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ATMOSPHERIC POLLUTANTS

Report of a WHO Expert Committee

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WHO EXPERT COMMITTEE ON ATMOSPHERIC POLLUTANTS

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ATMOSPHERIC POLLUTANTS

Report of a WHO Expert Committee

1. INTRODUCTION

A WHO Expert Committee on Atmospheric Pollutants met in Geneva from 15 to 21 October 1963. Dr P. Dorolle, Deputy Director-General, opened the meeting on behalf of the Director-General. The Committee elected Mr V. G. MacKenzie as Chairman, Professor V. A. Rjazanov as Vice-Chairman, and Dr P. J. Lawther as Rapporteur.

Air pollution has received attention at several meetings of experts under the sponsorship of WHO and has been the subject of a number of publications issued by the Organization.[1, 2, 3, 4] The Committee noted particularly the report of the recent WHO Inter-Regional Symposium on Criteria for Air Quality and Methods of Measurement and has drawn freely on it. As the Committee wished to avoid, where possible, the mere recapitulation in its report of material already published, it referred the reader for background information to the fifth report of the WHO Expert Committee on Environmental Sanitation.[1]

A consideration of air pollution by radioactive materials was not within the Committee's terms of reference, but the current progress being made in the control of such pollutants was noted with interest and satisfaction.

2. REVIEW OF PROGRESS IN AIR POLLUTION CONTROL

The control of air pollution necessitates the possession of legal instruments by which control can be effected, of technical means whereby the

[1] Expert Committee on Environmental Sanitation (1958) *Air Pollution*, Geneva (*Wld Hlth Org. techn. Rep. Ser.*, No. 157).

[2] *Air pollution*, by various authors, Geneva, 1961 (*World Health Organization: Monograph Series*, No. 46).

[3] Lawther, P.J., Martin, A.E. & Wilkins, E.T. (1962) *Epidemiology of air pollution: report on a symposium*, Geneva, World Health Organization (*Public Health Papers*, No. 15).

[4] World Health Organization (1963) *Air pollution : a survey of existing legislation*, Geneva; *Int. Dig. Hlth Legis.*, 1963, **14**, 187.

control of pollutants and their emission can be undertaken, of a control organization to see that these things are done and, usually, of monitoring equipment to check the results of the actions taken. In addition, it must always be remembered that the good will of the population and good relations between the population and the control authorities are essential.

2.1 Legal controls

Throughout the world, legal instruments for the control of air pollution have been newly created or improved. In the USA, laws have been passed by many of the states and also by local authorities. In addition, the Federal Government has proposed an increase in the powers of the Public Health Service, enabling it to undertake control where there are interstate situations in which control by state legislation is not easy.

In the United Kingdom, France and Germany, legal measures for control have been improved or amended. In the USSR and in countries on her borders, legal control of air pollution has been extended. In Australia, New Zealand, Chile and Japan, laws have been passed during the last few years and in other countries legislation is under consideration.

In all the new laws, the principles set out in the fifth report of the WHO Expert Committee on Environmental Sanitation [1] have been followed in the main, with modifications to suit local conditions. The WHO survey of air pollution legislation, although incomplete, lists thirteen countries in which legislation has been enacted.

2.2 Technical means for controlling air pollution

During the 6 years that have elapsed since the publication of the fifth report of the WHO Expert Committee on Environmental Sanitation, considerable progress has been made in the development of the means for reducing the concentrations of pollutants in the ambient air. It is not appropriate to list all of these, but some instances will be given.

2.2.1 *Development of arrestors*

Much technical research has been directed to the development and improvement of such equipment as inertial separators, electrostatic precipitators, scrubbers and fabric filters. Reports of these developments have appeared in the technical literature and abstracts of these articles are published regularly by a number of national bodies. The abstracting services devoted directly to air pollution matters can be considered as making a major contribution to the control of atmospheric pollutants.

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[1] *Wld Hlth Org. techn. Rep. Ser.*, 1958, **157**.

2.2.2 *The control of emissions from motor vehicles*

Motor vehicles contribute to air pollution by emitting hydrocarbons, carbon monoxide and oxides of nitrogen; these emissions occur both from the exhaust and from the crank-case ventilator tube (or down-draught tube). In strong sunlight, certain of these hydrocarbons and oxides of nitrogen may be converted in the atmosphere into a "photochemical" pollutant of oxidizing nature. In addition, diesel engines, when misused or badly adjusted, are capable of emitting black smoke. To deal with these forms of pollution a number of means are being developed.

Emissions from the crank-case are being controlled by means of a device that returns them to the engine intake. To control hydrocarbon emission in the exhaust, devices are being developed that will burn the hydrocarbons in the exhaust system of the car. These devices are not yet fully satisfactory but considerable progress has been made. Thinking amongst research workers is turning towards the use of improved forms of fuel supply to the engine and this should reduce the concentration of hydrocarbons in the exhaust.

Work has also been undertaken on the use of liquid petroleum gas as a fuel for internal combustion engines, with the aim of reducing hydrocarbon emissions. The smoke from the diesel engine can be eliminated by careful control of the conditions of use and maintenance of the engine. A number of countries have enacted legislation specifying these desirable conditions and have instituted a programme of regular inspection to ensure that the vehicles travelling on the highways are properly maintained.

2.2.3 *Coal-burning equipment*

In countries where, for historical and economic reasons, the major atmospheric pollutant is smoke from domestic sources, strong efforts have been directed towards the development of efficient domestic equipment for the burning of coal. In addition, much work has been done on solid fuels, resulting in the production of reactive cokes for burning in open fires. There seems to be little hope, however, of eliminating the emission of sulfur dioxide from domestic appliances burning solid fuel. In all countries with air pollution control programmes, much progress has been made in the smokeless combustion of coal in industrial furnaces.

2.2.4 *Indirect means of reducing air pollution*

A number of technical changes and developments have in some countries contributed towards a reduction of atmospheric pollution by smoke, and, in some cases, by sulfur dioxide. These are indicated below:

(*a*) Increased use of hydro-electric power and of electricity from atomic power stations.

(*b*) The supply of heat to whole districts by hot water or steam from central thermal stations.

(*c*) Greatly increased use of natural gas, electricity and high quality oil for heating, cooking and sometimes lighting, and in some places for generation of electric power.

(*d*) The use of electric power and efficient diesel engines for traction.

(*e*) The development of satellite towns in which no fuel is used that produces pollution.

(*f*) The recognition that the avoidance of air pollution is an important factor in town planning.

(*g*) The establishment of " green belts " between industrial areas and residential areas in newly established towns.

(*h*) The use of meteorological warning systems to enable temporary steps to be taken to reduce the emission of pollutants during periods of intense atmospheric stagnation.

(*i*) Improvements in traffic management to reduce pollution from vehicles.

2.2.5 *Reduction of concentrations of sulfur dioxide*

At the present time there are no totally satisfactory methods of preventing the emission of sulfur dioxide from the burning of sulfur-containing fuels. For this reason, large industrial consumers of such fuels are making extensive use of very high smoke stacks to ensure adequate dissipation of the sulfur dioxide and an adequately low concentration at ground level. As an added safeguard to human health, some countries are adopting the expedient of siting power stations in open country far from towns, where circumstances permit. Studies are also proceeding at several centres to find methods whereby sulfur dioxide in flue gases can be absorbed without any cooling of the gases (so that the rise of the plume is not adversely affected) and the sulfur dioxide converted into sulfuric acid or elemental sulfur. Progress has been reported in these studies but much work still remains to be done.

2.3 Monitoring of concentrations of atmospheric pollutants

If any programme for the control and reduction of the emission of pollutants to the atmosphere is to be successful, it is necessary to monitor the concentration of the pollutants being emitted into the atmosphere or the concentration of the pollutants found in the atmosphere, or both. During the last six years, considerable progress has been made in developing equipment for the monitoring of stack concentrations and control has thereby been facilitated. For the measurement of concentrations of

pollutants in the ambient air, research is providing an ever-increasing number of methods which are becoming more reliable and more specific. In addition, relatively low-priced indicating or recording instruments are becoming available. These advances are facilitating the task of the pollution control official and are an aid to the research worker who wishes to study the behaviour of pollutants in detail.

2.4 Assessment of the results of efforts to reduce air pollution

During the past six years, in many urban areas and cities which had very obvious and serious air pollution problems, the application of control measures has resulted in a considerable improvement in the quality of the air, as shown by a reduction of deposits in deposit gauges and a decreased blackening of filter papers, or by reduced masses collected in high-volume samplers. In places where the degree of pollution was already moderate, it has not always been easy to demonstrate improvement by routine measurements. There are at least three reasons for this. Firstly, long-term changes in meteorological conditions may have occurred as a result of which the concentrations of pollutants in the ambient air have remained constant despite a reduction in emissions. Secondly, in accordance with the law of diminishing returns, a porportionately greater effort is needed to reduce a moderate concentration to a low one than to reduce a high concentration to a moderate one. Thirdly, parallel with a reduction in emissions from individual sources, there may have been population increases that have resulted in an increase in the total number of sources. It is therefore probable that the success of the efforts of public health authorities to reduce air pollution in their cities will be inadequately reflected in a relatively short series of routine measurements.

3. AIR POLLUTION PROBLEMS OF INTERNATIONAL INTEREST

The Committee considered that WHO might assist in promoting international action in regard to the following aspects of air pollution:

3.1 Pollutants from motor vehicles

High atmospheric concentrations of hydrocarbons and of photochemically produced pollutants arising from emissions from motor vehicles do not appear as yet to present a serious problem in most areas of the world. As economic prosperity increases, however, the number of motor vehicles in use tends to rise, with a consequent increase in the

volume of motor fuels burned per unit area of a city per day and a growing danger of air pollution from this source. A watch should therefore be kept for increases in the atmospheric concentrations of the substances already mentioned. In addition, a rise in the concentration of carbon monoxide in the air of city streets must be regarded as potentially serious. Pollution arising from fuel additives must be kept constantly under review. Research on the many compounds emitted by motor vehicles, including polycyclic hydrocarbons, should be urgently pursued.

3.2 Elimination of sulfur dioxide from flue gases

In section 2.2.5, reference was made to work on methods of removing sulfur dioxide from flue gases. There is a strong case for directing research work towards finding ways of eliminating sulfur from both coal and fuel oil so that on combustion they will yield flue gases free from sulfur dioxide. This is a difficult problem and it is therefore desirable that a co-operative effort be made to solve it; in view of its obvious international importance, the help of WHO may be needed.

3.3 Meteorological factors

There are two types of meteorological work that are of value in preventing air pollution. One is the forecasting of times of intense stagnation (see section 2.2.4) and the other is the surveying and construction of models of air circulation in given localities so as to assess the effects of the siting of industries in different parts of a populated area. At present, insufficient is known for the proper accomplishment of either of these tasks. The Committee therefore recommends that work on these problems in different member countries should be encouraged and the resulting information made generally available.

3.4 Loss of manpower through air pollution

Morbidity surveys planned in the future should have, among other objectives, the aim of assessing the cost to the community of sickness caused or prolonged by air pollution. The help of WHO may be needed in such surveys.

3.5 Combustion of coal in developing countries

In some developing countries that have coal seams near the surface, coal (sometimes of poor quality) can be won easily. Its domestic use

results in smoke pollution. Present methods for the production of smokeless fuels are technically sophisticated and expensive, and there is a need for the development of less expensive methods of treating coal which, even if they do not produce a fuel of ideal quality, will enable a reduction of smoke concentrations to be obtained and provide an interim solution to this problem.

3.6 Information service for air pollution control officials

During the last six years various countries have begun to control air pollution in their cities. The control officials are still relatively inexperienced and therefore find it difficult to deal with all the technical problems they meet. The regular publication of articles dealing with specific aspects of air pollution control, outlining the technical problems that may be met, describing how to deal with them, and indicating where fuller technical literature on the subject can be obtained, would be a valuable international service.

4. INTERNATIONAL STANDARDIZATION IN AIR POLLUTION: NOMENCLATURE, UNITS AND METHODS OF MEASUREMENT

Agreement between nations on nomenclature and methods of measurement of air pollution is obviously desirable if the results of research work in different countries are to be compared.

There is an urgent need to abolish from technical literature imprecise terms such as "smog" and "smaze"; scientists are obliged to describe air pollution in different parts of the world accurately in terms of its origin and constitution. It is particularly important to abolish the use of such a hybrid word as "smog" when it conveys an erroneous impression of the nature of the pollution.

Likewise, there is danger in the imprecise use of the meteorological terms "temperature inversion", "inversion base" and "inversion ceiling". These phenomena, being of various types and extent and capable of existing side by side, must be accurately defined.

In reporting concentrations and dimensions of pollutants the metric system should be used and temperatures should be reported in degrees centigrade. Concentrations of particulate and gaseous pollutants should be reported in terms of mass per unit volume, which necessitates standardizing the temperature and pressure of the unit of volume used.

Concern with standardization of units of concentration must not, however, lead to over-simplification of the description of air pollution. Pollutants have other dimensions and properties which must be described

as accurately as possible; mass per unit volume of a particulate pollutant is an adequate term only if its physical and chemical nature have been determined, since its biological effects may be almost wholly dependent on these properties.

It is important to state the periods over which samples are taken. These will obviously vary, depending on the purpose for which sampling is done: " spot " samples are important in some contexts (e.g., as random checks on pollution at many points) but they would be of limited value for defining the environment in epidemiological surveys. Where appropriate, continuous-recording instruments may be used from which peak concentrations (the acuteness of the peaks will depend on the time-constant of the instrument) can be read and average concentrations over specified periods calculated. Care must be taken in using such instruments since they often lack specificity. The results they give must therefore be subject to frequent critical scrutiny and checking by other analytical methods.

The nature of the pollutant under consideration also determines or influences the selection of the sampling period. Some compounds, for example polycyclic hydrocarbons, vary in their stability and may be oxidized or destroyed by light or by other pollutants. Allowance must be made for this fact when conducting surveys, for if samples are collected over too long a period the less stable compounds will be lost and therefore discounted.

For purposes of international comparison of routine measurements, a short-term sample might be defined as one taken over a period of 30 minutes and a long-term sample as one taken over a period of 24 hours. It is recognized that in some circumstances these periods may not be applicable, but it is recommended that they be used where possible.

Having stated in outline the principles to be observed in collecting and describing air pollutants, the Committee considered it essential to emphasize the importance of selecting sampling sites so that the samples taken are representative of the air actually breathed. Otherwise, the care taken in making measurements will be entirely in vain.

Air may be polluted by particles or by gases. A common particulate pollutant is smoke, which is an aerosol formed as a result of the incomplete combustion of carbonaceous fuels. In coal-burning communities this complex mixture of carbon, ash, crystals and tar is the pollutant most frequently measured. Traditionally, concentrations of smoke (or " permanently suspended matter ") are expressed in terms of mass per unit volume, but the figure is usually arrived at by measuring the soiling of a filter paper and subsequent reference to a calibration curve from which an assessment of mass concentration can be made. Obviously, the validity of smoke measurements in gravimetric terms must depend on the frequent reassessment of the calibration curves with respect to time, weather, and

changing habits of fuel usage. The optical assessment of blackness must obviously be made before the blackening of the filter reaches a maximum. Sampling rates must be adjusted so that the linear velocity at the face of the filter is such that only particles small enough to be inhaled are measured. The method of assessing particulate pollution by measuring the soiling of filter papers has much to commend it; it is technically simple and does not require expensive apparatus; moreover, it is possible that in some countries the blackness of the smoke may be more closely related to morbidity than the mere particulate mass. But there are many disadvantages of this method of assessment. Some pollution is now far less black than formerly, whilst some pollutants, e.g., diesel smoke, are much blacker per unit weight than coal smoke. There is no easy solution to these problems, unless the object of the sampling procedure is carefully defined. The object may be to measure blackness, particulate mass, or the surface area of the particles. The use of membrane or glass-fibre filters enables workers to weigh the particles or estimate their projected surface area, but it remains necessary to develop a chemically inert, non-friable, non-hygroscopic filter material of low resistance to air on which to collect adequate samples of particles.

In order to make intelligent investigations of the possible effects of particulate pollution, many microscopic examination techniques must be used, but as these are research tools the need for standardization is not so urgent.

Sulfur dioxide is probably the most important gaseous pollutant in coal or oil-burning communities, and many methods of estimating its concentration are at present in use. A common method is that in which air, after the removal of smoke by filtration, is bubbled through hydrogen peroxide solution and the resultant sulfuric acid determined by titration with standard alkali. This method is simple but lacks specificity, being a measure of acid gases rather than of sulfur dioxide, but since this gas is by far the predominant acid pollutant in most coal and oil-burning towns the results reflect with considerable fidelity the concentration of sulfur dioxide in the air. There are accurate colorimetric methods in use, and some workers favour the estimation of total sulfate which in their locality is closely related to the sulfur dioxide concentrations in the air. Increases in the conductivity of aqueous solutions and the decolourization of solutions of iodine are phenomena commonly used in automatic recording instruments and are adequate for monitoring if the composition of the pollutants remains reasonably constant. But gaseous pollution often varies in a manner that invalidates these methods; for example, ammonia may increase the conductivity of a solution and be reported as sulfur dioxide, and oxides of nitrogen might interfere with colorimetric reactions. Constant vigilance is therefore needed.

Some air pollution is characterized by its strongly oxidant nature

and this property has often been reported as being due solely to ozone. Research work in the last decade has shown that ozone is by no means the only oxidant that may be present in polluted air and that the oxidizing potential of the air ought not to be expressed as ozone unless the method of measurement used is specific for that substance. It has been suggested that the concentration of oxidant should be expressed in more absolute terms.

It is necessary constantly to bear in mind that in any method of assessing pollutants by bringing them into solution, there is the risk that only the algebraic sum of unlike chemical properties will be measured : thus free ammonia and sulfur dioxide can co-exist in the air but when sampled by aspiration through an aqueous reagent are enabled to react and only the resulting acid/base balance is measured by titration methods. Likewise, a true assessment of an oxidant is made difficult by the presence in the air of reducing substances, unless the method used is specific for the oxidant sought. It must always be remembered that air pollution is caused by minute amounts of gases and particles and that the simple laws of chemical equivalence cannot be applied to the compounds as they exist in extreme dilutions in the air.

Discussion here has been limited to the measurement of only three classes of pollutants. Many more of the numerous compounds found in the air are under study by workers in various countries; some of the methods used have already been published.

It cannot be emphasized too strongly that wherever the concentration, properties or composition of a pollutant are quoted, the methods whereby the results are obtained must be described in full. At the present time, many attempts to standardize routine methods of measurement are being made by international and national organizations: close attention and support should be given to these efforts and experiments to develop new improved methods continued.

There is an urgent need for international agreement to enable morbidity and mortality data to be compared. In the study of morbidity, enquiry into the prevalence of carefully defined symptoms and symptom complexes is greatly to be preferred to comparisons of diseases, in the defining of which diagnostic criteria may vary extensively between one country and another. The use of standard carefully designed questionnaires (as described by Lawther et al. [1]) is of great value in epidemiological studies. When studying mortality, great care must be exercised to ensure that the cause of death is known with reasonable certainty. Death certificates are notoriously unreliable; post-mortem data should be obtained and histological examination of specimens performed if at all possible.

[1] Lawther, P.J., Martin, A.E. & Wilkins, E.T. (1962) *Epidemiology of air pollution : report on a symposium*, Geneva, World Health Organization (*Public Health Papers*, No. 15)

5. CRITERIA AND GUIDES FOR AIR QUALITY

The Committee, in its deliberations on this subject, carefully reviewed the report of the WHO Inter-Regional Symposium on Criteria for Air Quality and Methods of Measurement, held in Geneva from 6 to 12 August 1963, and endorsed the general approach outlined therein and the principles and definitions quoted below:

" 1. Criteria for guides to air quality are the tests which permit the determination of the nature and magnitude of the effects of air pollution on man and his environment.

" 2. Guides to air quality are sets of concentrations and exposure times that are associated with specific effects of varying degrees of air pollution on man, animals, vegetation and on the environment in general.

"3. In the light of present knowledge, guides to air quality may be presented as four categories of concentrations, exposure times and corresponding effects. These four categories are defined by limiting values which may vary for a given pollutant according to the anticipated effect or the criteria used and in relation to other co-existing pollutants and the relevant physical factors, and which take into account the varying responses of different groups of human beings. The Symposium agreed to define the four categories in terms of the following levels:

" Level I. Concentration and exposure time at or below which, according to present knowledge, neither direct nor indirect effects (including alteration of reflexes or of adaptive or protective reactions) have been observed.

" Level II. Concentrations and exposure times at and above which there is likely to be irritation of the sensory organs, harmful effects on vegetation, visibility reduction, or other adverse effects on the environment.

" Level III. Concentrations and exposure times at and above which there is likely to be impairment of vital physiological functions or changes that may lead to chronic diseases or shortening of life.

" Level IV. Concentrations and exposure times at and above which there is likely to be acute illness or death in susceptible groups of the population.

" For some known pollutants, it may not be possible to state concentrations and exposure times corresponding to all four of these levels because (*a*) the effects corresponding to one or more of these levels are not known to occur with the substance in question, or (*b*) exposures producing effects corresponding to certain levels also produce more severe effects, or (*c*) the

present state of knowledge does not permit any valid quantitative assessment (e.g., of threshold levels for carcinogenic substances).

" The possibility that some pollutants may have mutagenic effects must be borne in mind; however, at the present time, too little is known about this subject to permit classification of such pollutants in the above categories. "

The Committee stressed that pollution of the air by biologically harmful substances resulting from man's activities should be avoided to the maximum extent possible.

The Committee agreed that international guides to air quality, embodying the principles enunciated above are desirable and should be compiled in the near future. It believed that guides can be most expeditiously developed for those pollutants that have received the most study and attention and that are most widespread in their distribution, for example, the oxides of sulfur. It suggested, therefore, that WHO take appropriate action to accomplish this aim. The Committee recognized the existence between Level I and Level II of a zone of concentrations and exposure times in which some pollutants may produce demonstrable responses, the significance of which is as yet uncertain.

Emission standards are obviously related to the concentrations of pollutants that will be found in the ambient air, but since this relationship is largely dependent upon local meteorological and other factors, international standardization of emissions of pollutants is virtually unattainable and the prescription of such standards must be left to the discretion of individual governments or local administrative authorities.

Specific programmes and problems on which research is needed are discussed elsewhere in this report (see sections 6 and 7). The Committee believed, however, that a programme of financial and technical assistance would be helpful in faciliting the exchange of information and the fostering of international studies relative to the development and justification of air quality guides.

6. EVALUATION OF RECENT INVESTIGATIONS AND RESEARCH ON AIR POLLUTION

The last ten years have seen a remarkable increase in the amount of research done in the field of air pollution in almost all countries of the world. Most of this research is directed towards the problem of detecting and measuring the pollutants present in the atmosphere and to the determination of the medical and biological actions of pollutants. Some studies have also been made of the prevention and control of air

pollution by eliminating contaminants at the source. Less work has been published on the meteorological and economic aspects of air pollution.

Much progress has been made in the detection, identification and measurement of air pollutants. The main problem, that of determining the exact state in which pollutants may be present, is being slowly elucidated by new methods of physical analysis. Chemical methods usually yield information on the final state of substances and the results are frequently disturbed by side reactions taking place in or on the sampling media. Physical methods of analysis, such as infra-red and mass spectroscopy, X-ray diffraction and chromatography have permitted much information to be collected on the exact physical state of the pollutants, and on transient intermediate stages of chemical interaction. Such methods have, for example, been of great importance in detecting the formation of free radicals and the reactions by means of which these participate in the production of ozone in oxidizing or photochemical air pollution. The Committee believed that these methods would be of great importance in the future, not only in studies of photochemical reactions, but also in the examination of acidic and other types of pollution.

Perhaps the greatest effort is being expended on studies of the action of air pollution on humans and on plants. With very few exceptions, studies on animals are directed towards clarifying some aspect or other of the action of pollutants upon humans. Studies on plants have been motivated mainly by the economic consequences of pollution upon crops.

In the biological field there are at present in progress the following types of studies: large-scale epidemiological studies; studies on the action of pollutants upon the central nervous system and on the autonomic nervous system; research on the biochemical and immuno-chemical responses to stimuli. All these promise valuable results.

The study of industrial populations has yielded much information concerning the reaction of man to exposure to substances that are present in working environments in concentrations greater than those found in the ambient air. Studies of this type should be extended and continued as valuable supplements to laboratory experiments with toxic substances.

More and more attention is being paid at present to the action of combinations of pollutants that might be present simultaneously or consecutively in the atmosphere. In these cases, not only simple additive effects but also synergistic and antagonistic effects become possible. Attention is also being paid to the carcinogenic properties of substances other than the polycyclic hydrocarbons.

There are, however, a number of aspects of research on air pollution that require additional emphasis. Among these, mention might be made of meteorology and economics. Information on the meteorological conditions in a city usually relates to the gross meteorology of the city as compared with that of the country as a whole, and the information

is usually collected for the purpose of weather forecasting. Since the local meteorology of an area is generally one of the fundamental factors in determining the presence or absence of air pollutants, particularly in those cases where unfavourable geographical or topographical conditions limit the dilution or dispersal of pollutants, the Committee believed that the factors governing local weather conditions and the movement of air masses in, around, and between cities are important and must be given urgent study.

Research on the economic consequences of air pollution has likewise been very limited, despite the great influence air pollution may have on the economy of a whole area of a country. In this context, research should not be limited to the assessment of losses caused by air pollution but should also cover the economic aspects of the possible application of air quality standards, since conceivably these might be formulated so stringently that the economic life of an area would be stifled by attempts to enforce them. Finally, the economic aspects of the installation of control equipment for the abatement of air pollution are worthy of study.

Regarding the question of control equipment, the Committee found a notable absence of reliable information on the relative collection efficiencies and costs of operation of control equipment for the diminution of pollutants at the source. Remarkably little work has been published on this subject. This lack makes it very difficult for the control engineer to discriminate intelligently between the rival merits of much of the new equipment offered to him.

Retrospective epidemiological investigations of morbidity and mortality in relation to air pollution have yielded, and continue to yield, invaluable results, but it is realized that prospective surveys, in which changes in the environment can be anticipated and taken into account, are to be preferred and encouraged. It is especially important to continue the research already in progress on international surveys of the prevalence of chronic bronchitis and lung cancer.

7. RECOMMENDATIONS FOR FURTHER ACTION

7.1 Studies

In the fifth report of the Expert Committee on Environmental Sanitation,[1] consideration was given to the recognition and evaluation of potential or actual conditions of air pollution. This is, of course, a basic problem in any country and already member countries have asked WHO for assistance in solving it. A study by WHO of the present position among member countries with regard to the evaluation of the air pollution potential

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1958, **157**.

and its severity would be valuable, for it would give a forewarning of the degree of assistance likely to be required in the future.

A second study that should be undertaken is of the potential demand for the training of senior officials in countries in which a programme for the control of air pollution is already under consideration or has recently been started.

There are a number of areas where the border between member countries runs through industrialized or densely populated country. It is certain that any programme for the control of air pollution in these areas will involve co-operation across the border and a study of such areas of potential activity is indicated, so that helpful suggestions can be made when the need arises.

7.2 Improvement in the qualifications of personnel

Discussion meetings should be arranged at which officials from member countries that have started, or are about to start, air pollution control programmes, may meet their counterparts from countries having had considerable experience in this field. These meetings would not replace or interfere with the arranging of visits by senior officials from one member country to another.

It is known that in some member countries comprehensive studies are being made of the technical problems involved in the control of emissions from a variety of chemical engineering processes. The information obtained from these studies will be invaluable to other member countries and wherever possible attempts should be made to make such information available through WHO. It would be sufficient if from time to time WHO were to supply information concerning the titles, content, publishing office, and price of such literature.

In some of the member countries educational literature designed to acquaint the public with the implications of air pollution and ways of controlling it is available through government agencies and associations formed specifically for the purpose of combating air pollution. In countries about to embark on a programme for combating air pollution, the responsible officials often do not known that such literature, films, photographs, diagrams, etc., exist or do not know to whom they should apply in order to acquire them. It would be useful if WHO could collect information about this sort of literature and transmit it to member countries.

It is recommended that WHO should consider means for the dissemination on an international basis of information designed to assist air pollution control authorities in widening their technical knowledge (see section 3.6). The good offices of WHO might also be used to facilitate the exchange of rare chemicals, spectroscopic standards, and measuring equipment for the purpose of comparison between countries.

7.3 Research

WHO should periodically review research problems in order to keep the members of the different scientific disciplines who are working on air pollution problems informed on progress in the various aspects of this complex field of study. The collaboration of scientists from the different member countries would be of great help in the preparation of such reviews.

There is a need for liaison visits between research workers in allied fields of air pollution research, and also for longer study visits by research workers to laboratories in other countries. WHO assistance in this respect should continue.

There are research fields, such as that of epidemiology, where co-operative work between two or more member nations is very valuable. WHO should continue to encourage such work.

The award of WHO fellowships which allow workers in the field to spend a fairly long period in one or two laboratories has long been in operation, is much appreciated and should be continued.

It is recommended that a glossary of terms and phrases used in the description of work on air pollution should be prepared to facilitate international communication.

The Committee recommends further study by WHO of internationally acceptable guides to air quality in accordance with the principles laid down in section 5 of this report, and in collaboration with other appropriate organizations.

Further work by member countries to develop methods for removing sulfur from fuel and sulfur dioxide from flue gases is recommended (see sections 2.2.5 and 3.2).

The exchange between member countries of research information on meteorological studies concerned with air pollution is recommended (see sections 3.3 and 6).

It is recommended that member countries that have the facilities investigate the possibility of low-cost production of smokeless solid fuel for domestic use in countries in the process of development (see section 3.5).

Research on the economic consequences of air pollution and its control is recommended (see section 6).

7.4 Standardization of sampling methods, nomenclature and units

The attention of member countries is drawn to the recommendations on sampling methods, nomenclature and units of measurement given in section 4 of this report.

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