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GEMS: Global Environment Monitoring System

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BIOLOGICAL MONITORING (PLANTS)

EXECUTIVE SUMMARY

Technical Report

Prepared by
MONITORING AND ASSESSMENT RESEARCH CENTRE
King's College London, University of London

With the support of:
UNITED NATIONS ENVIRONMENT PROGRAMME

Biological Monitoring of Environmental Contaminants (Plants)

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EXECUTIVE SUMMARY

1. Introduction

A wide range of contaminants enter terrestrial, freshwater and marine habitats. Concentrations of specific contaminants can be measured by physicochemical methods; however, the response of plants to elevated concentrations is modified by other environmental factors such as moisture and nutrient status, by interactions between contaminants and by the physiological stage of the plants. The integrated effects of these factors and contamination are assessed by monitoring the plants directly. Their sensitivity to some contaminants may lead to visible injury, which can indicate the presence of elevated concentrations in the environment; in other cases, tolerance to high concentrations can be utilized in identifying contamination through chemical analysis of tissues. Effects on species distribution and on morphology, growth rates and metabolism can also be examined in relation to pollutants. Accumulation and effects of metals, organic and gaseous contaminants and radionuclides have all been investigated in a great variety of plant species. In addition to measuring deposition to plant surfaces and thus estimating inputs to ecosystem components, biological monitoring methods can be used to estimate the incorporation of contaminants into food chains and the economic importance of changes in productivity of agricultural and forest crops.

2. Terrestrial environment

I Metal pollutants

Emissions from mining, metal processing industries, from automobile exhausts and from fossil fuel combustion are the main sources of metals which can be monitored with plants. The majority of surveys have been analytical, and concentrations of selected metal contaminants, Pb, Zn, Cu and Cd in particular, have shown the spatial distribution of contamination in relation to distance from sources and in relation to changes in emission levels with time. Lichens and mosses have been the most frequently sampled plants and reflect the deposition of metals from localized sources and also on a regional scale. Foliage and other plant parts of trees, herbaceous species and field crops also have been sampled to detect contamination, though uptake from contaminated soil via the roots has to be considered in addition to deposition to foliage. Where dietary intake and food chain bioaccumulation are of concern, both sources are important. Plant species which accumulate exceptionally high concentrations of particular metals are known from several plant groups including fungi which appear to accumulate several metals to potentially toxic levels for consumers. Monitoring of metal concentrations in plants is only occasionally compared with soil or atmospheric levels. Changes in fungal species distribution occur in highly contaminated areas. Reported effects of metal contamination on plants include cellular injury, reduced rate of metabolic processes and growth and foliar damage which are species and metal dependent. Deposition of metals has been measured after specified periods by means of transplants of mosses, lichens and of higher plants to locations with different degrees of contamination.

II Organic compounds

Few data are available for analytical surveys of plants compared with those of fauna. Accumulation of PAH, PCBs and several pesticides has been demonstrated in the foliage of rooted plants and in epiphytes including mosses and lichens. On a regional scale, it appears that the spatial distribution of pesticides measured in plants can be related to the use pattern.

III Gaseous pollutants

A very large volume of information is available, dealing chiefly with visible injury to plant foliage and on the effects of gaseous pollution on the distribution of sensitive species, of mosses and lichens in particular. These have, in a few well-investigated cases, been shown to correspond to the air concentration of pollutants. Emissions of SO_2 from fossil fuel combusion and from industrial processes have the clearest effects on distribution; elevated concentrations of SO_2, F and O_3 and other photochemical oxidants may cause visible injury to foliage and reduce productivity. Other effects include ultrastructural damage to cells, injury to leaf surface wax and changes in enzyme activities. Analyses of S in plants are not often reported, but levels appear to reflect the higher concentrations present in the vicinity of sources.

Accumulation of F in various species increases with time of exposure and proximity to emission sources in foliage of higher plants and in mosses and lichens. Injury to transplanted mosses and lichens and accumulation can also be measured. Sensitive cultivars of higher plants which show pollutant-specific injury symptoms can be used as bio-indicators on a semi-quantitative basis: homogeneous populations are transplanted in a network of sites and foliar injury monitored at regular intervals. Analysis of the foliage can provide information on the distribution of gaseous pollutants.

IV Radionuclides

Concentrations of fall-out radionuclides, in particular ^{137}Cs, from testing of atomic weapons have been monitored in plants, and data for determinations in lichens, for example, show time trends; peak levels were recorded in the 1960s and have subsequently declined. Important components of food chains have been monitored, chiefly in lichens in the chain from lichens to reindeer to man in arctic regions, and of pasture grasses for estimating contamination of milk. Radionuclides from nuclear processing facilities can be monitored in plants to show the pattern of deposition in relation to distance from source.

3. Freshwater environment

I Metal pollutants

Elevated metal concentrations in rivers and lakes are found in the vicinity of mining and metal processing industries, and a wide range of other industries discharge metal-containing effluents into freshwater systems. Levels of metal accumulation in submerged species of plants show a better relationship to concentrations in water than those in emergent species. Algae have been monitored chiefly for their species distribution in relation to metal contamination, though a few macro-algal species, together with bryophytes, pteridophytes and angiosperms have been sampled for chemical analysis. Analytical data have yielded the major information on monitoring of metals using freshwater plants. High bioaccumulation allows the detection of metals present at very low concentrations in water. Transplanted samples also accumulate metals relative to the degree of contamination and length of time of exposure.

II Organic compounds

Few data are available on interactions of organic chemicals with plants in fresh water contaminated by industrial effluents and run-off from agricultural land. From the few surveys conducted, high accumulation and retention of pesticides indicate that plant analysis could provide information on distribution and on pollution episodes, where levels are below detection in water samples except for short time periods. Very extensive surveys of plant distribution have been carried out in fresh water polluted by high levels of organic matter from agricultural or domestic wastes. Changes in the species composition of algal communities have provided the basis for pollution indices which may be applied for assessments of water quality in conjunction with indices based on the invertebrate fauna.

III Radionuclides

Detection of radionuclides in freshwater plants has demonstrated accumulation in the vicinity of nuclear processing facilities and industrial effluents. Levels in submerged mosses and angiosperms have been monitored but there are very few data.

4. Marine environment

I Metal pollutants

Seaweeds, mainly the brown algae, have been analysed for metals fairly extensively to detect gradients of contamination in coastal waters, particularly where mining and industrial effluents enter the sea. Whole fronds can provide data on average concentrations, and analysis of shoot tips has indicated that short-term fluctuations can be detected. Estuarine algae also reflect the metal concentrations in water.

II Organic compounds

Elevated concentrations of organochlorine compounds have been detected in phytoplankton samples. Estuarine and coastal seaweeds have also been monitored to show spatial and time trends in levels of PCBs and organochlorine compounds. Populations of marine algae which may initially be depressed by oil pollution incidents seem able to recover fairly rapidly; more attention has been paid to monitoring the recovery of plant communities than to details of adverse effects of oil pollution. Changes of species dominance in algal communities have been described in water enriched in organic matter from sewage effluents.

III Radionuclides

Radionuclide contamination of seaweeds, chiefly the brown algae, is monitored to detect time trends and levels of contamination in waters receiving effluents from nuclear processing facilities. Bioaccumulation allows detection of radionuclides, for comparative purposes, more readily than direct measurement of concentrations in water samples.

5. Conclusions

A large amount of data has been reported on monitoring of plants in contaminated environments. Knowledge of contaminant concentrations, which can be obtained by physicochemical methods, does not necessarily indicate their significance to plant populations and communities within ecosystems. Accumulation within plants facilitates analysis of contaminants which may be present at very low levels in the environment and may show the spatial distribution and changes in the level of contamination with time. Effects on species distribution within plant communities and visible injury to foliage may also be related to levels of contamination. These approaches are applicable to many types of aquatic and terrestrial habitats and, since plants form the major part of the living biomass in ecosystems, species can be selected which are appropriate to the area and the contaminant to be monitored. Species used to investigate the input of contaminants from atmospheric deposition, for example, may differ from those used to assess transfer through food webs.

Mosses and lichens have been particularly widely used in many countries to show the distribution of metals and radionuclides on local and regional scales and also, more recently, of pesticide contamination. Visible injury to foliage of higher plant species may reflect atmospheric concentrations of gaseous pollutants and monitoring networks of transplanted sensitive species can provide information on contaminant levels on a regional scale. Changes in species composition, especially of lichens, have also been related to the degree of contamination.

In view of the complex interactions between contaminants and other environmental factors, biological monitoring forms an essential part of scientific investigations in contaminated areas. The methods adopted for using plants in monitoring programmes need to be examined in a wide range of habitats to obtain reliable information which is relevant to the long-term functioning of ecosystems.

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The objective of the MARC core research programme is to develop and apply techniques for the assessment of pollution problems of global, regional or local significance. The programme is mainly carried out by means of reviews which synthesize existing relevant knowledge from a wide range of disciplines.

MARC currently receives financial support from the United Nations Environment Programme (UNEP) and the World Health Organization (WHO).

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