ABSTRACT

This paper describes the background and elucidates the need for an integrated global background monitoring network. This network should have as its objectives the following:

1. Establish reference levels for pollutants that have potential for global contamination.

2. Serve as an early warning system for detecting global spread and trends of pollutants.

3. Establish background levels for selected ecosystem parameters against which data from more impacted areas can be compared.

4. Contribute to the study of biogeochemical cycles.

This paper proposes the following:

1. Establish an integrated global background monitoring network for pollutants and ecosystem parameters.

2. Pollutant measurements be multi-media.

3. Carry out ecosystem parameter studies in conjunction with pollutant measurements.

4. The network, in principle, be maintained for an indefinite period of time.

5. The network be established using suitable international biosphere reserves as the universe from which a subset of monitoring sites are drawn.

6. That the network becomes an integrated part of the Global

Environmental Monitoring System.

7. That, wherever possible, the network be cooperatively operated with the BAPMoN* of WMO.

The paper also describes studies at two of three IM** pilot stations, of a three station pilot network which are the first step toward the implementation of a full scale network.

* BAPMoN = Background Air Pollution Monitoring Network
** IM - Integrated Monitoring

INTEGRATED GLOBAL BACKGROUND MONITORING NETWORK

by

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INTRODUCTION

Pollution transcends political boundaries. Pollutants emitted in one location may persist for long periods of time in the atmosphere and then may be deposited thousands of kilometers from the original source.

For example, Elgmork et al. (1973) found that snow in remote areas of Norway contained high levels of sulfur and lead levels of 98 ug/liter. It was concluded that the pollutants originated in urban and industrial areas in western and central Europe. Johnson et al. (1972) and Schlesinger et al. (1974) reported high acidity, lead, cadmium, and mercury levels in mountainous areas of northern New England in the United States (US). It was postulated that the pollutants originated in the densely populated, industrial areas of the central and mid-Atlantic regions of the US. Hirao and Patterson (1974) concluded that 97 percent of the lead found in a remote site in the western US came from anthropogenic sources. Anas and Wilson (1970) reported DDT levels in the milk and fat of the pups of northern fur seals. A number of other studies (Lannefors et al., 1983; Carlson 1981, and Rahn, 1981) examine potential contamination of the arctic atmosphere from a variety of mid-hemisphere populated and industrialized areas.

Some researchers, however believe that even the low levels of certain atmospheric constituents such as lead detected in remote areas are primarily anthropogenic in origin. Patterson (1980) estimates that 99% of global lead emissions are anthropogenic in origin.

Other studies, however, have been carried out to try to establish reference levels of compounds that have both natural and anthropogenic sources. For example, some researchers have looked at the composition of precipitation from remote areas of the world. Included were such constituents as hydrogen ion concentration, calcium, magnesium, sodium, potassium, ammonium, sulfate, nitrate, chloride, silicates and phosphates as well as pH measurements (Keene et al., 1983; Galloway et al., 1982). Others have looked at atmopsheric concentrations over continental and marine areas at varying altitudes for nitrates, sulfates, chlorides and ammonium (Huebert and Lazrus, 1980).

Trace metals also have natural and anthropogenic sources. Rahn (1976) reviewed the literature up to 1975 concentrating on the composition of the atmospheric aerosol with emphasis in remote areas. This effort was updated in 1985 by Wiersma and Davidson.

In summary, many compounds that are called pollutants have natural existing background levels. It is necessary to determine the background or reference levels to aid in interpreting data from more impacted areas where many of the same constituents are considered pollutants.

This paper examines the history of background pollution monitoring at the international level, describes current activities in the field of "integrated" monitoring (see footnote on page ii), and proposes criteria for the development of a global effort to coordinate background monitoring on the presence, accumulation and behavior of pollutants in remote ecosystems.

OBJECTIVES

The objectives of the integrated global background monitoring network are:

1. Establish reference levels for pollutants that have potential for global contamination.
2. Serve as an early warning system for detecting global spread and trends of pollutants.
3. Establish background levels for selected ecosystem parameters against which data from more impacted areas can be compared.
4. Contribute to the study of biogeochemical cycles.

BACKGROUND MONITORING

A US Presidential Advisory Committee had called for background ecosystem studies as early as 1965, suggesting that the studies should be worldwide (Wenger et al., 1970). Lundholm (1968) recommended the establishment of a global monitoring system for remote background areas. His reasons for establishing such a system are as pertinent today as they were 16 years ago. He stated:

"Society is to an ever-increasing degree demanding information on how production in the natural environment is and will be affected by pollution. One reason why the value of the ecologist has not been sufficiently recognized by governments is that often he did not have the basic environmental information on which he can assess changes and base recommendations for action or advance warnings on the effects of man's activities on the natural habitats.

There is an urgent need to create a kind of an early warning system based on long time series of environmental data from strategically situated stations or sampling areas. In order to follow the changing situation in the biosphere, we need a network covering the globe. As the interest is focusing not on the local variations, but on the background levels and changes, the number of stations (or sampling areas) in such a network can be kept rather low...The aim is to erect a global network of baseline stations (sampling areas) devoted to monitoring biotic as well as abiotic factors in the environment. The purpose is to have a means of assessing short term and long term changes caused by a selection of factors, including many forms of pollution. The erection of the network is motivated mainly by the threat of pollutants..."

Since then, scientists throughout the world have reemphasized the need for a global monitoring system and for the establishment of a global network of ecological baseline stations (Ecological Research Committee 1970, Ad Hoc Task Force on GNEM, 1970). Jenkins (1971) suggested that the stations should be representative of the major ecological biomes of the world and be equipped to measure pollutants. Sokolov (1981) also urged that particular attention be paid to integrated background monitoring(1). Izrael (1982) pointed out the early warning value of a global network of background monitoring sites. Rovinsky and Buyanova (1982) observed that such a network of background monitoring sites could provide a basis for international environmental protection agencies.

The WMO Executive Committee (now 'Executive Council') in its Resolution 17 (EC-XXVI; 1974) proposed that "for general scientific and economic reasons, members of WMO should...as far as possible be prepared to meet requirements for environmental monitoring in other media (than air) as formulated by national or international organizations...; ...monitoring in soil and biota should also be accepted to be carried out at background air pollution stations as far as feasible."

The idea of a Global Environmental Monitoring System (GEMS) was debated in Stockholm, Sweden in 1972 at the UN Conference on the Human Environment, and a GEMS/Program Activity Center was established in 1974 within the Nairobi, Kenya headquarters of the United Nations Environment Program (UNEP).

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(1) Integrated monitoring was defined by a January 1980 Expert Group Meeting in Geneva as: "the repeated measurement of a range of environmental variables or indicators in the living and non-living compartments of the environment, and the investigation of the transfer of substances or energy from one environmental compartment to another.

An interagency working group (Task Force II - Committee on International Environmental Affairs, 1976) was convened in 1974 to determine what should be monitored and to make recommendations for the structure and operation of an environmental assessment service within UNEP. The working group proposed an "Earthwatch" component within UNEP having four integral parts, namely: monitoring (GEMS), research, evaluation, and information exchange.

The working group also established the principle that environmental assessment should be carried out, wherever possible, in cooperation with similar activities, either existing or planned activities:

> "Earthwatch reference sites would be expected to provide a coherent, integrated base of benchmark data and information on physical, chemical and biological conditions for determining long-term trends of environmental processes. These sites should include selections from ongoing and planned activities, such as (a) World Meteorological Organization (WMO) baseline and upper atmospheric programs; (b) hydrology stations; (c) lake biome programs, (d) Man and the Biosphere (MAB) biome programs; (e) open ocean baseline sites; (f) river outflow stations; and (g) inventory programs including those for deserts, forests, wetlands, and grazing lands."

From the above, it is obvious that the MAB program was conceived as having intimate connections with Earthwatch. In addition, the International Environmental Programs Committee (1976) of the US National Research Council suggested linking MAB's Biosphere Reserve program (which concerns setting aside remote areas in perpetuity) to terrestrial monitoring within GEMS. Franklin (1977) also argued that Biosphere Reserves be considered a component of GEMS. Hermann et al. (1978) and Wiersma et al. (1978) described potential monitoring activities in US Biosphere Reserves. Finally, the International Coordinating Council of the Program on Monitoring and Biosphere (Anon, 1978) officially recognized the link between GEMS and the Biosphere Reserve System.

Currently, only WMO/UNEP has a worldwide background air pollution monitoring network, named BAPMoN (Kohler, 1980). However, only about ten percent of the 100-odd BAPMoN sites are truly "baseline" (de Koning and Kohler, 1978). The terminology is slightly confusing: WMO uses "background monitoring" to refer to the entire BAPMoN network, and "baseline" to designate very remote sites, which in this paper are referred to as "background"(1).

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(1) In BAPMoN, the term "baseline" is being replaced by "global" indicating the largest representativeness of a monitoring location (>3000 km). Other categories of monitoring locations are designated "continental" (>1000 km) and "regional" (>300 km).

Several workers (Jensen and Brown, 1980; Anon., 1980) have stressed a need for terrestrial background monitoring stations that could provide correlated measures of pollutant behavior in different environmental media (air, water, soils, plants and animals). Particular attention has focused on the BAPMoN baseline site.

The Geophysical Monitoring for Climatic Change (GMCC) program (Mendonca, 1979) and the Global Precipitation Chemistry Project (Keene et al., 1983) and other similar programs also collect data on atmospheric constituents in remote areas. While more limited in scope than the Integrated Global Background Monitoring Network, the data collected should be valuable and should be considered in the development of the Integrated Background Monitoring Network.

APPROACH AND DESIGN PRINCIPLES

Because of space it is not appropriate to go too much into the details of sampling and monitoring design. Much of this work has been done and can readily be adapted to monitoring on background areas (Wiersma and Brown, 1980; Wiersma and Brown, 1981; Wiersma et al, 1978; Wiersma, 1981[a]; Davidson et al., 1985). However, it is important to outline the principles under which a background monitoring program will operate on the 3-station pilot network and eventually in a full scale global background monitoring program. These principles are:

1. The monitoring system is multi-media (integrated).
2. A systems approach is used to relate media and help understand possible interactions between pollutants and ecosystem parameters.
3. Multi-element compound chemistry analytical procedures should be used where possible.
4. Key ecosystem parameters should be measured.
5. Quality assurance techniques will be applied during all phases of the project.

Multimedia

An ideal monitoring system, in principle, should be able to trace a suspected pollutant from a source to a sink or exit point. On most terrestrial remote areas the pollutant input to the reserve site is via the air route. The ultimate sources, while normally associated with man's activity in general, are in practice difficult to locate.

Therefore, input should be measured in the form of atmospheric concentrations, as well as dry and wet deposition. Output from most biosphere reserves will be streams and rivers draining the area and the loss of pollutants via this route can be determined by sampling representative drainages.

Currently, sampling is done in air, wet deposition, water, soil, forest litter and several vegetative species.

Finally, the multimedia monitoring approach integrates readily with the data on ecological processes which is simultaneously collected. We hasten to point out that it will be highly unlikely to detect pollutant related effects in remote areas. The greatest value will be in establishing baselines and long-term trends and helping to understand cycling of compounds in the studied ecosystem. Also if long term changes in the ecosystem parameters are noted, then a good pollutant database, coordinated with the ecosystem parameters exists.

Systems Approach

Munn (1973) states that it is essential that GEMS be designed in such a way that interactions between media can be studied, permitting delineation of the pathways of biogeochemical cycling. This requires a systems approach and is as applicable to the design of a system on a reserve as it is to putting the entire GEMS system together. A promising technique for accomplishing this is the use of kinetic models. Theoretical bases and applications of these models have been described in detail by O'Brien (1979), Miller and Buchanan (1979), Barry (1979), Eberhart (1979), Wiersma (1979) and Wiersma et al. (1984).

Pollutants (Abiotic Parameters)

Many compounds exist in the world which have both natural and anthropogenic sources. Indeed, one of the objectives of Integrated Global Background Monitoring Network is to establish reference levels which will help separate natural influence from man's influence. However, for simplicity in writing, we have used the term pollutant to refer to any measured compound recognizing upfront that many of these compounds have natural as well as man-made origins. Earlier, the selection of a limited number of pollutants to measure in background areas had been a common recommendation by many scientists concerned with monitoring systems development on background areas (Munn, 1973; Task Force II - Committee on International Environmental Affairs, 1976; Ad Hoc Task Force on GNEM, 1970). Virtually all the pollutants suggested had a potential for long-term transport. However, advances in chemical analytical techniques allow us to reconsider this approach. For example, trace element techniques for a variety of media are now multi-elemental (Jaklevic et al., 1973 and 1976; Dzubay and Stevens, 1975; Alexander and McAnulty, 1981; Kahn, 1982). Multi-residue techniques for trace organics are also available. They are more expensive than multi-elemental techniques. Multi-residue techniques are available for the major types of pesticides and toxic organics in most environmental samples. In situ measurements are necessary for parameters such as pH, conductivity, O_3, NO_x, SO_2, etc.

Key Ecosystem (Biotic) Parameters

There is no unanimity of opinion on the array of ecosystem parameters that should be selected for study as a part of a monitoring network. Extensive lists of such parameters have been developed (Anon., 1980; Institute of Ecology, 1979; National Science Foundation 1977, 1978). While many of the proposed measurements are potentially of value, their number alone induces paralysis.

General agreement does exist on the need for measures relating to nutrient cycling, productivity, and populations of selected species. The selected species may either be dominant in the ecosystem or sensitive to partucular perturbations, such as pollutants. Parameters that meet these critera include; litterfall or leaf fall (McShane et al. 1983[a]); tree growth; tree reproduction; tree mortality; changes in the compliment of foliage, e.g., years of conifer needle retention; and changes in the composition of the decomposer community. Sensitive species may be plants (e.g., some lichen species) or animals (e.g., some birds and small mammals) and their sensitivity may be reflected in their population structure or growth rates. A similar selection of parameters can be made in stream or lake ecosystems. Ecosystem processes are a challenging aspect of any monitoring program. Background data must be developed for natural, unpolluted systems if it is not currently available. These data can then be used as a baseline against which other, presumably polluted, ecosystems can be compared. The selection of specific parameters and sampling techniques is complex. Ecosystems are a complex web of linkages which can make it difficult to isolate the phenomena of interest in either the sampling or analytic phase of the research. The possibility of observer effects is always present especially since measurements are to be repeated over many years. The statistics of the candidate ecosystem parameters is also critical (Hinds, 1984). It is necessary to select processes that are sensitive to subtle changes and have natural levels of variability that allow statistical detection of such departures from the norm (McShane et al., 1983[b], Hines, 1984).

Permanent plots are an important element in the ecosystem monitoring program. Monumented field sites are critical for accurate re-measurements of ecosystem or demographic processes. Sampling of permanent plots can also provide thorough descriptions of key community and ecosystem parameters (e.g., standing crops of organic matter) essential to measurement or interpretation of parameters of more specific interest in the pollutant monitoring program. One scheme for establishing permanent sample plots is the reference stand system used at Olympic (Franklin, 1982). H. J. Andrews (Hawk et al., 1978) and Sequoia-Kings Canyon Biosphere Reserves.

Quality Assurance

A complete quality assurance program should cover the following elements:

- organization and personnel
- facilities and equipment
- analytical methodology
- sampling and sample handling procedures
- quality control
- data handling

Eventually the quality assurance program for Integrated Global Background Monitoring Network must be developed around all of the above elements. This will help ensure data comparability amongst sites.

Currently, our quality assurance activities concentrate on analytical methodology, sampling, sample handling procedures and quality control. Examples of a few of these procedures are described below.

Field sampling must be as representative as possible. Terrain considerations sometimes preclude totally random sampling. In these cases, a grid sample is sufficient. Sample handling is minimized. All vegetation, forest litter and soil samples are composite samples made up of a minimum number of 10 subsamples. These samples collected for trace elements in the field are placed in clean plastic bags. Each set of 10 subsamples is collected wearing a new pair of plastic gloves. Plastic bags and gloves are not used when sampling for trace organic compounds. Similar procedures are followed in the laboratory to minimize handling and potential cross-contamination. Water samples for trace elements are placed in acid washed polyethlene bottles. Both filtered and unfiltered samples are collected and samples are acidified with ultrex nitric acid in the field.

Extreme care is taken with air samples for trace elements and sulfates, nitrates, and other pollutants that can be trapped on filter media. All sample heads are triple bagged in Class 100 laboratories, and all subsequent analyses take place in Class 100 laboratories. Additional details are available from Wiersma (1981[a]), Davidson et al. (1985), Wiersma and Brown (1980) and Wiersma et al. (1978).

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

THE INTEGRATED MONITORING PILOT PROJECT

At a series of United Nations interagency and expert group meetings in Geneva and Nairobi (Anon, 1980) in the early 1980's, steps were taken to effect the recommendations described in the Background Monitoring section of this paper. UNEP agreed to establish background integrated monitoring in three biosphere reserves as part of the renewable resource monitoring component of GEMS, in cooperation with WMO and UNESCO. The reserves were to be located in Chile, the Soviet Union (USSR) and the US.

A tentative design for monitoring basic ecological processes as well as pollutants was established (WMO, 1980) and a project implemented initially in two Biosphere Reserves: the Torres del Paine National Park in Chile and the Olympic National Park in the US. Thus, in accordance with the various recommendations, GEMS is now using the biosphere reserves as part of its terrestrial renewable resource monitoring programme.

The pilot network has the following objectives:

- To develop a strategy and guidelines for global integrated background monitoring (site selection, sampling programs, sampling procedures, parameters monitored, data reporting and handling, etc.) on a routine basis, using the most cost efficient approaches;
- to establish reference levels for pollutants that have already produced low-level, global contamination;
- to establish baseline levels for selected ecosystem parameters against which data from more polluted areas could be compared; and
- to serve as an early warning system for detecting long-range transport of pollutants and changes in ecosystem processes.

This project has now substantially progressed. Cooperating national level agencies are the U.S. Park Service, National Atmospheric Deposition Program, Global Precipitation Chemistry Project, NASA Global Habitability Project, U.S. MAB/U.S. State Department, DOE - Idaho National Engineering Laboratory, U.S. Environmental Protection Agency, and the U.S. Forest Service, and CONAF (Corporacion Nacional Forestal) in Chile, Meteorological Service of Chile, and independently cooperating, the USSR State Committee for Hydrometeorology and Control of the Natural Environment.

Cooperating Universities are: University of Santiago - Chile, Magellanes University - Chile, Oregon State University, and Carnegie-Mellon University.

In the USSR, there have been many activities in the area of background integrated monitoring. Rovinksy and Buyanova (1982) describe 22 background locations in the CMEA (Council for Mutual Economic Assistance) countries. Rovinsky et al. (1982) also describe three sites within the Soviet Union at which integrated background monitoring is taking place. These are Borovoje, Berezinsky and Repetek. Rovinsky et al. (1983) reported on background monitoring in the Berezinsky Biosphere Reserve. They describe the sampling locations, the monitoring program, and results carried out from 1980 to 1982. In addition, there is also an excellent background monitoring site at the Caucasus Biosphere Reserve (Figure 1). It is hoped that a joint coordinated monitoring effort can be established between the U.S. and the USSR under the auspices of the US-USSR Bilateral Agreement on the Environment, Project on Biosphere Reserves. This would jointly contribute to the UNEP/GEMS project. Hopefully, additional countries will join in the near future.

CURRENT ACTIVITIES AT TORRES DEL PAINE NATIONAL PARK AND OLYMPIC NATIONAL PARK

The foregoing discussion presupposes sufficient funds and such is never the case. Therefore, the projects in Chile and the U.S. reflect the principle as stated, but operate at levels consistent with currently available funding. The data sets collected in Torres del Paine National Park and Olympic National Park will be integrated using the systems approach as described and referenced in a previous section of this paper.

Torres del Paine National Park

The following activities are underway at Torres del Paine National Park (Figure 2 and Figure 3).

A Strohlein HV 150 high volume air sampler is being operated according to specifications required by WMO. Sampling times are for alternate 10 day intervals. Samples are analyzed for Al, Ba, Ca, Fe, Mg, Mn, Na, Ti, Ag, As, Cd, Cu, Pb, and Zn. A low volume solar powered air monitor is also operating and samples are analyzed for the same elements as above but also include SO_4, NO_3, Br, and F.

Only wet deposition samples are collected. Dry deposition samples are planned, however they will be held in abeyance until an internationally accepted standard dry deposition sampling procedure is developed. Two wet deposition samples are operating at the park. One is an Aerochem-bucket sampler (two buckets) operated by the Global Precipitation Chemistry Project. The second sampler is an Erni automatic one bucket sampler. For the first year of the study, samples from both devices will be analyzed by the Global Precipitation Chemistry Project. In the second year, samples will be split between the IAEA laboratory in Vienna and the Global Precipitation Chemistry Project. A DeSaga automatic impinger sampler, prepared for sampling SO_2 will also be used to sample SO_2 in the park.

Water samples are collected monthly from a stream draining the water shed containing the reference stand. Vegetation is collected twice a year, and soil and forest litter samples are collected yearly in a reference stand located just to the west of the major Cordillera in the Park. The samples are analyzed presently for 20 to 30 trace elements using spark source emission spectroscopy and inductively coupled plasma emission spectroscopy.

The reference stand is a mature lenga stand (Nothofagus pumilio). It was selected to be representative of the characteristics of mature lenga stands in the area. Detailed ecological studies are currently being designed by the University of Chile staff. These studies will follow the same general approach as outlined in the section on key ecosystem parameters. Actual measurements will be analagous to those made at Olympic National Park.

A quality assurance program has been instituted for this project. Weather parameters are also measured in the Park.

Olympic National Park

The following activities are underway at Olympic National Park (Figure 2 and Figure 4).

A low volume air sampler is currently operating in a clearing in the established research stand in the Hoh River Valley. A high volume air sampling station is being established at a site yet to be determined. Its siting is critical to avoid local contamination from slash burning, campfires and parking lots. Analyses will be the same as for Torres del Paine National Park with the addition of nitric acid in the high volume air samples. Sampling periods are approximately the same as for Torres del Paine National Park. It is also planned to eventually sample SO_2, NO_x, O_3 and CO_2.

As in Chile, dry deposition measurements are not being made at this time. Wet deposition samples are being collected at an NADP* sampling station at the Hoh River Ranger Station.

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* National Atmospheric Deposition Program

The reference stand is located at the Twin Creeks Natural Research Area in the Hoh River Valley. Water, soil, forest litter, and vegetation samples are being collected at this site. Analyses are for trace elements by spark source emission spectroscopy and inductively coupled plasma emission. In addition, priority pollutant scans for approximately 100 organic compounds are being made on the soil, litter and vegetation samples.

The reference stand has been established. It is primarily a Sitka Spruce - Western Hemlock ecosystem. Six ecosystem parameters are being measured. These are:

1. Lichen productivity,
2. moss productivity,
3. leaf litter fall,
4. litter decay rates,
5. nutrient flux in the soil, and
6. needle population structure.

In addition, a significant study is also underway by the University of Washington on nutrient cycling on a watershed basis in the same area.

A quality assurance program has been instituted for this project. Weather parameters are being collected at the park, within the stand, and are also available from the U.S. Weather Service Station at Quillayute.

The Berezinsky Biosphere Reserve

The 76000 ha area includes 63000 ha mixed forest, 1000 ha meadows, 1800 ha water bodies, the rest being swamps, marshes, heathlands, and forest clearings. Since the area is not extremely far from built up and industrialized locations, the impact of man's activities can be directly observed, which was an intended characteristic for its selection. The abiotic sampling program, introduced in 1980 includes sampling and analysis for lead, mercury, cadmium, arsenic, 3,4-benzpyrene, DDT, DDD, DDE, some organics, aerosols, SO_2 and O_3, as appropriate in air, precipitation, surface water, bottom sediments, soil, and vegetation. The sampling program is adjusted to obtain monthly averages.

A PROPOSED GLOBAL NETWORK OF BACKGROUND MONITORING SITES

The pilot network, to be truly effective, must eventually be expanded to give a greater coverage of representative biomes of the world. The preceding description gives an idea of the type of monitoring of pollutants and ecosystem parameters that could take place on a much wider network of background monitoring sites. Estimates vary of the number of sites necessary for a representative global coverage. Rovinsky and Byuanova (1982) estimated that 30 to 40 sites would be needed. Jensen (1971) estimated 20, with at least two stations in each of the following biome types: deciduous forest, coniferous forest, tropical forest, savanna, thorn scrub, grasslands, desert and tundra.

There are 226 Biosphere Reserves in 62 countries; forty are located in the US. Obviously, the existing Biosphere Reserves are far too many for an operational global network. Moreover, many of them are not suitable. Wiersma (1981[b]) examined the Biosphere Reserve system in some detail in order to determine which reserves were possibly suitable for background monitoring.

In the following pages, there is an attempt to identify a subset of reserves that are most suitable for background monitoring. The establishment of selection criteria is critical to making an effective choice. The most applicable criteria would seem to be those established for the WMO Background Monitoring Stations as modified in 1979 (WMO 1979).

A second set of site selection criteria was presented by WMO in 1980. They appear more directly applicable to the selection of Biosphere Reserves for background pollutant monitoring. With the removal of reference to specific sites which are not appropriate to this discussion, these criteria formed the basis for the final selection criteria used. These selection criteria were then divided into two categories: 'mandatory' and 'desirable'. A site to be selected had to meet the mandatory criteria but not necessarily the desirable criteria. Both sets of criteria are described in Table 1.

The actual selection of a subset of the reserves based on the above criteria is preliminary at this time. The selection was made based only on the information present in the Directory of Biosphere Reserves (UNESCO, 1979). This directory covered the 171 biosphere reserves established at that time. The number of biosphere reserves currently in the system has expanded and the new additions should eventually be reviewed for possible use in a background monitoring network. Also, additional information is necessary to develop a final list. Examples where additional information would be needed beyond that found in the

Directory of Biosphere Reserves are:

1. Inventories of pollutants' emissions and anthropogenic activities within several hundred km of the study area and for a foreseeable future time.
2. More information on availability of flora and fauna data.
3. More information on past and current research programs.
4. Review of existing data bases covering physical data sets (i.e., meteorology, hydrology, soils, etc.)
5. More details on the site facilities available.
6. Evaluation of reserve position vis a vis major air mass.
7. Evaluation of the reserve's situation with regard to major climatic regimes (including types of prevailing air masses).
8. Ability and willingness of host country to carry out pollutant monitoring program.
9. Types and quality of graphical support data (i.e. maps, aerial photographs, satellite photographs.

Also, the final selection of integrated global background monitoring sites should not necessarily be limited to Biosphere Reserves only. Other sites should be considered as appropriate.

Using the ten criteria defined in this paper, an initial screening of the 171 reserves listed in the Directory of Biosphere Reserves yielded 41 potential reserves for background monitoring (Table 2). The geographical distribution of these reserves is shown in Figure 2. In general, they present a good distribution pattern on a global basis.

Distribution by Udvardy geographical provinces and biomes is also shown in Table 2. The 41 reserves cover eleven of the fourteen potential biomes. Certain biomes are more heavily represented than others. The mixed mountain and highland systems zone has a large number of reserves. Other biomes with a relatively large number of reserves present are the tropical dry or deciduous forests and the subtropical and temperate rain forests.

CONCLUSIONS

The current experience in integrated monitoring in Biosphere Reserves, an examination of the criteria for background monitoring and an examination of the characteristics of existing Biosphere Reserves, leads to the following conclusions:

1. An integrated global background monitoring network for pollutants and ecosystem processes should be established.
2. Pollutant measurements should be made simultaneously in a number of environmental media.
3. Cross-correlated ecosystem parameter studies should be carried out simultaneously with pollutant measurements.
4. Monitoring in the proposed international network should be continuous and open-ended.
5. The proposed network should consist of sites chosen as appropriate from the international MAB Biosphere Reserve system.
6. The network should be under the overall coordination of the Global Environmental Monitoring System (GEMS) of UNEP, and, as such, it should be operated in close cooperation with the Background Air Pollution Monitoring Network (BAPMoN) which is managed by WMO.

Table 1. Selection Criteria

Mandatory Criteria	Desirable Criteria
1. Size. The size of a reserve can help ensure that several of the WMO integrated monitoring site selection criteria can be met. For example, adequate size will help minimize local influences. It would help ensure that an adequate core area existed and would help shield it against changes in economic activity in surrounding areas. Size chosen was 20,000 ha.	1. Undeveloped surrounding areas. This would ensure the size and existence of a buffer zone. This criteria, however, was partly met by a mandatory criteria on size; and, therefore, this criteria was listed as a desirable rather than a required criteria.
2. Access. The area should be reasonably accessible, but intensive activities such as a large number of automobiles, etc. should be restricted.	2. No history of disturbance. While this would ensure a natural ecosystem in the reserve, in practice it would be difficult to find very many of the reserves that can meet this criteria absolutely.
3. Protection. The area should have institutional protection (i.e. government/state) in perpetuity. This will not only help protect the area, but in some cases could significantly alter economic development in the surrounding areas.	3. Permanent staff greater than five. This is based on the premise that the larger the resident staff, the greater is the possibility that the reserve will have suitable facilities and ongoing activities that would be useful to the monitoring program.
4. Staff. The reserve should have a permanent staff. This will increase (but not guarantee) the probability that the following services will be available: i) protective oversight; ii) scientific studies; iii) logistical staging areas; and iv) personnel available to carry out routine measurements (i.e., change sample filters).	4. Scientific research underway. Three kinds of research were envisioned: i) pollutant monitoring (abiotic monitoring), ii) impact studies - these could include pollutant monitoring, and iii) basic ecology studies.
5. Vegetation. The reserve should have a vegetation type approximately representative of a major biogeographical type in the world.	5. Data availability. The presence of background data for a reserve is not ensured merely because research activities are underway. Examples of data that are essentially required are: meteorological, hydrological, geophysical, soils, geohydrological and biological. The latter would include items such as species lists, forest type, maps, census data, etc.

Table 2. Biosphere reserves selected as candidate sites for Integrated Global Background Monitoring Network

Biosphere reserve	Realm	Biogeographical province	Biome
Conservation Park of South Australia, Australia	Australian	southern mulga/ saltbush	warm deserts and semi-desert
Fitzgerald River Park, Australia	Australian	western sclerophyll	evergreen sclerophyll
Prince Regent River Nature Reserve, Australia	Australian	northern coastal	tropical dry or decidous forest
Southwest National Park, Australia	Australian	Tasmanian	subtropical and temperate rain forest
Parque Nacional Pilon-Lajas, Bolivia	Neotropical	Maderian	tropical humid
Reserve Biologica de Ulla Ulla, Bolivia	Neotropical	Puna	mixed mountain highland
Waza National Park, Cameroon	Africotrop-ical	Western Sahel	tropical dry or deciduous
Waterton Lakes National Park, Canada	Nearctic	Rocky Mountains	mixed mountain and highland
Bamingui Bangoran Conservation, Central African Republic	Africotrop-ical	West African woodland	tropical dry or deciduous
Laguna San Rafael National Park, Chile	Neotropical	Chilean Nothofagus	subtropical temperate
Torres del Paine National Park, Chile	Neotropical	Southern Andean	mixed mountain and highland
Parc National d'Odzala, Congo	Africotrop-ical	Congo rain forest	tropical humid forest
Trebon Basin Reserve, Czechoslovakia	Palaearctic	Central European highlands	mixed mountain
Northeast Greenland National Park, Denmark	Nearctic	Arctic desert and icecap	tundra communities
Rio Platano, Honduras	Neotropical	Central American	tropical dry or deciduous

Biosphere Reserve	Realm	Biogeographical Province	Biome
Parc National de Tai, Ivory Coast	Africotropical	Guinean rain forest	tropical humid
Mount Kenya Biosphere Reserve, Kenya	Africotropical	East African highlands	mixed mountain and highland
Reserve de la Michilia, Mexico	Nearctic	Madrean-Cordilleran	mixed mountain and highland
Northeast Svalbard Nature Reserve, Norway	Palaearctic	Arctic desert	tundra communities
Reserva de Huascaran, Peru	Neotropical	Southern Andean	mixed mountain
Reserva del Manu, Peru	Neotropical	Amazonian	tropical humid forest
Reserva del Noroeste, Peru	Neotropical	Equadorian dry forest	tropical dry or deciduous
Slowinski National Park, Poland	Palaearctic	Middle European forest	temperate broad leaf
Swiss National Park Switzerland	Palaearctic	Central European highlands	mixed mountain and highland
Aleutian Islands National Wildlife Refuge, USA	Nearctic	Aleutian Islands	tundra communities
Desert Experimental Range, USA	Nearctic	Great Basin	cold winter desert
Everglades National Park, USA	Neotropical	Everglades	tropical dry or deciduous
Glacier National Park, USA	Nearctic	Rocky Mountains	mixed mountain and highland
Great Smoky Mountains National Park, USA	Nearctic	Eastern Forest	temperate broad leaf
~~Mount McKinley~~ National Park, USA	Nearctic	Yukon Taiga	temperate needle leaf forest

Biosphere Reserve	Realm	Biogeographical Province	Biome
Noatak National Arctic Range, USA	Nearctic	Alaskan tundra	tundra communities
Olympic National Park, USA	Nearctic	Oregonian	subtropical and temperate rain forest
Rocky Mountain National Park, USA	Nearctic	Rocky Mountains	mixed mountain and highlands
Three Sisters Wilderness, USA	Nearctic	Sierra Cascade	mixed mountain and highland
Yellowstone National Park, USA	Nearctic	Rocky Mountains	mixed mountain and highland
Berezinsky Biosphere Reserve, USSR	Palaearctic	Middle European forest	temperate needle leaf forest
Caucasian Biosphere Reserve, USSR	Palaearctic	Caucaso-Iranian Highland	mixed mountain and highland
Repetek Biosphere Reserve, USSR	Palaearctic	Turanian	cold winter desert
Sikhote-Alin Biosphere Reserve, USSR	Palaearctic	Manchu-Japanese mixed forest	temperate needle leaf forest
La Reserve Ecologique du Bassin de la Riviere Tara, Yugoslavia	Palaearctic	Balkan Highlands	mixed mountain and highland
The Velebit Mountain, Yugoslavia	Palaearctic	Central European Highland	subtropical and temperate rain forest

Figure 2. Biosphere Reserves potentially suitable for biosphere reserve monitoring.

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Figure Captions

Figure 1. Caucasus Biosphere Reserve. A Soviet background monitoring site.

Figure 3. Torres del Paine National Park. Part of the international biosphere reserve system and a pilot site for integrated global background monitoring.

Figure 4. Olympic National Park and Biosphere Reserve. This is a pilot site for integrated global background monitoring.