an average warming of the global surface temperature by roughly 0,5°C.

Atmospheric aerosols attenuate solar radiation by absorbing and scattering (re-directing) it and are thereby potentially capable of affecting local and global climate. The nature of the climate change (warming or cooling) depends on the relative importance of these two radiative processes as well as the character of the earth's surface. In addition, atmospheric particles can affect the physical processes of precipitation and cloud formation through their role as condensation nuclei. Recent estimates have indicated that on a global basis, man's production of atmospheric particles is now roughly 10 to 50 percent of the natural rate. Locally, of course, the man-made contribution may far exceed that occurring naturally.

Changes in the earth's reflectivity (albedo) are dominated by variations in cloudiness. Thus, any activity of man that affects large-scale cloudiness is likely to have an impact on climate. Potential examples of such activity include subsonic and supersonic aircraft flights that add moisture to the atmosphere at high altitude, atmospheric particles that serve as condensation nuclei, and attempts at weather modification.

Man-made changes in the earth's surface can affect the albedo and the availability of solar energy. Examples of such changes include deforestation, erosion, extension of arid or desert land, irrigation, urbanization, and the creation of artificial lakes. Although large local climatic effects result from these activities, the global consequences are not well understood and may be insignificant.

The combustion of fuels and the use of energy result in the liberation of heat. In large, temperate-latitude cities during winter this man-made energy can often equal or exceed that naturally available from solar radiation. Man-made energy is, however, not yet significant on a global scale but within 30 to 40 years it will equal several percent of the available solar energy over large, highly industrialized regions. The specific regional climatic consequences are unknown but are likely to be significant.

Plans to build commercial fleets of supersonic aircraft that cruise in the lower stratosphere have caused some scientists, but certainly not all, to become concerned about possible stratospheric contamination. The exhaust products from these aircraft–soot particles, water vapour, nitric oxide, etc.–could attenuate solar radiation, increase cloudiness or decrease ozone concentrations. Since these substances would have a much longer average lifetime than those emitted near the earth's surface, a relatively small stratospheric emission rate could lead to significant ambient concentrations. Thus an early programme is needed to obtain baseline measurements of substances in the stratosphere and to determine whether they have a natural or man-made origin.

5.2.2. Potentially Adverse Changes on Biota and Man from Contamination by Toxic Substances including Radionuclides

This is one of the most complex and widespread of the environmental problems because many potential contaminants are involved, with the list growing each year, and immense number of species that could be affected. Many cases of local catastrophes or widespread poisoning in man and wildlife have already occurred.

The more hazardous toxic substances include heavy metals (lead, mercury and cadmium), organochlorine compounds (DDT, its degradation products and metabolites, polychlorinated biphenyls) and possibly petroleum products. Contamination occurs in all media: air, land, water and biota. Of particular importance, however, are those parts of the biosphere where the substances show long residence times, namely in soils and sea water. The sea is the ultimate repository of almost every kind of pollutant material created by man. Industrial effluents and biocides are discharged directly into coastal waters or carried to the sea by rivers. Toxic materials are often dumped in quantity on the sea bed or into the open waters of the oceans. Hazardous cargoes, transported by ships as freight or fuel, are released either by accident or design into the sea. Pollutants transported by the atmosphere are continously transferred by precipitation or direct diffusion onto the surface waters.

The use of the biosphere as a recipient for toxic and other waste products will inevitably affect animal and plant species, their growth and reproduction. Every kind of pollutant in some measure affects the character of an ecosystem structure by decreasing the species diversity. Toxic substances may endanger man's health directly or by passage and accumulation through food chains.

The effects of contaminants on biota can be studied by considering various biological effects, such as changes in the numbers and distribution-ranges of organisms, changes in the structure of plant and animal communities, replacements of whole ecosystems and changes in productivity. Thus, by assessing selected parameters which describe changes in single species or biological systems of higher order, both specific and general effects on biota can be determined.

Important changes in many species populations, including extinctions, are well known. Inadvertant or deliberate simplifications of ecosystems with a resulting decrease in stability and tolerance of environmental stress have occurred many times. The transfer of natural ecosystems to monocultural agricultural systems constitute the best examples of ecosystem simplification which now need continuous management to preserve the desired state. In some cases whole ecosystems have been completely replaced by new ones because of intensive pollution or grazing by domestic animals. Possible adverse effects on agricultural productivity are of special concern because any factor that tends to decrease the production of food and fibre must receive a high priority in the monitoring system. To arrive at the optimal combination of exploitation and management of natural resources, programmes must be developed that provide continuous information on the use of these resources and permit evaluation of the consequences of predicted future developments.

In contrast to the above problems, monitoring of radioactive contaminants is currently being efficiently provided by UNSCEAR, IAEA and other agencies. Thus, it is not anticipated that any new programmes, other than support of the current effort, will be necessary for this very important problem. In the future, however, the predicted growth of nuclear-powered electrical generating plants will necessitate greater awareness of the potential hazards from storage of radioactive wastes.

5.2.3. Potentially Adverse Changes in Biological Productivity Caused by Improper Land-use

The land surface in extensive parts of the world is changing because of the intense agricultural methods necessary to provide for a growing population with an increasing per capita consumption. In many parts of the world, improper land use has resulted in irreversible degradation of soils and vegetation. Soil erosion by wind and water, leaching of nutrients, salinization and extension of arid zones have been caused by such improper land-uses as overgrazing in arid zones, deforestation in areas with unstable soils and over-use of both surface and ground-water resources.

Usually, these problems are local or regional in nature and are the responsibility of individual governments. However, because similar changes in soil fertility have occurred throughout the world in many nations, a global, multi-governmental approach to the problem is appropriate. Moreover, because the local effects of decreased soil fertility may be very significant, the economy of adjacent regions may also be affected. Extension of arid zones can also induce large-scale climatic changes by allowing considerable amounts of windblown dust to become airborne.

5.2.4. Potentially Adverse Changes in the Growth, Structure and Distribution of the Human Population

The fast growth of the human population in combination with changes in its distribution pattern, particularly the strong and increasing tendency towards urbanization, constitutes one of two major factors responsible for the creation of environmental problems; the other being technological developments. Among the variety of environmental problems that are affeted by population growth and urbanization are: over-utilization of land; deterioration of natural areas; ecological changes; depletion of natural resources; dietary deterioration; increase of urban pathology; increased wastes; and the consequences of national policies to reduce or increase fertility.

We are satisfied that the United Nations will continue to improve its already valuable collection and evaluation of information on population size, vital statistics and demographic data which will provide supporting information both to the environmental monitoring system and to other international and national activities, particularly those related to human health monitoring.

5.2.5. Changes in the Subjective Human Perception of the Environment

Changes of the environment may or may not be harmful to man. However, both kinds of change may be perceived by people as annoying, dangerous or even irrelevant. This not only applies to laymen, but also to environmental scientists, planners and decision makers. Consequently the subjective perception of environmental problems constitutes an important factor in relation to environmental monitoring activities. It may serve as a kind of qualitative evaluation of the results of control management. Thus, although the Commission recognizes this environmental problem, it is not included as an operative part of the system.

5.2.6. Eutrophication of Waters

Both natural and man-made lakes have suffered from eutrophication and its secondary effects. In lakes receiving nitrogen and phosphorus compounds and other agricultural fertilizers, unprecedented blooms of algae have occurred. The algae themselves can spoil water quality and recreational conditions. When they die and decay, the oxygen demand may exceed the supply with resultant fish kills. The average oxygen content of some fresh water bodies has decreased very markedly in historic times. The effects of added nutrients on marine life are not well known but there may be particularly important synergistic effects, for example, if the oxidation of oil in the sea is biologically controlled. Fertilization of the seas may enhance the production of directly economically valuable species. Because eutrophication is primarily a local problem, it has not been included in the global environmental monitoring system.

5.2.7. Decreasing Freshwater Resources

The availability to man of freshwater of high quality is becoming an acute problem in many countries. Water requirements continue to increase with the growth of populations and living standards and the expansion of agriculture and industry. Water is needed for power generation irrigation, navigation and community water supply. Often it is drawn from international rivers or lakes and in many instances international co-operation is needed in the allocation of water and the financing and technical aspects of water resource development projects. The availability of ground water is most often a local problem but it has international implications in relation to the general effects which a depletion of ground water may have within a larger region.

5.2.8. Natural Disasters

Although natural disasters constitute a very important environmental problem, it is not pertinent to include a programme directly related to natural disaster monitoring or warning within the global environmental monitoring system. It is appropriate, however, that the system should provide assistance in reporting phenomena that relate to natural disasters.

6. Environmental variables appropriate for monitoring

6.1. INTRODUCTION

Chapter 5 above outlined the three major problem areas considered to be most relevant for early implementation in any global monitoring programme as follows:

1. Potentially adverse climatic change resulting from human activities
2. Potentially adverse changes in biota and man from contamination by toxic substances, including radionuclides
3. Potentially adverse changes in biological productivity caused by improper land-use (reduced soil fertility, soil erosion, extension of arid zones etc.)

We now have to discuss which environmental parameters describe and quantify these problems in a useful way. These can be broadly classified under the following headings:

1a. Physical and chemical data from the atmosphere pertinent to climatic change potential

b. Physical and chemical data from air, water, soils and biota pertinent to human health and welfare

2a. Physical, chemical and biological data reflecting the state of human health

b. Biological data reflecting the performance of biological systems

6.2. PHYSICAL AND CHEMICAL DATA FROM THE ATMOSPHERE PERTINENT TO GLOBAL CLIMATIC CHANGE

In the previous chapter the important global environmental problems related to climatic change were discussed: increases of carbon dioxide and particulate matter in the atmosphere, changes in global albedo and the earth's surface, changes in cloudiness, production of waste heat, and contamination of the stratosphere. Since this discussion focuses on climatic changes of global significance the measurements and observations must be representative of large portions of the atmosphere (background values) and free of local contamination. The atmosphere has few mixing constraints and, therefore, this can be achieved by measurements in remote areas and in the upper atmosphere.

Carbon dioxide. Our knowledge of the historical trend of atmospheric carbon dioxide as well as estimates of future concentrations are based primarily on a sole set of continuous observations, which dates only from 1958. Additional and continuing baseline data are necessary to determine the global representativeness of the current trend, to verify the future estimates and to study the partitioning of CO_2 between the atmosphere, oceans and biosphere.

Aerosols and particles. Aerosols and particles in the atmosphere play a special role in the atmospheric energy balance and in physical processes important in the formation of clouds, precipitation, fogs, etc. Moreover their role depends not only on the total particle count but also on the number of particles of various sizes and their distribution with height. The rapid development of vertically directed LIDAR as a measurement technique gives promise of an early capability for monitoring the vertical distribution of particle loadings well into the stratosphere. This technique should be utilized as soon as feasible to complement or perhaps replace periodic aircraft sampling. By monitoring the intensity of solar radiation at selected narrow-bands in the visible and ultra-violet spectral regions (e.g., 0,50 and 0,38 micrometers), direct information can be obtained on the total atmospheric loading of aerosols (atmospheric turbidity) in the optically effective size range.

Solar radiation. Since solar radiation is the critical energy source to the earth and atmosphere, comprehensive monitoring is required for trends in the solar energy received at the surface. Instruments for the following measurements are commercially available and are used in operational programmes:

a) Broad-band direct and diffuse radiation (e.g., measurements of all wavelengths >0.40, >0.53, and >0.70 micrometers)

b) Narrow-band direct radiation (e.g., measurements between the wavelengths of 0.30 to 0.35, 0.35 to 0.40, . . . 0.55 to 0.60, 0.60 to 0.70, 0.70 to 1.00 and 1.00 to 1.80 micrometers)

c) Net (incident minus reflected) all-wave radiation.

Meteorological data. Standard meteorological surface observations, including wind, temperature, humidity, pressure, prevailing weather, etc., should also be obtained to complement the basic measurements. In addition, vertical observations of temperature, humidity, pressure and wind velocity by rawindsonde should be made.

The earth's surface. Various land-use practices that significantly alter the earth's suface such as deforestation and creation of man-made lakes, can affect local climate by influencing the energy balance. To determine whether large-scale changes have occurred, global land-use should be inventoried periodically, for example, every five years. Such a survey can best be carried out by satellite measurements.

Cloudiness and albedo. Since global climate is particularly sensitive to changes in cloudiness, surveys by satellite of this parameter should be encouraged even though there is no definite indication that man has as yet caused wide-spread alterations in cloudiness. Measurements of stratospheric cloudiness and water vapour may have to be made from aircraft. Another particularly useful satellite measurements is that of whole-earth albedo. Variations of the earth's reflectivity, which can be affected by land-use, cloudiness, etc., can be documented by such measurements.

Waste heat. Because of the increasing rate of energy consumption throughout the world, the amount of waste heat produced by man could become a significant regional climatic factor in several decades. Therefore, energy-use statistics should be inventoried continuously on a regional basis to determine their current importance.

Nitric oxide and ozone. Concentrations of these trace gases in the stratosphere may be affected by the operations of supersonic aircraft. Background concentrations of nitric oxide, a product of combustion, and ozone, a product of stratospheric gas reactions, should be determined before large scale supersonic flights begin.

On the basis of the above considerations we recommend as follows:

We recommend that the following variables be initially monitored at low exposure (baseline) stations: Atmospheric carbon dioxide content: atmospheric turbidity; solar radiation (including broad-band direct and diffuse radiation, narrow-band direct radiation, and net all-wave radiation); standard meteorological variables.

We recommend that the following variables be considered for inclusion at a later date: Vertical distribution of aerosols; size distribution of aerosols; rawindsonde data; surface vertical fluxes of carbon dioxide; global albedo (by satellite); ozone, water vapour and trace gases in the stratosphere (by aircraft).

We recommend that the following variables be monitored at medium exposure (regional) stations: Atmospheric turbidity; solar radiation (including broad-band direct and diffuse radiation and net all-wave radiation); standard meteorological data.

6.3. PHYSICAL AND CHEMICAL DATA FROM AIR, WATER, SOILS AND BIOTA PERTINENT TO HUMAN HEALTH AND WELFARE

6.3.1. The Media Approach

Before considering in detail, the range of variables from air, water, soils and biota for possible inclusion in a monitoring system it is useful to stress the dynamic interrelation of these media via the geophysical, geochemical and biological transport mechanisms operating in the environment. Effective analysis of any secular trends for potentially hazardous substance will be made much simpler and detected earlier if we know the flux rates of these transport mechanisms for each substance. This involves a study of the sources and rates of injection of each substance into each environmental medium and the rate of removal into other media, i.e., residence times. We must also know the ultimate fate of each substance, whether it accumulates irreversibly in any one medium or whether it continues to cycle indefinitely.

Air. Residence times of substances emitted to the lower atmosphere are generally short (weeks or less) unless they enter the stratosphere where they can remain for many months or years. The atmosphere is thus more appropriately regarded as a transport mechanism with rapid and efficient mixing, making it possible to obtain accurate representative measurements of atmospheric constituents by sampling at a few selected points only.

When monitoring the quantities of the different substances it is necessary to take into consideration whether the substance occurs as a gas, as particles or attached to particles. The actual size distribution of particles is very important when considering their availability to organisms, including man.

From the budgeting point of view it is important to monitor injections of substances to the air and the transfer mechanisms from the air to water and soil. The interfaces between atmosphere and water and between the atmosphere and the continents deserve particular attention.

Of special significance among the transfer mechanisms is precipitation since it has an important scrubbing action on atmospheric gases and particles. Its composition (precipitation chemistry) is a useful guide to the nature and amount of airborne substances carried to the earth's surface and available to interact with biota.

Water. Residence times in water are longer than those of air and the presence of serious mixing constraints in oceans makes representative sampling much more difficult unless many more sites are involved. Despite this qualification, bodies of salt and freshwater reflect the history of surrounding land use in an informative way. Substances released into rivers etc. find their way into aquatic biota and bottom sediments which may often irreversibly accumulate many substances and thus act as a valuable historical record of previous changes and trends. The output from rivers to the oceans is not only a national and regional problem but also of concern to any global budgeting of critical substances essential for the global monitoring system.

Soils. Soils like sediments are often the ultimate sinks of many important substances particularly in low rainfall areas. They are the most intensively used resource of any nation and the irreversible accumulation of substances in them is thus of critical importance. Mixing constraints are of course greater in soils than in air or water and there are large-scale geographical differences in the accumulation and loss of substances to soils, depending on local usage by man, soil chemistry, rainfall etc. They not only receive substances by dry deposition and precipitation from the air but are the source of dusts and gaseous exhalations which can be atmospherically transported over great distances. Volatile substances such as organochlorine compounds and dimethyl mercury are of interest in that they may evaporate from warmer soils and condense in soils of cooler regions. Special attention should be paid to the occurence of new technical substances in the soils of tropical regions.

Biota. The reason for monitoring certain substances in biota is twofold. They may cause adverse biological effects and they may be in greater concentrations and therefore more readily detectable. Knowledge about the levels found may be used in risk evaluation. For substances with threshold-effects the existing levels should be used for an estimate of the safety margin before effects appear.

Organisms are important as a means of transport for substances through the biosphere. They can take up and accumulate certain chemicals and transmit them through food chains, by a process of biological magnification, where an increased accumulation at higher trophic levels occurs. Therefore the effects are often most pronounced at the tops of the food chains. The transport of substances along food chains takes time and it is thus of great importance to detect any significant accumulation of substances at the lowest trophic levels. By using sophisticated chemical methods it is now possible to detect even very minute amounts of substances. Organisms at the bottom of the food chains contribute to an early warning system.

Even similar substances may behave differently in the same food chain. This depends on different metabolic patterns and abilities to excrete substances. We also have differences between sexes and individuals of the same species. This variability has a marked genetic component and is partly the explanation of the development of tolerance. In aquatic organisms, the direct uptake of substances from water may sometimes be more important than via the food chains.

When chemical methods are not sufficiently sensitive to estimate the trace amounts of a substance in the abiotic environment, accumulator organisms may be analysed instead. Bioaccumulators also often integrate the chemical environment both in time and space. A fish in a lake may integrate the conditions in that lake over a long period of time and wide ranging marine organisms may reflect the situation in extensive marine areas. In certain cases specific organs may give additional information on the chemical situation in the environment. For example, different amounts of mercury accumulating in the feathers of migratory birds formed at their summer and winter quarters respectively, indicate geographical differences in mercury exposure.

In certain cases organisms may be used as indicators of the presence or absence of a specific substance or of certain levels of it in the environment.

The foregoing discussion emphasizes the need to sample and measure environmental substances in such a way in all media that their flux rates can be calculated and an "environmental balance sheet" drawn up for each substance. This will help us to gather valuable information such as, for example, whether a detected increase of a substance in one medium represents a real overall global increase or merely the appearance of the substance working its way through the environmental cycles from another medium. We will also know how long such a process is likely to take and thus the overall exposure times for biota (including man).

Since nearly all scientific competence in investigating the environment is traditionally media oriented, it is unrealistic to erect a completely new system based on this dynamic approach. It is thus proposed to discuss below the range of monitorable parameters in each of the media separately and to attempt a synthesis at the end which once more emphasizes the need for a dynamic overview of the whole environment.

6.3.2. Atmosphere

Carbon dioxide. Land plants obtain all their carbon from atmospheric carbon dioxide and from carbon dioxide released from soil respiration. All animals, including man, exist from the carbon compounds made by plants. Changes in the amount of atmospheric carbon dioxide might have an influence on global climate as previously indicated or may alter primary productivity in green plants since carbon dioxide is sometimes a limiting factor to plant growth.

Sulphur dioxide and hydrogen sulphide. Numerous epidemiological studies clearly indicate an association between sulphurdioxide and health effects of varying severity. Other studies have shown that chronic injury to plants can occur with prolonged low concentrations of these gases as well as adverse economic and aesthetic phenomena related to atmospheric visibility, and the soiling, and corrosion of materials.

Carbon monoxide. This gas is known to have important physiological effects on man at the increased levels found in dense traffic. It is now known that the surface of the oceans releases substantial amounts into the atmosphere. However, its fate in the atmosphere is not known and it is of some importance to ascertain whether the gas is accumulating there.

Nitrogen oxide and nitrogen dioxide. These gases play important roles in the formation of "photochemical smog" which is being recognized as an increasing problem to man and plants in and about urban complexes in the temperate zone. When released into the lower stratosphere by high flying aircraft, these gases possibly may interfere with the ozone balance.

Ozone (and ozone precursors). These substances have an important chronic and acute impact on biological systems by the impairment of performance, on pulmonary function, and by vegetation damage.

Ammonia. Almost all of the ammonia in the atmosphere is produced by natural biological processes although considerable increases are found over industrial cities. The ambient air concentrations are lower than those hazardous to plants and animals. However, a long-term trend would have an important biological significance.

Aerosols and particulates. The impact of these substances on biological systems covers a wide range of important physical and pathological consequences, both direct and indirect. For instance, Aitken Nuclei of less than 0.1 μ radius are important in the formation of precipitation, fogs, and haze, etc. The so-called "large" particles in the 0.1–2 μ range affect optical phenomena such as visibility and turbidity and can be important lung irritants in man, especially the particulate decay products of sulphur oxides, which can carry absorbed or adsorbed gases deep into the respiratory system.

Insecticides, herbicides and other biotoxins (in air and precipitation). The bio-environmental problems associated with the use of insecticides and herbicides and a number of other biotoxins, particularly those from industrial processes, fuel and refuse burning have been well documented. Since one of the most rapid and effective methods for distribution of these materials on a global basis is via the atmosphere, early detection of significant changes in their distribution could be achieved by monitoring the concentrations of these materials in air and precipitation.

Chlorinated aliphatic hydrocarbons. Carbon tetrachloride, trichlorethylene and similar compounds used in cleaning may become important atmospheric constituents in the future.

6.3.3. Water

Although the organizational pattern required for monitoring freshwater is likely to differ substantially from marine monitoring, many of the critical variables to be studied are the same in both media. The following discussion, dealing principally with the marine environment, also applies to freshwater unless otherwise stated.

There are two major groups of parameters of potential importance in water monitoring.

1. Biological stimulants
2. Biological toxins including radionuclides

Biological stimulants. The problems of eutrophication were mentioned in Chapter 5 where it was concluded that they needed further study prior to their inclusion in any integrated monitoring system.

The effects of biostimulants on the environment are usually observed on a local scale and may result in unsightly blooms of aquatic vegetation, algae and bacteria. Unless these products are removed from the system and allowed to decay elsewhere, premature deoxygenation of the aquatic environment can occur. Chemical species known to stimulate the growth of primary and heterotrophic producers include NO_3^-, NH_3, PO_4^{3-}, K^+, CO_3^{2-}, HCO_3^- and organic matter, along with various trace metals.

Other substances regarded as biostimulants are a variety of organic compounds such as vitamins, hormones and other unidentified "growth factors" present usually in trace amounts, particularly in domestic sewage.

In coastal areas, estuaries, fjords, lagoons and epicontinental seas, the increasing input of nutrients and potential nutrients from sewage and industrial outlets as well as from dumping is often the cause of a disturbance in the normal biological equilibrium. Because of sampling and storage problems, it seems inadvisable at present to split up the different phosphorus and nitrogen containing nutrients into subgroups. However, total phosphorus and total nitrogen (excluding gaseous nitrogen) both in dissolved and particulate form should be included in a monitoring system for the seas. This restriction to total P and total N may be less satisfactory for freshwater.

Because of the anticipated effects that a rise in the carbon dioxide content of the atmosphere might have on climate, it is necessary to understand the circulation of carbon dioxide not only in the atmosphere but also in the oceans, and especially the exchange of carbon dioxide between sea-surface and atmosphere. It is expected that an increasing amount of information about carbon dioxide in the sea and components of the carbonate system will be achieved by ongoing research and survey activities within the next five years. This will be accomplished through improved methods and instrumentation.

Continental erosion, industrial activities, sewage injection and dumping of mass residues from chemical production e.g. red mud, nutrification and overproduction might change the turbidity of surface waters considerably. Such events might also effect offshore areas all over the world and become an international problem, especially when the dumping of large quantities of relevant material is carried out in off shore waters.

Unusual depletion of oxygen normally indicates high organic loading of water. This is certainly not a world wide issue, but may be a regional problem, especially in such areas where natural processes and man-included effects both lead to stagnation and emphasize an already existing natural tendency of oxygen deficiency as is the case in the Baltic. It is therefore desirable to include oxygen measurements in a monitoring system.

Biological toxins. Potential toxins include almost all heavy metals and many organic compounds. Toxicity may manifest itself at any level of the food chain or may significantly alter the species composition of biota by enhancing those populations of organisms differentially tolerant of the specific toxin involved. In other cases, where substances are not directly toxic, they may concentrate in tissues of living organisms making them unfit for consumption by other organisms, including man. Such materials, if they are persistent in the environment, can increase in concentration in aquatic systems.

Many metals, including mercury, lead, cadmium, vanadium, chromium, copper, zinc, iron, arsenic and selenium and their related inorganic and organic compounds are considered to be potentially hazardous. The levels of mercury and lead are believed to have risen considerably in the surface layer of the oceans through man's production and use of them. Both have regional if not global effects on the marine ecosystem and are accumulated in food chains. The other metals mentioned here are mostly of local or regional interest only.

Chlorinated organic compounds such as DDT and its metabolites, Aldrin, Dieldrin, Endrin, residues from the fabrication of polyvinyl chloride and similar chlorination products, i.e., aliphatic, chlorinated hydrocarbons, polychlorinated biphenyls, and residues from the fabrication of such compounds, alicyclic chlorinated compounds such as Lindane (γ – BHC) are considered to be potentially hazardous.

The toxicity of various oils and oil-products varies widely depending on the combination of environmental factors and also on the biological state of the organisms at the time of contamination. Different species and different life stages of organisms have been demonstrated to show different susceptibilities to pollution. Natural biogenic hydrocarbons on the other hand may have well defined biological functions. Therefore methods for oil pollution monitoring must be able to deal with the entire spectrum of oils and oil-products at high and low concentrations as well as with the natural hydrocarbons in sediments and organisms. Further, for pollution research and for law enforcement there is a need for differentiation between natural hydrocarbons and pollutants and for the recognition of oils form different sources and among oil-products resulting from different refining processes. Existing analytical technology, using gas-liquid chromatography is well on the way to achieving this.

Many organic compounds, which occur naturally or are emitted by human activity, may influence biota indirectly through their capacity to complex with or in other ways modify the chemistry of inorganic ions. These processes may alter the biological availability not only of the toxic heavy metals but also of essential trace metals required for the normal growth of organisms. The full magnitude of such problems cannot be understood until the organic contaminants are identified and their chemical stability and affinity for metals assessed. For the present, wherever possible, metal analysis should differentiate between species in ionic solution and those in organic combination.

The availability or toxicity of metal ions is also strongly dependent upon concentrations of accompanying ions, particularly hydrogen, calcium and magnesium. Metal toxicity to fish is known to be reduced by factors of ten to a hundred in "hard" as against "soft" waters.

6.3.4. Soil

Soil composition. A great deal is already known about the physico-chemical composition of the world's soils, largely as a result of the long-term painstaking surveys of surface geology and soil patterns necessary for mapping the potential mineral and agricultural resources of a nation. These are essentially national or regional problems. A recent and more sophisticated development has been the use of stream sediment analysis. Stream, lake and marine sediments average the prevailing soil chemical conditions for trace elements over a wide area and their use as indicators is proving a valuable tool in studying the occurrence of mineral deficiencies. In future it may be possible to use this method for studying the regional build-up of aerially distributed pollutants which fall onto and accumulate in soils often thousands of kilometers from their source. The great value of the analysis of plant and animal tissues as indicators of prevailing soil conditions is already well understood.

Non-ferrous (heavy) metals emitted to the air or directly deposited on soils can be fixed, particularly by soil organic matter. Many of the metals including lead, arsenic, antimony, nickel, indium, mercury, cadmium, zinc, cobalt and chromium are known or suspected to be a hazard to human and animal health, several having been linked with the occurrence of cardiovascular disease and gastric and other cancers. Mercury can be alkylated in certain soils to highly toxic forms by soil bacteria. DDT, PCB and other organochlorines may be fixed in certain soil horizons and also have significant effects on biota in soils. Any of these contaminants may undergo a process of biological concentration as they pass up the human food chain. Studies of the dynamics of their accumulation, movement, and their residence times in soils are needed using soil, plant and animal analyses. Macronutrients (S, N, P and C compounds) constitute major factors of soil fertility. Problems may arise in connection with the wide and intensive use of fertilizers or improper land use.

Soil structure and cover. Under intensive grazing and/or mineral fertilizing, soil structure and the vegetational cover of soils often suffer a decline. This is normally a local problem but may be a matter of international concern where extensive deforestation or overgrazing, overburning or other human pressure leads to a loss of soil organic matter, to bare soil, to windblown soil and even perhaps to the extension of arid zones. This can be particularly serious where plant regeneration is very slow. The extension of bare ground can be registered by satellite sensing.

6.3.5. Organisms

Organisms will collect and sometimes accumulate from air, water and their food, certain toxic substances and radionuclides. The relevant substances are those mentioned above in sections 6.3.2., 6.3.3. and 6.3.4.

The coverage of the monitoring programme should include monitoring at the four main trophic levels: primary producers (green plants); primary consumers (herbivores); secondary consumers (predators); decomposers and scavengers.

It also follows that particular attention must be paid to those organisms that show high accumulation rates. These can be used as test organisms and temporal integrators. It should also be recognized that organisms that feed over a wide area can effectively integrate geographical variation in contamination levels.

6.3.6. Critical Groups of Substances

The above general review of a wide range of variables needs to be followed by a discussion of groups of critical substances leading to a selection of the priority substances for the initial stage of the monitoring programme. We have here taken note of the preliminary results of a special working party of SCOPE dealing with: "Materials which may significantly alter the biosphere and their determination and assessment". This working party will later report on analytical methods for different critical substances. We have considered the relevance and technical feasibility of monitoring the priority variables and are satisfied that they are appropriate to the problems, and can be monitored with available techniques. Special operational manuals have to be prepared at a later stage when the final decisions about variables have been made.

Pesticides and related substances. DDT and its metabolites and degradation products may serve as a valuable model for the monitoring of pesticides in general. Our knowledge of the global circulation of this substance, although much improved during the last few years still needs many more data. It should be given high priority. Other persistent organochlorines are aldrin, dieldrin, BHC, endrin, methoxychlor, lindane and heptachlor. Some of these compounds are widely used, but it is not yet proved that they have the same general global distribution as DDT. Polychlorinated biphenyls (PCB) are very resistant to biodegradation, have a global distribution and marked effects on biota. They should be given high priority in any initial monitoring programme. Substituted phenoxy acetic acids (herbicides) and organophosphorus compounds may be considered later for further inclusion in the global system. It has yet to be established whether these compounds have a global distribution.

Non-ferrous (heavy) metals. Once liberated to the environment from mineral extraction and purification, these will always be a potential hazard as they are never biodegradable. It is possible that they may eventually become immobilized as very stable substances in marine sediments but more information is needed on this. We also need to know more about the chemical forms through which they pass during their residence in the environment. One particular difficulty is that unlike organochlorine compounds, metals already occur in the natural environment so the problem of arriving at natural levels is much more difficult. We have concluded that first priority should be given to lead, mercury and cadmium as these three metals are already significantly involved in environmental problems. Other metals such as arsenic, zinc, vanadium, selenium, berylium, nickel, chromium and manganese, may be included in the monitoring system at a later date.

Organic substances in the oceans. The occurence of petroleum products in the oceans is regarded by some scientists as a very serious global problem. The compounds from crude oil may enter the oceans from oil spills, during the transport of oil products over the seas or, in the case of volatile fractions, through aerial transportation. The oil problem is important and possible global effects are foreseen. Pilot activities are given high priority.

The chlorinated aliphatic hydrocarbons, waste products from the plastics industry, have been found to have an extensive distribution in the North Atlantic as a result of ocean dumping. Even if they are rather toxic, they are broken down within a comparatively short time. These substances do not have the same priority as PCB but may be considered for inclusion in a global system at a later date.

Substances in relation to geochemical cycles. Human activities may change the geochemical cycles of the major macronutrient elements at least in local areas. Much attention has been paid to the environmental problems relating to the sulphur cycle. As the man-made emissions of sulphur to the atmosphere have about the same size as the natural emission, it is possible that man's activities have changed the sulphur cycle in a profound way, with resultant effects on ecosystems. The "acid rain" problem is linked to this. For the present moment, extensive research activities are being undertaken which might contribute to a better understanding of the mechanisms involved. This work is an essential prerequisite to any future global monitoring.

Our knowledge about man's impact on the processes in the nitrogen cycle are still insufficient. Extensive emissions both to air (NO_x automotive emissions) to waters (sewage) and to the soils (artificial fertilizers) may have global importance.

Changes in the phosphorus cycle may also be critical as this element may play an important role in the eutrophication of water. On the other hand phosphorus is an element which might be limiting to agricultural productivity in the future and resource conservation and management may be very important.

Another critical substance is carbon, by some regarded as the limiting substance in eutrophication. Carbon dioxide levels in air are also of great importance for organic productivity.

We are not yet prepared to recommend immediate implementation of monitoring programmes for the geochemical cycles, but research and pilot activities directed towards their inclusion at a later stage are recommended.

On the basis of the foregoing considerations, we recommend as first priority that data be collected on the following substances in air, water, soils and biota, at a number of stations for the purpose of assessing secular trends in relation to the pollution of the biosphere:

1. Mercury
2. Lead
3. Cadmium
4. DDT, its metabolites and degradation products
5. Polychorinated biphenyls (PCB)

We further recommend that the following substances be considered for a later inclusion in this network.

6. Petroleum products
7. Persistent organochlorine compounds other than DDT
8. Chlorinated phenoxyacetic acid derivates
9. Organophosphorus compounds
10. Chlorinated aliphatic hydrocarbons
11. Other metals (As, V, Zn, Se, Cr, Cu, Be, Ni, Mn)
12. Relevant compounds in the cycles of S, N, P and C
13. Oxygen in water

6.4. PHYSICAL, CHEMICAL AND BIOLOGICAL DATA REFLECTING THE STATE OF HUMAN HEALTH

6.4.1. The General Problem

The interest expressed in the idea of environmental monitoring by various governments and by the world scientific community stems from a basic concern with the safeguarding of human health and well-being as defined in the very broadest sense, i.e., any phenomenon which can be detected as a significant disamenity to man. Thus, apart from the direct harm to human health, arising from exposure to incipiently pathogenic agents (e.g. harmful micro-organisms, toxic substances) in air, water and food, indirect harm could arise from: certain forms of climatic change; a reduction in the productivity of crops; other changes in livestock and biota; modified aesthetic values and environmentally induced social problems. This is the total human environmental problem and further clarification is required to obtain a more practical view of human health in the context of the present discussion.

The indirect effects referred to above, i.e. any future climatic change or future reduction in biological productivity, can influence nutritional and living-standard factors, which could predispose man to succumb more readily to pathogenic agents on a much wider scale in the future than he does at present. We are already familiar with the action of such indirect effects in areas of the world where because of adverse local climates or poor soils, underfed populations living in extreme poverty exhibit high moribundity and mortality rates from pathogenic agents. Such nutritionally generated health problems have been with us for many years, aggravated by bad housing, defective sanitation and pest-infestations. Existing national and inter-governmental health organizations still recognize this as their basic area of involvement and continue to be very active in this field.

6.4.2. The Special Problem

Apart from this more traditional area of concern, there exists a strong feeling that nowadays, man may be exposed to an additional and growing burden of environmentally induced health hazards generated by his intensive agricultural and urban-industrial use of the environment. Thus, superimposed on the patterns of disease characteristic of pre-urban-industrial or pre-intensive agricultural societies we can discern a newer component which is either known or suspected to be induced by exposure to these 20th century conditions. They include: diseases of the blood and circulatory system (e.g. anaemia, hypertension, arteriosclerosis and ischaemic heart disease): certain forms of cancer (e.g. leukaemia, kidney, liver, stomach, lung, bladder); respiratory complaints (e.g. asthma, emphysaema, chronic bronchitis); impairment of nervous function (e.g. encephalopathy, mental disorders); teratogenic effects (e.g. congenital malformations) and mutagenic or allergy effects. The possible causal agents here are generally agreed to be one or more of the following, some less certain than others: oxides of sulphur and nitrogen, ozone, carbon monoxide, non-ferrous metals (e.g. Pb, Hg, Cd, As, Be, Ni, Zn, Cr); radionuclides; nitrates and nitrites; organochlorine compounds (e.g. pesticides, chlorinated dioxans, polychlorinated biphenyls, chlorinated aliphatic compounds) and other more or less complex pharmaceutical substances and food-additives with poorly understood side-effects.

It is generally agreed that we need a more thorough registration of morbidity and mortality attributable to these diseases or some form of index-parameters to these (e.g. crude morbidity and mortality rates in excess of normalized data, perinatal mortality, rates of first admission to mental-care as against re-admission rates). This survey may be carried out in four broad strata or critical groups:

a) Very high exposure groups at special risk from the suspected causal agents listed above. We already have a considerable body of knowledge derived from workers with occupational exposure to these substances and this should be systematically extended.

b) High exposure groups below occupational exposure levels but having higher than average exposure on account of living in large cities, or intensively industrial or agricultural regions.

c) Medium exposure groups living in rural parts of densely populated countries with a high level of technology and/or intensive agriculture but not at risk levels (a) or (b) above.

d) Low exposure (baseline) groups living in remote regions of the world practising primitive agriculture, pastoralism or hunting.

Along with such studies, a simultaneous programme of exposure assessment should be conducted. This would attempt to evaluate the levels of the suspected causal substances in the local air, food (including imported food-stuffs) and drinking water and relate it to the levels actually present in human tissues (e.g. bone, liver, kidney, spleen, blood, skin, hair, body fat). It is important here to analyse materials for as many substances as possible at the outset. Multifactorial statistical processes will later enable the investigators to concentrate on a priority list of two or three substances for each disease category. The ways in which such causal substances accumulate with age in the various categories (a) – (d) above has already proved valuable for Cd and Pb.

This kind of knowledge, acquired directly from field studies can be effectively supported by long-term chronic toxicological studies carried out on experimental animals in order to induce experimentally the various types of illness by the administration of trace amounts of suspected causal agents, over several generations if necessary. Another valuable experimental approach is a biochemical search for impaired enzyme activity, the apperance of intermediate metabolites accumulating in tissues or body-fluids of affected organisms, including man, as a result of impairment of metabolic function (e.g. δ-amino-laevulinic acid dehydrogenase activity and the appearance of this acid in urine of lead intoxicated subjects).

This combined field- and experimental- approach helps to associate with more certainly each disorder with its specific causal agents. It also provides information on what threshold levels of each substance are harmful to human health.

Without these critical values it will not be possible to assess the seriousness of current global levels of the various substances and much time and resources will be wasted in a costly and elaborate monitoring process which cannot be evaluated.

Many technical problems exist in obtaining representative sampling, natural ranges of genetic tolerance, synergistic effects and the computation of reliable threshold dose levels. This latter difficulty has been avoided for radionuclide exposure by adopting the simple concept that there is no zero-effect dose of a radionuclide and that all exposures are cumulative and additive with an effect proportional to the final dose received by the body or population studied. This operational concept used by UNSCEAR and IRCP of calculating the so called "overall harm commitment" of a population and relating it to a stochastic index of damage to a human population merits attention for pollutants. There is already some evidence indicating that some pollutants may act like radionuclides are supposed to behave in having no toxicity threshold, and attempts to follow this radionuclide approach for contaminants such as lead or methyl mercury where we already know a good deal about the clinical symptoms of chronic toxicosis may well break new ground. Again it is important to recognize from the outset that in assessing "total harm commitment" for a contaminant it is necessary to make an "ecological" approach to the dynamics of the substance studied. Thus, one must know its rate of supply to the body via food-webs, its absorbtion rates in gut and lung, its elimination rate by the body as well as its environmental stability or persistence.

It is also important to continue to review new chemical substances for their possible long term harm to man.

In the light of the above remarks we recommend that the geographical distribution of the following be periodically surveyed wherever data can be obtained:

1. Human life expectancy
2. Population age-structure
3. Excess crude mortality
4. Growth rate in terms of body weight and height
5. Frequency of diseases of blood and cardio-vascular system (anaemia, ischaemic heart-disease, arteriosclerosis, hypertension)
6. Frequency of certain forms of cancer (leukaemia, cancer of stomach, liver, kidney, bladder, lung)
   Surveys should be carried out in various age groups and in the following four critical groups representing various degrees of exposure:
   (a) Very high exposure (occupational)
   (b) High exposure (urban-industrial, or intensive agricultural exposure)
   (c) Medium exposure (rural populations in densely populated countries)
   (d) Low exposure (populations from remote regions)
7. A simultaneous programme of tissue analysis (bone, blood, liver, kidney, spleen, body fat) for lead, mercury, cadmium, DDT and its metabolites, polychlorinated biphenyls, should be carried out on postmortem and other material, carefully selected to represent various age-groups and levels of exposure.

Data collected under 1–6 above should be correlated using traditional threshold-dose-level quality criteria and also attempts made to use the "no zero-dose effect" method used for radionuclides.

8. We recommend a periodic review of other potentially hazardous substances, including new chemicals, to help determine whether they have any long-term effect on human health.
9. We recommend research to establish biochemical monitors of disease e.g. accumulation of intermediate metabolites in the human body.

6.5. BIOLOGICAL DATA REFLECTING THE PERFORMANCE OF BIOLOGICAL SYSTEMS

Relevant physical and chemical measurements of the abiotic environment will not in themselves be informative concerning actual effects on biota. The rationale for monitoring animals and plants and their associations is that only by doing this can we obtain information on these effects. Moreover, the whole concern about the environment has evolved because from time to time directly adverse effects on biota and man have been observed.

Biological parameters therefore constitute an indispensible, if not the most important part of any comprehensive environmental monitoring system. Monitoring of the physical or chemical properties of the environment is relevant only in conjunction with established or strongly suspected effects on biota. The view taken in this report, that biological parameters constitute effect parameters means that there is motivation for biological monitoring even if a direct and specific cause and effect relationship has not yet been established. Observed adverse changes in the living environment will provide warning signals and detection mechanisms and will draw attention to the fact that research is needed to clarify the underlying cause as a preparation for corrective management.

Biological systems are extremely complicated and possible variables for monitoring very numerous. It is thus essential to find those biological variables that most efficiently provide reliable information about effects on biota. However, our existing knowledge is too limited to do this at once. We have instead to approach the problems in a more practical way. We have to consider first the feasibility of performing observations and measurements most likely to be informative and then, by developmental research, further refine them into workable parameters.

The effects on biota that need to be monitored are caused by (1) more or less direct human impact, (2) climatic changes and (3) biologically active chemicals introduced into the environment. The variables selected should be informative regarding at least one of these three groups of causes.

The biological parameters may be sought at different levels of biological organization, from the lowest level of molecules, via populations to the levels of whole communities and biocoenoses. When looking into the problems at the highest levels it is necessary to take the totally integrated picture of the biotic and the abiotic environment into consideration. Therefore studies on ecosystems and biomes must be carried out and the biological monitoring activities integrated with physical and chemical monitoring.

Our approach here will be to make a broad review of different possible areas where effects can be expected and to isolate those where monitoring is both feasible and relevant. The following list includes those kinds of biological parameters that will be considered in the evaluation of a minimum programme.

1. Biome studies
2. Distribution of vegetation types
3. Species diversity
4. Primary productivity, biomass and growth rate
5. Size and distribution of species populations
6. Specific population characteristics: reproductive success, mortality, age structure and migrality
7. Physiology, ontogeny and pathology
8. Genetics
9. Behavioural responses and mental performance
10. Phenology
11. Registration of short lived biological phenomena

Biome studies. When trying to improve our knowledge on the structure and function of the biosphere in order to provide a basis for rational management of its natural resources we recognize that we have to deal with a multitude of different ecosystems, all with different floras, faunas and edaphic conditions. It is an impossible task to analyse each of them separately. However, there is enough evidence to indicate that a number of basic principles are the same over large regions with roughly similar ecosystem structures, e.g. within tundra ecosystems or within tropical forest ecosystems. Regions with similar ecosystems are called biomes, and the logical approach is to call for studies in representative ecosystems within each biome, i.e. biome studies.

From the monitoring point of view, biome studies should provide information on where in the total circulation of energy and substances the critical points are located in terms of sensitivity to environmental stresses and to human control. Information of this kind is of great importance for the determination of the most efficient biological and other parameters for monitoring.

By comparing states and processes of comparable ecosystems in low, medium and high exposure situations it will be possible to detect effects caused by human impact without time-consuming long-term monitoring at fixed plots.

The biome studies will, if properly designed, constitute indispensible parts of a global monitoring programme as centres for research and analysis activities directed to the integrative evaluation of complex biological processes and to the isolation of specific parameters suitable for large scale routine monitoring.

Distribution of vegetation types. The surface of earth is continuously changing. Ecosystems are disappearing and being replaced. It would be an important task to make repetitive surveys of the occurrence and distribution of different ecosystems on a global scale. The amount of work involved is however so great that we do not see any possibility to implement such a programme in the near future. We therefore have to make a more simple and practical approach. We believe that it will be feasible to use remote sensing techniques for general surveys of the distribution of different gross vegetation types. Such surveys would be of great value even if the whole globe could not be covered. A concentration on critical regions, for example regions where we already know or suspect that major changes can occur (desert borders, intensively grazed or cultivated areas in dry regions etc.) would be enough. We also recognize the importance of continous monitoring of the so called endangered or vanishing ecosystems of the world. Such a programme will be fairly easy to implement since activities in that direction are already going on.

Species diversity. It is well known that one of the major criteria for the health of ecosystems is their degree of stability. A useful measure of the degree of stability is species diversity. Agents causing environmental damage generally cause decreased species diversity. Measurements of species diversity are difficult to carry out expect for very limited parts of total biota because we cannot as yet identify or quantify the occurrence of all the different species accurately enough by present methods. We therefore hesitate to recommend that species diversity in general be applied as a routine variable in environmental monitoring. Instead we suggest that pilot research for the development of suitable methods be included in the biome studies. We particularly recommend that these studies include activities in three groups, namely soil organisms, marine algae and air plankton.

The soil still remains the most important and intensively used part of the biosphere, and soils are not renewable in the same way that air or water is. Toxic substances often accumulate in soils and changes in soil quality tend to be more or less irreversible. It is therefore particularly important to detect changes in soil quality as early as possibble. We therefore recommend that a programme for monitoring species diversity of certain groups of soil organisms be developed. The programme should include sampling of representative soil transects from low exposure to high exposure situations in relevant biome types. Identification of species will generally not be possible and therefore the relative occurrence of different ecological groupings of organisms has to be used.

An interim approach to soil health monitoring pending the development of methods for a more detailed programme is to use gross soil respiration as an index of biological activity of soils.

Aquatic algae often show very early and characteristic reactions to changes in the physical and chemical properties of water. They are particularly sensitive to increased levels of nutrients but also to toxic chemicals. Paricular attention should be paid to changes of the algal communities in the marine environment, since changes there may mean that global effects of pollution are occurring. We therefore recommend that a programme is developed to register changes in species diversity of algae in the seas covering areas of different degrees of exposure.

Air plankton (pollen, fungal spores, bacteria, etc.) are often carried long distances by moving air masses. The quantitative and qualitative composition of air plankton may provide information on the movements of specific air masses across continents, assist in forecasting animal and plant diseases and allergies in man and contribute to the detection of major changes in the general composition of vegetation and microfauna and microflora. We therefore recommend that a pilot study be initiated for the assessment of the relevance of aerobiology in global environmental monitoring.

Primary productivity, biomass and growth rate. These variables depend primarily on climate, water and soil quality but may also be affected by toxic chemicals. It seems however that the prospects for detecting effects of human impact upon these parameters are not great. Natural ecosystems have generally a high buffering capacity and modified ecosystems are generally managed with the purpose of preventing changes of any kind. However, these are a group of parameters that should be carefully analysed in connection with the biome studies for possible future inclusion in the routine programme.

Size and distribution of species populations. One of the most characteristic and significant adverse effects of man's impact on the environment is that many species decrease in number or in distribution range. Some species even become extinct. These effects have been observed particularly in birds and mammals but also in other vertebrates, plants and in some invertebrates and micro-organisms. The decreases in population size in many birds, particularly birds of prey, as a consequence of reproductive failure induced by mercury compounds and organochlorines have been particularly instructive. These decreases in population size, whether caused by toxic chemicals or by other forms of human impact, have been of tremendous importance in establishing the present concern about the environment.

When looking further into the problems of defining suitable organisms it is recognized that a very restricted number of groups are suitable for monitoring. These groups are: (1) Vanishing or endangered vertebrates, because they are sensitive to environmental changes and because monitoring programmes already exist which have provided useful information, and (2) Birds, because they have proved to be responsive to a wide range of environmental changes, because they are easy to monitor (taxonomically well known and easy to count) and there are numerous reputable ornithological organizations capable of taking part in a programme at minimum cost.

Specific population characteristics: reproductive success, life expectancy, mortality, age structure and migrality. Certain specific population characteristics may often be detected much earlier than changes in population size or distribution because most species reproduce at a rate much higher than necessary to keep the population level constant. It is now known that the decreases in population size of many birds of prey is caused by reproductive failure, i.e. decreased natality. However, it takes some time before this affects the population size. Increased mortality has been observed for many animal species without accompanying population decreases. Life expectancy and age structure are important from the point of view of evaluation of the cause and effect relationship. Migrality is also necessary in the same context.

We are not in the position to recommend any routine monitoring programme for any of these parameters. But we strongly recommend that pilot research be initiated to isolate those that are relevant and feasible for monitoring and to design methods for measuring them. This can be done in association with the biome studies.

Physiology, ontogeny and pathology. Organisms respond to environmental stresses in many different ways. Effects of air pollution can be detected in the blood of vertebrates, congenital malformations are known to be partly environmentally induced and it is well known that plants react to different toxic substances with sometimes very specific pathological symptoms.

We believe that the use of certain sensitive plants for the detection and monitoring of effects from air and other forms of pollution is promising. In many cases naturally occurring plants such as mosses, liverworts, lichens, may be used, particularly in high exposure situations. Promising results have been obtained with specially planted species selected either because of their general sensitivity to pollutants or because of their specific sensitivity to certain other substances.

Genetics. A number of substances released into the environment including the radionuclides are known to cause genetic changes, either affecting genetic variability or mutation rates. We see a number of possible ways to monitor the effects of such substances: studies of the genetic variability and mutation rates of a number of natural and laboratory populations of standard strains of animals, plants and micro-organisms. Suitable organisms include genetically well known standard strains of cultivated plants, *Musca, Drosophila* and laboratory mice and rats. There are however for the present no preparations for such a programme. We recommend that pilot research into this area be initiated as soon as possible.

It is known that some organisms may rapidly become adapted to tolerate elevated levels of toxic chemicals. This property provides a possibility of determining recent history of exposure by tolerance bioassays or by following gene-linked morphological changes as with industrial melanism.

Behavioural responses and mental performance. Extremely early effects from low levels of toxic chemicals can be detected on a laboratory scale in the behaviour and performance of animals, for example in relation to mating behaviour, learning ability. The techniques available are however not yet standardized. We cannot propose the setting up of a programme immediately but recommend that pilot research be initiated for the development of routine procedures for monitoring behavioural responses from low level chronic exposure of contaminants.

Phenology. The biological effects of climatic change are expected to be apparent first as changes in the seasonal timing of different biological phenomena (flowering of plants, arrival of migratory birds, mating, pupation and flying of insects etc).

Extensive observations have been made of regional and local variations in time of flowering of widely distributed and genetically uniform species such as the common lilac *(Syringa vulgaris).* German foresters have made extensive use of phenological observations in the planning of forest operations. Worldwide studies of phenology were proposed as a part of the International Biological Programme, but this work was carried out only in a few countries. Such a programme requires a large number of observations with a representative geographic distribution.

A principal advantage of the use of phenology in environmental monitoring is that many competent amateur observers can be enlisted. It might also be possible to use remote sensing techniques for registering the flowering of certain trees.

Short-lived biological phenomena (local catastrophes). A number of short-lived biological phenomena may serve as very informative detectors of unknown environmental problems. Extensive kills of sea-birds have occurred from time to time along most coasts of the world. To some extent they may be caused by bad weather conditions but toxic chemicals and/or heavy metals have been supposed to constitute an important contributary factor. Thus, such observations may deserve monitoring in order to be reported in a systematic way so that research efforts can be diverted to the problem immediately in order to find out what the cause was. If the results show that some neglected environmental factor was responsible, it should be decided whether it deserves more or less permanent inclusion in the monitoring system.

Other short-lived phenomena that could be mentioned as possible candidates for inclusion into the reporting system are sudden plankton blooms in the oceans, certain kinds of pest outbreak, certain rapid and unexpected species extinctions etc.

In the light of the above considerations we recommend that biome studies be started immediately. These biome studies should be designed to provide information on the structure and functioning of representative ecosystems pertinent to the rational management of their resources and to obtain methods for monitoring the effects of environmental change on biota.

We recommend that systems be immediately developed for monitoring the following groups of biological parameters.

1. Vanishing or endangered ecosystems
2. Vanishing or endangered vertebrates
3. Population size and distribution of birds
4. Short-lived biological phenomena

We further recommend that pilot research programmes be immediately started in order to prepare early implementation of monitoring systems for the following groups of parameters.

5. Global distribution of major vegetation types
6. Species diversity of soil organisms, marine algae and air plankton
7. Specific population characteristics: reproductive success, life expectancy, mortality, age structure and migrality
8. Pathology of selected standard plants
9. Phenology

We also recommend that a number of additional parameters be carefully considered for relevance and feasibility, viz. species diversity as a general index of ecosystem stability; primary productivity and biomass; genetical changes in selected standard strains of organisms and behavioural responses.

7. The design of global environmental monitoring

7.1. INTRODUCTION

In the previous chapter the variables relevant to the environmental problems which should have the highest priority were examined, and those considered the most suitable for monitoring were selected. Other relevant variables discussed were those that are regarded either as having lower priority or as being difficult to measure accurately at present.

The variables referred to as "biological" are much more difficult to measure and interpret than the physical and chemical ones. For some of the latter type, monitoring programmes are either well-established or planned. For example, measurements of climatically related variables are co-ordinated by WMO and those variables related to human health by WHO. However, no such coordination exists in certain other areas, especially those involving biological variables. Such deficiences must be eliminated by establishing a monitoring system that covers all aspects of the human environment. At the same time, all the parts of the monitoring system must be co-ordinated, a feature which can be promoted by proper design of the system itself.

From the viewpoint of economy, a variable should not be measured at more sites, transects or areas than are necessary to establish global trends. On the other hand, as many variables as possible should be measured at the same location; such measurements will support each other and favour an integrated evaluation. An integrated monitoring system should be designed to measure both causal and effect variables, such as DDT and species reproductivity, with the different measurements correlated in space and time. This approach most effectively utilizes stations or monitoring areas in which many activities are concentrated. Some variables, such as atmospheric carbon dioxide, require measurements at very remote sites with a minimum of human activity. Measurements of another group of variables cannot be confined to a restricted number of sites. This type arises in such studies as comprehensive surveys e.g. vegetation mapping, land use, distribution and disease frequencies in organisms including man. Thus, the overall monitoring system must be designed with sufficient flexibility to include the demands of these various specific sub-programmes.

The global environmental monitoring system proposed consists of reference areas (or stations), high exposure areas (or stations) and other monitoring systems not tied to a restricted number of such areas or not at all tied to fixed locations.

7.2. REFERENCE AREAS

Two types of reference areas are proposed: Baseline, or low-exposure areas and regional, or medium exposure, areas.

The baseline areas should be located in very remote regions with no nearby sources of pollution. The functions of the measurements should be to provide information on the current background situation and to determine globally significant trends in the abiotic environment as well as in biota. Thus, they should be planned to operate "indefinitely". The stations selected should be representative of fairly large areas of the globe, because of the primary functions for baseline stations and the desirability of maintaining a minimum number of monitoring stations.

The reference areas should if possible represent all the major biome types, namely:

1. Tundra
2. Coniferous forest
3. Deciduous forest
4. Tropical forest
5. Savannah
6. Thorn scrub
7. Grassland
8. Desert
9. Open ocean
10. Upwelling area
11. Coastal shelf
12. Estuary
13. Epicontinental or semi-closed sea

Although there are marginal zones between biome types, the above biomes embrace almost all the earth's surface and are found in both the northern and the southern hemisphere. To obtain representative measurements of bioenvironmental conditions, at least two stations should eventually be located in each of these biome types; in the first phase, a total of not less than ten terrestrial baseline areas should be established.

The baseline monitoring areas within each biome type should be well removed from local areas which have already been significantly altered by man's activities and land usages. Although very little land surface on the globe has not been affected in som degree by man, substantial areas, particularly those deliberately reserved as wilderness areas, show minimal direct impact from man, and these should receive first priority in siting. Since the monitoring programme is to operate indefinitely, these sites and their surroundings should be dedicated to monitoring in perpetuity. As a general rule, land-based reference stations should be located in natural areas which are approximately 100 kilometres removed from any significant human settlements and large-scale agricultural activities. The observing station itself should be designed for minimum impact on the natural biota and environment, or need not necessarily be located within the baseline area.

Although, open ocean monitoring poses less stringent requirements for representativeness, it does pose substantial logistical and operational problems. Current efforts within the International Decade of Oceanographic Exploration to obtain an initial survey of the biotic component of the oceans, as well as environmental surveys of temperature, currents, and nutrients, are badly needed for a more definitive design of a longer–term monitoring programme in the earth's seas.

In arriving at these recommendations, we have been keenly aware of the need both for representative monitoring locations in all parts of the world and strict comparability and reliability of the data gathered by the network. Since areas chosen for the global environmental monitoring system may serve both national and international purposes, international agreements on the station's mode of operation will be required. Also, so that all interested nations may be included, and have the benefit of comparative analyses, the basic parameters must be minimal in number and measurable at reasonable costs.

The second classification of reference sites are the "regional", or medium exposure areas. These areas will also be located in regions fairly remote from strong contamination sources, but this criterion is not as stringent as that for the baseline stations. Consequently they will often be areas with "normal" agricultural or silvicultural conditions. The purpose of these stations is to document changes in regional environmental quality and to provide data useful in determining the budget of various contaminants. Since these sites will occasionally experience high concentrations of pollutants, they will typically not provide measurements representative of global background conditions; instead, they will give an indication of the general state of contamination over the settled areas of the globe.

To accomplish this global survey, a minimum of 100 areas should be established. Every country, regardless of size, will be invited to participate. The largest countries might each offer ten or more such areas. The siting criterion is simply that it be representative of an integrated region, which may be defined on the basis of geography, biota, climate, land use, etc. The initial list of variables to be monitored at each area will be similar to that for the baseline areas, but not as comprehensive and requiring less sophisticated instrumentation so that countries with modest resources can participate.

At least two of the initial set of reference areas should be designated as international research areas. The stations serving these areas should be internationally staffed and funded. One should be located in the tropics. Their functions will be to develop standard measurement methods, to conduct pilot studies and to determine which additional variables should be included in the monitoring system. The nations should be invited to nominate sites for these stations.

7.3. HIGH EXPOSURE AREAS

In choosing the numbers and locations of high exposure areas it is necessary to consider the wide variety of exposures which may be of importance. These range from acute air and water pollution episodes on an urban or regional scale through extensive ecological, meteorological, and hydrological alterations induced by large-scale land use practices (urbanization and agricultural practices) to long-term degradation of the soils by increased salinity induced by irrigation practices. In general, these impacts produced or augmented by human activities are local or regional in extent and therefore currently pose a variety of problems around the globe. Some of them are becoming so widespread that even though they do not constitute a global problem by virtue of transport mechanisms, they are of common concern to many people.

The main purposes of these stations are to study the effects of contamination on man and biota and to follow trends in densely populated areas. Since they will be located in the vininity of areas with strong pollution sources they will not provide information on global conditions. They should, however, provide an opportunity to detect significant cause and effect relationships in the bioenvironmental system long before they become widespread.

Criteria for choices of impact stations should again be based primarily on biome type with subtypes defined by human activities, and they should emphasize the most common types of bioenvironmental problems. These include urbanization and industrialization of land areas, agricultural and forest management of land areas, and mineral exploitation and associated distributional activities. Thus, the high exposure sites should be located in or near cities, areas of intense farming, and areas of mining, petroleum production or transport. These activities are now represented in essentially all of the biome types. Therefore, the minimum number of high exposure stations should be approximately three times the number of baseline stations. A special type of high exposure stations is that needed to record the output from the large rivers to the oceans.

No attempt has been made to provide a unique list of substances to be measured at these sites since the important, high-concentration contaminants will vary from station to station. A general list would, however, include many of the high priority substances recommended for the baseline areas, such as the heavy metals and common pesticides. Other toxic, but relatively short-lived pollutants like sulphur dioxide will also be included that are not recommended for baseline monitoring. In addition, a strong emphasis will be placed on measuring the effects of the contaminants, such as the symptoms of human health disease.

7.4. OTHER MONITORING SYSTEMS (REGIONAL AND GLOBAL SURVEYS)

7.4.1. Variables in Relation to Climatic Changes

In the SCEP and SMIC studies it was pointed out that global censuses repeated at regular intervals are needed for assessing climate trends. Several of these censuses could be carried out by means of remote sensing from satellites with techniques in existence or in the process of development. These variables are related to conditions at the earth's surface such as:—The temporal and geographical distribution of the earth-atmosphere albedo and outgoing radiation flux over the entire globe (with an accuracy of at least 1 %); high resolution registration of the global distribution (horizontal and vertical) of cloudiness; the extent of polar ice and snow cover (recorded with lower resolution), and the surface temperature of the oceans. There are also variables related to human activities, which can be measured from satellites at longer time intervals, e.g., areas under irrigation, artificial lakes or dams, the extent of urbanization and changes in vegetation. Because of the special technique involved, measurements by satellites must be treated as a separate system. A special satellite system for these variables only will be expensive, but there are possibilities of using satellites with other functions (weather surveillance) to reduce operating costs.

7.4.2. Source Monitoring

Information on substances emitted to the environment is important to any global monitoring system and is especially needed for global budgeting. Data are readily available for some of these substances, e.g., the amount of oil transported over the oceans, but in general we need to develop new methods for data gathering for critical substances. Substances which have been selected for global monitoring (mercury, lead, cadmium, DDT, PCB and combustion products of fossil fuels) should have first priority. These data must be based on national production statistics in industry, mining, etc. but there should be international agreement to transmit certain types of data to one central coordination body.

To assess present and future environmental risks it is important to have a continous record of critical chemical substances emitted to the environment. At the same time these substances should be evaluated in regard to possible health risks to human beings and to ecosystems. To assess these environmental emissions it is necessary to have a detailed knowledge of the techniques of industrial processes. Special attention has to be given to impurities in crude chemicals and to organic chemicals which have high biological activity even in extremely small amounts, e.g., hormones and antibiotics. An ultimate aim of such an international registry will be to record the amounts of all old and new potentially dangerous substances added to the environment every year. It has to be stressed that a very large number of new substances are added to the environment each year but only a few of these may be of potential risk in the future. A registry may thus not only give information on the dangerous substances but also information on substances which are harmless to the environment.

7.4.3. Variables in Relation to Biological Changes

Repeated biocensuses and surveys have been suggested as suitable variables for global environmental monitoring. These may have different priorities. Some can be started at once, others need research and development before inclusion in a global system. Registers of vanishing or endangered species and certain types of bird censuses should have high priority. Registration of endangered species is already carried out on a global basis by IUCN.

Internationally co-ordinated census programmes for waterfowl and sea birds also exist in several regions and in many nations extensive census schemes for passerines are in an advanced state. These programmes only need consolidation and extension. The distribution of species highly sensitive to certain specific substances or variables in relation to phenology and aerobiology may be included at a later date.

All these variables need a very special kind of organization to be monitored effectively, and it seems proper that each of these variables should be treated as a special subsystem.

The registration of gross vegetation changes by satellites is a high priority variable. The newly emerging system using Earth Resource Technology Satellites seems to be the appropriate way to register these changes. It is essential that an international framework be created to handle this type of information. In the future it is likely that satellite registration of biological variables in the oceans may be of great importance to global monitoring.

7.4.4. Short-lived Phenomena

The present system used by the Smithsonian Institution for registering short-lived phenomena may, if extended, be a very valuable tool to record events which are indicators of environmental change. The biological aspects have been previously stressed, but other records such as oil spills and volcanic activities are also important for the global environmental situation. We recommend that this system should be enlarged and internationally supported.

7.5. DATA HANDLING

Data handling involves several separate fuctions including collection, processing, transfer, publication and storage. Within each of these functions the specific activities may depend on the media being monitored, whether the data must be used on a real-time basis, on the specific parameters monitored, etc. Thus, the data handling system must be designed with flexibility to include a variety of measurements, to allow for inclusion of additional variables at future dates, and to include the cataloguing of past data.

The primary office for data handling within each country should be an international data centre, or centres designated by that country. This centre would have the responsibility of collecting the relevant data obtained by the nation and disseminating it to users and a central repository. Most observations obtained by the global environmental monitoring system will not be used on a real time basis and could be made available to the scientific community on a monthly, quarterly, or longer basis depending on measurement frequency. In some cases these centres might also carry out certain analyses to indicate trends for key environmental factors. The international publication of these data should be organized by the co-ordinating unite of the global environmental monitoring system. This unite will also be responsible for a central data library, in which records of all published data are available.

The central data library could have either of two forms. First, it could be one large central facility in which the data from all countries and all disciplines or media are filed. A new body would have to be established for this function. Second, the data could be stored in several dispersed centres, each representative of a certain monitoring area. Several such world data centres were established for the International Geophysical Year for meteorology, oceanography, and a number of geophysical disciplines. The WHO has established centres for storing key health data. If the multi-centre system is adopted, a strong effort must be made for co-ordination between centres and for a referral system, organized by the global environmental monitoring central unite, to provide users with information on availability and location of environmental data. We believe that the second system is the more practical method for the present. Regardless of whether the first or second approach is adopted, these centres will be a primary source of data for research on environmental processes and for determining long-term environmental deterioration.

Real time distribution of data will be necessary in some circumstances, such as petroleum spills, natural disaster observations or hazardous concentrations of air and water pollutants. The mechanism for this distribution currently exists within the framework of the World Weather Watch and its system of world and regional centres. This system, which is funded and operated by individual nations, could readily be slightly expanded to accommodate these environmental data.

7.6. PILOT STUDIES TO DEVELOP GLOBAL MONITORING

7.6.1. General Remarks

Additional research and development is needed both to start and to improve a global environmental monitoring system. This can be done through a series of pilot activities. The international science community has a great responsibility and must in our opinion play an important role in the initiation and design of monitoring. We believe that SCOPE could provide a valuable service in this context since it has been set up to examine global environmental problems. In SCOPE, all the different scientific unions with interests in the global environment are represented. SCOPE has an initiating and co-ordinating role but at present no operational function. For the operation of international scientific programmes. ICSU has special bodies such as SCIBP, GARP, SCOR, SCAR, COSPAR, etc. These bodies could be used for operating international pilot monitoring projects. We recommend however, that for the time being, SCOPE should offer to take the responsibility for these pilot studies after consultations with the proper organizations and nations concerned. The tasks of the ICSU organizations will be briefly examined below. The very special conditions in the marine area will be treated in a separate more extensive section.

7.6.2. Pilot Studies in the Non-Marine Aeras

Within the International Biological Programme, several activities are of importance as potential pilot projects. The role of the biome studies has been discussed in relation to the reference stations. Biome studies will have a special status in relation to the global environmental monitoring system as permanent research projects. Ongoing work on the tundra biome is a typical example of such activities.

Intensive studies have been carried out by scientists from nine nations operating within the IBP which will indicate those aspects of the tundra ecosystem that are particularly sensitive indicators of environmental change. The tundra biome workers should be specifically requested to focus their attention on to this point, both in their current research and in their final synthesis in 1974. A continuing terrestrial ecology monitoring programme should be initiated in 1975, based on the recommendation of the tundra biome working group.

Other parts of the present International Biological Programme may also be used for the selection of proper variables for global monitoring. The IBP Aerobiology Programme is now preparing plans for aerobiology monitoring based on a global network of stations. A co-ordination between these pilot projects with other similar activities aiming to have similar parts included in the permanent global environmental monitoring is essential. As mentioned earlier, world-wide studies of phenology have also been proposed within the International Biological Programme.

When the International Biological Programme is replaced by a new international programme, these activities may be taken up in a more extensive way in order to find useful variables for global monitoring.

It is important to all monitoring studies to separate and recognize the natural phenomena, which are superimposed on each other and which interact and give very complicated patterns and variations. These natural mechanisms have to be studied if it should be possible to identify and discriminate the human impact. It is thus of great importance to study natural rhythms in relation to physical variables such as different kinds of radiation and their biological effects (e.g., heliobiological rhythms) both on species and on ecosystems. Such research projects should be supported on a national, regional and international basis.

A study of the environment of Antarctica and the Sub-Antarctic Islands provides another opportunity to initiate pilot projects and to find suitable variables – both biological and physico-chemical. The Antarctic Treaty facilitates open research on the Antarctic continent by all nations. There is also an ICSU organization – SCAR – to give advice and operate pilot projects.

In developing programmes in relation to climatic changes the natural organization is GARP, which is backed by ICSU and WMO. This organization may serve as a good model for co-operation between a non-governmental scientific organization and an intergovernmental agency.

A new area where a similar development should take place in relation to pilot projects for monitoring is remote sensing from satellites. The

ICSU-body representing the space technique is COSPAR and the ecological aspects should be represented by IUBS or IBP.

7.6.3. Pilot Studies in the Marine Area

The following suggestions have emerged from discussions with marine organizations, from existing published documents and from contacts with marine scientists. Here, only the essentials of a possible framework are outlined, leaving the elaboration of detailed operational plans to inter-governmental working parties with their respective international scientific advisory bodies. There seems to be a consensus in the marine scientific community that a future global system for marine pollution monitoring should progressively evolve from national and regional networks.

International plans already exist for a programme to collect physical information for the marine area under the auspices of IGOSS. This programme will form the necessary basis for understanding the spread, transport and accumulation of marine contaminants and the effects on biota. Several inter-governmental and non-governmental organizations have stressed the need for the immediate development of a marine pollution monitoring system co-ordinated with other marine activities by a suitable inter-governmental body with proper resources.

International plans already exist for a comprehensive monitoring system of the physical conditions in the oceans and their short, medium and long term variations with a strong emphasis also on meteorological and chemical aspects. This internationally agreed cooperative plan for an Integrated Global Ocean Station System (IGOSS) stands under the aegis of the Intergovernmental Oceanographic Commission (IOC) with strong cooperation with WMO, and is supported by many countries. Joint working groups for preparatory and organizational tasks, such as network design, reporting and communication of data, data collection and processing, coordination of requirements, investigation of use needs, etc., have been established and are supported by a number of scientific advisory groups of experts.

It is of extreme importance for the functioning of a marine pollution observation network and especially for the interpretation of the data on critical substances obtained, that IGOSS is in operation and that a strong coordination is built in between IGOSS and a marine pollution monitoring system, and that IGOSS network is made operational especially in the areas suggested for pilot operations in pollution monitoring.

The initial work will be of greatest practical benefit if it is confined to the monitoring of water, top-sediments and biota for the levels of a few critical substances. This can be done from a small number of carefully selected areas. Although modest in scope and of a pilot nature, we feel that a great deal will be learned if in the beginning, the early programmes contain a large mission oriented research component. The organization suited to handle the development and co-ordination of such international pilot programmes are IOC, representing the inter-governmental executive functions and SCOR with an advisory function, representing international science.

After an initial phase of planning and creation of pilot projects with a strong research oriented component the final monitoring and surveying programme will progressively evolve and should be executed by governmental institutions. IOC should be given sufficient resources to mount the task of international coordination. Such a task is demanding a special permanent secretariate for pollution monitoring within IOC.

The necessary steps to develop a final monitoring programme from pilot programmes are indicated in the following three phases.

The preparatory phase. This should be started as soon as possible and should consist of a number of future regional programmes co-ordinated by an appropriate and generally acceptable inter-governmental marine organization with the assistance and advice of SCOR. Pilot programme should be planned on a regional basis and it would be sensible to use for this purpose existing regional international marine organizations which have already given thought to these and have access to the most knowledgeable experts of the region in question. Where no appropriate regional organization exist, one could probably be constituted with assistance from the nations concerned and the non-governmental marine science community. The basis of each region's pilot programme should be dedicated to studying the problems special to the particular region. In order to ensure intercalibration and standardization of methodology, and data collection between regions, the inter-governmental body should co-ordinate these aspects centrally. During this preparatory phase, regional working groups should be set up and at the same time an international marine research and reference station should be established.

There are a number of functions which are essential for the execution of the pilot programmes. These functions can be carried out by working groups which might have a regional character in the beginning. The functions are specified as:

a) Interdisciplinary workshop for the marine sciences of the special region under study. This workshop should make an inventory of relevant knowledge and available information, identify the gaps in knowledge and information, and initiate complementary research.

b) Working group on modelling. This would design appropriate methods of sampling in space and time for the pilot study. This involves developing a preliminary model of water exchange and balance and of the sources, distribution and sinks of the critical substances.

c) Working group on data processing. This would examine appropriate means for data transfer, collection and processing. All regional and national data should be handled in such a way that future integration into a global system is made possible.

d) Working group on methods and standards. This would survey existing methods relevant to the problems of the region. This working group would also have the responsibility for intercalibration of the recommended methods.

e) Regional training workshops. The sophisticated methods which have to be applied to the analysis of most substances and the problems imposed on the analytical work by the need of specialized sampling, preservation and preparation previous to analysis, require special training courses or workshops within the region. It would be a valuable service if universities and similar institutes would serve as hosts for such courses. The finance needed should be provided by international or multinational funding. The participants in such training courses would be the later executors of the programme and they must have a sufficient background education as well as experience in field and laboratory work.

Non-governmental and intergovernmental marine organizations have suggested the establishment of an international institution. Several functions need to be fulfilled by such an institution, or as alternative, by several national institutions with international specialized working groups as coordinators and clearing houses under the auspices of SCOR.

a) Research and development of hardware for sampling critical substances.

b) Research on methods of measurement and analysis, especially analytical methods for new compounds which are expected to cause environmental problems in the near future.

c) Research on reliable standards.

d) Preparation, control and exchange of standards.

e) Training of scientists and technicians.

f) Advice, guidance and personal help during the installation of new laboratories and study areas, especially in less developed countries.

g) The curatorship of a sample bank for reference and standard samples and selected check samples from baseline stations.

It must be stressed, that especially the functions described under c, d and g are essential for the execution of internationally organized pilot programmes.

The phase of establishment of regional pilot programmes. Every region has its special conditions and problems. However, for each region there should be a planning group which, based on the material and activities during the preparatory phase, should plan and probably operate the pilot programme.

The selection of suitable regions for such pilot programmes has already been considered by different bodies representing both intergovernmental and non-governmental organizations. The following regions have been recommended as having the highest priority:

a) North Sea
b) Baltic Sea
c) Mediterranean
d) Puget Sound

Additional regions can also be recommended:

e) Carribbean Sea and Gulf of Mexico
f) Norwegian Sea
g) Northern North Atlantic
h) Black Sea
i) Japanese Sea
j) Chinese Sea

For several reasons, most of the regions indicated above demand an intensified and dense sampling programme over a period sufficient to cover all possible seasonal alterations and other fluctuations. It is suggested that for each of the regions mentioned under a) – d) about 20 stations in coastal areas and 20 stations in the open sea should be operated monthly or at least once every season. Another 20 stations will be needed for each region to cover the main points of injection, *i.e.*, river mouth stations or estuary stations. It is supposed that ongoing and planned national activities within the field of marine pollution monitoring will provide intensified information about the pollution situation and possible fluctuations during the period of the pilot programme for the near-shore areas. The sampling programme for the impact stations at the major points of injection must be rather dense and should apply *in situ* sensing techniques and automated analysis for as many of the critical parameters as possible.

For other regions, especially for the open oceans, seasonal and incidental fluctuations might not play an important role so that a sampling programme with a relatively large grid will provide the necessary baseline information. Such information can certainly be obtained by individual research cruises and through sampling programmes during ongoing and planned research and survey cruises for other purposes and also from weather ships.

There seems to be a consensus in the relevant bodies among the marine scientific community that the data obtained from the regional pilot programmes should be handled by the existing national and regional oceanographic data centres. It may be supposed that the amount of data from the pollution monitoring programme will be much less than the data from physical observations obtained from ongoing research and survey activities. The pollution data, however, will be much more heterogeneous. A careful investigation of possible formats of collaboration between the existing data centres should be carried out to provide for a rapid exchange and processing of data. The adopted system should be flexible enough to allow adjustment to new hazardous compounds and should furthermore allow an integration into a world-wide system.

Before entering the final monitoring programme it is desirable to reduce the number of observation points in the pilot programmes to the minimum possible. This is necessary for three reasons:

1. To warrant the execution of a long term programme for the remainder of the stations.
2. To keep the cost of the monitoring programme as low as possible, and
3. To transfer the programme from being the joint efforts of both research and governmental institutions to governmental institutions only, it being obvious that the execution of routine monitoring programmes is not the task for research institutes.

The phase of the final marine environmental monitoring programme. The final world wide network for marine pollution monitoring is expected to grow from regional nets and their stepwise integration into a global system. The global system must be flexible to allow for the measurement of new hazardous substances. The probable appearance of such "new" substances can be deduced from the records in the planned World Registry of Chemicals. The necessary methodology and hardware should be developed in due time by the International Research Reference Station described earlier.

It is, however, of utmost importance that this system for marine environmental monitoring is fully integrated with the global environmental monitoring system. The essential co-ordination is a free flow of information from the marine system to the global system. In order to reduce the information as much as possible, it seems most appropriate that only processed data are exchanged.

In relation to the evaluation of the results from the monitoring activities it would seem appropriate that we should not only make an evaluation of the global system but also a special evaluation concentrated on the marine environmental problems. Since, however, this final phase is rather far in the future, it is not much use to elaborate on possible details and organisational alternatives which have to depend on experiences and results from the earlier phases.

7.7. ACTIVITIES TO SUPPORT AND PROMOTE ENVIRONMENTAL MONITORING

7.7.1. "Historical Monitoring"

One of the main objectives of the reference stations is to establish trends. In addition to this it is important to extend the "baseline" backwards in time by a process of "historical monitoring". The chemical stratigraphy of marine and lake sediments, peat bogs, glacier and ice cores and similar time-layered materials should be analysed. Coral reefs, tree rings, herbarium and museum specimens of biota collected in former times have all been shown to be highly informative in this respect. As an extension of this activity, it would be essential to develop an efficient storage of collected samples as an environmental archive. Soils, water, biota and air filter samples preserved by deep freezing could be of great value in future.

7.7.2. Environmental Archives

The main purpose for the establishment of environmental archives is to keep samples for future analytical work, i.e. checking earlier results with new methods or to supply material for testing and samples for newly appearing substances in the environment. From a biological point of view it is also important that samples are available for taxonomic checking in the future. We are well aware that such checking is only possible for certain types of substances and certain types of samples such as air filters, water samples and biological specimens. This storage is only partly possible in the traditionally existing museums, as new methods for preservation may be needed and will have to be developed as soon as possible.

It would seem desirable that these environmental archives should be housed in close contact with the reference stations. It is, however, important to get international agreement regarding the use of these archives to guarantee both that material is available for international purposes and also that material is preserved for the future. An international register of existing material should also be kept.

7.7.3. Training (Scientific and Technical) for Monitoring

The success of a global monitoring programme may to a large extent be determined by the personnel available. There are many scientific fields supporting the monitoring programmes and thus there is a need for a specific, broad-based training of all specialists to understand the interacting biosphere. The main groups of sciences are physico-chemical sciences, biomedical sciences, geographical sciences, mathematical sciences and sciences relating to data handling and analysis. Accordingly, the personnel involved in global monitoring will include representatives from many specialities from senior scientists to technical assistants.

This training could be concentrated in special centres in order to promote an unified technical approach to the problems. To promote co-operation and standardization of methods international and multilateral training courses should be supported.

It is of special importance that internationally funded training facilities be made available to the developing countries. Here the International Research Reference Stations, which have been recommended in this Report, will be of great use. It must also be emphasized that reference stations set up in the developing countries by international or national aid organizations from the very beginning act as training centres for scientists and technicians.

The importance of a sound environmental training for the general public, industrial personnel, as well as for administrators, decision- and policy-makers is also stressed. They must all be well informed and made fully aware of the implications of environmental problems emanating from national, regional and international practices and legislation. It is particularly important to inform these people about the benefits from environmental monitoring.

8. Operational and institutional arrangements

8.1. FUNCTIONS

A correct and complete evaluation of environmental data is only possible when the environment is treated as a unity. The interactions of the processes in space and time make it necessary to consider information from all different media of air, water, soil, and biota including man. This integrated view is essential when dealing with the situation at a specific locality. The same considerations have to be made – on an even larger scale – when we are dealing with global conditions. In addition, the interactions between the different media and their roles as transport mechanisms must also be considered.

The approach to environmental problems has traditionally been media orientated e.g. air pollution problems, water pollution problems etc. This media approach has been promoted by an interaction between national and international levels. As a result there are well-established or planned media-orientated monitoring systems both on national and international levels. Important co-ordination work has been done by different international agencies, especially within the UN-system.

The co-ordination has been focused on intercalibration and standardization of methods. These activities and the experiences gained from them should be used as guidance for a future integrated global monitoring system. The main task is to establish a high degree of co-ordination and to permit an integrated evaluation of the problems in the total environment both from a national and global point of view.

8.2. CO-ORDINATION

8.2.1. Introduction

In designing a coherent global environmental monitoring system, the basic problem is how to set up the simplest and least costly structure, in terms of money and technical manpower, which is nevertheless effective as regards global coverage, accuracy, reliability, speed and flexibility of response.

Three possibilities exist:

1. To use the data emerging from existing or planned programmes
2. To re-design a completely new global system
3. To develop co-ordination machinery to obtain from existing programmes data on an internationally agreed set of priority variables which may or may not be currently measured globally.

We can benefit from a study of the organization and methods of the large number of ongoing monitoring activities already being carried out by governments, inter-governmental and non-governmental bodies. These current and planned programmes are extremely valuable in covering national environments or selected parts of global problems. At present, little or no co-ordination exists between them in terms of standardization of sampling and measurement techniques and hence in the collective evaluation of results. This makes comparisons quite impossible on a global scale at present.

In the present Report, we are more concerned with problems which are becoming global in extent either because they are being simultaneously generated in countries all over the world or because geophysical, geochemical and biological transport mechanisms are spreading contaminant substances globally from point sources. A completely new comprehensive programme to deal with these situations would involve a large number of variables to be monitored in air, water, soils and biota (including man) all over the world. The design of it would raise so many complex financial, organizational and technical problems that it is fairly obvious that no completely new and untried system can be erected in entirety within the near future. There is little doubt that the least wasteful final design will be arrived at by evolving from a modest beginning. This process may take far too long in view of the urgency of obtaining some global overview of at least a few world environmental problems.

International co-ordination appears to be the most practical way forward at present. Since governments will be the users of global monitoring information, it would seem logical to obtain international agreement on a basic set of high priority environmental variables to be measured on a global scale. It might then be appropriate to develop some kind of inter-governmental co-ordination machinery to standardize or inter-calibrate sampling and measurement methodologies so that the basic agreed variables can be measured by existing national and inter-governmental programmes with minimum disturbance and interference to their ongoing internal monitoring priorities.

8.2.2. The Monitoring Office

We are convinced that to succeed, any integrated monitoring system must at first be rigorously selective about which variables to monitor globally. It must choose only those where it is absolutely certain that urgency for global knowledge exists and where reliable and reproducible methods for sampling and measurement can be successfully operated on a global scale. For these and other reasons, a large amount of national monitoring and regional work already being carried out by inter-governmental or non-governmental efforts would be of little or no interest to any proposed global system. However, existing monitoring bodies might be able and willing to modify their current programmes to allow for the collection and transmission of selected data directly useful to a global system.

A practicable method of arranging this would be to invite each government, UN agency or other inter-governmental and non-governmental body actively involved in monitoring to nominate a committee or group (Monitoring Office) to be the correspondent for all matters where its affairs relate to global monitoring. By previous agreement, this might involve selected material emerging from a nationally controlled reference or high exposure area, health monitoring data or relevant information obtained in some other agreed manner. Aside from its activities as regards global monitoring, this Office might have the role of co-ordinating all monitoring activities internal and private to its government or agency and of no concern to the global system. By international agreement, this Office would not only transmit certain data to any inter-governmental co-ordinating machinery but would also receive as required all data from the global system. Other matters of concern to the Office would be the adoption of recommended standardized or inter-calibrated sampling and measurement techniques and the interchange and training of scientists and technicians.

All these activities would presuppose that the Office, by permission of its parent body (nation, etc.) had access to the required data via its monitoring programmes, data banks, environmental archives, etc. Future developments might involve its handling any internationally agreed data on quantities of the various potentially hazardous substances released to the environment and such programmes as the monitoring of vegetation boundaries, land-use, soil-erosion, etc. by satellite sensing.

The Office would be able to contribute to the process of international review of all aspects of the global programme as regards current and future content and administration.

8.2.3. A Central Monitoring Co-ordinating Unit

By international agreement, a special Central Monitoring Co-ordinating Unit should be set up immediately. The basis for the work of this body should be the wide range of competent ongoing and planned environmental monitoring programmes. These include (a) territorial monitoring activities which are the sole concern of each national government, (b) regional programmes where a shared resource or region is collaboratively monitored by those governments directly affected and (c) the UN agency and other inter-governmental or non-governmental programmes for climatic change, human health and toxicology, marine conditions, radioactivity, education and training.

This Co-ordinating Unit should have the following functions:

a) Delineate programmes and continuously overview global environmental monitoring activities to make certain that the system operates with maximum efficiency and relevance and that optimum output is achieved.

b) Co-ordinate ongoing monitoring programmes and recommend new activities to ensure that the requirements of the system are satisfied.

c) Standardize the methods of observation in order to ensure comparability of data.

d) Take the necessary steps to provide the monitoring system with appropriate means for data handling and dissemination.

e) Evaluate advice from its independent scientific advisory body, the UN agencies, other international organizations and nations.

f) Report to UN on the state, needs and results of the global environmental monitoring system.

It is quite conceivable that by international agreement, parts of these co-ordinating and evaluating activities for selected media may be specially delegated to a relevant organization e.g., a UN agency or inter-agency alliance with the Monitoring Co-ordinating Unit retaining ultimate overall responsibility.

In addition to the above considerations, a body is necessary to provide technical assistance and serve as a distribution point for supplementary funding of monitoring programmes at scientifically desirable sites where "national" funding is inadequate. Since an important characteristic of the monitoring effort is its global extent, many sites will be required in political jurisdictions where the scientific and technical problems of comprehensive environmental monitoring are new to the country. The Co-ordinating Unit must therefore be responsive to requests for technical assistance in setting up the reference stations. This can be done either by staff attached to the Unit, or by the Unit serving as the co-ordinating body to produce such assistance from another national government or, for example, a UN agency. With respect to supplementary funding, the Co-ordinating Unit should have a strong voice in its allocation. This is to make sure that the money is distributed in the best interest of the total monitoring effort rather than in national interest alone.

8.3. EVALUATION

The most critical point in relation to the monitoring activities is the evaluation of the results. For this reason we think that the UN should ask the International Council of Scientific Unions to establish permanent institutional arrangements to provide scientific assistance in the evolution and design of the global environmental monitoring system and in the analysis and interpretation of data.

8.4. MONITORING AND OTHER UN ACTIVITIES

We recognize that the global environmental monitoring system is an integrated part of a much more comprehensive framework for policies, research and actions in the field of environmental affairs in general and that monitoring cannot operate with maximum efficiency without close connection to these other environmental activities. We also recognize that no organization presently exists with the competence of co-ordinating all global environmental activities.

We therefore recommend that the United Nations seriously consider using an existing body or establishing a separate body directly responsible to the General Assembly of the United Nations with the competence to perform overall co-ordination, integration and policy definition for the whole field of global and international, governmental, inter-governmental and non-governmental environmental programmes and affairs.

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LIST OF ACRONYMS OCCURRING IN THE REPORT

COSPAR	Committee on Space Research
FAO	United Nations Food and Agriculture Organization
GARP	Global Atmosphere Research Programme
IAEA	International Atomic Energy Agency
IBP	International Biological Programme
ICSU	International Council of Scientific Unions
IDOE	International Decade of Oceanographic Exploration
IGOSS	Integrated Global Ocean Station System
IGU	International Geographical Union
IHD	International Hydrological Decade
IOC	Intergovernmental Oceanographic Commission
IRCP	International Registry of Chemical Compounds
IUB	International Union of Biochemistry
IUBS	International Union of Biological Sciences
IUCN	International Union for Conservation of Nature
IUGG	International Union of Geodesy and Geophysics
IUNS	International Union of Nutritional Sciences
IUPAB	International Union for Pure and Applied Biophysics
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
IUPS	International Union of Physiological Sciences
IUTAM	International Union of Theoretical and Applied Mechanics
MAB	Man and Biosphere
SCAR	Scientific Committee on Antarctic Research
SCEP	Study of Critical Environmental Problems (Man's Impact on the Global Environment, the MIT Press, Cambr., Mass. 1970)
SCIBP	Special Committe for the International Biological Programme
SCOPE	Scientific Committee on Problems of the Environment
SCOR	Scientific Committee on Oceanic Research
SMIC	Study of Man's Impact on Climate (Inadvertant Climate Modification, The MIT Press, Cambr., Mass. 1971)
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSCEAR	United Nations Scientific Committee on Effects of Atomic Radiation
WHO	World Health Organization
WMO	World Meteorological Organization
WWW	World Weather Watch