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ORIGINAL: ENGLISH

UNITED NATIONS ENVIRONMENT PROGRAMME

WORLD HEALTH ORGANIZATION

REPORT OF THE MEETING OF A GOVERNMENT EXPERT GROUP ON HEALTH-RELATED MONITORING

Geneva, 28 March - 1 April 1977

I. Introduction

1. The meeting[1] was opened on behalf of the Director-General of the World Health Organization by Dr Vouk, Chief, Control of Environmental Pollution and Hazards, who welcomed the Government Experts and said that the subject before the meeting was not new to WHO as the epidemiological surveillance of communicable disease, for example, was already an established programme. The monitoring programme covering chemical contamination of the environment dated back to the WHA Resolution 24.47 adopted in May 1971, which emphasized the need for national and international efforts in the development of epidemiological health surveillance. Two years later following the establishment of UNEP, the 26th World Health Assembly requested the Director-General to accord high priority to "the development of systems for the monitoring of pollutants and other environmental factors that may be harmful to health in air, water, food, soil and the working environment". A meeting of experts was therefore convened in July 1974 in Geneva to prepare the framework for a WHO environmental health monitoring programme. WHO, working with UNEP, has established an operational programme within GEMS and studied the methodological problems of health related monitoring. Dr Vouk outlined the operational programme indicating the agencies which were associated with the various aspects of it.

2. In welcoming the Government experts on behalf of the Executive Director of UNEP, Dr Sella outlined the aims of the Global Environmental Monitoring System and the activities carried out under its aegis. These fell into four major categories - health-related monitoring, climate-related monitoring, monitoring of the oceans and ecological monitoring of the soil and vegetation cover. Groups of Government experts had been convened earlier to consider ecological and ocean monitoring. This Group would be concerned with health-related monitoring and should aim at providing the Executive heads of UNEP and WHO with advice on how to integrate current activities and supplement them with additional ones that would make possible the assessment of human exposure to pollutants. Dr Sella asked the participants to consider carefully the proposals that were contained in the background paper in order to evaluate their adequacy and to indicate where modifications and adjustments were required. It would then be up to the two Organizations to find the means for the early implementation of the recommendations of the Group. UNEP expected that the recommendations of the Group would greatly contribute to the development of a coherent, comprehensive and strongly interlinked programme for effectively monitoring chemical pollutants that threatened human health.

3. The Government Expert Group (hereafter referred to as the Group) elected Dr Ordonez de la Mora and Professor Biersteker as Chairman and Vice-Chairman respectively. Dr Buxton was appointed Rapporteur of the Group.

II. Recommendations

4. The Working Group reviewed the background paper on health-related monitoring.[2] In general it was felt that the document was well written and the proposals well motivated. The Group thus recommended that the proposals be implemented, taking into consideration the following detailed comments and recommendations. These follow the background document. When comments or recommendations are not given in regard to specific sections, this implies that the Working Group did not see any reason to modify what was proposed in the background document.

A. Current activities

5. Current activities were not discussed in any detail as there was not enough information in the background document to make such a discussion fruitful. After receiving additional information from the Secretariat the Group felt, however, that the activities should be continued and whenever possible, integrated with the new activities proposed.

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[1] The list of participants at the meeting is attached (Annex 1)

[2] See Annex 2

B. Proposed activities

1. General

6. All Member States should eventually be encouraged to take part in the proposed study. Initially, however, the study should be conducted on a limited scale but should, from the start, involve developing countries. When necessary, these countries should be assisted as far as possible under the programme to acquire the expertise and equipment required for their participation. The initial study should also be limited with regard to the selection of pollutants, but participating countries could expand their activities to include additional pollutants to which they attached particular importance. In meeting the aims indicated in paragraph 27 of the background document, the study should include actual sampling and analysis of biological specimens from the start. The initial phase of the study should be completed within a period of about three years.

7. Because environmental monitoring (air, food, and water) may not always yield information of immediate relevance to the assessment of human exposure, the Group emphasized the need to integrate the biological monitoring activities proposed with ongoing environmental activities. However, in order that the programme might be implemented at an early date, biological monitoring might be started in some cases even if environmental monitoring had not yet started. The Group also noted that a number of biological monitoring programmes were already in progress in several countries and underlined the benefits to be gained by these countries and by GEMS from close coordination of the respective programmes.

8. The Group considered that the selection of substances proposed in the background document was appropriate for the initial phase of the study, and did not think it necessary to indicate priorities among the substances.

9. With regard to populations to be studied, the aim should be to select segments of populations from defined geographical areas with a view to establishing representative background data on the exposure of general populations. In addition, participating countries might consider that such data could also include information concerning groups at higher risk from the known pollutant (in terms of exposure and/or sensitivity) to obtain a more comprehensive assessment of the health risk. However, the assessment of occupational exposure would not be part of this study.

10. It is of greatest importance that the groups from the different countries should be comparable with each other, e.g. policemen or pregnant women. The groups should be described carefully with reference to age, sex, ethnic origin and socio-economic conditions. It is also important to obtain data on smoking habits, nature of residence, occupation, and food habits. For this purpose, a short questionnaire should be used in connection with each project on biological monitoring. Further specific recommendations are given in the sections dealing with selected pollutants.

11. While the group did not feel it advisable to recommend specific analytical methods, it emphasized the need for the successful implementation of the programme, of rigid quality control procedures ensuring comparability of results between methods and laboratories. The development of this aspect of the programme, including intercalibration and the provision of reference samples, should be assigned the highest priority and particular attention should be paid to the need for minimizing the contamination of samples by appropriate choice of instruments, containers, and other relevant equipment. Because the programme would be carried out in different countries, a training programme for participating countries should be developed with a view to briefing the scientists responsible for the national programmes and training the technicians who would undertake the sampling and analytical work.

12. As will be seen in later sections, analyses of blood samples is often recommended. Wherever feasible the same samples should be used for the simultaneous determination of the various elements in question. The possibility of analysing hair samples for several elements simultaneously should also be considered as this may be a convenient non-invasive technique. Great caution, however, must be exercised in regard to contamination from different external

sources, both of hair in vivo and of the collected samples. Because of the potential value of hair sample analyses and of the possible fallacies that may be involved, the Group recommended that a small group of experts should be convened as soon as possible to discuss the extent to which hair analyses could be used in connection with the biological monitoring of the metals chosen for the present study. Such a meeting could be organized through the International Atomic Energy Agency.

13. The Group recommended that the ethical problems arising from the implemention of the programme should be given due consideration. These are likely to differ from country to country.

2. Sulfur oxides and particulates

14. It was recommended that more developing countries should be included in the ongoing programme since the air pollution situation in such countries might be quite different from that in industrialized countries and might require different approaches to monitoring. On the other hand, the number of pollutants monitored in the ongoing programme should be expanded as soon as possible at least to include oxides of nitrogen and photochemical oxidants. The possibility of including carbon monoxide monitoring should also be considered.

15. Isopleths should be prepared for a few large cities known to be significantly polluted, in order to provide data on the size of the populations exposed to different levels of pollutants. Local meteorological organizations should be involved in the programme in order that meteorological variables may be taken fully into account. Indoor air quality and its relation to the ambient air quality needs further particular attention.

3. Lead

16. The background document recommended the selection of children as the population to be monitored. The Group felt that children represented an important group but that other age groups should be included as well, in order to assess the exposure of the general population.

17. The background document recommended that lead, ALA-D and protoporphyrins should be determined in blood. However, because of the analytical difficulties involved in the other methods, the Group felt that only analyses of lead in blood should be made obligatory. This, however, should not prevent countries from conducting the other analyses as well, if they felt it feasible and appropriate. The Group indicated that determinations in hair samples could provide useful information of past exposures to lead.

18. In analysing results, account should be taken of seasonal variations in lead levels.

4. Cadmium

19. The Group agreed on the desirability of determining body burdens by measuring cadmium levels in liver and kidney obtained at necropsy. These would provide information on the cumulative exposure of the individual. In addition the Group, while aware of the analytical difficulties, recommended that the current exposure should also be assessed, by means of analyses of blood and/or faeces. Hair measurements could also be used to supplement these, but caution should be exercised to guard against external contamination of the hair.

20. Renal or hepatic pathology which could be attributed to cadmium exposure should not be a reason for exclusion of individual samples, but should be assessed and recorded whenever applicable.

5. Mercury

21. Mercury exposure should be assessed in individuals representative of the same population considered for the assessment of lead and cadmium. However, because regular fish eaters[3]

[3] Regular fish-eaters here refers to individuals consuming a substantial amount of freshwater or sea fish, or other seafood daily.

are the only section of the population likely to have appreciable mercury body burdens, this population segment should also be included in the study as a separate group.

22. The biological specimens taken for mercury assessment should consist of blood and hair (provided the possibility of external contamination can be excluded) as indicators of mercury exposure. Hair analysis would be of particular value for the assessment of past mercury exposure.

6. Organochlorine compounds

23. The intake of organochlorines should be estimated through analyses of the total diet since a wide range of foodstuffs could be contaminated. Human milk would provide suitable material for assessing the exposure of lactating mothers and possibly of the general population of these compounds. Because organophosphorous compounds are widely used in a number of developing countries, some experts felt that consideration should also be given to the possibility of monitoring these compounds in the diet.

24. With regard to the statement in paragraph 68 of the background document concerning the adverse effects on child growth of organochlorine compounds in human milk, the group felt that the existence of such effects should be better substantiated before it could be accepted without serious reservations, since it might lead to the abandonment of breast feeding and consequent possible harmful effects on the child under unfavourable sanitary circumstances.

7. Organization

25. The Group agreed that it was premature to go into details regarding the organization of the project. Protocols would have to be developed when contacts had been made with individual countries and once it had been decided which countries should participate in the programme and which substances should be monitored in each. At this time details concerning sampling and sample treatment and analysis should be specified for each pollutant, taking into consideration all host and environmental variables that should be recorded to make the interpretation of results possible. At the same time decisions should be made as to which reference laboratories should be involved in the study at regional and global levels.

26. Strengthening of regional laboratories in developing countries should be supported by UNEP and WHO. Such strengthening would greatly facilitate the implementation of the entire programme.

27. Methods of biological monitoring will be discussed in detail at a workshop arranged by the Commission of European Communities in collaboration with the US Environmental Protection Agency and the World Health Organization. In preparing detailed guidelines for the implementation of the monitoring programme under discussion, note should be taken of the recommendations arising from that meeting.

28. The implementation of the proposed study would benefit from the establishment of a group to provide guidance on the scientific and technical aspects of various phases of the programme. The study should be reviewed periodically, particularly with regard to the choice of the pollutants to be included.

29. The Group noted that the implementation of the new activities recommended in the report would depend on the availability of other resources in addition to those already committed to current projects by international organizations.

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CEP/77.6

ANNEX 2

UNEP/WHO Group of Government
Experts on Health-Related
Monitoring

CEP/77.1

ORIGINAL: ENGLISH

Geneva, 28 March - 1 April 1977

HEALTH-RELATED MONITORING

(Background paper)

Note: This paper has been prepared by the UNEP and WHO Secretariats and with the assistance of consultants

CONTENTS

I. BACKGROUND

A. Introduction

1. The basis for a joint UNEP/WHO programme on health-related monitoring designed to assess human exposure to pollutants is described. This programme would be a component of the Global Environmental Monitoring System (GEMS).

2. GEMS is a coordinated effort on the part of Member States, United Nations Agencies and UNEP to ensure that data on environmental variables are collected in an orderly and adequate manner so as to provide a quantitative picture of the state of the environment and to determine the natural and man-made trends undergone by critical environmental variables, particularly at global and regional levels. In its broadest sense, GEMS is therefore a system which includes the different monitoring components operated by various members of the United Nations system.[a]

3. This paper was prepared by the WHO and UNEP Secretariats following two informal consultations of experts. The contributions of these experts (see Annex) are gratefully acknowledged but the responsibility for the paper rests with the Agencies' Secretariats.

4. The aim of the document is to present monitoring activities that are implemented within GEMS and to propose additional activities that will make possible the development of a coherent and comprehensive programme of health-related monitoring.

5. The Government Expert Group is requested to review the current activities and the proposed additions to them and to make recommendations on the value of the proposals and the possibilities of implementing them. It should be noted that the recommendations of the Government experts do not necessarily imply a commitment by the expert's country to participate in the programme.

B. Basic concepts of health-related monitoring

6. The adverse effects of many environmental agents - be they physical, chemical, or biological - on human health are already well established, although for many diseases an environmental etiology is only suspected - not proven.

7. In order to assess the hazards of pollution for human populations or individuals it is necessary to have a knowledge of the exposure to the pollutant. The exposure to a given pollutant is a measure of the contact between the pollutant and the outer or inner (e.g. alveolar surface or gut) surface of the human body. It is usually expressed in terms of concentrations of the pollutant in the medium (e.g. ambient air and food) interfacing with the body surfaces. Once absorbed through body surfaces, the pollutant gives rise to doses in various organs or tissues. Doses are measured in terms of concentrations in the tissues. Records of exposure and dose should include an indication of the time and frequency at which an individual is subjected to them.

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[a] Details on the GEMS activities will be provided in a separate information document.

8. In order to assess the exposure of human populations to environmental agents, an integrated approach to monitoring is required. In this manner the total exposure of a population at risk can be evaluated in terms of the relative contributions from each route of exposure. Once the relative contribution of each environmental pathway, e.g. air, water, food, has been determined, routine monitoring - for assessment purposes - can be limited to the critical routes, making monitoring more cost-effective. Thus, it is now known that methylmercury, a highly toxic form of mercury, reaches man mostly through fish and need not generally be monitored in other foodstuffs.

9. Environmental monitoring of pollutant levels in such media as air, water, food, or soil provides one approach to the assessment of human exposure. Another approach is provided by biological monitoring - the determination of pollutant levels (i.e. of doses) in human biological samples. If possible, these samples should be taken from the critical organs so that a direct measure of the relevant dose can be obtained. The critical organ is that in which the earliest detectable adverse effect occurs under specified conditions of exposure to a toxic substance in a given population. In some cases the concentration of a pollutant in other human tissues and fluids is related to the concentration in the critical organ or tissue and can therefore be used as an indicator of that concentration. Typical human tissues and fluids used for biological monitoring are blood, urine, hair, milk, liver, kidney, and bone. In some cases biochemical or morphological tissue changes may be used as indicators of the dose.

10. The immediate advantage of biological as compared with environmental monitoring is that in principle it makes it possible to obtain a direct measure of dose or exposure. Biological monitoring should be considered as an important adjunct of environmental monitoring, providing an essential link to health effects monitoring.

11. It is through environmental and biological monitoring that information on the magnitude of exposure to or dose of environmental agents in man is obtained. That information must then be related to the health effects produced by the pollutant. A direct causal relationship between the exposure to a single pollutant and the appearance of recognized biological effects has only been established in man in a limited number of cases. In other cases, which include some of the most important non-communicable diseases, the role of environmental agents is not well established, for the disease results from the combined action of a variety of environmental and host factors.

12. In spite of the difficulties, monitoring of diseases with suspected multi-factorial (including environmental) etiopathogenesis is an important task. Very serious changes in the incidence of some non-communicable diseases have been shown to coincide with the progress of industrialization in the developed part of the world and monitoring of these health effects is therefore of particular importance in the developing countries, where corresponding environmental changes can be expected to occur very rapidly in the near future.

13. Health effects monitoring could be achieved by linking existing mortality statistics and morbidity registries to environmental and exposure data. In addition epidemiological and occupational studies, and toxicological data derived from animal or biochemical experiments are required. Because important environmental effects may occur during the early period of life and in view of the good coverage of child populations by regular health examinations, existing or planned in many countries, monitoring of health effects in children, including malformations monitoring, deserves particular attention. However, health effects monitoring is not discussed in this paper but was considered recently by

a WHO Scientific Group.[b]

C. Objectives and benefits

14. The long-term objectives of any health-related monitoring programme are:

(i) to achieve an integration of environmental and biological monitoring for a total assessment of human exposure to pollutants through close coordination of all health-related monitoring activities in the various media;

(ii) to aid the elucidation of the dose-response relationships of specific environmental pollutants;

(iii) to determine risks to defined populations using easily determined and comparable monitoring data;

(iv) to predict future risks from present environmental practices.

15. The benefits that would accrue from the successful implementation of a comprehensive health-related monitoring programme are:

(i) identification of those human populations that are subjected to high exposures of environmental pollutants;

(ii) increased safety in the use of industrial and agricultural chemicals that are potentially harmful to human populations;

(iii) ability to provide early warning of environmental health problems;

(iv) provision of reliable information to the world public on specific environmental health problems;

(v) identification of relevant research problems in the area of health-related monitoring.

16. The additional value of undertaking such a comprehensive study at international level would be:

(i) the provision of the machinery necessary to obtain comparable data through international exchanges of analytical standards, and intercomparison and intercalibration of sampling and analytical methods;

(ii) the possibility of centralizing or regionalizing the training of technical personnel, particularly from developing countries, in the use of commonly recommended techniques;

(iii) the improvement of monitoring capabilities through the provision of an adequate amount of expertise and equipment to developing countries;

(iv) the possibility of a better utilization of world-wide analytical capabilities through the distribution of certain analyses to existing laboratories with spare capacity.

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[b] Monitoring of Health Effects of Environmental Agents. Report of a WHO Scientific Group, 7-13 December 1976

II. THE GEMS HEALTH-RELATED MONITORING PROGRAMME

17. The subsequent sections will:

(a) summarize the ongoing health-related monitoring activities in air, water, and food, and

(b) indicate the additional activities required to develop the programme into a coherent whole. These activities will include further measurements needed to assess the human exposure to SO_2 and suspended particulates and the biological monitoring of selected pollutants.

A. CURRENT ACTIVITIES

1. Air pollution

18. Air quality monitoring, implemented in cooperation with WMO[c] has as its principal objectives:

(a) collaboration with Member States in their efforts to establish and develop air monitoring systems needed to protect human health;

(b) international exchange of information on levels and trends of air pollution and the use of this information for the assessment and improvement of air quality.

19. Fourteen monitoring locations, in as many countries, provided data during 1973-76 on the levels of sulfur dioxide and suspended particulates. The project is being extended to some 70 cities in 50 countries giving an approximate total of 200 sampling stations. Among the pollutants measured, it is planned to include nitrogen oxides, carbon monoxide and the chemical analysis of suspended particulate matter. In each participating city, two or three sites have been selected. Usually one site is in an industrial area, another in a commercial area and a third in a residential area where there are no dominating industrial or commercial sources of air pollution.

20. Although measurement of ambient concentrations of sulfur dioxide and particulates at fixed stations serves as an index of urban pollution, it does not provide an adequate measure of human exposure. Some of the more specialized measurements required for that purpose are described in the pilot study outline.

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[c] A separate activity concerned with atmospheric monitoring is being implemented by the WMO with the aim of determining the long-term changes in air composition at sites distant from sources of pollution. The importance of these changes (e.g. in CO_2 content) is in relation to their possible effects on the stability of the climate.

2. Water quality

21. Water quality monitoring has recently been initiated in cooperation with UNESCO and WMO with the following long-term objectives:

(i) to collaborate with Member States in the establishment and strengthening of water quality monitoring systems;

(ii) to improve the validity and comparability of water quality data within and between Member States;

(iii) to assess on a global basis the extent and trends of pollution of surface water bodies by some persistent and hazardous substances.

The project covers selected surface fresh waters used for community water supply and is designed to operate at three levels: national, regional and global. Initially there will be approximately one station on average for each 5 million people.

22. The parameters to be determined fall into three categories:

(i) basic parameters for general assessment of water quality, such as temperature, pH, dissolved oxygen, chloride, nitrate nitrogen, fluoride;

(ii) optional parameters selected in relation to their importance to actual or planned use of the water, e.g. sodium, chromium, nickel, lead, arsenic, zinc, copper;

(iii) substances whose discharge into the environment are of long-term global significance because they are toxic at low concentrations, persistent, and/or bioaccumulable, e.g. cadmium, mercury, organohalogens and organotin compounds.

23. It will be noted that among the pollutants to be monitored are lead, cadmium, mercury, and organohalogen compounds. It would be of great value, therefore, to be able to collate the data on these compounds in water with those obtained through biological and food monitoring.

24. For that purpose it is proposed to add to the water quality component of the programme a cross-sectional survey to determine the concentrations of some hazardous substances in drinking water supplies at selected locations. Monitoring of these substances could then be undertaken if the results of the survey indicated the need for it. The most likely substance for inclusion in the survey is lead because of the problems of plumbosolvency in some areas giving high lead concentrations in tap water.

3. Food contamination

25. The main objectives of food and animal feed contamination monitoring are the following:

(i) to determine global trends in food contamination;

(ii) to determine the geographical spread of specific toxic substances;

(iii) to identify groups within a population that may be at high risk;

(iv) to determine the total intake of the pollutants under consideration.

26. It is proposed to collect data on the following contaminants during the period 1977-79:

(i) organochlorine pesticides and PCBs in milk and milk products, including human milk, fish, cereals, fruits and vegetables;

(ii) lead in a range of vegetables, molluscs, crustacea, and total diets;

(iii) cadmium in shellfish, cereals, potatoes and total diets;

(iv) mercury in fish and canned fish;

(v) arsenic and aflatoxins in selected foods and total diets.

B. PROPOSED ACTIVITIES

1. Introduction

27. Monitoring of pollutants in air, water, and food seldom yields information directly relevant to the assessment of human exposure. For that purpose additional measurements are required and the inclusion of additional components into the programme is proposed in order to answer that need. At this stage, however, it is merely planned to initiate pilot activities aiming at:

(i) ascertaining the feasibility of developing at international level the proposed additional activities, particularly biological monitoring;

(ii) determining the organizational requirements (including training and technical assistance) and the costs of undertaking such additional activities on a broader and longer-term basis.

28. No more than five environmental pollutants will be included in the pilot study that will be carried out at a limited number of locations in various countries. Particular attention will be given to the reproducibility and reliability of analytical methodology, methods of collection and transport of samples, assessment of results etc. If the results of the pilot study are promising, the UNEP/WHO health-related monitoring programme will be extended to experimental and eventually full-scale monitoring throughout the world.

29. The sites chosen for the pilot study will be those where there are potential environmental health problems but the study will not aim at monitoring exposure inside plants or in their immediate vicinity. It is considered particularly valuable, if at all possible, to coordinate at one location the collection of environmental monitoring samples from air, drinking water, and food with biological monitoring samples from human tissues or fluids. In this way a coherent picture will be developed of the total exposure to a pollutant experienced by the population at that specified location.

30. The following general criteria were used to choose the pollutants:

(i) importance of suspected or known adverse effects on health with particular emphasis on long-term effects;

(ii) persistence in the environment and accumulation in man;

(iii) likelihood of human exposure;

(iv) widespread occurrence in the world;

(v) size of population exposed and frequency of impact;

(vi) feasibility of measurement of pollutants in defined media.

31. Using these criteria the following pollutants were chosen as model compounds for the pilot study: sulfur oxides and particulates, lead, cadmium, mercury, selected organochlorine compounds. The limited nature of the pilot study made it essential to choose pollutants that not only met the above criteria but were representative of a range of environmental health problems.

32. A number of other pollutants which met the general criteria were not incorporated in the pilot study for a variety of reasons. The concentrations of chlorinated dibenzodioxins and dibenzofurans in the environment were considered too low to be included in the study. Aflatoxins, benzo(a)pyrene and other polynuclear aromatic and nitroso compounds were excluded because their determination was considered too difficult. Arsenic was considered to be a local problem in a number of regions and it was suggested that monitoring of arsenic in tissues should await the results of monitoring in air and water.

33. In planning biological monitoring, a critical question is the right choice of population groups and the proper statistical design of the study. In particular, it should be decided whether segments of population to be monitored represent the general population or certain groups at risk (highly exposed or highly sensitive) or both and a detailed protocol should be worked out for each pollutant.

34. The costs given for the analysis of samples are rough estimates of the commercial charges, in North America, for the analysis in the given medium and are included for exemplification purposes only. Though detailed figures could not be obtained for inclusion in this document, it is expected that costs may be lower in other areas. The charges do not include the costs of sample collection, storage, and transportation. No estimate has been given of the cost of establishing and equipping laboratories capable of performing the analyses nor of the cost of training and educating staff, providing library facilities, data evaluation etc. The costs are provided simply to give a rough measure of the financial scale of the pilot study.

2. Sulfur oxides and particulates

35. Sulfur oxides and suspended particulates are air pollutants derived largely from the combustion of fossil fuels. The main substances emitted are: gaseous sulfur dioxide, sulphates and sulfuric acid; suspended particulates composed of incompletely burned carbonaceous material and ash from complete combustion. The most clearly demonstrated effects of short-term (24 hours mean) increases in concentrations (above 250-500 $\mu g/m^3$) of these substances are a rise in morbidity and mortality, principally among people with pre-existing cardio-respiratory disease. These effects can at present only be ascribed to the mixture of air pollutants as a whole. Although some studies have implicated one component as the main culprit, the question must still be regarded as open. Sulfur dioxide is a soluble gas and is largely absorbed on inhalation whereas the fraction of inhaled particulates deposited in the respiratory pathways depends upon the particle size distribution: only particles below a size of about 5 μm are retained by the lung.

36. Since other sulfur compounds are ingested through diet and sulfur is widespread in tissue, it is not feasible to use the sulfur content of tissue as an index of exposure to atmospheric sulfur and sulphates. The only available indicator of exposure to sulfur oxides and particulates must then be their concentrations in air. At present there are already in existence extensive networks measuring these pollutants for purposes other than

exposure assessment (comparison with standards, evaluation of control measures). Results from such networks do not adequately determine the exposures of people living in these areas. Moreover, concentrations at any one site are liable to vary greatly with time; indoor concentrations may be very different from those outside and people move about during the day encountering a great range in concentrations.

37. It should also be noted that experience with air pollution monitoring is wholly derived from developed countries. Air pollution situations may be quite different in other countries and call for alternative approaches.

Proposed study

38. It is proposed that monitoring activities should be expanded at selected sites within the existing WHO/UNEP air quality monitoring project. At least one station should be chosen in each of the six WHO regions. A further station should be so selected that North and South America can be considered separately. It is proposed that the stations chosen should be those where a standard high volume sampler is already in operation and where estimates of SO_2 and suspended particulates are performed routinely. At each of these selected sites the following measurements should be made for a period of at least one year:

(i) Smoke measurements. A low-volume smoke sampler should be installed alongside the high volume sampler to help characterize the primary source and type of pollution.

(ii) Size separation. Provision should be made for size separation of material collected by the high volume sampler into respirable and non-respirable fractions. This should be accomplished by a cyclone separator attached to the high-volume sampler or preferably by a separate instrument incorporating a size separator. Where suitable facilities exist, limited investigation of the physical characteristics (shape etc.) of the respirable fraction of suspended particulates should be done by electron microscopy.

(iii) Analysis of particulates. The respirable fraction of high volume composite samples should be analysed monthly to provide information on the amount of benzene soluble material (tar), the amount of water soluble material, the total sulphate content, and the amounts of some of the heavy metals being studied in the proposed pilot study, i.e. lead, cadmium. Analyses for vanadium could be used as an index of pollution from heavy oil combustion.

(iv) Settled dust. Dust that settles by gravity on surfaces because of large particle size may be ingested by children and thus, in some circumstances, give rise to health hazards. Some analyses of the lead and cadmium contents of such dust could therefore be included in the present study.

(v) Short-term variations in SO_2. To examine the extent to which SO_2 concentrations vary during the day, one continuous automatic monitor for SO_2 should be included in each city at the most polluted site.

(vi) Additional outdoor stations. The total number of stations in each city measuring SO_2 and particulates in selected cities should be increased from the normal minimum of 3 to about 8 to provide a better indication of the spatial distribution of pollution. The selection of the additional stations should be made in consultation with the local meteorological services so as to take full account of the relevant meteorological variables that will, inter alia, be of value in testing models linking emission to exposure.

(vii) Indoor stations. To assess differences between indoor and outdoor concentrations in the circumstances prevailing in each city, two indoor locations should be selected, one in a domestic and the other in a working environment, each close to an outdoor station. While high-volume sampling methods are not practicable indoors, low-volume smoke and SO_2 measurements can be performed. Lead analyses may be possible on filters accumulated from these samplers. To sample a number of different domestic and working environments, it may be possible to rotate the equipment between several sites, sampling only for limited periods at each (say one month, although care would have to be taken with seasonal effects). Particular attention should be given to the effect of indoor heating and stoves used for cooking.

(viii) Personal samplers. It is proposed that in only two of the selected cities (with contrasting conditions) a small scale study should be done with personal samplers, to obtain the most direct estimates of exposure possible. These samplers should be distributed to people living and/or working near fixed sites, so that some comparisons could be made. Four samplers per city are suggested, with the possibility of rotating them between people in different parts of the city (this might be integrated with the scheme suggested for the indoor samplers). Suspended particulates could be analysed for lead, and the possibility of determining SO_2 using miniature bubblers should be considered.

39. This study should be integrated with the existing air quality monitoring component of the programme. Supervision would be largely by the existing personnel so that little extra labour costs would be required. Smoke monitors are at present included at some of the stations, additional units will cost about $400 each. Provision of six size separators would cost $15 000 to $30 000. Analysis of particulates will cost about $25 per sample. Equipment for the short-term measurement of SO_2 levels costs about $7000 each, or $50 000 for seven units. Increasing the number of stations from three to eight at seven sites (for measurement of SO_2 and particulates) would be at least $90 000. Two indoor stations at each city would cost $20 000. Three sets of personal samplers for use at two cities would cost about $4000.

3. Lead

40. Lead is widely dispersed in the environment and the levels found in blood samples from the general population are relatively close to those where the first biochemical changes occur. It is also known that lead accumulates in the bones of humans, the levels generally increasing with age.

41. In man the critical organs for exposure to lead are thought to be the blood-forming organs and the nervous systems. It is known that the chronic effects of lead, including those on the kidney, are related to levels of lead in blood. Because of the very high gastrointestinal absorption of lead in infants and children, and the assumed high sensitivity of their tissues, children have to be considered as the critical group in the general population.

Exposure assessment

(a) Environmental monitoring

42. Levels of lead in food, air, and drinking water can be used to estimate the intake by man. Usually food is the major source but where levels in the air or in drinking water are high these may contribute significantly.

(b) Biological monitoring

43. Blood levels of lead are usually considered as the best indicators available for assessment of exposure and absorption of lead: analysis in blood is used in biological lead monitoring in several countries. Levels in bone can be considered as an indicator of past exposure to lead. Where bone samples are being collected for other analysis,

e.g. the UNSCEAR/WHO strontium-90 in bone programme, it would therefore be profitable to make measurements of lead also. It would also be useful to determine the concentration of lead in human kidney, as samples are collected for cadmium determinations.

44. There are two known biochemical indicators of lead absorption that correlate with blood lead levels. δ-aminolevulinate-dehydratase (ALA-D) activity in blood decreases with increasing blood lead levels. Free erythrocyte protoporphyrin (FEP) and zinc-protoporphyrin levels increase once the lead blood concentration exceeds about 40 µg/100 ml. Both the activity of ALA-D and the concentrations of the protoporphyrins in question can be measured by relatively simple techniques and are currently being used in assessment of the effects of lead exposure both in general populations and occupationally exposed groups.

Proposed study

45. Since children are the critical group in the general populations, it is recommended that the pilot study determine the average level of lead in different groups of children in different localities. It is suggested that approximately 50 children be included in each group. Simultaneously with lead blood determination biochemical effects should be measured, using ALA-D and protoporphyrins determination. A 1 ml sample of venous blood is regarded as suitable. Biological monitoring should be linked in space and time with lead monitoring in environmental media, i.e. air, food, and water. As mentioned, the existing or planned programmes in which bone or kidney samples are being collected should also be used to obtain data on lead concentration.

Sampling and analysis

46. Flameless atomic absorption spectrophotometry should be used for blood lead determination. The low limit of detection of this method allows small samples to be used. However, this increases the risk of errors arising from contamination. Particular care is therefore needed to avoid contamination of samples during their collection and handling before analysis.

47. The cost of analysis is about $20 per sample. Measurements of lead in bone and kidney would be carried out in a few central laboratories, already equipped to do this. The number of samples would be much smaller than for blood and the unit cost would be about the same.

4. Cadmium

48. High, often increasing, levels of cadmium are found in the environment and in man in many communities, industrial and municipal wastes being one of the main sources of pollution. Cadmium enters the body primarily by the ingestion of food but inhalation may contribute significantly in smokers and in people occupationally exposed to high levels of airborne cadmium. The biological half-time of cadmium is of the order of decades and man accumulates cadmium at a roughly constant rate up to the age of about 50. Kidney (renal cortex) is the critical organ for chronic cadmium exposure. Approximately half the body burden is in the kidney and liver. Reported average cadmium concentrations in the kidney cortex (wet weight) of an adult man vary from approximately 10-15 mg/kg in adults in non-industrialized countries to 100 mg/kg and above in more polluted areas; liver concentrations are usually about one order of magnitude lower. However, with very high cadmium exposure, in industry or in highly polluted areas, cadmium content in the damaged kidney can decrease substantially, while liver concentrations remain high.

49. Renal changes resulting in tubular proteinuria should be considered as the critical effect of long-term exposure to cadmium. High prevalence of this type of lesion was observed in general population in areas contaminated by cadmium; the critical

concentrations of cadmium in the renal cortex for the appearance of tubular proteinuria are between 100 and 300 mg/kg (wet weight). In some cases, renal damage resulting from long-term cadmium exposure can be associated with changes in calcium metabolism and/or bone pathology.

50. Cadmium has been considered as a factor of importance in cardiovascular pathology, particularly in essential hypertension. Although this relationship has not been proven, its potential significance is so great that it argues strongly for keeping the body burden of cadmium as low as practical.

51. Human activities connected with industrial and urban development are generally considered to be responsible for environmental pollution by cadmium which could be regarded as a model pollutant in this respect.

Exposure assessment

(a) Environmental monitoring

52. Staple foods, such as cereals, usually have moderate concentrations of cadmium, but a gradual, significant increase of cadmium content in wheat and grain has been detected in some countries. Very high cadmium concentrations can occur in less frequently used foods, such as shellfish, kidney or liver. Cadmium is also present in cigarettes, drinking water, and airborne dust.

(b) Biological monitoring

53. The best assessment of cadmium body burden can be achieved by determining the cadmium concentrations in kidney (renal cortex) and liver. Urinary cadmium excretion probably reflects body burden in persons who have not been excessively exposed but the urinary concentrations are low and their use for monitoring would be difficult on a large scale. Cadmium in blood, hair, and nails do not correlate well with body burden.

Proposed study

54. In the pilot study cadmium levels in kidney (renal cortex) and liver would be determined for several areas taking in each 30 to 50 samples from human cadavers - either accident victims or deceased hospital patients. Subjects chosen should be between 40 and 50 years old and should have died without significant loss of weight and no significant renal or hepatic pathology, as shown by microscopic examination.

Sampling and analysis

55. For kidney and liver, as well as for food and cigarettes, atomic absorption analysis after acid digestion or ashing below 450°C is a suitable method. A 200 mg aliquot of renal cortex and liver is needed. The determination of cadmium in kidney cortex and liver where concentrations are relatively high, could be undertaken in local laboratories. Information that should be supplied with each sample include age, sex, medical, occupational, geographical and smoking history. The cost of the analyses would be about $25 per sample.

5. Mercury

56. The major health hazard to the general population is considered to be due to the presence of mercury in fish where it is almost entirely in the methylated form. Food is the main source of mercury in non-occupationally exposed populations, and fish and fish

products account for most of the methylmercury in food. Mercury in food other than fish is usually present at concentrations below 60 µg/kg, but the chemical form of mercury there is not known. In aquatic ecosystems mercury in any chemical form is converted to methylmercury which accumulated in aquatic organisms.

57. In most countries the daily intake of methylmercury is less than 20 µg but in certain subgroups with unusually high fish consumption (dieters) the daily intake may rise to 75 µg and may even be as high as 200-300 µg (in coastal villages dependent on large oceanic fish as the main source of protein). In areas of high local pollution, daily intakes could be well in excess of 300 µg and these levels have led to two recorded outbreaks of methylmercury poisoning.

58. In contrast to mercury in other chemical forms, ingested methylmercury is almost completely absorbed in the gastrointestinal tract; biological half-time estimates range round seventy days.

59. Nervous system effects are critical with methylmercury exposure, concentrations of methylmercury in blood reflecting reasonably well methylmercury brain concentrations. Close correlations have been established also between steady state blood concentrations and long-term methylmercury intake in food. Blood red cells contain about ten times higher concentrations of methylmercury than blood plasma. Concentrations of methylmercury in hair samples closely reflect the blood concentrations at the formation of the hair and the distribution of mercury along the hair reflects the past exposure of the subject.

60. Reported levels of mercury in red blood cells of persons without known occupational exposure and with moderate, low or no fish consumption are in general lower than 20 ng/g red cells. The ratio of hair to blood concentrations is about 250.

61. Concentrations of 20-50 µg/100 ml in whole blood and of 50-125 µg/g in the hair have been associated with the earliest effects in adults. There are indications that prenatal life is the stage of development most sensitive to methylmercury.

Exposure assessment

(a) Environmental monitoring

62. Monitoring is generally to be confined to the determination of mercury in edible fish and fish products.

(b) Biological monitoring

63. Mercury concentrations in blood, particularly red blood cells, and in hair are good indicators of exposure to methylmercury in the general populations and can be regarded as reflecting methylmercury concentrations in brain in persons not exposed to substantial amounts of mercury in other chemical forms. Urinary concentrations of total mercury do not correlate with blood levels after exposure to methylmercury. The concentration of mercury in breast milk is approximately 5% of the concentration in the mother's blood, and breast-fed infants can accumulate dangerously high blood concentrations if the mothers are heavily exposed. Blood and/or hair concentration in newborns and sucklings and in pregnant and lactating women could provide important information on the exposure to methylmercury during the sensitive periods of intrauterine and early post-natal life.

Proposed study

64. The problem of the hazard to human health from exposure to methylmercury is limited mainly to groups consuming large amounts of fish. It is suggested that in such

groups about 50 subjects be selected for the pilot study. Emphasis should be placed on infants and pregnant women as categories subject to special risk. Whenever feasible blood and hair samples should be taken in the initial phases of the programme. The pilot study should draw on environmental monitoring data already available from the monitoring of food and water performed under the programme. Hair sampling could be coordinated with the neutron activation analytical programmes of IAEA. Wherever possible selenium determinations should be carried out in combination with those for mercury. This will be easier when neutron activation is used. The data are particularly required when high mercury levels are detected or in geographical areas with a high or low selenium exposure.

Sampling and analysis

65. Blood samples (5-10 ml) can be conveniently collected in "vacutainer" tubes in the presence of anti-coagulants. Red blood cells analysis is of advantage, particularly at low exposure levels. With whole blood analysis haematocrit values should be determined.

66. Flameless atomic absorption spectrophotometry should be used for blood samples. The detection limit is about 1 ng mercury and recovery >90%. Neutron activation analysis should be used for the hair analysis. Here the detection limit is about 0.1 ng mercury, and the sample size about 0.1 g. The total cost of analysing a blood sample is in the region of $20. It is slightly less for a hair sample.

6. Organochlorine compounds

67. Organochlorine compounds can become pollutants of the environment in several ways. These include: use as agricultural chemicals, use and disposal of products containing these compounds, improper disposal of industrial waste and industrial accidents.

68. Many organochlorine compounds are stable, move through the environment and concentrate in various food chains. Some of their degradation products may be more stable and toxic than the original compounds. It is probable that all humans store these pollutants in their body tissues. Because of their lipophilic properties the compounds are excreted in human milk and some infants may receive amounts greater than the acceptable intakes recommended by WHO/FAO. Some epidemiological studies have suggested that high levels of some organochlorines in human milk may be associated with adverse effects on child growth. In animals, high dietary levels of some of these compounds may exert adverse effects on nervous, endocrine and immune functions and can bring about morphological changes in certain tissue.

69. Organochlorine compounds of concern in health-related monitoring are: DDT and DDE, PCBs, dieldrin, hexachlorocyclohexane isomers and heptachlorepoxide.

Exposure assessment

(a) Environmental monitoring

70. The human intake of these compounds is essentially all through contaminated food, particularly fish, meat, eggs and dairy products.

(b) Biological monitoring

71. The measurement of the organochlorine content of human milk can be considered as an indicator of maternal exposure to organochlorines and makes possible the assessment

of the exposure of the breast-fed child. The organochlorine content of adipose tissue is a suitable index of the exposure of the general population over a long time period.

Proposed study

72. A pilot study should be undertaken in which the following compounds would be determined in mothers' milk: PCBs, dieldrin, hexachlorocyclohexane isomers, heptachlor-epoxide, DDT and DDE. The study should be carried out in two regions, one in an area of high exposure, for example among agricultural workers in the tropics, another in a less exposed population, e.g. Europe. Mothers sampled should be in the 18-30 year age group and a sufficient number (50-100) should be sampled to determine reliable mean values. Milk could be sampled during the stay in hospital after childbirth and subsequently on visits to post-natal clinics. If compatible the project could be initiated by using the existing WHO study on breast milk as a base.

Sampling and analysis

73. Milk samples (10-20 ml) should be collected and stored frozen in clean glass containers until analysis. Analysis of samples should be done by electron capture gas chromatography, after preliminary clean-up on a chromatographic column. About 10% of samples should be analysed on a gas chromatograph coupled to a mass spectrometer. Simultaneous lipid analysis should also be performed. Information that should be supplied with each sample include, age, medical and occupational history, geographical history, smoking history, and for nursing mothers, previous deliveries and elapsed time between parturition and sampling. The cost of analysis is approximately $100/sample for the range of organochlorine compounds. Mass spectrometry confirmation would be $100/sample.

7. Organization

(a) Linkage

74. For each of the proposed projects in the pilot study, linkages from the results of biological monitoring to environmental monitoring and effects monitoring must be considered. The simplest way to achieve this would be to initiate biological monitoring in areas where food and water monitoring are already being carried out under the programme. Alternatively, one could envisage the initiation of biological monitoring in an area and its eventual supplementation with environmental monitoring as may be suggested by the results of biological monitoring.

(b) Collaborating laboratories

75. There is a need to assign one, or two at most, reference laboratories to coordinate the work on each type of pollutant, to prepare and distribute standard samples, and to organize intercalibrations. These laboratories would also undertake the less frequent and more sophisticated analytical measurements requiring very specialized equipment. One or more laboratories could be devoted to cadmium, lead and mercury analyses, with a separate centre assigned to organochlorines. Sulfur oxides and particulates could probably be handled within the present organization of the WHO air quality monitoring project.

(c) Data evaluation

76. Some data evaluation could be done in the reference laboratories to assess whether the data are reliable, accurate, and reproducible, and how much needs to be collected to give statistically significant information. Production and distribution of standard samples for analysis will need to be centrally organized and coordinated. The final evaluation of the pilot study would best be done by WHO experts in collaboration with these central laboratories. Recommendations for the large-scale implementation of the activity initiated under the pilot study would depend on the results of this evaluation and the estimates of the costs and requirements provided by the pilot study.

Annex

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