SEMINAR ON AIR POLLUTION
TEHERAN, 21 - 29 APRIL 1969

WORLD HEALTH ORGANIZATION
EASTERN MEDITERRANEAN REGION
ALEXANDRIA

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REPORT ON THE SEMINAR ON AIR POLLUTION

TEHERAN, 21-29 APRIL 1969

EMRO/70/992

Participants who attended the Seminar on Air Pollution

Teheran, 21 — 29 April 1969

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

PART I

SUMMARY REPORT OF THE SEMINAR

I INTRODUCTION

The pollution by man of the atmosphere, which has now become a problem in many countries, has increasingly attracted the attention of the World Health Organization which has sponsored several meetings of experts, conferences and seminars to study this aspect of the pollution of the environment.

Great efforts have also been made, during the past fifteen years, by various governments and agencies concerned, including the World Health Organization, to define the air pollution problem and its effects, to develop methods for measurements of pollutants and devise means for control. The air pollution problem is, nevertheless, on the increase everywhere. Indeed, if technical progress and economic expansion are the very characteristics of our modern society, they have at the same time produced by-products - many of them unwanted or unexpected - resulting in various forms of environmental pollution including air pollution, the impact of which is now felt by millions of people.

It is realized that the pollution of the air is not severe in all areas of the Eastern Mediterranean Region. However the need for more information on this problem and its effects on man and its environment has been recognized; also the need for information, to be made available to the countries of this Region, on means of technological control and in particular on means for prevention. These topics were reviewed at the Seminar reported on here and several papers dealt in detail with the various effects of air pollution and the important aspects of pollution abatement and control including legislation and health education. The usefulness of the subsequent technical discussions, summarized in this document, were underlined by many participants. The hope was expressed that WHO's assistance to Member States in the field of air pollution would continue and expand.

This Seminar was the first one in this field organized in this Region by the Regional Office for the Eastern Mediterranean of the World Health Organization.

II THE PURPOSE OF THE SEMINAR

The purpose of this meeting was to exchange information on the air pollution problems of this Region, to direct attention to the increasing need for prevention and to provide guidance, notably as regards air monitoring programmes, for countries now undergoing rapid industrialization and urbanization likely to face problems of air pollution now or in the near future. The Seminar was also designed to provide an opportunity for the participants to exchange experience, to discuss specific problems and to make appropriate recommendations which would assist in defining action towards air pollution control.

It was gratifying to see that the responsible departments of governments of this Region are already finding it desirable to assess the current and potential air pollution situation and that efforts for prevention have been or are beginning to be made, based on the premise that no one should use the atmosphere inconsiderately as a receptacle for wastes which may affect the health, comfort or property of people. Emphasis is being placed at the same time on the need for proper planning and for setting out of priorities based on precise data to be established by systematic air pollution surveys, the scope of which was discussed at the Seminar, and also the need for training of personnel - including professionals and technicians of adequate number and quality without which no programme, however well planned, can ever be implemented.

III ORGANIZATION

This Seminar on Air Pollution, convened by the Regional Office for the Eastern Mediterranean of the World Health Organization, was organized with the assistance of the Government of Iran, the host country. It was held in Teheran from 21 to 29 April 1969. Participants from nine countries attended the meeting, namely from Cyprus, Iran, Iraq, Kuwait, Lebanon, Pakistan, Southern Yemen, Sudan and the United Arab Republic. In addition two countries from the European Region of the World Health Organization, Rumania and Turkey, attended the Seminar. The list of participants, consultants and staff is given in Annex I.

The Seminar was opened by H.E. Dr. M. Shahgholi, Minister of Public Health, Iran, who introduced the problem of air pollution, mentioning WHO's assistance in this field to his country and welcoming the participants. Dr. A.H. Taba, WHO Regional Director, Eastern Mediterranean Region, addressed the Seminar on behalf of the World Health Organization and then Dr. N.F. Izmerov, Assistant Director-General, WHO, Geneva, and Dr. M. Saleh, ex-Minister of Public Health and ex-Chancellor of Teheran University addressed the meeting.

After the opening ceremony, the following officers were elected :

H.E. Mr. M. Assar — Chairman
Under-Secretary of State, Planning and Programmes,
Ministry of Public Health, Teheran, Iran

Dr. Z. Rahman — Vice-Chairman
Deputy Secretary and Deputy Director-General of Health,
Ministry of Health, Education and Social Welfare,
Islamabad, Pakistan

Dr. A.A.A. Amer — Vice-Chairman
Director, Industrial Health Department,
Ministry of Public Health, Cairo, United Arab Republic

Dr. Y. Osman — Rapporteur
Chief, Occupational Health Division,
Ministry of Health, Khartoum, Sudan

Some general statements and a broad outline of the subject of the Seminar were presented by Mr. L.J. Lovelace, WHO Secretariat, who then introduced the WHO Temporary Advisers, Professor M. Katz, Dr. H.C. Wohlers and Professor P.J. Lawther.

The WHO experts presented a series of papers on specific aspects of the air pollution problem, which were discussed in Plenary Sessions, as summarized under Part II.

IV METHODS OF THE SEMINAR

The methods of the Seminar involved the preparation and presentation of twenty-two papers followed by discussions between the participants and the lecturers. Considerable interest was shown by the participants who appreciated the masterly presentation made of the various topics by the WHO Temporary Advisers.

Some basic documents were sent to the participants for their advance information prior to the meeting, and an outline of the papers was handed to them before the start of the Seminar. Background material on air pollution was also on display during the Seminar and was distributed afterwards, as requested, to persons interested. The list of these documents is shown in Annex IV.

The programme of the Seminar covered all the aspects of air pollution from the exposition of the problem and its effects on man's health, on vegetation and property, to air pollution emission inventories, air pollution monitoring and control programmes, including organization, training and legislation. The air pollution problems in the Eastern Mediterranean Region were also reviewed and statements were made by participants concerning the situation in their respective countries. A field trip was organized to Palasht School, Varamin Plain, for demonstration of apparatus and analyses of air pollutants. The agenda and list of basic documents are given in Annexes II and III.

The work and activities of WHO in the field of air pollution was discussed, and is summarized under Part II.

V THE AIR POLLUTION PROBLEM

In the presentation of the problem of air pollution and its effects, which was covered in six lectures, a review was made of the situation in various countries as would apply to this Region.

The effects of pollutants on man's health were presented by Professor Lawther in his lecture which aroused the greatest interest and was followed by lively discussions, the summary of which is given under Part II.

The effects of air pollution on vegetation and of meteorological conditions on the dispersion of pollutants were the subject of two most interesting and highly technical presentations by Professor Katz, while the kinds and amounts of pollutants found in the atmosphere, including those emitted from various sources, and the other effects of air pollution were taken up in three presentations of great interest by Dr. Wohlers. The text of the papers presented and the following discussions are also recorded under Part II.

In the presentation of these subjects, thought-provoking ideas were expounded by the WHO Consultants and general views expressed among which the following may be briefly mentioned.

Air pollution is a most complex problem, and the emissions of so many different pollutants into the air, their transport through the atmosphere and their effects directly or indirectly upon man and his environment do require studies and activities involving a number of different disciplines.

In fact, no single discipline, including ecology and epidemiology can alone appraise the complexity of the air pollution phenomena. Yet the numerous facets of this multidisciplinary problem may not all be accessible to a satisfactory scientific exploration.

It was noted that air pollution is not a new problem of man's technological advances, but a problem as old as humanity. The advent of fire for cooking and heating purposes could be considered as man's first experience with air pollution. Yet in early times man could move to a new location whenever his environmental problems, including air pollution, became intolerable. Today, it is not possible to move cities, and man is discharging pollutants at a rate exceeding the capacity of natural regeneration of the air. Man has therefore to find a form of coexistence with nature; he must and, fortunately, can solve the air pollution problem. The higher the air quality desired, the greater of course will be the cost of control. It has been emphasized that the lack of control causes more monetary losses to the public than does the cost of control.

It was stated that meteorology plays an important part in air pollution control. Air pollution episodes may and usually do occur when winds do not blow; under these conditions the dispersion of pollutants is minimal. Human deaths have occurred when these weather conditions existed concurrently for several days or more. Attempts have been made to use dispersion equations to prepare mathematical models for urban areas. The recent use of computers has greatly facilitated the more accurate development of dispersion formulae. They should now serve as an important indicator for the removal of pollutants not being considered as a specific method of control.

A review was made of the dynamics of wind motion which included discussions on the pressure gradient force, the horizontal deflecting force due to earth's rotation, the effect of wind friction, and the variation of wind velocity gradient with height. The thermodynamic significance of changes in lapse rate was reviewed; this covered the dry adiabatic, superdiabatic, and natural lapse rates.

Atmospheric diffusion of matter was reviewed, account being taken notably of the behaviour of smoke plumes, of the measurement of atmospheric disturbance, of the Gaussian distribution of airborne material and of the statistical treatment of lateral and vertical distributions of concentrations of pollutants.

With regard to the effects of air pollution on man's health, it was recognized that air pollution does affect those individuals with respiratory illnesses, but it was pointed out that the effects of city air on healthy persons are still being debated throughout the world. Research on the effect of air pollution to human health should, preferably, be conducted on human populations rather than on animals and studies should be carried out on individuals who are exposed to sufficiently high pollutant levels as they perform their daily tasks.

It was noted that the effect of air pollution on human health is complicated because man does not breathe pure air plus a single pollutant, say sulphur dioxide. Man breathes air that may contain a mixture of all of the elements and compounds known and hitherto unknown to man. Synergistic or antagonistic effects of all or even of combinations of possible pollutants are not known; perhaps these effects will never be known for those in good health or in bad health.

From this standpoint of human health, the complexity of the response of man to air pollution precludes a definition of air quality for health purposes which should be acceptable to all scientists involved. For visibility reduction and for vegetation, definite air quality standards are however possible.

It was finally stressed that air pollution should be controlled to the maximum extent possible, using most modern technical processes and equipment. In fact equipment is available now to control almost all air pollution problems at a cost which will not affect the economy of a country but will actually save economic losses from the detrimental effects of air pollution.

Developing countries in particular should take advantage of advances in air pollution control in other countries and prevent the discharge of pollutants from all sources in their cities. The prevention of pollutant emissions now will definitely be less costly than the control of air pollution at a later time.

VI AIR POLLUTION PROBLEMS IN EMR COUNTRIES

The increasing importance of air pollution has already been considered at several meetings of WHO Expert Committees, and WHO is assisting already, as part of its duties toward Member States, in the assessment of their air pollution problems and in taking appropriate measures where necessary for control or prevention.

Mention was made that during the past five years requests for WHO assistance had been received from various EMR countries, as a result of which a number of surveys were undertaken. The problems of air pollution were in general not severe as they were most often localized and as such did not affect great sections of the population. The information provided by the surveys was then reviewed.

The situation as regards motor vehicles was discussed first and attention focussed on the fact that some of the larger cities of this Region, such as Teheran, were likely to face air pollution problems in the future with the increasing number of vehicles. Photochemical smog formation was, at times, noted in that city. The problems of pollution from industrial sources including cement factories, brick factories and refineries were discussed. The particular problem of municipal solid wastes disposal and its implications in relation to the increase of general air pollution over urban areas was considered as well as the special problems of dustfall from sandstorms.

Following the exposé of the situation in this Region, as per documents available at the Regional Office for the Eastern Mediterranean Region, the participants submitted up-to-date descriptions of the air pollution problems in their respective countries.

VII MONITORING AND MEASUREMENT OF AIR POLLUTION

Field survey techniques and related problems of sampling and measurement of air pollution were discussed in a series of six papers: Dr. Wohlers discussed the methodology for conducting odour surveys in the field and source emission inventories. The kinds of equipment available for measuring specific air pollutants were described by Professor Katz, while the criteria for evaluating ambient air quality in relation to public health were discussed by Professor Lawther.

It was noted, amongst other points of interest, that in most humans the sense of smell is well developed, and that adverse conditions of ambient air quality are frequently detected by changes in odour before other physical and chemical effects are noticed. Because of its intrinsic relation to the specific chemical compounds in the air, changes in odour are associated with chemical changes, particularly oxidation, of these compounds. This fact is most important in making odour surveys in the field. The use of the "odour triangle" technique for making odour surveys in the field was described in detail, and the complicated problem of multiple emission sources and the need for taking into account meteorological factors was stressed. The concept of threshold odour unit was then reviewed. It was noted that gas samples can be removed from stack flows of known volumetric rate by suitable dilution techniques and the discharge in terms of "odour units" determined. Details on the above are also given in Part II.

Another aspect of any air pollution control programme is the air pollutant emission inventory which, it was stressed, is a necessary part of the activity of all air pollution agencies. The development of an inventory must include location of all sources of emission on a map, identification of the types of discharges, and complete measurements of the quantities and intensities of the particular constituents of interest. This information is used for subsequent establishment of proper locations for air sampling stations and for determining the analyses which will be required to assess the air pollution problem in the community. Periodic revision of the inventory is an aid to evaluating the progress of the control agency in the abatement of air pollution.

Many other points were discussed, as shown in Part II of this report, and also the following: it was explained that measurements of flow rates and concentrations of individual chemical compounds in gaseous and particulate emissions from pollution sources are required in order that air pollution surveys may be evaluated quantitatively. Professor Katz discussed some of the routine and special problems of sampling and analyzing stack flows as well as ambient air, and he briefly described the various types of equipment which have been developed so far.

The pressing need for standard analytical procedures and for standards of air measuring equipment was stressed by Professor Katz. He reported that a task committee in the United States is currently compiling a manual of "standard methods" for air pollution testing. The importance of this effort was emphasized by the many questions and extended discussion from the floor regarding the testing for even such common pollutants as SO_2 and CO. Professor Lawther noted some of the special requirements involved in measuring the health effects of various pollutants; in particular he described the survey techniques employed by his own research group in the United Kingdom.

It was noted that criteria of air quality in respect of human health represent the bounds within which air pollution must be held to prevent undesirable physiological reaction. These and current research needs were discussed and illustrated by Professor Lawther. Air quality standards formulated on the basis of known criteria and emission standards that may be applied to sources of pollution to meet desired air quality standards were considered by Dr. Wohlers.

VIII WHO ACTIVITY IN THE FIELD OF AIR POLLUTION

The work of WHO in this field since 1955 was reviewed and summarized. WHO supports studies to develop methods of detection and measurement of concentration of air pollutants; takes part in developing suitable methods for air quality and epidemiological surveys in connection with various air pollution problems; encourages studies on guides to acceptable air quality and stimulates international collaboration in this field; supports studies on control devices or control measures for those pollutants for which adequate control does not yet exist, as well as encourages research into all aspects of air pollution.

As part of its research programme, at the end of 1967 WHO established an International Reference Centre on Air Pollution, and a number of regional and national reference centres and collaborating laboratories are now being designated to form together a world network of institutions. The functions of the International Reference Centre is to advise on research results regarding the health effects of air pollution, on the organization of air pollution surveys, on the identification and measurement of air pollutants and on control methods. It will provide consultant services on research and technical problems, it will carry out research on behalf of WHO, co-ordinate research and evaluate the results obtained by collaborating laboratories and national institutions, and advise WHO on new research needs.

In addition, training of personnel in the prevention and control of air pollution is already being provided by WHO, but increased support is essential both for existing institutions and for the creation of new ones, wherever needed.

IX ORGANIZATION OF MONITORING PROGRAMMES

Three papers were devoted to the planning and administration of air pollution control programmes. Implementation of such programmes requires that ambient air and emission sources be monitored in order that progress of the control measures may be ascertained.

Professor Lawther discussed the planning of an air monitoring programme. He stressed the need for giving adequate thought to the reasons for monitoring pollution and for organizing the field and laboratory work in such a way that the desired objectives would be achieved. The tendency for making such programmes unnecessarily comprehensive, thereby taxing the often limited resources of money, facilities and personnel, should be avoided.

This concept was further developed by Dr. Wohlers in the discussion on the kinds of activities carried out by governmental air pollution control programmes. Each country has its own organizational requirements and philosophy and must develop its programme with the framework of its existing legal structure. The experience of developed countries may, however, serve as a guide for the purpose of writing legislation to permit effective enforcement of adopted standards of air pollution. The enforcement activity requires adequate information on the status of air pollution and this is obtained from the type of planned monitoring programme outlined by Professor Lawther.

It was noted that air pollution legislation tends to present a confused state of affairs, as it involves concurrently air quality criteria, air quality standards, emission standards and finally enforcement. These terms, indeed, are all simple in definition, but are often confusing in practice.

When the monitoring programme is badly planned or when the basis of control and enforcement fails to conform impartially to scientifically sound standards of evaluation, problems of legal validity arise. This aspect was discussed and means were suggested by which these problems may be eliminated. Summaries of the aboe discussions are presented in Part II.

In addition, it was pointed out that the budget for governmental air pollution control agencies is, in general, minimal, except in a very few areas. A minimum budget means a minimum number of personnel and hence minimal air pollution control enforcement. The public has not as yet realized that each sum of money spent on air pollution control means almost a geometrical return in the reduction of losses from air pollution effects.

An air pollution agency, it was emphasized, should have capable personnel in the many technical fields. Air pollution is concerned among others with engineering, chemistry, biology, meteorology, statistics, legislation, business, economics, sociology, public relations, etc. Research into air pollution problems of concern to the agency would add more to the already long list of disciplines.

Ideally a division or a section of a control agency should incorporate comparable disciplines in a manner most suitable to the community. A technical division and an engineering division would be the simplest organizational basis of an agency; modifications can take place from this arrangement.

If the agency does not have the needed personnel, excellent use can be made of existing talents within the community. Industrial personnel, consultants, retired personnel and college students could be asked to assist on specific projects.

The participants, many of whom represented administrative and enforcement agencies in their respective governments, showed by their questions and discussion that the points covered by the lecturers were indeed real problems. There was particular interest in the assistance which the World Health Organization might be able to give EMR countries in the organization of air pollution survey and control programmes and in the training of personnel.

X CONCLUDING OBSERVATIONS AND RECOMMENDATIONS

The concluding discussion centered on subjects of common interest to the participants and specially on air pollution programmes to be carried out in countries of this Region which are undergoing rapid industrialization and urbanization and likely to face problems of air pollution now or in the near future. Also the participants of countries where air pollution activities have already started placed emphasis on the necessity to take further action towards control of air pollution problems.

Note was taken of the usefulness of WHO-sponsored seminars, such as the present Seminar in Teheran, in bringing together professionals concerned with air pollution and making it possible for them to exchange information. Appreciation was also expressed of the assistance that has been provided in this field by the Regional Office for the Eastern Mediterranean Region of WHO.

It was unanimously agreed and recommended that :

a. The recognition of the problem in the Eastern Mediterranean Region countries necessitates that appropriate air pollution surveys be undertaken in order to identify causes of pollution and to assess problems where they exist in view to eventually taking appropriate measures for prevention or control.

b. Detailed recommendations on how to carry out such surveys and how to collect air pollution data are needed and that assistance from the World Health Organization in this regard, as a follow-up of the Seminar's recommendations, would be valuable.

c. Emphasis must be placed on the prevention of pollution, as prevention of air pollution is less costly than subsequent control and as moneys thus spent are repaid many-fold in savings from the deteriorating effect upon man, his well-being and his property; that prevention of air pollutant emissions should be initiated now, as equipment for the abatement of pollution is available.

d. Co-operation between physical and social scientists and technicians in government, industry, universities, and the public must be developed, and that the attempt should be made to prevent air pollution by co-operation and persuasion; if the method is not successful, legal steps should be taken to prevent air pollution emissions.

e. Assistance from international agencies may be needed regarding the setting up of air pollution laboratories, in particular as regards the equipment required and also laboratory development.

f. It is important that where serious air pollution exists clinical data are carefully collected by proper methods so that clinical effects may be investigated by the use of follow-up studies.

g. Experimental work on the effects of air pollutants must be properly designed, special attention being given to the need for double blind cross-over trials and strict assessment of results.

h. That proper public transport-systems be planned in developing cities to alleviate the problems caused by motor vehicles.

i. That training of air pollution personnel represents an essential aspect of an air pollution programme and that continuous efforts to that end by the Governments are required, possibly through training courses in air pollution control and the award of individual fellowships.

j. That WHO and other competent organizations should continue their endeavours to achieve uniformity in measurements and in the reporting of data on air pollution.

PART II

TEXTS OF THE WHO TEMPORARY ADVISERS' PRESENTATIONS

AND

STATEMENTS BY THE PARTICIPANTS

1. EFFECTS OF POLLUTANTS ON MAN'S HEALTH (DRAMATIC EPISODES)

by

Prof. P.J. Lawther*
WHO Temporary Adviser

The talk was illustrated by slides. The positive correlation between air pollution and mortality and morbidity was demonstrated by using special techniques in large populations. The relationship between exacerbations of existing illness and air pollution was demonstrated by the use of a simple diary technique using bronchitic patients. The more severe the patient's illness, the more easily were the correlations seen, though in individual cases the response was not invariable.

In order to try to understand the mechanism by which these changes occurred, normal anatomy and physiology was discussed and current theories concerning the development of chronic bronchitis and emphysema demonstrated. Laboratory experiments in which different methods of measuring changes in airway resistance following inhalation of mixtures of gases and particles were described and the failure to demonstrate any consistent effects on inhalation of realistic concentrations of sulphur dioxide was noted as being of great importance. In one subject who was insensitive to 30 ppm SO_2, there was, however, a positive correlation between daily measurements of airway resistance and pollution (using smoke and SO_2 as indicators) following a two-mile walk and this was interpreted as evidence that there was in London air a substance other than SO_2 which was capable of increasing resistance to air-flow.

The decline in smoke following the implementation of the Clean Air Act in the United Kingdom was producing an opportunity to follow this correlation between pollution and disease and death. Studies with diaries repeated over the years and continuous observations of mortality and morbidity indices was, happily, indicating that the effects of pollution were decreasing markely.

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* Director, MRC Air Pollution Research Unit, Professor of Environmental Medicine, St. Bartholomew's Hospital, Medical College, London

Summary of Discussions

In the discussion which followed, the question was asked whether other methods of measuring ventilatory functions could be used. The merits of the light spirometer were emphasized.

Professor Katz asked if the use of a subject resistant to sulphur dioxide was appropriate in the "London Bridge walk" experiment but it was pointed out that the experiment was designed not to demonstrate the inefficacy of SO_2 but the presence of a complex broncho-constrictor. The effects of exercise were mentioned.

Other participants discussed other gases, and the value of the study of industrial populations exposed to pollutants was emphasized. Professor Katz mentioned Bell's survey of sputum productions near a smelter and the various technical difficulties involved in this sort of work were discussed briefly.

2. KINDS AND AMOUNTS OF POLLUTANTS IN THE ATMOSPHERE

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

The World Health Organization defines air pollution as the presence in ambient atmosphere of substances put there by the activities of man in a concentration sufficient to interfere directly or indirectly with his comfort, safety or health, or with the full use and enjoyment of his property. In general, it does not refer to the atmospheric pollution incident to employment in areas where workers are employed, nor is it concerned with air-borne agents of communicable diseases, nor with overt of covert acts of war.

The definition clearly implies that air pollution is a people's problem ---

A. People cause air pollution,
B. People pay for air pollution effects,
C. People pay for air pollution control, and most important,
D. People decide on the quality of air they wish to breathe.

The air resources management concept involves the five "E's" of air pollution -- emission, exchange, effect, environment, and enforcement, as shown in Figure 1. Obviously, if there were no emissions, there will be no air pollution. Once the emissions are put into the air, they must be exchanged by the wind to a location where an effect is exerted upon some receptors be it a man, animal, vegetation, or inert material. In addition to the direct effect of air pollutants, there is an indirect effect of air pollution on the environment, i.e. how does man physically and mentally react to a murky atmosphere? Finally, the enforcement of air pollution can be controlled to the extent desired by the populace.

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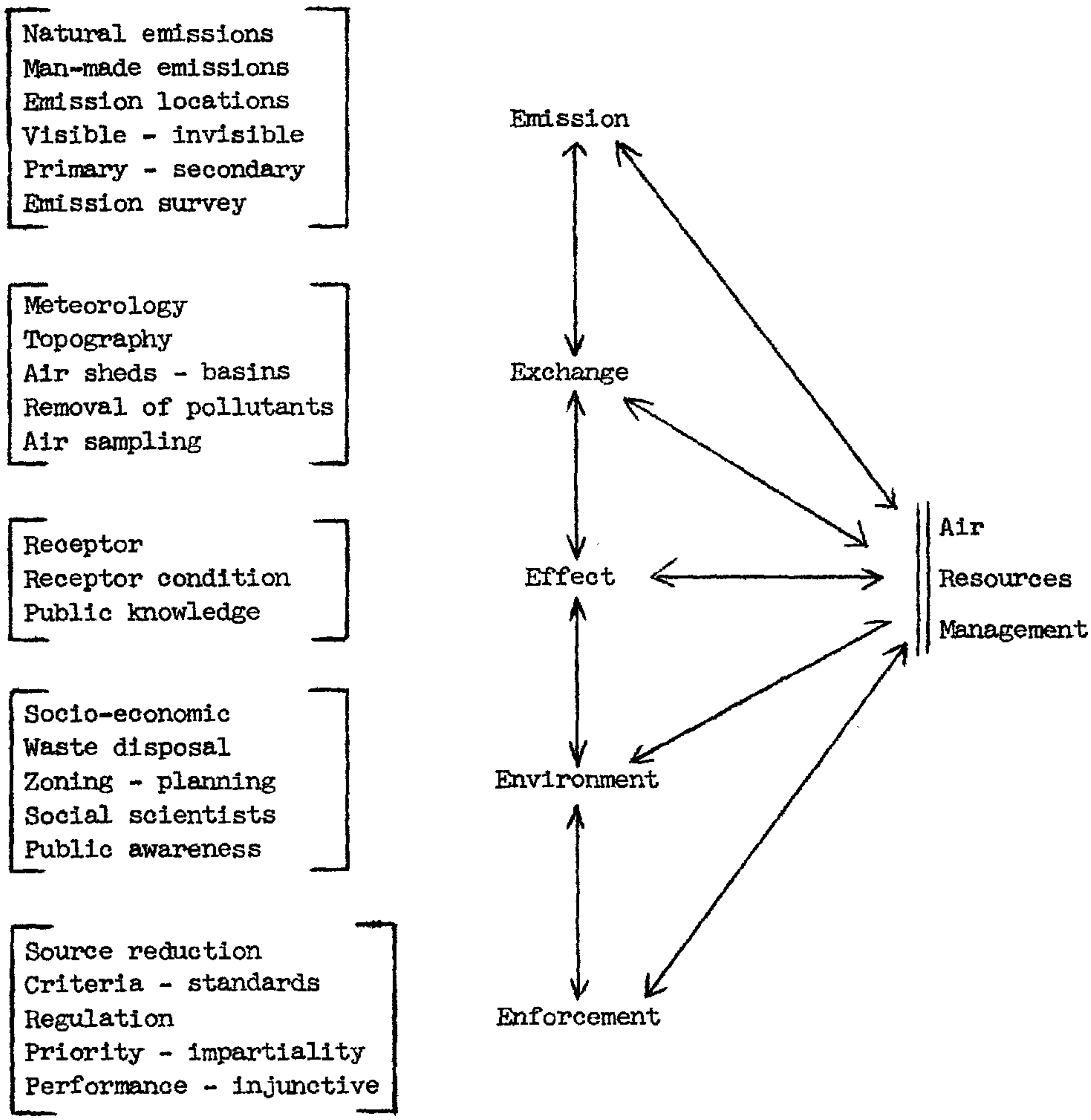
* Professor of Environmental Science, Department of Environmental Engineering and Science, Drexel Institute of Technology, Philadelphia

Figure 1

The Blending of the five "E's"
Spellout Air Resources Management



One can describe two major types of air pollution mixtures. The first is the London type of air pollution and the second is the Los Angeles type. The major difference between these two types of air pollution mixtures is the fuel used for combustion purposes. Coal and oil are the primary fuels used in London; natural gas is the primary fuel used in Los Angeles. In London, the atmosphere has a reducing effect on the re-agents, while the Los Angeles air pollution mixture has an oxidizing effect on chemical reagents. Interestingly, the London type of air pollution mixture is most severe in the months of December, January, and February when temperatures are relatively low, humidities relatively high, and wind speeds almost zero. On the other hand, the Los Angeles air pollution mixture occurs most severely during August and September, usually occurring during midday with temperatures in the range of 80°- 90°, relative humidity less than 75%, and wind speeds of the order of five miles per hour. It is not meant to imply that all air pollution problems can be designated by either one or the other of these types. Many locations may be experiencing both the London and Los Angeles types of air pollution mixtures simultaneously. The only known way of reducing the effects of these types of air pollution is to prevent air pollutant emissions to the atmosphere.

The atmosphere weighs approximately 5×10^{15} tons. Approximately 95% of this weight is located in the troposphere (0-8 miles high). It is instructive to realize that the nitrogen content of the atmosphere is equivalent to 780 900 parts per million by volume (ppm) or 78.09%. When we speak of air pollution, we are dealing in concentrations as low as 0.01 ppm or in some cases less than one part per billion (ppb).

In the United States during 1966, 26 million tons of sulphur dioxide were emitted; of this weight, 12 million tons were emitted by electric generating plants and 9 million tons were emitted by industrial operations. For oxides of nitrogen, 13 million tons were emitted yearly, with 6 million tons from motor vehicles, 2 million tons from industry, and 3 million tons from electric generating plants. As regards organic compounds, 19 million tons were emitted yearly of which 12 million tons came from the automobile and 4 million tons from industrial operations. When one considers carbon monoxide, it is surprising to realize that 72 million tons were emitted during the year; of this tonnage, 66 million tons were emitted from the automobile and minor amounts from other sources. Finally, the weight of particulates discharged yearly into the air amounted to 12 million tons, of which 6 million tons are attributed to industry and 3 million tons attributed to electric generating plants. Thus, out of the total of 142 million tons of pollutants discharged yearly, there are three major contributing sources -- motor vehicles, industrial operations, and electric generating plants.

Pollutant levels in the United States cities resulting from these emissions are as follows : sulphur dioxide, 0.02 to 0.13 ppm as a yearly average, nitrogen oxides 0.06 to 0.16 ppm, carbon monoxide 4 to 17 ppm, oxidant 0.02 to 0.03 ppm, hydrocarbons 23 ppm as C, and particulate matter 60 to 155 micrograms per cubic meter. These yearly average concentrations are for the cities of Chicago, Cincinnati, Denver, St. Louis, Philadelphia, San Francisco and Washington D.C.

In addition to the major emissions noted above, there are many sources of minor pollutants which are normally not considered. As shown in Table 1, rubber from automobile tyres amounts to 4.3 tons per day per one million population. Salt spray in areas close to the ocean amounted to 140 tons per day per 1000 square miles. In addition to minor components, one should not forget radioactive materials in the atmosphere; strontium-90, strontium-131, and cesium-137 are considered the three most important elements in that the half-life ranges from 8.1 days to approximately 30 years.

Table 1

Estimated Emission of Minor Pollutants - USA, 1965

Source	Tons/day per 10^6 population	Tons/day per 10^3 miles^2
Rubber (tyres)	4.3	-
Perfumes	0.5	-
Ground dust	430.0	-
Cigarette smoke	3.2	-
Cosmic dust	-	0.02
H_2S - natural	-	0.07
Salt (ocean)	-	140.00*
Vegetation decay	-	110.00
Aerosol cans	5.4	-
Cigar smoke	0.6	-
Leather (shoes)	0.8	-
Moth balls	0.1	-

* Within 200 miles of coast.

Table 2 is a summary of pollutant emissions on a world-wide basis. It is instructive to know that based on 146 million tons of sulphur dioxide emitted throughout the world, the atmospheric background concentration level for sulphur dioxide approximates 0.2 parts per billion and the calculated atmospheric residence time approximates 4 days. Perhaps the most important item in Table 2 is that emissions of carbon dioxide far overshadow that of any other pollutant from either man-made or natural sources.

Table 2

Summary Table on Pollutant Emissions - world-wide

Contaminant	Tons Estimated Emissions		Atmospheric Background Levels	Calculated Atmospheric Residence Time	Major Sources
	Man-Made	Natural			
SO_2	146×10^{6}	None	0.2 ppb	4 days	Coal, oil
H_2S	3×10^{6}	100×10^{6}	0.2 ppb	2 days	Volcanoes, swamps
CO	220×10^{6}	11×10^{6}	0.1 ppm	<3 years	Autos
NO/NO_2	53×10^{6}	500×10^{6}	1 ppb	5 days	Combustion
NH_3	4×10^{6}	$5\,900 \times 10^{6}$	6-20 ppb	2 days	Waste treatment
N_2O	None	$1\,000 \times 10^{6}$	0.25 ppm	1-3 years	Biological
Hydrocarbons	88×10^{6}	480×10^{6}	CH_4: 1.5 ppm non CH_4 <1 ppb	16 years (CH_4)	Combustion
CO_2	1.3×10^{10}	10^{12}	320 ppm	4 years	Combustion
Total	1.3×10^{10} (CO_2)	10^{12} (CO_2)	-	-	-

In summary, an Air Pollution Credo is shown in Figure 2. The most important item in the Credo is that the success of an air pollution control programme depends upon the co-operation of public, industrial, and governmental groups.

Figure 2

Air Pollution Credo

1. The air quality has deteriorated in most areas, principally as a result of people crowding together in urban areas.

2. The decrease in air quality has an adverse effect on health, vegetation, animals, material objects and man's well-being.

3. Air quality improvement should be rational and not emotional.

4. Air pollution control should be evoked when the need is demonstrated.

5. Practical and economical tools are available to resolve almost any air pollution problem.

6. The cost of air pollution control is dependent upon the degree of control desired by the public.

7. The success of an air pollution control programme depends upon co-operation of public, industrial and governmental groups.

8. Improvement in air quality is a never-ending job.

9. A strong investment in research is continually required.

Summary of Discussions

Dr. Wohlers was asked whether air pollution effects from automobile tyre wear arise from rubber particles or from degrade by-products. He replied that much of this appears as fine particulates of rubber which can be air-borne and constitute a form of air pollution.

The question of allergistic response to air pollutants was raised and whether this was a natural phenomenon or might be conditioned by economic standards of living. Dr. Wohlers noted that in general the lower income groups live closer to the sources of air pollution and that people living in "dirty" air seemed to be sick more frequently. He said that the data given in his talk was for urban rather than rural areas.

The desirability of using zoning to keep potential pollution sources remote from living areas was brought up. Dr. Wohlers noted that this would be separately discussed, but that in general prevention was a more sound approach than expensive emission control. Comments from participants indicated agreement with this principle.

Dust from unpaved roads and street sweeping practices in certain Middle East countries also constitute sources of air pollution and point up the need to consider local customs as a factor in air pollution control.

3. EFFECTS OF POLLUTANTS ON VEGETATION

by

Professor M. Katz*
WHO Temporary Adviser

Summary

Agricultural crops, ornamental plants and trees may be injured by gaseous or particulate air pollutants. During the early history of the metal smelting industry, extensive areas of land were completely denuded of vegetation by the emission of sulphur dioxide from low stacks or from "heap" roasting operations. The uncontrolled discharge of dust and fumes containing arsenic, lead, copper and zinc resulted in the deposition of these toxic metals on forage crops used as food for livestock, causing fatal effects.

Sensitive species of vegetation may be employed as biological indicators to assess the nature and magnitude of an air pollution problem. Many gases are much more toxic to plants than to animals or man at equivalent concentrations. Leaves of plants exposed to air pollutants during the growing season will accumulate and concentrate these substances. Consequently, the nature of substances such as sulphur dioxide, fluorides, sulphuric acid, toxic metals, cement and alkali dust, etc., may be identified and their rates of accumulation demonstrated by chemical analysis of leaf samples at regular intervals during the growing season.

Patterns of injury

The injurious effects of pollutants on vegetation may be classified as: (a) acute injury involving collapse of leaf tissue and development of necrotic areas of damage, (b) chlorotic or chronic injury accompanied by loss of chlorophyll, (c) growth alterations, including stunting of growth, early abscission of leaves and fruit, and other abnormalities. The affected leaves may develop distinctive colour patterns.

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Factors influencing Susceptibility to Air Pollutants

Many internal and external factors determine the response of plants to a specific air pollutant. Some of these may be listed as follows:

1. Genetic factors that govern variations in susceptibility between species and variability in response within different varieties of the same species;

2. Concentration of the pollutant and duration of exposure;

3. Environmental factors such as light intensity and duration, temperature, relative humidity and carbon dioxide concentration (in greenhouses);

4. Soil factors such as amount of moisture in the soil, fertility of the soil;

5. Stage of growth of the leaves and of the plant.

In general, plants are more sensitive to injury by an air pollutant in daylight than in darkness, during the active period of the growing season and under conditions of high relative humidity and optimum soil moisture. The greatest sensitivity is manifested by newly matured leaves. Older leaves and very young leaves are more resistant. Resistance also increases rapidly under conditions of moisture stress (near wilting point), low relative humidity and low temperature.

Sulphur Dioxide

This gas may injure sensitive plants such as cotton, barley and alfalfa in concentrations of about 2.9 mg/m^3 for one hour or 1 mg/m^3 for 8 hours. However concentrations of less than 0.3 mg/m^3 may be present throughout the period of growth of a crop of alfalfa without causing injury. Sulphur dioxide at a concentration greater than about 1.2 mg/m^3 will commence to inhibit photosynthesis and short exposures to higher concentrations exert an increasing inhibitory effect. Such fumigations at higher concentrations disrupt the diurnal movement of the stomata, instituting closure in daylight. Other effects of high concentration involve transformation of the chlorophyll to phaeophytin by replacement of the magnesium in the nucleus with acidic hydrogen. Prolonged fumigations of sensitive plants with SO_2 in concentrations greater than about 0.3 mg/m^3 may cause chlorotic injury due to the accumulation of this gas in the leaves, mainly as sulphate.

Hydrogen Fluoride and Volatile Fluorides

The toxicity of hydrogen fluoride to sensitive species of green plants is about two orders of magnitude greater than that of SO_2. As little as 1 microgram/m^3 of HF may be toxic to certain varieties of gladiolus, corn, apricot, Italian prune, peach, grape and pine. Discolorations indicative of necrotic areas may appear on the tips, margins or intercostal portions of leaves, similar to those caused by SO_2. Species that are resistant to HF include cotton, alfalfa, tomato and cabbage (species that are sensitive to SO_2). Plants accumulate airborne fluorides in the leaves and concentrate them throughout the growth period. Forage crops fed to animals may cause fluorosis of the teeth and long bones of the legs, necessitating eventual destruction of the exposed livestock. The maximum allowable accumulation of fluoride in forage crops is about 35 milligrams per kilogram of dry weight.

Other effects of fluorides in plants consist of inhibition of photosynthesis, interference with activity of enzyme systems and premature ripening of fruit. The latter effect on fruit often results in serious economic damage involving "soft suture" or rotting of the injured parts.

Ozone, Oxidants and Photochemical Pollutants

There are characteristic differences in the leaf damage caused by ozone as compared with photochemical oxidants such as peroxyacetyl nitrate (PAN), that are present in "smog" of the Los Angeles type. Ozone produces dark, stippled markings or spots on the upper surfaces of leaves. Such damage may occur to some varieties of tobacco after exposure to about 0.1 mg/m^3 for 4 hours; or to pinto beans with 0.2 mg/m^3 for about 4 hours.

Photochemical oxidants or PAN cause the silvering, bronzing or glazing of the lower surfaces of leaves of many plant species, including sugar beet, celery and lettuce. Sensitive plants may be injured by about 0.27 mg/m^3 of PAN after 4 to 8 hours exposure. Oxidants inhibit photosynthesis, promote the abscission of leaves and suppress growth.

Ethylene

This hydrocarbon is present in the exhaust gas of motor vehicles and produces characteristic signs of injury to many plants. Ethylene damage consists of epinasty of leaves and shoots; the stimulation of abscission cells causing loss of leaves and flowers; and interference with normal hormone activity which leads to abnormal floral and plant development. Such injury may be caused to tomato plants after several hours of exposure to 0.12 mg/m^3, or to marigolds after exposure to 0.06 mg/m^3. Orchid flowers are highly sensitive to ethylene and the sepals are injured by exposure to as little as 6 micrograms/m^3.

Particulate and Aerosol Pollutants

Aerosol pollutants may be highly toxic to green plants. Sulphuric acid mist causes a "pock mark" type of injury when deposited on the upper surface of leaves, particularly in the presence of high relative humidity or fog. Plants injured in this manner have been found in the vicinity of strong sources of sulphur dioxide and SO_3.

Particulate matter and smoke are significant pollutants in many urban areas. Such particles are deposited on the leaves of plants, accumulate in the guard cells and stomata, interfere with photosynthesis and retard growth. Eventually, the susceptible species of vegetation disappear through excessive mortality, premature senescence and defoliation.

Dust from cement kilns, when deposited on leaves, is absorbed in the presence of moisture and eventually kills the palisade and parenchyma cells. Other types of dust may act similarly. As a result, the yield of agricultural crops in the affected area is reduced and growth of trees is retarded. The exposed vegetation is rendered more susceptible to infection by fungi.

Finally, green plants absorb, accumulate and concentrate radioactive pollutants which then enter into the food chain of all species of animal life, including man.

Summary of Discussions

The difference in the damaging effects of gases on the upper and lower surfaces of leaves was commented upon and Prof. Katz was asked about the causes of the difference. Prof. Katz pointed out that the manner in which the gas affects the cells of the leaf is selective in its action. For example, ozone injures the palisade cells of the upper part of a dicotyledonous leaf, whereas oxidants, such as peroxyacetyl nitrate, destroy the guard cells of the stomata and the spongy parenchyma of the lower surface.

A question was asked about the effect of inorganic dust from cement works and whether such dust has any pollution effects on plants and vegetation to which the lecturer answered that it has a very definite effect. Particulate pollutants in the form of lime dust from cement kilns may kill the palisade and parenchyma cells. The dust is deposited mainly on the upper surface of deciduous species but it can cover the entire surface of coniferous leaves. As a result, yield of agricultural crops is reduced and growth of trees is retarded.

In reply to a question about the action as a catalyst of suspended particulates in the air causing increasing effect of SO_2, the lecturer stated that in the presence of sunlight and moisture, SO_2 is oxidized into SO_3 and then forms sulphuric acid. This reaction is accelerated by the catalytic action of metal oxides and salts in the suspended particulate matter.

Regarding the manner of uptake of hydrogen fluoride and whether it is done through the leaves or the root system of plants and the effective fluoride concentration in this action, Prof. Katz explained that the uptake is directly from the air. Plants have a mechanism whereby the intake of excessive amounts of fluoride from the soil through the roots is prevented. As little as 1 microgram/m^3 of fluoride in air may be harmful.

In answer to a question concerning the time necessary to convert SO_2 to SO_4, the WHO adviser noted that in favourable circumstances it will be about 1% per hour; thus a concentration of 1 mg/m^3, about 10 micrograms/m^3, will be oxidized per hour. The oxidation takes place through the agency of sunlight and in particular ultraviolet light. An active SO_2 molecule is created and enters into the oxidation process. Irradiation in daylight produces a sufficient number of active SO_2 molecules to continue the reaction during some of the night hours.

Another question related to the toxicity of fluorine compounds discharged from factories like fertilizer and aluminium manufacturing plants, and to the selection of vegetable plants that could be grown, for example, in America to be used for food. The reply was that forage crops must be analysed by fluorine content before being fed to animals. If the content is greater than 35 milligrams per kilogram of dry feed, the forage should not be used unless it is mixed with other feed of low fluoride content to reduce the total fluoride below the limit mentioned.

The question of the effect of radioactivity on plants was raised and the following facts were stressed. Plants act as accumulators of radioactive materials. There is much concern over the effects of radioactive iodine, strontium and cesium being deposited on or near the vegetation and accumulated therein. Plants are fed to cows and radioactive iodine appears in the milk. Harmful effects will appear in the fresh milk drinkers. In such situations fluid milk may be dangerous. Hence, powdered milk might be used instead, after sufficient radioactive decay has taken place to render it harmless.

A litigation case in Egypt was noted regarding a suit by banana farmers cultivating near a sulphuric acid plant. The wind currents apparently caused a one-month exposure of the banana leaf to the supposed pollutant effect. The case aroused some discussion, and the usefulness of chemical analyses of leaf samples from the nearby cotton plantation in conjunction with the banana leaves was further stressed.

4. OTHER EFFECTS OF AIR POLLUTION
(Visibility Decrease, Soiling, Corrosion, and Neighbourhood Decay)

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

In Figure 3, the air pollution loss syndrome is depicted. If we neglect human and animal health, we arrive at monetary losses from air pollution within the United States amounting to approximately 30 billion dollars per year. A curve showing the comparison of air pollution losses, not only in the United States but also in Great Britain and France, is shown in Figure 4.

Visibility interference may be best understood by considering the effects of a dirty automobile windshield upon the visibility of the driver. The dirt on a windshield is not very bothersome when driving in the shade or at night when there are no on-coming automobiles. However, when strong light from the sun or vehicular head-lights strike the dirty windshield, the visibility of the driver is impaired. There is almost no light obscuration; impairment of visibility is caused by the intense scattering of the on-coming light because of the dirt (small particles) on the windshield. The dirty windshield simulates a polluted community atmosphere where maximum visibility reduction occurs, on the unit weight basis, when the particles approximate 0.1 to 0.3 microns in diameter. Visibility may be correlated as a function of particulate matter in the atmosphere. At a particulate concentration of 100 micrograms per cubic meter, visibility approximates 12 miles; at a particulate concentration of 600 micrograms per cubic meter, visibility approximates 1.5 miles.

As regards the corrosion of metals, sufficient evidence has been presented to indicate that as the suplhur dioxide concentration in the atmosphere increases, the rate of corrosion of most metal also increases. In the United States, cities with the highest population, and thus the highest sulphur dioxide emissions, have the highest rate of corrosion of metal specimens. An exemption to this statement is that in areas where natural gas (very low sulphur content) is the prime fuel, the rate of corrosion is minimal. In addition to sulphur dioxide and other acidic gases, the rate of corrosion depends upon temperature, and relative humidity.

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Figure 3

Air Pollution Loss Syndrome

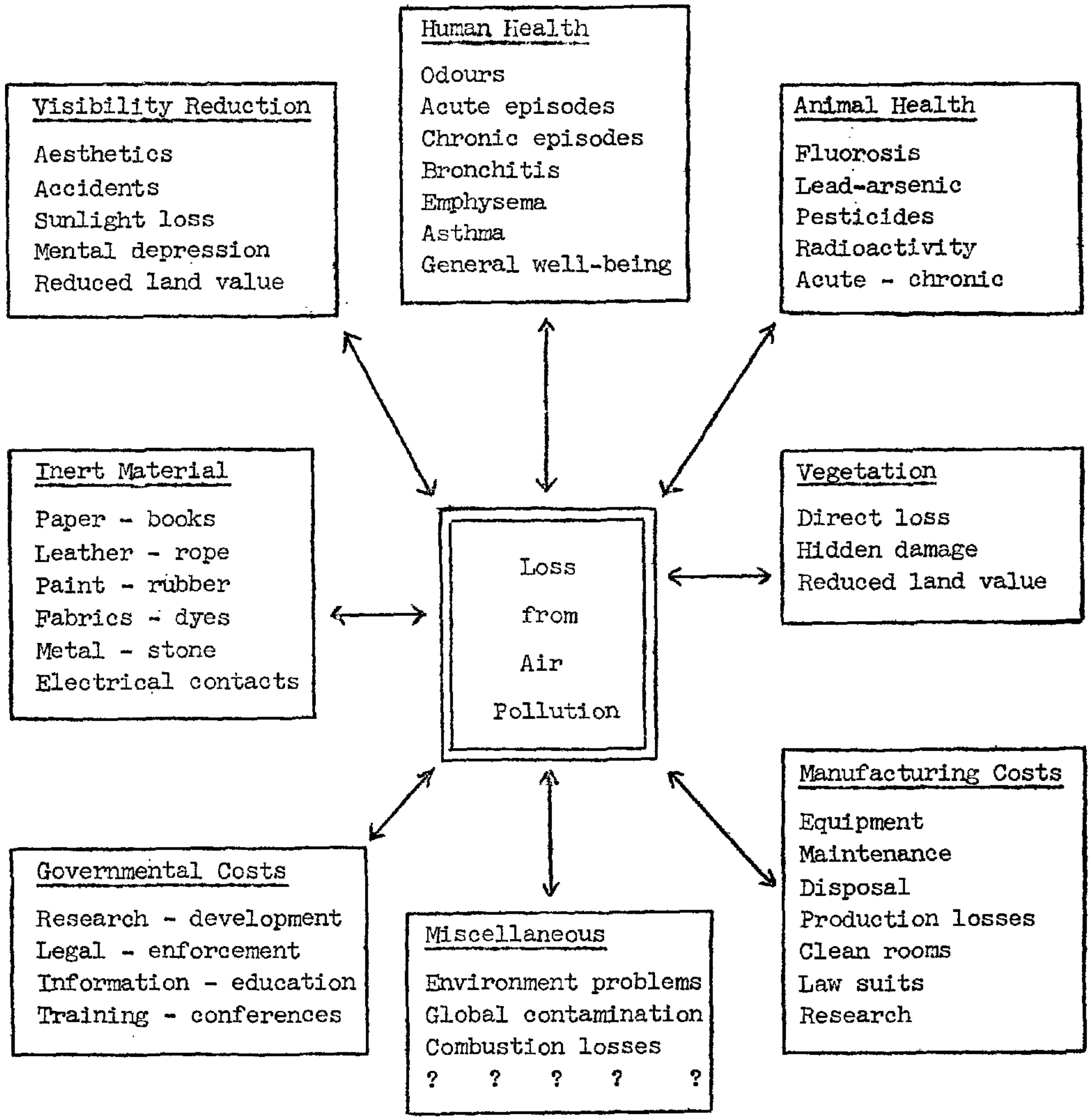
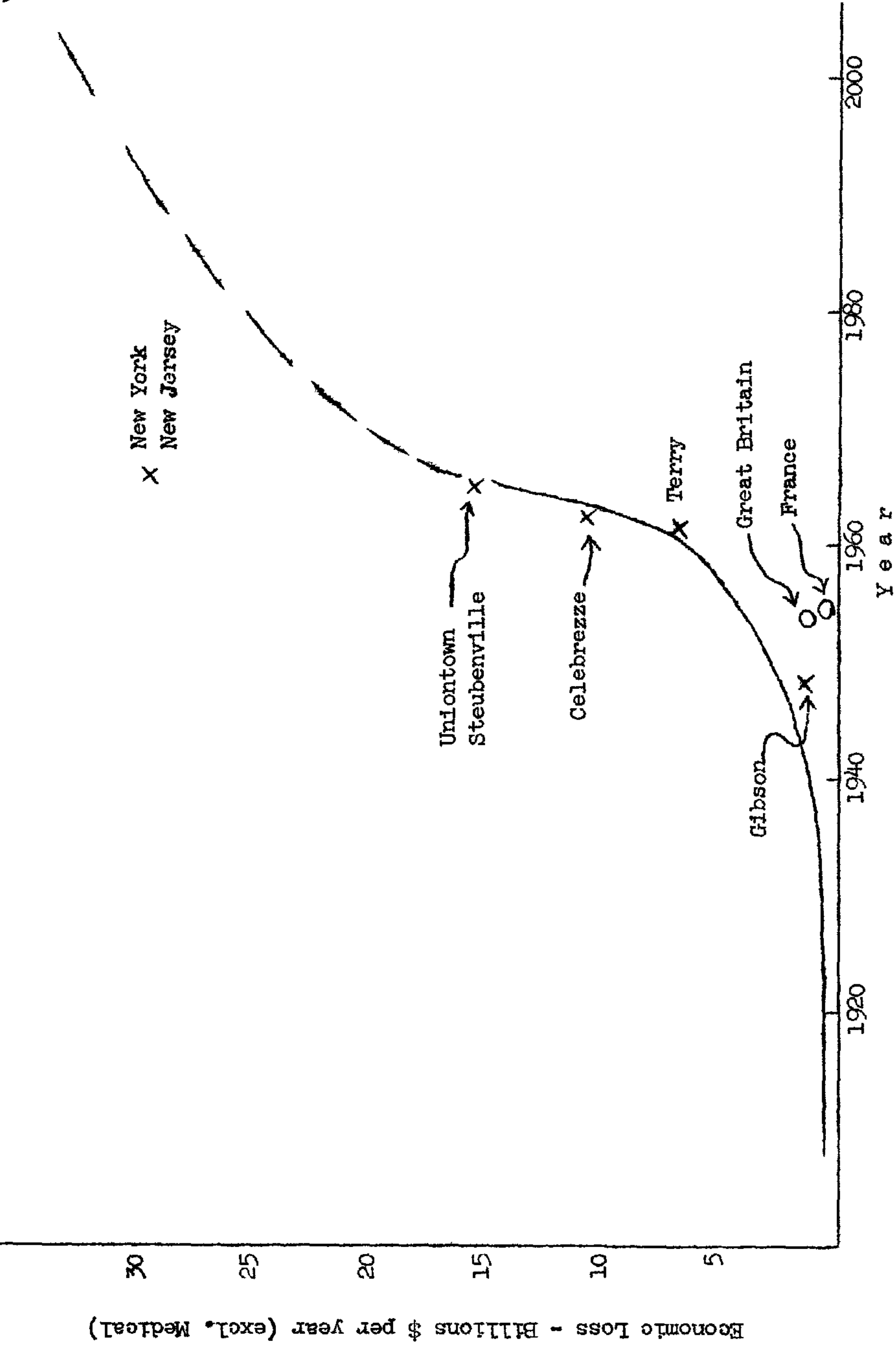


Figure 4

Comparison of Air Pollution Losses



Building stone is attacked by sulphur dioxide and acidic gases at a rapid rate. Dolomitic stone is attacked very rapidly because the carbonates react rapidly to form calcium sulphite which is eventually oxidized to calcium sulphate. The calcium sulphate, as well as the calcium bicarbonate which is also formed, dissolve more rapidly from the stone than the original dolomite. On the other hand, the grains gneiss and sandstone are cemented without carbonates and hence are relatively resistent to acidic gases in the atmosphere. Although in the latter case the stone itself may be resistent to acidic gases in the atmosphere, the cement used between stones is not resistent and the acidic gases can react on the cement.

Fabrics are affected by gases in the atmosphere, particularly sulphur dioxide, oxides of nitrogen, and ozone. Experiments have shown that when cotton fabric is exposed to sulphur dioxide, the breaking strength of the fabric is drastically reduced over a period of 3 to 6 months. Further the rate of loss of the breaking strength of the fabric decreases as the concentration of sulphur dioxide increases. Oxides and nitrogen and oxidant levels adversely affect the colour dyes in cotton fabrics.

Paper and leather goods adsorbe sulphur dioxide almost at a linear rate to many hundreds parts per million. Analysis of leather and paper analysed from 1.5 to 5% sulphuric acid. In another study, the leather safety belt of window washers analysed 6 to 7% sulphuric acid. In fact, a window cleaner fell in the line of duty, claiming that the air pollution had weakened the safety leather straps, and sued the company for the fall.

Rubber cracks under stress by ozone in the atmosphere. Both the number of cracks and the depth of cracks increase with increasing oxidant concentrations. Silver contact points of relays are also badly affected by atmospheric concentrations of organic compounds. In the presence of organic compounds, a resistent crust is formed on the silver contact, increasing the resistence across the contact points eventually causing failure.

External house paint of the lead base type may darken or blacken within a length of minutes if the concentration of hydrogen sulphite approximates 0.1 parts per million and the conditions are optimum for such colour change. A study has shown that the frequency of exterior house painting varies with the concentration of suspended particulate matter in the air. As the concentration of the particulate matter increases, the frequency of repainting homes also increases.

All these effects of air pollutants on inert materials result in a loss of money to individuals and hence to the countries involved. It has been estimated that these costs for the United States could be as high as 30 billion dollars a year. If only a small fraction of this money was spent on air pollution control, there would be a net saving in air pollution losses by the public.

Summary of Discussions

It was stated from the floor that some of the worst conditions of poor visibility (i.e. less than 3 metres) occur in natural fogs in which the water droplets are commonly between 50 and 100 microns in diameter. Dr. Wohlers noted that for a given aerosol mass per unit volume maximum visibility reduction occurred when the particles were in the 0.1 to 0.3 micron diameter range.

For larger aerosol particles (i.e. above 10 microns) settling times can be estimated from Stokes Law but actual conditions of wind speed and turbulence would modify these; below the 10-micron size settling was usually negligible (reference was made to WHO Monograph Series No. 46 for details).

The effects of reduced atmospheric visibility on automobile driving and accident rates was discussed. It was noted from the floor that in Britain, studies by the Road Research Laboratory suggest a psychological loss of speed sense and road orientation by drivers under severe visibility conditions; this condition frequently resulted in an apparently unconscious speeding-up, as well as a more or less random crossing of lanes, with a large increase in accident incidences.

Regarding the feasibility of a standard of visibility index, Dr. Wohlers noted that under ideal conditions in clean air, visibility could be in the order of 50 miles. He said that at least one State in the U.S.A. had established that any condition in which the visibility was less than 3 miles, when the relative humidity was below 70%, indicated a situation requiring improvement.

It was stated from the floor that in Rumania, a good correlation was found between air pollution and problems of arcing electrical transmission lines due to reduced dialectric strength of air. Dr. Wohlers noted that similar problems have occurred in the United States. This was more of a problem, he said, in dry areas of infrequent rainfall where there were long periods for accumulations of air pollutants on insulators to build up. These pollutants act as an electrolyte when rains finally occur. Frequent rains were more apt to keep the insulators clean so that this problem does not then occur.

5. EFFECTS OF METEOROLOGICAL AND TOPOGRAPHICAL CONDITIONS ON DISPERSION OF POLLUTANTS

by

Prof. M. Katz*
WHO Temporary Adviser

Introduction

Meteorological processes that participate in the transport, dilution and removal of air pollutants discharged as waste products to the atmosphere are: stirring and diffusion; fallout, rainout and washout; and atmospheric chemical and photochemical reactions promoted by solar radiation. Atmospheric motions, that diffuse gases and aerosol particles and result in the transfer of momentum, heat and water vapour, occur in most cases on a scale that is much larger than molecular diffusion. The transport of matter and properties take place in the form of exchanging parcels of air called eddies. These consist of random motions that may be treated statistically on the basis of the turbulent diffusion theory. On the other hand, non-random motions, called stirring, may lead to an increase in the average gradient in a given region, which is subsequently reduced by diffusion of turbulent mixing.

Relation of Temperature and Wind Structure to Atmospheric Stability

Temperature structure: Rate of decrease of temperature with height or lapse rate exerts a marked influence on atmospheric stability.

Dry adiabatic lapse rate, $\frac{dT}{dz}$ = approx. 1°C per 100 metres of altitude

Saturation adiabatic lapse rate is approx. 1°C per 103 to 104 metres for saturated air.

Superadiabatic lapse rate - The temperature decreases with height at a rate greater than the adiabatic rate. In this case vertical motions

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upward and downward are accelerated and the atmosphere is unstable. If the environmental lapse rate is less than the adiabatic or if it shows an increase in temperature with height, the atmosphere becomes stable or represents inversion conditions. Vertical motions are resisted. Inversion is denoted by a "negative" lapse rate.

Lapse rate exhibits a typical diurnal variation in the lower atmosphere, with clear skies and weak winds. Strong inversions at night may be prevented by stirring due to strong winds aloft, or by the presence of clouds or precipitation.

Potential temperature, $\frac{d\sigma}{dz} = \frac{dT}{dz} + T$ where T is the dry adiabatic lapse rate.

If $\frac{d\sigma}{dz}$ is negative, a parcel of air is in unstable equilibrium.

For similar wind conditions, instability is more frequent and of greater degree in daytime than at night, and on clear days than on cloudy days.

Formation of nocturnal inversions may be accompanied by fog if the moist air cools below its dew point. During conditions of air stagnation, fog and accumulation of pollutants, there is a marked decrease in solar radiation in the lower atmosphere.

Wind structure: In the lower atmosphere, up to heights of several hundred metres above ground, the wind speed "u" varies with height, "z", according to a power law $u/u_1 = (z/z_1)^p$; where "p" lies between 0 and 1. If the environmental lapse rate is adiabatic and terrain is level, with low surface cover, the value of "p" is approximately 1/7.

In the lowest few hundred metres above ground, the wind speed exhibits a diurnal variation with a maximum in the early afternoon, and a minimum in the hours after midnight. Wind speed is generally higher in winter than in summer, with a tendency towards maximum wind speeds in spring.

The vector forces which determine the speed and direction of the wind are the pressure gradient force, the horizontal deflecting force (Coriolis force), centrifugal force and frictional or shearing stress forces. Wind speed increases and changes its direction with height. At some height above the friction layer, the wind speed attains the "geostrophic wind" which blows in a direction parallel to the isobars with a speed inversely proportional to the isobar spacing. The gradient wind takes into account the curvature of the isobars.

Atmospheric turbulence or eddies may be classified as mechanical (shearing stress) or thermal (convection). Mechanical eddies prevail on windy nights with neutral advection. Thermal eddies prevail on sunny days with light winds. Eddies or gustiness types have been classified in accordance with observed wind direction fluctuations of an anemometer. The horizontal component of turbulence exceeds the vertical component and this excess increases when averages are taken over greater time intervals.

Topography

The topography by virtue of the combined effects of surface friction, drainage and radiation modifies the temperature and wind profiles. Local effects of topography are sea-land breezes, mountain-valley winds, fohn winds, etc.

Large Scale Wind and Temperature Changes

Most changes in weather elements such as wind, precipitation and stability, etc., are due to the Primary, Secondary and Tertiary circulations.

Applications to Air Pollution Problems

Meteorological factors and conditions must be assessed in relation to the following :

1. Location of air sampling stations and meteorological stations.

2. Analysis of pollutants - particulate and gaseous; concentration and frequency distribution in relation to wind roses of speed and direction, and of atmospheric stability or lapse rates.

   Non-turbulent dispersal and scavenging - rainout, fallout and washout of pollutants.

3. Mathematical models of urban air pollution.

   a. Inventory of sources → Fuels → Heating, power, steam
      Fuels → Transportation
      Inventory of sources → Domestic fuel use
      Inventory of sources → Industrial sources

b. Inventory of emissions

c. Location of sources

d. Concentration levels of particulate and gaseous pollutants at sampling stations

e. Construction of pollution level contours of urban area and adjacent areas on maps

f. Relation of average and maximum levels of pollutants, frequency distribution, etc., to ambient air quality standards for designated areas

g. Application of plume rise and diffusion theory to stack emissions and estimated ground concentrations under various prevailing meteorological conditions for strong point sources and for weaker line sources or area sources

Sutton Diffusion Equation

$$\text{Concentration} \quad z = o = \frac{2\,Qm}{\pi C_y C_z\, u\, x^{2-n}} \exp - \left[\frac{He^2}{Cz^2} + \frac{y^2}{C^2 y} \right]$$

$$\text{Distance} \quad X \ \text{max.} = \left[\frac{He^2}{Cz^2} \right]^{\frac{1}{2-n}}$$

$$\text{Max. conc.} \ z = o = \frac{2\,Qm}{\pi e\, u\, He^2} \ \frac{Cz}{Cy}$$

Gaussian form of Sutton Equation (Pasquill - Meade)

$$\text{Concentration} = \frac{Qm}{\pi\, \sigma_y \sigma_z u} \exp. - 1/2 \left[\frac{He^2}{\sigma_z^2} + \frac{y^2}{\sigma_y^2} \right]$$

σ_y and σ_z are standard deviations of the horizontal and vertical concentration distributions.

i. $\sqrt{2} \quad \sigma_y = C_y x^{(2-n)/2}$

ii. $\sqrt{2} \quad \sigma_z = C_z x^{(2-n)/2}$

iii. $\sigma_y^2 = 1/2\ C_y^2 \ x^{2-n}$

iv. $\sigma_z^2 = 1/2\ C_z^2 \ x^{2-n}$

In the above equations, "Qm" is the mass rate of emission of the pollutant, "u" is the wind speed, "C_y" and "C_z" are virtual diffusion coefficients in the crosswind and vertical directions, "x" is the distance from source downwind, "y" is the distance crosswind, "n" is a stability parameter which varies between 0 and 0.5 and "He" is the effective height of emission. Consistent units must be used.

Factors in Air Resource Management

Air resource management deals with a system consisting of a variety of sources and mass emission rates, a wide range of pollutants, a high degree of variability in the transport and dilution or diffusion capacity of the atmosphere, chemical and photochemical interaction of atmospheric waste products and differing effects on receptors that consist of living or inanimate material. Management decisions may curtail or suppress emission sources and protect or remove receptors. But the weather is the most difficult portion of the system to control, except by scientific weather forecasting.

The atmosphere is a finite natural resource for the waste disposal of gaseous and particulate pollutants. Although, in a strict sense, the atmosphere cannot be controlled, it can be regarded as a replenishable resource as long as a suitable equilibrium is maintained between the input of pollutants and natural air cleaning processes that promote their removal by precipitation, chemical reaction, deposition and absorption by land, water, vegetation and other receptors. Accumulation of pollutants occurs whenever this equilibrium ceases to be maintained and the results may sometimes lead to air pollution disasters and other highly adverse situations.

The primary objective of air resource management is to exploit the natural capacity of the atmosphere to transport and dilute the waste products of population and industry; without the risks attending the deterioration of the quality of the atmosphere that might lead to economic losses to property of harmful effects on vegetation and health. The meteorological component of an air resource management system must meet the following fundamental requirements :

1. Establishment of the limits for atmospheric transport and dispersion of pollutants in a given urban and industrial areas, or air resource region.

2. The utilization of the variabilities in space and time of atmospheric transfer and diffusion properties to the best advantage for design and control of sources and for protection of receptors.

3. A practical definition of the meteorological input into the management system that will enable it to maintain the established air quality criteria and standards.

The Role of Mathematical Models in Air Resource Management

Mathematical model simulation of the source - atmosphere system is useful to assure the following management decisions: (a) specification of source distributions, (b) control of source rates of emission. Two approaches to mathematical models may be employed :

1. History of air pollution sources (inventory), ambient air quality measurements and meteorological data may be employed to construct statistical models of the air pollution system.

2. A physical model may be constructed from a knowledge of the processes of atmospheric transport and diffusion and an understanding of the time and space distributions of emission sources and resultant influences on air quality.

Both, statistical and physical methods may be employed concurrently in order to combine the predicted variables of this prediction system.

Statistical Models of the Air Pollution System

Independent variables are source strengths and distributions, location and building or chimney heights, wind speed and direction, lapse rates, precipitation, cloudiness, visibility, intensity of sunlight and atmospheric stability classes, etc.

Dependent variables include measurements of pollutant concentration levels, their distribution and frequency in space and time, etc.

The solutions reveal predictive relations between these variables and the exposure history and effects on receptors.

Summary of Discussions

See page 40. Combined with discussions of Lecture No. 6.

6. CALCULATING DISPERSION OF POLLUTANTS FROM STACKS

by

Prof. M. Katz*
WHO Temporary Adviser

Mathematical equations have developed to calculate downwind concentrations of stack discharges under a variety of meteorological conditions. The diffusion equations are most helpful for an estimation of ground level concentrations. The equations cannot be used to determine precise calculations.

The earliest work on this area was done by Sutton based upon a Gaussian model. Subsequent dispersion equations were developed by Pasquill, Bosanquet, Holland, and many others. Each equation should be carefully evaluated for the specific problem.

A comparison of dispersion estimates with actual measurements of gas concentrations should be made. After such data are obtained, a revision of empirical constants in the dispersion equation will improve the accuracy of the calculated concentration.

Summary of Discussions of 5 and 6 above

In answer to a question concerning the proper height of stacks for dust-emitting industries such as cement works, Prof. Katz stated that, as with other types of industries, stack design must be on the basis of effective plume height and calculated ground level concentrations downwind, coupled with specifications for proposed air pollution control equipment. All meteorological, climatic and topographic information should be considered and the design should be related to local air pollution regulations. Specifications for a proposed stack should be submitted to authorities for approval.

Asked whether short stacks would contaminate a smaller ground area and, therefore, be preferable to high stacks, Prof. Katz noted that his was a

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fallacy and that short stacks would result in very high pollutant concentrations. Also, since installed dust-collecting equipment has a limited efficiency, finer dust would still be emitted and would behave as a gas. Adequate stack height was needed to insure that ground level concentrations will not exceed acceptable values. In general particulate levels should be less than 100 to 150 micrograms per cubic metre. An industry may extend its property line to include areas having greater than 100 to 150 micrograms per cubic metre, but the visible effects of dirty plumes may still be objectionable and subject to regulation.

Because atmospheric stability and wind speed will vary, no rule of thumb can be used for calculating the distance of maximum ground level concentration as a simple multiple of stack height. This must be determined for a range of wind speeds and possible stack heights according to the best available dispersion theory.

Developing countries would be well advised to survey the meteorological conditions and other pertinent background data for use in pollution prevention planning prior to developing and industrial area. This type of approach for predicting ground concentrations under given conditions, whether based on statistical models or on physical models, is quite sophisticated and requires the advice of experts.

If a meteorological study of an area is made, the known properties of dispersion phenomena can be applied since the basic principles are applicable anywhere.

7. NATURE AND AMOUNTS OF POLLUTANTS EMITTED FROM VARIOUS SOURCES (STATIONARY AND MOBILE)

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

The source distribution for selected air pollutants for the United States in 1965 is shown in Table 3. As noted in an earlier report, three categories of industry, transportation, and electric generating plants, account for 80 to 90% of the weight of air pollutants emitted in the United States.

Table 3

Source Distribution for Selected Air Pollutants - USA - 1965

	Percent of Total				
	Oxides of Nitrogen	Carbon Monoxide	Partic-ulates	Oxides of Sulphur	Organic Compounds
Industry	20	3	50	38	25
Refuse	1	2	5	1	7
Transportation	40	92	15	2	65
Power Plants	30	1	20	45	1
Space Heating	10	3	10	15	3
Total Emissions 10^6 tons/year	8	65	12	23	15

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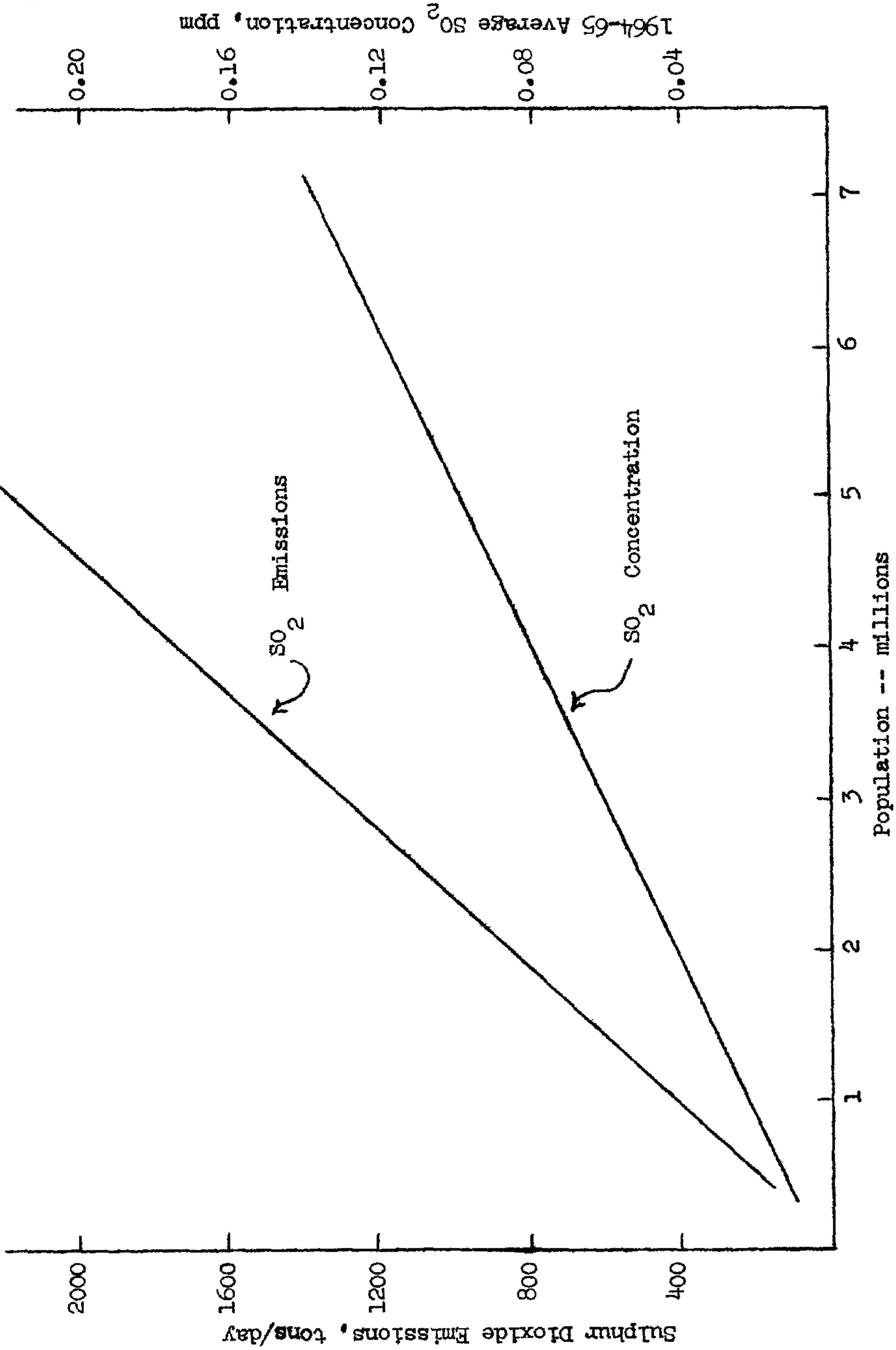
Figure 5 shows the relationship between population and sulphur dioxide emissions and concentrations. For sulphur dioxide, there is a direct correlation between emissions and population to approximately an urban area of 6 million people, emitting of the order of 2500 tons per day of sulphur dioxide. Also shown on Figure 5 is the variation between population and sulphur dioxide levels on a yearly basis. For a population of 5 million people, the sulphur dioxide yearly concentration approximates 0.1 part per million. The information shown in Figure 5 has been duplicated for oxides of nitrogen, carbon monoxide, and organic compounds with high correlation coefficients. No correlation was found between particulate emissions and population, although a relationship is available for particulate concentration and population.

The study of sulphur dioxide between the years 1950 and the year 2000 may be used as an indication of future air quality. It has been estimated that if the present emission trends continue without air pollution control measures, the emission of sulphur dioxide in the United States will be more than double by the year 2000. It may be assumed that if emissions double, the sulphur dioxide levels will also double. If reasonably good progress is made towards the control of sulphur dioxide, the air concentrations will be approximately 25% greater in the year 2000 than they were in the year 1965. If maximum possible progress is made in the control of sulphur dioxide to the atmosphere, the emission of sulphur dioxide in the year 2000 will be less than that in 1965, and hence the sulphur dioxide level will be less than that in 1965.

Of the mobile sources of air pollution, the automobile is by far the greatest contributor. The emissions from automobiles are particularly significant in those areas which are bothered by photochemical air pollution. The automobile gives off large concentrations of organic compounds and oxides of nitrogen which react in the atmosphere to form photochemical air pollution. It has been determined that of the weight of fuel supplied to the internal combustion engine, 6.5% is discharged in the exhaust, 2.1% is discharged from the crankcase, and 1.5% comes from the carburettor and fuel tank. The exhaust contains the highest levels of organic compounds which are most photochemically active. The emission of organic compounds, oxides of nitrogen and carbon monoxide vary with the type of driving, engine cycle, speed of the vehicle, as well as between automatic and manual transmissions.

Figure 5

Population versus SO_2



Devices are available to control all sources of emission from the automobile. For the organic compounds which pass the piston ring on the power stroke (crankcase emissions), the gases are vented to the carburettor where they are again burned. For exhaust emissions, four types of control devices have been suggested, a direct flame afterburner, a catalytic unit, an air injection system, and the Clean Air Kit. The air injection system consists of an air pump attached to the fan-belt which forces air at the exhaust porte, burning the exhaust gases to carbon dioxide and water; the Clean Air Kit is an improved tuning of the engine by modifying the carburettor and the distributor so that the exhaust levels are below those required by regulation.

In the United States, the diesel engine is not as serious an air pollution contributor as that of the gasoline engine; only 1 to 5% of the total vehicular fuel is diesel. In the United States, diesel exhaust is an odour nuisance. Diesel exhaust could be important in areas where large quantities of diesel fuel are used. Because of the high air to fuel ratio in the diesel engine, carbon monoxide emissions from the diesel engine are lower than those of the gasoline engine, organic compound emissions are lower, but oxides of nitrogen emissions are higher on a per-gallon consumed basis.

Standards have been devised by the United States for automobile emissions, as shown in Table 4. The concentration of carbon monoxide in the automobile exhaust cannot exceed 1.5% by volume and hydrocarbon emissions cannot exceed 275 parts per million. In the upper half of the table, the emission limits are expressed in grams per vehicle mile in contrast to a volume unit. The 1968 standard for carbon monoxide is 33 grams per vehicle mile and the proposed standard for 1970 is 23 grams per vehicle mile. By comparison, the hydrocarbon standard for 1968 is 3.2 grams per vehicle mile and the proposed 1970 standard is 2.2 grams per vehicle mile.

Emissions from stationary sources may be found in numerous publications by the National Air Pollution Control Administration.

Table 4

1968-1970 Federal Motor Vehicle
Exhaust Emission Standards

Pollutant	Grams per Vehicle Mile		
	Typical Uncontrolled Vehicle	1968 Standard	Proposed 1970 Standard
Carbon monoxide	71.0	33.0	23.0
Hydrocarbons	9.7	3.2	2.2

1968 Federal Motor Vehicle Standards

Engine Displacement cubic inches	Carbon Monoxide %	Hydrocarbons ppm vol.
<50	*	*
50 - 100	2.3	410
101 - 140	2.0	350
>140	1.5	275

* Unrestricted

Summary of Discussions

There was considerable discussion in relation to automobile emissions and their control. Dr. Wohlers noted that Public Health Service studies in the United States over the past few years have not shown any dangerous levels of lead in the atmosphere but that studies on this are continuing. He said ethyl bromide was used in petrol as a scavenger for lead (from tetraethyl lead, an anti-knock agent). This forms volatile lead bromide which is blown out in the exhaust. After-burners of various types have been developed for exhaust control but these are currently more expensive than other methods of exhaust control; prices of \$ 50 for catalytic units, good for about 12 000 miles of service, to about \$ 150 for direct flame after-burners, good for the life of the car, were noted. Because of the wide-range of exhaust flow rate, absorbent units did not appear to be feasible.

As a substitute for internal combustion engines, Dr. Wohlers said that electric motors and steam powered engines hold the best promise. Turbine power units have been developed and these are an improvement over piston-type engines in respect to air pollution.

Concerning diesel engines, Dr. Wohlers said the main problem here is odour, though perhaps one can also expect more nitrogen oxides and less CO than from engines using gasoline.

8. SOME EPIDEMIOLOGICAL THOUGHTS ON AIR POLLUTION

by

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Introduction

Among the many research projects which are presently under investigation, the field of biomedical research has gained the strongest impetus in recent years. Efforts are directed toward conquering the diseases which alter man's normal course of existence. Although diseases have been with man since his existence it was not until the past century that he developed the tools and techniques to discover the etiology and thus control many of these diseases. There are still, however, many diseases whose origin cannot be readily determined and hence it is difficult to find the proper means for the study of these diseases. Many of these diseases are, unquestionably, the result of the vast advancement of scientific technology.

While the epidemiological aspects of most communicable diseases have been studied with varying degrees of success for many years, the epidemiology of the non-contagious diseases have focussed the greatest attention on the public in the last two decades. Many investigators believe that the air pollution problem is responsible, to a great extent, for the increase of non-contagious epidemics that have occurred in many areas of the world. Unfortunately the search for adequate proof of the correlation of disease to air pollution has been greatly hindered because (1) no single source could be demonstrated as the only cause of the adverse effect, immediate or delayed, (2) in most cases air pollution epidemics were recognized some time after they had occurred, and (3) no exact disease pattern could be demonstrated in any of the previous episodes. Hence, the study of air pollution epidemics includes a number of variables, in addition to human factors, that may result in a completely different conception of the term epidemiology. Perhaps only one certainty exists at the present, and that is much work and effort need to be accomplished for the demonstration of this complex "cause - effect" relationship.

The Problem

In the "classical" approach of studying epidemics, it has been customary to accept the causative role of the mechanisms of bacterial infection. Even if a patient shows symptoms having little resemblance to the "classical" reaction, the diagnosis may be defended with the understanding that the pathologic conditions produced by any infective process are, among other things, a function of the host tissue, as well as the activities of the agent and thus an induced risk of error is recognized.

There are no ready-made recipes to be followed in the study of air pollution, nor is there general agreement among scientists upon the application of "Koch's postulates" to this problem. But to clearly establish the fact that an air pollution epidemic is or has been present the following conditions must be met :

1. There is, or has been, recognized a number of cases of respiratory illness clearly in excess of normal expectation.

2. The number of excess cases demonstrate symptoms of a toxic effect.

3. A pollutant capable of causing this respiratory toxic effect is, or has been present.

4. All of the cases admitted are, or have been, exposed to this pollutant, and

5. There are no other sources which cause, or could have caused, this epidemic.

In addition the "toxic effect" must be characterized by the manifestation of symptoms that can be diagnosed by the clinician. The occurrence of a toxic pollutant then must be demonstrated by the quantitative and qualitative examination of the air. The interpretation that can be drawn from this study, whether or not a toxic pollutant exists, will also depend upon the association of time and place. Furthermore, the absence of any other causative agent must be clearly ascertained and the effect of the pollutant must be clearly demonstrated. In many cases, air pollution has been accused of being the cause merely because of the increased prevalence of nonspecific illnesses reported which may be entirely due to the variation in severity occurring all the time. Therefore, the most important factors that must be determined are (1) there must be a "population at risk", and (2) there must be an "excessive exposure". But in order to define "excessive exposure" there must be a sufficient concentration of a toxicant prevailing for a certain time period in a certain area and an unquestionable toxic effect must occur within this certain time period. If this condition can be, or is, met then the validity of evidence for the clarification of this problem is clearly established.

The Present Status of the Epidemiological Aspects

Unfortunately, the above statement in its present form may be too rigid to be generally acceptable to the scientist because the above conditions are not exactly met nor are they applicable to the normal urban environment. In all known air pollution disasters no single pollutant ever could be demonstrated as the causative agent. The cause-effect relationship has been demonstrated mainly in the older age groups and in those persons already suffering from respiratory or cardiovascular disease. Furthermore, in some episodes a "quick" as well as a "slow" consequence was observed; and hence would aid to the puzzle of this complex problem. In addition, the various types of pollution and the variables existing from one region to another region greatly hinder any recognition of an epidemiologic pattern.

The existence of an air pollution epidemic was recognized but too late in most of the known episodes. A review of the "London Epidemic" showed clearly a sudden increase in the mortality rate in excess of normal expectation; even though these rates are recognized, albeit belatedly, it is difficult to retrospectively analyse the situation and, hence to find a conclusive cause-effect relationship. The other difficulty with retrospective studies arises in the determination of whether there was a specific or a nonspecific chronic disease present and to what extent personal atmospheric "pollution" i.e. "cigarette smoking" contributed to the disease. In spite of these disadvantages, it is evident that the retrospective study plays a vital role in epidemic investigations because (1) they provide data that may be useful for future studies, (2) the mode of occurrence may be determined more readily, (3) some responsible factors may be detected that have not been detected previously, and (4) some logical patterns are existing and their recognition will enable the prevention of some future epidemics

Toxicological studies have played an important part in the determination of the effects of pollutants upon laboratory animals. Of the many studies that are presently under investigation, studies of the toxic effect of pesticides, radionuclides in the air, and the exhaust from moving vehicles have gained the strongest impetus in recent years. The threat of these pollutants to the environment has been recognized and, thus, may be the possible reason for this intensified research. There are, however, limitations in the evaluation of the results obtained from these laboratory studies. These limitations are (1) the experiments are performed in a "controlled environment", and (2) the very same toxicants may not produce the same symptoms in animlas as in man. The differences in anatomical structures and in metabolism of the various species used in investigations play an important role in the determination of the toxic effect of some pollutants. The use of primates in the study of the possible effects of pollutants has gained much attention in recent years. The close evolutionary relationship of these animals to man, and the fact that these animals adapt well to the outdoors, may result in studies that simulate more closely the conditions to which the population is at risk.

Possible Future Trends in Epidemiological Studies

The need for further intensified field and laboratory studies of the many problems brought about by air pollution is apparent. These studies are not only justified by reason of human health, but also by the economic loss that is associated with this problem and for pure aesthetic reasons. In many instances unusually strict control measures are imposed upon the sources of pollution, even though the limitations of the atmosphere in coping with the ordinary emissions are not well recognized for lack of knowledge. These control measures forced the industries and the communities to accept an additional financial burden without really demonstrating a reduction in the harmful effect to man and his environment. This may be a reasonable approach to the problem but, needless to say, it also causes a great deal of frustration and, usually, leads to fruitless discussions. The latter being mainly due to the inability of trapping all wastes from all sources or because the process is uneconomical. This may lead to the assumption that this type of "nonspecific" control does not satisfy the requirement and hence the "calculated risk" can be demonstrated again.

The epidemiologists studying the patterns of infectious diseases have recognized some fundamental approaches for some time. Some of these approaches are the intensive clinical study of the disease process, the demonstration of the agent and its culture, the study of the population at risk under different degrees of exposure, and to support their findings with laboratory experiments. The study of environmental pollution epidemics has not, unfortunately, developed this classical approach. The reason for this slow development may be found in the relatively young problem and also in the complexity of this type of study. The methods usually employed in this type of epidemiological study were confined to the determination of simple incidence and point prevalence of some diseases and to the calculation of specific mortality and morbidity rates. These methods are basic, to say the least, for little is known about the person, the place, and the time. Furthermore, little information can be retrieved about the environmental factors that may be, in part, responsible for the clinical symptoms or for the possible reason of Exitus. It is evident that the approach to this type of study must be executed on a broad scale in order to effectively determine the magnitude of the problem; needless to say this is not an easy venture.

The primary problem may be the inability to recognize the disease entity and thus the possible cause-effect relationship. This indicates that, regardless of the diagnostic procedures used, any inference drawn will automatically be received recessive, depending upon the motives of the individual. Consequently, the investigator should rely for his indices on those diseases that are suspected to bear a relationship to the prevailing atmospheric conditions. To do this the atmospheric conditions must be analyzed with respect to the type and magnitude of air pollution, and to meteorological patterns. This analysis may prove to be difficult for there are many variables that must be taken into consideration. But if and when these two conditions are met, then the causal relationship of agent-disease may be established, provided that the responsible "reservoir" of the agent can be found. This might be very difficult to prove for there are many different materials found in air. Unless the mode of transmission can be clearly demonstrated, which is peculiar to one agent, it is unlikely that the presence of air contaminants can be shown as the primary cause and not merely as being a possible contributing factor.

To better understand some of the aspects of the epidemiology of airborne outbreaks, it appears necessary to refine and to expand the data on incidence and point prevalence. This does not, necessarily, require a sophisticated method for a statistical analysis of the data, but should be directed more toward comparing different sample populations which are exposed to different levels of the environmental conditions. The degree of susceptibility of an individual to air pollution should also be established with particular emphasis to the specific age groups, the socio-economic level, the geographic location, and his habitats. Another factor that must be included into this data is the type of work the individual performs. This may lead to a better understanding of the clinical findings.

As mentioned previously, in most known episodes the most affected people were the elderly or those persons with chronic respiratory or with cardiovascular symptoms. Consequently, the determination of the age-specific attack rate will result in the best index of the problem, particularly when compared to other population samples. The socio-economic level of the sample may be of greatest interest to the study because it may reveal several important factors. These factors may include the type of housing, the degree of susceptibility within one group, the nutritional level of the sample or of the population, and the living pattern of the individual in the sample. The geographic location of the sample is important because (1) unusual topographic features will determine the greatest possible variation in the amount of exposure, and (2) the meteorological conditions vary greatly from one place to another.

Carefully planned and executed laboratory studies will greatly enhance the success of any field study. The present status of laboratory investigations is not overwhelmingly optimistic; the problem though is not an easy one. More investigations must be performed with animals that resemble more the patho-physiological patterns of humans, and more studies must be conducted under more natural environmental conditions. With a gain in scientific knowledge from these laboratory investigations a better understanding of the epidemiological aspects in air pollution will be achieved and new and better tests will be developed for a more precise diagnosis of the disease.

Conclusion

It is appreciated that the study of the epidemiological aspects of "airborne contaminants" is not an easy venture nor is it an inexpensive one. The solution to this problem has not been answered satisfactorily even though some progress has been made in recent years. But the need for further study of this complex problem is apparent, not only by those few idealistic investigators who are dedicated to science and to this society, but every individual can and must help, if only for the sake of his own comfort. Finally, it is hoped that this statement of the problem may help in securing the concern and the thoughts of the individual for an emphatic support to a "reasonable" solution of this paramount problem.

Summary of Discussions

Prof. Lawther said that Dr. Fritschi's definition of epidemiological work should be enlarged to embrace long-term studies of disease among the people as well. He agreed that many air pollution effects will be successfully handled only on an epidemiological basis and he noted a need to standardized questionnaires on symptom complexes. He felt that cohort analyses would also be valuable in air pollution studies. It was not always necessary, he said, that a specific toxic chemical be identified but that non-specific factors can also be used. Dr. Fritschi, in reply, was of the opinion that the study of long-term effects among industrial workers was more properly related to industrial hygiene.

Prof. Katz noted that the Costa Rica air pollution episode was the only one in which a specific cause-effect relation was clearly demonstrated. In acute cases, he felt, it is sufficient if one can show that an occurrence of air pollution coincides with a rise in the number of deaths. It is more important, he felt, to measure the day to day effects of air pollution, using not only epidemiological studies but all aspects of toxicology and related disciplines as well.

Dr. Fritschi noted the early study of John Snow in 1849 in the case of the Broad Street pump in London and cited this as a classical epidemiological study in sanitation. Prof. Lawther agreed with this and commented that John Snow had spotted cholera cases, noted their relation to the use of the pump and broke the cause-effect chain by pulling the handle off the pump - "this is what we should do in air pollution", he said.

9. AIR POLLUTION PROBLEMS IN EMR COUNTRIES

by

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Introduction

The interest of the World Health Organization in air pollution problems both at the international level and, in particular, in the Eastern Mediterranean Region stems from its duties to assist Member States in taking appropriate measures for the protection of health and the control of the environment. This interest is underlined by the responsibilities assigned to the Environmental Pollution Unit of WHO, the functions of which, in respect to air pollution are as follows (WHO Document EH/68.1):

> "To collect and disseminate information on the increasingly complex problem of air pollution, with special reference to the situation and trends in industrial areas and large towns, and facilitate exchange of information. To provide technical guidance on the prevention of air pollution and encourage the training of qualified personnel. To advise on air pollution control measures by technological and other means, such as administrative regulations and urban planning, and stimulate relevant work in this field."

In accordance with the recommendations of the first WHO Expert Committee on Air Pollution, particularly in respect to the collection of information on sources of pollution and their control, and of further meetings including the second WHO Expert Committee on Air Pollution, which upheld and elaborated upon the conclusions of the first one, the interest of a number of countries of this Region was aroused and requests for WHO assistance were made to the Regional Office, with a view to surveying air pollution problems and submitting appropriate recommendations for control and in some cases simply for prevention. WHO was glad to co-operate and agreed to their request with the result that a number of WHO consultants have visited at least six countries of the Region to carry out air pollution studies. Their reports have been published and some of them have been distributed to the participants.

It is realized that a complete survey of air pollution problems in the Middle East cannot be made at once. This will take time; but from the WHO reports already published and from the reports of WHO project engineers, information has been gathered from which it appears that the air pollution problems in this Region are, in general, not severe. They may be related more specially to the following:

Motor Vehicles

Motor vehicles are one of the main sources of air pollution and of complaint in many parts of the world. They discharge into the air tons of pollutants, which interfere with our comfort and can be detrimental to our health. It is worth indicating in this respect that in 1966 in the United States motor vehicles discharged into the atmosphere 66 million tons of carbon monoxide and 12 million tons of hydrocarbons. As is well known, carbon monoxide can be quite toxic and hydrocarbons are very important in the formation of photochemical oxidants.

In the same context, it is of interest to note that, according to a study made in California, about 70% of the emission of hydrocarbons from motor cars come from the carburettor and the tank, and are lost through evaporation.

This study verifies that an improperly controlled vehicle will waste, as unburnt or partly burnt fuel, one gallon out of every ten gallons put into the tank. This may be unbelievable but it is a fact. This amounted in Teheran in 1964 to a loss through evaporation of about 28 million litres of petrol. This quantity has, of course, now greatly increased and may well have reached in 1968 60 million litres. The importance of controlling emissions from cars, even if it be only from the economic standpoint, is therefore obvious.

In general, air pollutants emissions from motor vehicles represent a problem in many countries, especially in the highly industrialized cities of Europe and America. In most of the Middle East countries, however, the situation does not appear to be serious. This is reflected in the WHO documents mentioned above. The information provided in this respect is summarized below:

Situation in Cyprus

In Cyprus, which was visited by a WHO consultant in 1967, the records show that the total number of vehicles licensed in 1965 was about 70 000 including 4 000 of the diesel type. The estimated consumption of fuel was approximately 120 000 tons/annum which represents an equivalent sulphur dioxide release to the air of about 2 000 tons/annum. This has indeed very little significance. In fact, the total release of SO_2 for 1966 for all the fuel from petroleum products used in the whole island was not more than 12 000 tons/annum, for a total fuel consumption of about 350 000 tons, which is low. The conclusion of the survey is that there was no particular problem in relation to motor vehicles. The growth of traffic in Cyprus is typical of a developing country in which people appear to have increasing means and increasing standards of living. Some advice was however given regarding the operation and maintenance of diesel vehicles, as they are likely to give off black smoke, which may, at times, be very objectionable.

Syria and Jordan

From WHO field staff reports it was learnt that in Syria and Jordan the further import of diesel vehicles has been prohibited by law. In Amman records show that in 1967 there were 4 600 diesel vehicles out of a total of 19 000 licensed vehicles. The liquid fuel consumed is produced at the Jordan Petroleum Refinery and the total production for the country was 393 000 tons for 1967 or about as much as is used in Cyprus. There is really no serious air pollution problem to report here. However, complaints about diesel vehicles exhaust have been reported, and it is assumed that this was one of the main reasons for prohibiting their further importation.

In Syria the total amount of petroleum consumed in 1968 is given as 1.58 million tons approximately, including 800 000 tons or slightly more than half for gas oil. Information is not available at the Regional Office concerning the problem of diesel vehicles in Syria but it may be assumed that complaints could have been received in this respect, resulting in the present prohibition of the import of diesel cars.

It should be pointed out in connection with pollutant emissions from motor vehicles that both petrol and diesel vehicles do not emit nitrogen and sulphur oxides to a great extent. From WHO Document WHO/AP/67.28 on the Public Health Aspects of Air Pollution from Diesel Vehicles it may be seen that "the sulphur content of petrol is sufficiently small to be ignored but diesel engine fuels commonly contain sulphur compounds equivalent to a sulphur content of the order of half of one per cent. Even so, the amount of SO_2 emitted under normal operation is usually regarded as sufficiently small to be discounted as an air pollutant except, possibly, in circumstances where ventilation may be inadequate."

Teheran - Iran

The situation in Teheran was studied by Mr. Schueneman (reference WHO document EM/ES/82) who provides relevant recommendations for the abatement and eventual control of the diesel vehicle problem.

As at July 1965 there was already in this capital city about 7 500 diesel buses and cars out of a total of 77 000 vehicles. Approximately 375 000 m^3 of gas oil were used in the city for an equivalent SO_2 release to the air of over 6 000 tons per year, the total release of SO_2 for general fuel consumption in Teheran being 47 000 tons. This is relatively, not very much, but what matters most, as pointed out by Mr. Ireland (reference WHO document EM/ES/94) is not the emission of sulphur dioxide, but the concentration reaching the lungs and it will be interesting to have the results of the monitoring programme for this gas. The total mass emission is not high, at present, compared with many modern cities, but it may increase with increasing industrialization unless natural gas becomes available in large quantities.

The problem of diesel engines as related to air pollution is discussed in WHO document WHO/AP/67.28. This document stresses that there is no justification for the attacks so frequently made against the diesel engine on the grounds of its supposed effects on health. It is true that smoke, although harmless, is accompanied by the formation of carbon monoxide and, in this respect, the continuous emissions of thick black smoke by an engine, labouring at the limit of its power, is both harmful and unnecessary. However if a diesel engine including its fuel pump is well regulated and maintained and the vehicle is well driven this is not likely to occur. As pointed out in the document, the very dense smoke should be blamed not on the engine but on the misuse of it.

On the other hand, it must be mentioned that carbon monoxide emissions which are so dangerous in heavy traffic, come mainly from petrol-driven vehicles, and hardly at all from diesels. In 1966 there was ten times as much carbon monoxide emission in the United States from automobiles than from all the other sources combined. It will be recalled that carbon monoxide is very toxic and will kill at high concentration. At about 100 ppm, a concentration of which was found occasionally during observations in heavy traffic in Oxford Circus, London, and in Detroit, most people experience dizziness, headache, and other forms of CO_2 poisoning. The "serious level" of carbon monoxide, in the ambient air, adopted in the United States is 30 ppm for 8 hours or 120 ppm for 1 hour, the "serious level" being defined as the level at which there will be alteration of bodily function.

The Smog Problem

Photochemical "smog" is another type of air pollution problem to which reference should be made in connection with motor vehicles. It results from the reaction of nitrogen oxides and hydrocarbons in the presence of sunlight. Smog can severely damage crops, reduce visibility, irritate mucous membranes and reduce resistance to respiratory diseases. It has been observed in a number of cities in the world and particularly in Los Angeles where hydrocarbon emissions are very great. Seventy per cent of them come from the 3 1/2 million cars circulating in the city.

Little information is at present available at the Regional Office concerning photochemical smog in this Region. It is thought that this type of air pollution may only occur in a few cities, possibly in Cairo or in Teheran where, as reported in WHO document (reference EM/ES/82), the general air pollution by nitrogen oxides and hydrocarbons might have, already in 1965, reached levels high enough to cause photochemical smog.

Industrial Sources

The present information available regarding air pollution from industries in this Region is confined to the situation in Lebanon, Kuwait, Cyprus and the City of Teheran

The problems appraised were often localized, as for example the Heri Cement Factory in Lebanon. As such they did not affect a great section of the population. However, in other cases the pollutants from the stationary sources were important enough to call for strong recommendations on the part of the consultants towards their abatement and control. Such was the case in Kuwait for the Chemical Fertilizer Company. A brief account is given below of some of the main sources studied.

The Cement Industry

Both in Lebanon and Teheran, there are a number of cement factories which were the cause of complaints from the population, especially in Lebanon.

It will be recalled that the manufacture of cement is a dust-forming operation and that the complete elimination of dust is practically impossible. The most serious problem from a technological standpoint involves dust separation from the hot kiln gases.

In all the countries involved in the study, one of the main problems was, in effect, the lack of dust arrestors in the kilns resulting in important emissions of dust. The consultants have reported observing very dense plumes of dust being emitted from kilns. Without exception no tests were made to determine the dust load in the waste gases. The dust problem remains important and it is suspected that dust concentration is often above the recommended amount of 450 mg/m^3. It must be added that cement itself may also create a nuisance even greater than the dust from the kiln gases and every effort should be made to restrict cement dust from being blown about. However, it is satisfying to note that in all the countries visited, the packing and cement clinker grinding sections were fitted with bag filters which are very effective.

The other problem was the emission of hydrogen sulphide about which complaints were received in Lebanon and Cyprus. With the exception of the Lebanese plants, all the cement factory kilns mentioned in the consultants' reports were not fitted with oxygen indicators to determine the oxygen content. Finally, it was noted that in all cases the chimneys were not high enough to ensure perfect dispersion of the gases. As may be recalled, hydrogen sulphide can be tolerated up to a concentration of 5 ppm in the flue gases if the chimney is high enough.

The situation described above will not necessarily be the same elsewhere, but the general recommendations made by the WHO consultants can be useful. They concern the necessity of carrying out tests on waste gases from the kilns to determine whether dust arrestors are required, the need to provide bag-filters to cement-clinker and grinding sections and to make systematic tests for hydrogen sulphide. All new kilns should be fitted with proper indicating and control instruments to maintain oxygen content at the correct level of 1.5% to 2% minimum, and should have chimneys with adequate height and with an efflux velocity not less than 15 m per second at maximum production.

Brick Factories

This problem is mentioned as it constitutes quite a nuisance in Baghdad as well as in Teheran and possibly in other cities of the Middle East.

Reports from WHO staff in Iraq state that great concern has been expressed by the authorities regarding brick factories to the extent that it has been decided to gradually eliminate them from the city's boundaries. According the the WHO Engineer's report, the brick factories are very conspicuous with their thick black smoke indicating the type and extent of the air pollution problem created.

In Teheran, the situation is about the same. It has been reported that there are well over 200 brick factories in Teheran. Nearly all the kilns, in which the bricks are baked, are fired with a mixture of coal and oil which is heavy oil containing an average of 3% of sulphur. The kilns produce a dense black smoke during a high percentage of the time they are fired. Some of the kilns are fired exclusively with heavy oil and air is injected into the furnace under pressure with the use of an air compressor. The proportioning of air and oil is said to be controlled by hand. The smoke problem is considered severe and the decision has been taken to encourage owners to move the brickworks for several kilometres to the south of the existing brick-fields and eventually into the desert.

Another observation made concerns the height of the kiln chimneys. Most of them have a brick stack about 30 metres in height, a few of them are only slightly higher than the kiln. The chimney will normally provide natural draught to assist combustion and its height and diameter are determined by the amount of draught required and the velocity of gas passing through it. If low chimneys are used, draught must be provided by fans.

The two WHO Consultants who studied this problem are of the opinion that it is possible to obtain a better combustion by using in the first place either coal without addition of oil or by using a recognized grade of oil, and then by applying well known principles of combustion to the design and operation of the combustion equipment. In short, consideration must be given to proper air-fuel ratios and proper mixing and to sufficient ignition temperature and sufficient time to burn all the fuel. If required, after-burners may be used. The above will apply to the various other light industries either in Teheran, such as the plaster works, or in some of the other countries visited by the WHO Consultants.

Smoke will remain for some time to come the public enemy number one in the field of air pollution. Historically, the first air pollution ordinances were concerned with smoke abatement, because of its widespread occurrence.

Although smoke reflects man's industrial progress, the scientist knows that it also shows man's inefficiency in converting fuel resources into useful energy. He also knows that technology is advanced enough to solve the smoke problem satisfactorily. Let it be hoped therefore that the action required will be taken as soon as feasible to clean the air of such impurities.

Refineries

WHO has little information concerning the air pollution problems created by refineries in this Region. From Baghdad it is learnt that the usual complaint concerns the unpleasant smell coming from gases emitted by the Daura Oil Refinery. In the immediate vicinity of the factory, damage to car paint has been observed.

It is realized that H_2S and the sulphur oxides, including probably SO_3 which would change into sulphuric acid in the atmosphere, are all involved, but no analyses of the flue gas have been made recently.

Air pollution problems related to refineries have also been reported in Kuwait but no measurement could be taken of the important gas contaminants for lack of measuring instruments.

However SO_2 and H_2S were intermittently smelt in some areas of Kuwait, particularly in the Shuaibah area. Ground level concentration of gases in suspected areas was estimated on the basis of stack design. They were found to be above usual concentrations (reference WHO document EM/ES/118). Note was also taken that one of the sources of air pollution was created by ground flares producing huge amounts of black smoke.

It is believed that similar air pollution problems related to refineries will be found in varying degrees in many other countries of this oil-rich Region. It should however be stressed that oil refineries have considerable air pollution potential and that great care and skill should be exercised in their design and operation.

This is a field for specialists and the petroleum industry needs many of them, as do the government authorities concerned with air pollution control. It may be noted that the new Air Pollution Engineering Manual (US PHS publication 999-AP-40) provides a number of suggested measures for reduction of air contaminants from petroleum refineries and thoroughly discusses various waste-gas disposal systems. This book which is in the list of background documents for this Seminar should prove very useful to air pollution control engineers and specialists.

It may be of interest to note that improvements in petroleum refineries' technology are reducing refinery emissions considerably - waste-gas flares for instance which are used to dispose of gases collected from small leaks were once a source of great amounts of smoke, as is at present the case in Kuwait. Now they are mostly of the smokeless type, as air or steam is injected into the flares to promote combustion. Also the recovery of sulphur, contained in the crude oil, is widely practised. Sulphur recovery efficiency as high as 99% has been reported.

Solid Wastes Disposal

A special case of solid fuel burning which, from the point of view of air pollution control, has some importance in many cities of Europe and America, is the burning of refuse by industry and specially by municipalities. This problem may not be severe in the countries of this Region. However, it should be noted that, at present, in almost all of them refuse disposal consists of open dumps and/or open incineration only. No incinerator is apparently used except in Cairo where about 10% of the solid wastes can be accommodated in a small incinerator. Eighty per cent is disposed of by sanitary landfill and 10% is transformed into organic fertilizer.

The table below summarizes the situation in some cities of the Eastern Mediterranean Region of WHO:

City	Distance to Disposal	Tons/day	Disposal Method
Aden (P.R.S.Y.)	21 km	approx. 20	Open dump, open incineration
Baghdad (Iraq)	9 and 5 km	1 650	Open dump, partial incineration
Chittagong (E. Pakistan)	11 km	170	Open dump, later destroyed by fire
Damascus (Syria)	12 km	200	Open dump, open incineration
Khartoum (Sudan)	8 km	230	Open dump, open incineration and filling borrow pits after burning
Riyad (Saudi Arabia)	20 km	210	Open dump, later destroyed by fire then covered with sand
Teheran (Iran)	25 km	950	Open dump
Zerka (Jordan)	6 km	2 650	Open dump

In the case of Baghdad and Zerka, where open dumps are relatively close to the city and the refuse collected more important, open burning of refuse, if practised, is likely to create a lot of nuisances, specially smoke which would add to the general air pollution problem of these cities. If refuse is to be burned, properly designed incinerators should be built, preferably of the multiple chamber type. If, on the other hand, refuse is disposed of by sanitary landfill, which is still one of the best known methods of solid wastes disposal when adequately carried out, there will be practically no air pollutant emission.

These questions were discussed in the recent WHO Short Course on the Collection and Disposal of Solid Wastes, held in Damascus, and should be kept in mind, specially where air pollution is of concern, when planning for better municipal waste disposal systems.

Dustfalls

In addition to man-made air pollution, the degree of which varies from place to place, the countries of this Region are in general suffering from another great problem due to natural causes, the sandstorms, against which very little if anything at all can ever be done. It is interesting however to mention the studies carried out in Kuwait by a WHO consultant to determine as exactly as feasible the amount of deposited dust from sandstorms. (Reference WHO document EM/ES/118).

For the purpose of this study collection of dust was made for the last twenty-two days of May 1968 and the results corrected for the whole month. The dustfall collectors used consisted of 1 litre cylindrical glass beakers, about 2/3 filled with distilled water. A table provided in the report shows that the average of nine stations excluding the Shuaibah industrial area and the fertilizer plant area was in the order of 400 tons per square mile, which is very high indeed. Dustfall would of course be much higher in the above two areas, (exactly 721.8 and 1464.0 tons respectively), because of the additional pollutants from the industries. In comparison, it may be recalled that the average dustfall for some cities, as given in WHO Monograph No. 46 on Air Pollution is as follows:

London: 97.1, New York: 85.8 tons per square mile, which shows how important the dust problem is in Kuwait.

The immediate effect of the storms is the decrease in visibility, the effect of which is so vital in various ways, specially in connection with plane landings and automobile accidents. The same document shows that in Kuwait the visibility is clear, being not more than 50 km, during 18.2% of the year only, and less than 5 km or 3 miles during 6.2% of the year. The latter is the adverse level according to the Standards for Ambient Air Quality adopted by the California Board of Public Health. This situation is perhaps the same in Qatar and the other cities along the Gulf.

Another interesting study was published last year in the magazine "Atmospheric Environment" by the Pergamon Press and concerns the dustfall caused in Cairo by the spring storms known as the "khamsin" storms. The study was undertaken by Dr. Abdul Salam and Mr. Sowelim, of the National Research Centre of Cairo. Cylindrical glass beakers, 17 cm high and 9.5 cm diameter were used for the study. The jars were changed every morning and evening, but if a storm should pass, the jars would be left in place until the weather cleared. Dust collected should consequently represent the dust deposited by the storm.

The results show that a very great amount of dustfall was collected. The figures obtained in tons per hour per square mile are 0.96, 1.95 and 1.41 for the three types of storms classified as coming respectively from the Mediterranean Sea, North Africa Coast and Central Africa. This amount is indeed considerable and the solution has been proposed by the authors that the Kattara Depression, which is on the way of the khamsin storms and appears to contribute a great deal to the amount of sand in the spring storms of Cairo, be filled with water from the Mediterranean Sea. It is thought that "the filled depression would be a source not of dust and sand but of water clouds and in this way might diminish the volume of dustfall during the spring season".

It cannot yet be known for sure whether this solution will help to a great extent in the abatement of Cairo dustfall during the spring, but the dustfall problem exists in sufficient degree not only in Egypt but in most countries of this Region to justify taking more effective action by all the authorities concenred with a view to preventing additional pollutants from being discharged into the atmosphere. The dust-storm problem is in effect unsolvable, and it will certainly pay very much not to add to it.

It is true that dustfalls have been occurring for centuries in the Middle East and that the people have learnt to live with it, but it is likewise true to state that industries are now expanding everywhere in this Region, polluting the environment, and that definite steps should consequently be taken to control these sources of man-made air pollution. This would very much prevent the atmosphere from approaching the limit of its capacities to absorbe contaminants and would indeed provide for the very protection of the health of the people. To that end, the World Health Organization will endeavour, in many ways, notably in helping to train qualified air pollution personnel, to be of service to the Member States concerned.

10. STATEMENT OF THE PARTICIPANTS

Following the exposé of the situation in this Region, as per documents available at the Regional Office for the Eastern Mediterranean, the participants submitted up-to-date descriptions of the air pollution problems in their respective countries. These included statements from Iran, Iraq, Kuwait, Lebanon, Pakistan, Southern Yemen, Sudan, United Arab Republic, Rumania and also Turkey, which is considered, geographically, as belonging to the Eastern Mediterranean Region.

IRAN

1. The sanitary action being taken throughout the country to solve air pollution problems is as follows:

   In accordance with the recommendations made by the "National Air Pollution Seminar" in November 1966, sanitary protection was carried out on air pollution from all possible sources, such as factories, workshops, premises, brick, lime-gypsum kilns, etc., throughout the country.

2. The monitoring programme in Teheran is summarized below.

3. The future action concerning air pollution in Teheran is as follows:

Within the five-year and twenty-five year town plan for Teheran, construction of:

a. Natural gas pipe

b. Underground (metro) transportation

c. New site for heavy industries and brick factories

d. Highroads

e. Artificial forests.

The above would solve the problem of air pollution in Teheran.

4. The future programme of air pollution control would be:

- To extend the Teheran air monitoring programme through general studies to individual plants.

- To extend the monitoring programme on air pollution to other industrialized towns, such as Abadan, Isfahan, Tabriz, Karaz.

Summary of Air Pollution Assessment and Control in Teheran, 1966-1969

1. Population and area:

Teheran has an area of 240 square kilometres, 3 million population with 5.6% population growth.

2. Study on meteorology and topography of Teheran.

3. Major sources of air pollution:

Cement manufacture, motor vehicles, general fuel oil combustion, small air pollution sources, refuse collection and disposal, brick, gypsum, lime manufacturing.

4. Studies on air pollution:

Total suspended particulate sampling and analyses	294
Soiling potential of atmospheric pollutants and analyses	450
Deposition of dust sampling and analyses	16
Sulphur dioxide sampling and titration	450
Carbon monoxide measurements	1549
Carbon dioxide measurements	153
Vehicle count	122186

5. Air quality data:

Measurements taken from 20 March 1967 to 20 March 1968.

5.1 Total suspended particulate matter:

The number of samples taken in three stations in Teheran by three high-volume air samplers was 344.

Maximum concentration of total suspended particulate matter from 20 March 1967 to 20 March 1968 in Sepah Square Sampling Station was 930 $\mu g/m^3$ and minimum concentration 140 $\mu g/m^3$.

5.2 Soiling potential of atmospheric pollutants:

The number of samples taken in three stations by three daily volumetric samplers was 344.

Maximum concentration of soiling potential of atmospheric pollutants in Teheran in Sepah Square Sampling Stations was 500 $\mu g/m^3$ and minimum concentration 50 $\mu g/m^3$.

5.3 Sulphur dioxide:

The number of samples taken in three stations by three daily volumetric samplers was 344. There is a very close resemblance between the increase of kerosene consumption and the increase of dosage of sulphur dioxide in Teheran. Maximum sulphur dioxide concentration is around 185 $\mu g/m^3$ and minimum concentration 10 $\mu g/m^3$.

5.4 Carbon monoxide:

1059 carbon monoxide measurements were made by squeeze tube carbon monoxide detector at different times of the day (9.30, 11.30 13.30 local standard time). Maximum concentration is 100 ppm and median average 20 ppm.

5.5 Dust deposit:

Eight samples taken in three stations by dust-fall jars show great variation in deposition of dust in different areas of Teheran. It varies between 61-489 tons per square mile per month and 306-518 tons per square mile per month.

5.6 Carbon dioxide:

The measurement of carbon dioxide in Teheran was made by the gas-chromatographic method in the Teheran University Nuclear Centre. It is measured in fifty main points of Teheran at three different times of the day and night (8.00, 13.30, 20.00 local standard time). The variation of CO_2 in the air was between 0.009 to 0.062%.

6. Air pollution control in Teheran

6.1 Development of green areas

6.1.1 Teheran has got twenty-five parks and children's gardens of an area of 3 056 000 m^2. The average area per inhabitant is equal to 1 m^2.

6.1.2 Arboriculture

A total of 100 000 trees were planted by the Municipality of Teheran during one year from 20 March 1968 to 20 March 1969.

6.1.3 Parks and squares under design

A number of seven parks and squares of an area of 50 000 m^2 were designed and technical plans were prepared during the year from 20 March 1968 to 20 March 1969.

6.1.4 Parks and squares under construction

A number of forty-two parks, squares and boulevards are under construction. Siting, design, and technical plans are being made for twenty new parks in Teheran.

6.1.5 Development of artificial forests

The report made by the Ministry of Natural Resources indicates that the area of artificial forests in the suburbs of Greater Teheran has been extended very greatly. Table 1 shows the area of artificial forests during the years 1964 to 1968.

Table 1

Development of Forests

March 1964	50 000 m^2
March 1965	950 000 m^2
March 1966	1 560 000 m^2
March 1967	6 500 000 m^2
March 1968	23 760 000 m^2
March 1969	23 760 000 m^2
plus	17 000 000 m^2 under development

6.1.6 To control sand movement in the area between Abardage, Desert and Saveh area, arboriculture plantation of 11 000 000 m^2 in the area between Abardage and Desert and 10 000 000 m^2 in Saveh area, 75 km far from Teheran, has started.

6.2 Demolishing of brick, lime and gypsum kilns

The existence of brick, lime and gypsum kilns in the south and south-east of Teheran was the main source of air pollution.

The Ministry of Public Health with the co-operation of the other Ministries and organizations and the Municipality of Teheran took a very strict step to demolish brick, lime and gypsum kilns, which were built in prohibited areas. The first official action started in 19 July 1966. During twenty months, the number of sixty-eight Hoffman brick manufacturing kilns, 365 gypsum manufacturing kilns and 17 lime manufacturing kilns have been demolished, after continuous official action.

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IRAQ

Air pollution is not considered as a significant problem in Iraq at the present time, but it should be regarded as a potential danger in the near future as the number and types of factories and the use of motor vehicles increases rapidly. No studies of the amount and types of air pollutants are undertaken yet, but they are mostly those that come from fuel combustion (industries and motor vehicles) and sand storms. Most of the factories in Baghdad area are near or among the residential places. The possibility of air pollution in Baghdad City comes from brick factories, oil refineries, cement and asbestos factories, edible oils and detergent factories, power houses, railway stations, motor vehicles and other small industrial establishments.

The master plan for Baghdad area will be of great help in reducing the amount of air pollutants; the brick factories are to be transferred gradually outside the city in the industrial zone. It is also planned that large industries be constructed in different parts of the country. Natural gas will be used in the near future instead of petroleum products as a source of power. Work started to surround all the cities with belts of trees to minimize the effects of sand storms.

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KUWAIT

Topography and population

Kuwait is a fairly flat country with no mountains and it lies at the northern part of the western side of the Arabian Gulf just to the south of the Republic of Iraq and north of Saudi Arabia. The inhabitants of Kuwait, according to the last census, are 467 339 as compared to 206 437 in the census of 1957. So the rate of increase of population in eight years was almost double. This is due to two factors: (1) increased migration into the country and (2) the high birth rate.

The number of non-Kuwaiti inhabitants is 247 280. The working population amounts to 68 433 of whom 6 858 are Kuwaitis and 61 575 are non-Kuwaitis. In the latest manpower survey carried out in 1967 the number of workers was found to be 184 318, of these 43 025 are Kuwaitis and 141 293 are non-Kuwaitis.

General Climatological Description

Dry hot summer with frequent sand storms, and cool winters with high relative humidity and occasional rains. Fogs **rarely** occur in Kuwait. The average monthly temperature in summer (June through September) is around 36°C with the highest average temperature being around 44°C. The average maximum sun radiation temperature reaches its peak during this season and is of the order of 74 °C. Summer is the highest sun-shine season with no precipitation. Relative humidities are, in the mean, within 26 to 30%, with an average maximum relative humidity of the order of 45%, the lowest being around 12%. The rate of evaporation of water is terribly high, reaching 24.6 mm per day in June when the sun radiation has its highest value and the mean wind speed reaches its maximum (14 miles per hour).

Air Pollutants in Kuwait

1. Natural dust
2. SO_2 - H_2S
3. Pollen of some trees

Measured Pollution Levels

Dust fall:

Average in May 1968	=	447.8 tons per $mile^2$
Average of nine months	=	1958.3 tons per $mile^2$

Gases:

SO_2 = 0.0675 ppm

H_2S = 0.4 ppm

SO_2 during the accident of 1966

at 6.00 p.m.	=	50 ppm
next day at 8.00 a.m.	=	20 ppm
at 4.00 p.m.	=	8 ppm

Asbestos:

100 metres away from the factory	=	25 million per m^3
1 km away from the factory	=	18 million per m^3
5 km away from the factory	=	9 million per m^3

Pollens:

Enumeration of pollens in Kuwait expressed in thousands per m^3.

Pollens of:	Mean Value
Prosopis Juliflora	81
Parkinsonia Aculeata	22
Calestemon Lanceolatus	38
Acacia Seyal	34
Eucalyptus Glanca	72
Albizzia Lebbec	27
Others	45

Industrial Process Emissions

The most important industrial plants are:

Sand-brick factories, asbestos-cement factory, cement-brick plants, metal works, foundries (both ferrous and non-ferrous), garages and car repair shops.

Oil refineries, chemical fertilizer plants, drilling mud plant, ground-flares for burning excess gases from the oil fields and refineries.

Transportation

1. The total number of cars running in Kuwait is 131 688, about 3 000 only use diesel oil. Of this total 7 496 motor-bicycles are included.

The average fuel consumption is about 4 gallons per day per car.

2. a. Traffic count - 28 000 cars per hour in the City.

b. No crankcase emission control apparatus is used in cars in Kuwait.

c. Fuels used are: benzene, diesel (very little).

Population number, Density, Distribution

The latest population number according to the last census is 467 339. Ninety per cent are located in Kuwait City and its suburbs. The largest desert areas are very scantly inhabited.

Fuel Use

Yearly consumption of liquid fuel in Kuwait - (1 000 gallons)

Year	Gasolene	Kerosene	Gas Oil	Heavy Residue Oil
1965	58 809	11 565	16 529	7.8
1966	67 181	11 237	22 407	5.8

This includes the commercial, residential and industrial processes.

No appreciable amounts of coal are used except small amounts used for domestic heating amongst the poorer classes in winter using open vessels as burners.

Almost all industrial establishments use gas oil for power generation.

Gaseous emissions are not yet controlled by scrubbers or other methods.

Refuse Disposal

1. Amount of refuse produced and disposed per day is 600 tons.

2. Refuse is burnt in special dumps in the desert 20 km away from the residential areas.

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LEBANON

Local authorities were first aware of the existence of an air pollution problem in Lebanon in 1955. In recent years, it has assumed more serious aspects owing to the fact that air pollution prevention and control in this area have not kept pace with industrial development and increased industrial production, population expansion and heavier traffic, and its impact on men, animals, plants and materials is being increasingly felt with the rise in the standard of living. It is particularly evident in the capital city of Beirut and the coastal plain extending from just north of Beirut and up to the south of Tripoli. While smoke, dust and sulphur oxides are apparently predominant, other contaminants are undoubtedly contributing to the polluted air situation. The high traffic count of Beirut, associated with the existence of high buildings, narrow streets and restricted wind movement, is responsible for the occasional haze during day time. As to stack emissions, industrial plants situated on the afore-mentioned coastal plain are considered as the most apparent major contributors to continuous pollution.

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PAKISTAN

Background Information

Pakistan is a country with a population of about 130 million people. Its climate ranges from below freezing point to 120°F. Its geographical topography presents hilly areas, plains, deserts and areas with abundant water resources. The rainfall also ranges from almost nil to more than 100 inches per year.

Population Trend in the Community

The rate of progress of industrialization has been remarkable. The rapid process of industrialization associated with urbanization is creating environmental problems. At present 20% of the population is urban.

Public Interest and Concern about Air Pollution

Recently complaints of chlorine gas and SO_2 were received by the Department of Occupational Health of the Provincial Government of West Pakistan. In 1968 an investigation was carried out of cement works and it was found out that dust and smoke from these works were having an adverse effect on the nearby vegetation.

Morbidity records too have shown an increased number of respiratory diseases presumably due to the increased number of motor vehicles emitting smoke, and dust and smoke from the increased number of industries.

Existing Sources of Air Pollution

At present the main sources of pollution are: motor vehicles, railways, aircrafts, industries, domestic fuels and refuse disposal. The domestic use of fuel (soft coke, charcoal, cor-dung and kerosene) form the major source of air pollution. However the increased number of industries like chemical, paints, roofing, rubber, soap, fertilizer, metal and mineral industries will be the potential sources in the years to come.

Current Air Pollution Control Activities

At present there are no air pollution monitoring stations set up as the problem is not yet felt. Although the problem of air pollution is negligible, health authorities have to be on the alert so as not to permit conditions to deteriorate to such degree as may constitute a serious threat to the community.

At present there is a dearth of standards for possible air pollutants and need is felt for much more investigation of atmospheric air polution. There is also a great need to practice preventive work by the education of industrialists and the general public. A survey must be made to determine the nature and concentration of air pollutants. Local atmospheric conditions will have to be studied to determine their impact on the problem of air pollution.

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SOUTHERN YEMEN

The possible sources of air pollution can be summarized as follows:

1. Motor vehicles

2. The refinery

3. The power station

4. Dust storms.

There was a project to plant a green belt of palms and shrubs west and south of the area affected by these storms, but for unknown reasons, the project was not executed.

The above sources of air pollution are still there, but the pollution caused is insignificant compared with the area of the Republic, which approximates 130 000 square miles, as this ensures an excellent dilution. However, as it is an expanding nation with aspirations to industrialization, air pollution hazards will be taken into consideration when the first project is launched.

At present, there is no law or legislation to cover supervision of industry, but it is high time to think seriously of it, even before the first step towards industry.

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SUDAN

The country is about a million miles, the largest in Africa. It stretches from latitude 5°N to 22°N covering a wide range of climates from the arid to wet tropics. Almost the entire economy depends on agricultural production including crops and animal products and the industries associated with them.

Air pollution does not yet constitute a particularly serious problem, but in view of the rapid industrialization and urbanization now undergone, it is by no means early to study the situation seriously.

Natural pollution by dust storms (haboobs) occurs in nearly all the cities of the Northern Sudan during the months of April to August, the average daily occurrence being about 5.6 a month.

The main industrial sources are cotton ginneries and textile mills, cotton-seed oil and soap manufacture mills, cement factories, native stacks and agricultural pump schemes. The fuel consumption in these being mainly diesel oil, wood and charcoal. The number of cars licensed in 1968 is about 17 000 of which 3 500 are diesel, and they all consume about 140 000 tons of fuel. Of other transport sources, railways and railway workshops at Atbara require a particular mention.

A unique pollution problem facing Aroma district in Eastern Sudan is castor-bean plantations and seed-mills. This causes severe upper respiratory and skin allergies.

Preliminary studies have been carried out, but further surveys will have to be widely done and effective control measures applied.

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UNITED ARAB REPUBLIC

There are two types of air pollution in the United Arab Republic, namely:

1. Natural pollution

2. Pollution caused by human activity, mainly by industry.

The natural pollution is temporary and occurs only during the khamseen wind activity in late spring and is associated with dust or sand storms. The pollution caused by human activity can be summarized as follows:

1. The haematite crusher near Aswan.

2. The soot particles of burnt bagasse from sugar refineries in Upper Egypt.

3. The cement plants, although the danger from cement particles, according to Gardner and others from the point of view of dust disease of the lungs, is trivial.

4. Air pollution caused by means of transport, namely:

   a. Railway engines - coal locomotives were replaced by diesel and electric locomotives. This lessened the pollution to a great extent.

   b. Motor-car vehicles - till now it is a potential hazard and it is under investigation by the Government for any future harm.

5. Ionizing radiations - till now no problem.

6. Local air pollution from sporadic factories such as lead smelting, tanneries, fertilizers producing plants, starch, glucose and dextrin producing factories. Each case is treated according to the condition present therein.

7. Aeroplane spray of insecticides. These are mainly used in combatting the cotton-plant insects. The hazard could be nullified when we take care of the direction of the prevailing wind.

Legislation and Governmental Efforts to Combat Air Pollution

1. The Law No. 453 for the year 1954 and the Ministerial Order No. 128 for the year 1957 signifying two categories of industrial, commercial and other workshops which may cause noise or ill-health or may be dangerous to people.

2. The Law of "Industrial Estates".

3. The Presidential Law of the "High Committee of Air Pollution" headed by the Minister of Health.

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RUMANIA

The sources of air pollution in Rumania became numerous and varied, in the last twenty years, concomitantly with rapid industrialization and urbanization.

The most common air pollution pollutants of urban areas, which interfere directly or indirectly with the well-being or even with the health of people, are the following:

> Sulphur dioxide, dust and other suspended matter, chlorine and its compounds, nitrogen oxides, fluorides, lead and lead oxides, malodorous pollutants, etc.

The research works on the influence of ambient air pollution on health or on living conditions, by the epidemiological approach, are carried out by the Hygiene Institutes and the Sanitary State Inspectorates.

A new legislation on air pollution control is being worked out at present aiming to increase the responsibilities of the designers of factories and of the staff in charge of technological processes in industries.

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TURKEY

1. Principal Locations and Sources of Air Pollution

Principal locations in Turkey where air pollution presents a problem are: Ankara, Istanbul, Murgul and Maden. Ankara, the capital of Turkey, and Istanbul are the places where air pollution is most likely to occur. In Ankara the factor of air pollution is the chimney smoke and gases coming into the air from buildings and factories (incomplete combustion of sub-bituminous coal and lignite) at the rate of 75%, and 25% due to industries and vehicles. According to research work of the School of Public Health, SO_2 and smoke concentration in the air of Ankara for 24 hours is as follows:

Year	SO_2	Smoke
1964	200 micrograms/m^3	164 $\mu g/m^3$
1965	244 micrograms/m^3	170 $\mu g/m^3$
1966	269 micrograms/m^3	280 $\mu g/m^3$

2. Legislation

A new Bill of Law has been introduced which is prepared by the Ministry of Health. The Ministry of Health is working on the preparation of legislative regulations after the approval of the law by the Parliament.

3. Encouragement Measures

The new clean-air bill gives strong encouragement to all industries to apply filters, and for the fitting of covers to vehicle exhaust pipes. It also provides for the establishment of stationary and mobile teams to control emissions and encourages the use of smokeless semi-coke for domestic heating, etc.

11. METHODS AND EQUIPMENT FOR MEASURING POLLUTANT EMISSIONS (STACK EMISSION TESTING)

by

Professor M. Katz*
WHO Temporary Adviser

Measurement of pollutant concentrations in the stack gas is difficult because of high temperatures, high dust and gas concentrations, as well as high water content. Standardized equipment and procedures have been developed, including for example pitot tubes for the determination of velocity pressure, stainless steel probes, alundum thimbles for collection of particulate matter, sorption units, and flow measuring devices.

For the collection of particulate matter, isokinetic sampling is necessary. The flow velocity in the sampling probe should be identical to that in the stack. Null type nozzles are available to insure isokinetic conditions in the probe. The lecture's outline follows:

1. Measurement of Gas Flow, Temperature and Humidity

   a. The standard pitot tube

      (Total or impact pressure) - (static pressure) = velocity pressure

      $V = 2g\ h$

      v = gas velocity, ft./sec.

      h = ft. of head of gas

      h_w = velocity pressure in inches of water gauge

      $h \times (\text{density of gas}) = \frac{h_w}{12} \times (\text{density of water})$

      g = gravitational acceleration, 32.2 ft./sec.^{2}

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$$V = \sqrt{2 \times 32.2 \times \frac{62.4 \times h_w}{12s}}$$

s = density of gas (Lbs/C.F.) at stack temperature and pressure conditions

$$V = 1096.5 \sqrt{\frac{h_w}{s}} \text{ ft./min.}$$

b. Location of pitot tube traverse points

Circular duct: 0.316 R, 0.548 R, 0.707 R, 0.837 R, 0.916 R

R = radius

c. Temperature and humidity of stack gas.

2. Collection of Stack Samples

a. Equipment for collection of particulate matter - sampling probe, nozzle and filter media.

b. Types of filter media; alundum thimbles; glass thimbles (S and S) or (MSA 1106-B); paper thimbles (Whatman); chemical filter papers, (cotton, wool, nylon, orlon, asbestos, etc.).

c. Equipment for collection of gas samples.

Absorption devices: standard or midget impinger, fritted glass bubbler, other types of bubblers.

Temperature control baths; condensers and freeze-out traps.

Adsorption devices: activated carbon, silica gel, alumina, etc.

d. Meters for volume flow or flow rate measurements: calibrated orifice; critical orifice, rotameter, wet and dry gas meters.

e. Pumps or ejectors.

3. Isokinetic Sampling for Particulate Matter

a. Errors due to non-isokinetic sampling.

b. Watson relation of validity of sample to duct and nozzle flow conditions:

$$\frac{C}{C_o} = \frac{U_o}{U} \left\{ 1 + \cdot(p) \left[\left(\frac{U}{U_o}\right)^{1/2} - 1 \right] \right\}^2$$

where

C = concentration measured

C_o = true concentration

U_o = stream velocity

U = mean gas velocity at sampling orifice

$p = \dfrac{d^2 s \ \ U_o}{18 \ nD}$

d = diameter (mean) of particles

D = diameter of orifice

s = **density** of particles (specific gravity)

n = viscosity of gas

c. Methods of attaining isokinetic conditions.

"Null" type nozzle; variation of the flow rate at each sampling point to match velocity in nozzle (of constant diameter); use of series of nozzles of different diameters.

4. Typical Calculations

Summary of Discussions

In answer to a question about making the stack air velocity measurement traverse, Professor Katz said this was done at radial locations along two diameters at right angles to each other, as specified in his outline.

12. DEMONSTRATION OF APPARATUS, ANALYSIS, AND CALCULATIONS

by

Professor M. Katz*
WHO Temporary Adviser

The analysis of pollutant concentration is difficult because of the low concentrations involved (parts per billion) and the presence of interfering substances in the air. Sulphur dioxide has been determined by a variety methods ranging from conductivity of a peroxide solution to the West-Gaeke method. The conductivity method gives accurate results when no interfering substances are present; in the presence of contaminants, the results may be either high or low. The West-Gaeke method (absorption in sodium tetrochlomercurate) is specific for sulphur dioxide.

Specific methods for the sampling and analysis of pollutants are described in the WHO Manual prepared by the author.

Summary of Discussions

Asked about a long-term programme of air monitoring following a two-year programme of sampling for 24-hour averages of SO_2 and suspended particulates at five stations in Teheran, Professor Katz said that this would be useful to verify the adequacy of sampling station siting and to give an indication of the major sources of air pollution. He suggested that the next step would be to install more sophisticated equipment for measuring fluctuations and diurnal variations in contaminant concentration.

There was considerable discussion about methods of measuring SO_2. The H_2O_2 method, Professor Katz said, is not specific for SO_2 but it is very useful in situations where other contaminants to which it is sensitive (NH_3, oxides of N, HCL, etc.) are known to be absent or are present at least in only small amounts. He also discussed several other methods for SO_2 measurement and referred the participants for more details to the recently released WHO Manual, on methods of air pollution analysis which was written by him.

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The question of physiological effect of acetylene on humans was raised. Professor Lawther answered this for Professor Katz, noting it is a good anaesthetic but that he knows of no long-term effects. Dr. Wohlers commented that acetylene played no role, as does ethylene, in photochemical smog reactions and that it was much less toxic than ethylene on vegetation.

Gas chromatography plus flame ion detection for hydrocarbons and other gases appears to be suited to cases of mixed gases. Carbon dioxide and carbon monoxide can be measured by infra-red absorption, while ultra-violet absorption may be used for oxides of nitrogen.

13. USE OF THE RINGELMANN CHART AND TRAINING OF PERSONNEL ON VISIBLE PLUME OBSERVATION

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

The Ringelmann Smoke Chart, devised by Professor Maximilian Ringelmann of Paris in 1890, is one of the most useful air pollution control devices and hence perhaps the most maligned of the air pollution control laws.

The Ringelmann Chart is a series of six cards ranging in number from 0 to 5; card 0 is all white and card 5 is all black. Cards 1 through 4 contain lines spaced at different intervals to give a greater appearance of darkness in going from 1 through 4. In operation, the Ringelmann Chart is held at arm's length while looking at a black plume. The comparison between the darkness of the plume and the card number is an indication of the smoke emission. Air pollution regulations normally require that the Ringelmann number should not exceed 2 or 3 for specified time periods ranging from two to six minutes a day. There is a recent trend in the United States to reduce the Ringelmann number from 2 or 3 to as low as 0 to 1.

The Ringelmann Chart is based upon a relationship between plume obscuration and optical density. There is a relationship between the percent light absorbed and the dust content of a stack. At a light absorption of 60% (Ringelman number 3) in a plume from a six-inch stack, the dust approximates 1.2 grains per cubic foot; this relationship will vary from stack to stack and is dependant upon the constancy of particle size and type within the stack.

In addition to the Ringelmann Chart which is specific for black smoke, an added advantage accrues if the term, "Equivalent Ringelmann", is used in air pollution regulations. The Equivalent Ringelmann is the plume opacity which obscures an observer's view to a degree equal to or greater than that of a number on the Ringelmann Chart. The distinct advantage of the Equivalent Ringelmann (equivalent opacity) is that it becomes possible to look at and evaluate not only black smoke but smoke of any colour.

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In using the Ringelmann Chart the individual should stand with his back to the sun and observe the plume at right angles to the stack plume with little or no cloud cover. Plume opacity is read at the point of stack discharge.

Many questions are raised concerning the use of the Ringelmann Chart or the Equivalent Ringelmann which cannot be fully and completely technically resolved. Scientists object to the use of the Ringelmann Chart because it is a test made by vision and not by mechanical apparatus. In spite of all the objections, a trained inspector can read equivalent opacity to a one-quarter of a Ringelmann number. Consequently an inspector can travel over a large area by automobile and when he sees and determines an Equivalent Ringelmann number which does not satisfy the regulation, he can take immediate action against the offender.

It is possible to either purchase or construct a unit which will emit black or white smoke at various Ringelmann numbers so that inspectors may be trained in the reading of Ringelmann numbers or equivalent opacity. The grey or black unit is similar to a forced-air or fire furnace; by varying the fuel pressure to the burner excessive oil is burnt and smoke is produced. The white smoke is generated by feeding diesel oil through a small spiral-tube into an air stream. During the calibration procedure, the men are trained against a Ringelmann Chart for both white and black smoke. Light meters inside the stack are then calibrated against the group observations. Finally the group is retrained against the light meters.

Summary of Discussions

Professor Lawther commented on interfering effects of reflectance in using Ringelmann Charts with the sun behind the observer. He was also critical of the reportedly accepted practice in the United States whereby industrial firms with stacks emitting plumes containing only condensed water vapour, but which give an unfavourable equivalent Ringelmann Chart result (i.e. one higher than the legal maximum Ringelmann number for particulate-containing plumes), were assumed in violation of the associated regulation on particle emission load until they proved otherwise. This he said was against a cardinal principle of English law that a man is innocent until proven guilty. Dr. Wohlers commented that the emitter was in violation of the law but that situations involving only obvious water vapour discharges, such as cooling towers, were not normally cited. He also noted that wet plume observations were made around midday condensed water vapour plumes were short lived due to low humidity. In reply to this, Professor Lawther noted that in London humidity was frequently high throughout the day and he also observed that in many places of the world the sun would be almost directly overhead, so that at these times it would be impossible to employ the charts according to specifications. In his opinion, he said, the Ringelmann Chart was a most unsatisfactory device. Dr. Wohlers said that in spite of the apparent defects of Ringelmann Charts, it was possible to train observers to accurately assess control plumes to within one-quarter of the correct Ringelmann number. He also noted that a straight line relationship was obtained between light obscuration and the calculated and measured grain loading of plumes.

14. CONDUCTING ODOUR SURVEYS IN THE FIELD

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

Although the perception of odorous contaminants cannot be precisely described, certain basis facts about human olfaction are known. With known facts or principles, it is possible to investigate odour complaints for air pollution control purposes.

Odour remains, however, a very intangible commodity. Odorous contaminant investigations must be related to the individual problem or locality. Air pollution control is one major reason for odorous contaminant measurement. The odour purposes may result from a nuisance complaint, a violation of an ordinance or a desire of an offender to determine the severity of the air pollution problem so that corrective steps may be taken.

To establish a violation of an ordinance it is necessary to determine that a nuisance or a specific violation exists, that it is caused by an odour, and that the odorous contaminant is emitted by the source charged.

To gather data necessary to correct an odour contaminant problem, one needs to know the extent and intensity of the odour downwind of the source for different meteorological conditions as well as pertinent process information within the plant.

Ordinarily as air is breathed in, it passes through the lower part of the nose, through the throat to the lungs. In normal breathing, the main air stream passes through the nose without passing over the olfactory receptor surfaces which are high up in the nasal passages. As the air stream passes through the nose, eddies are formed and some of these pass over the olfactory receptors creating the sensation of odour. If an odour is pleasant, the immediate reaction is to sniff, waylaying a larger portion of the air stream and increasing the intensity of the odour sensation.

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No present instrument for chemical analysis can completely replace the function of the nose. Factors regarding the nature of odorous effects on people which instrumental chemical analysis does not take into consideration include: (a) weak odours are not perceived in the presence of strong odours, (b) odours of the same strength may blend to produce a combination in which one or both of the components are unrecognizable, (c) the constant intensity of odours causes an individual to quickly lose the awareness of the sensation, and (d) the like and dislike for an odour often depends on an individual's association of the scent with pleasant or unpleasant experiences.

Many authors have attempted to classify odours, although realizing that primary bases for odours do not exist. One such odour classification was based upon six basic types, with possible combinations within the six — spicy, flowery, fruity, resinous, foul, and burnt.

For odorous contaminant measurements in the field, it is suggested that common language terms be used to describe the odour. For example, acetaldehyde odour may be described as fruity; cannery waste odour may be described as rotten egg; skatole odour may be classified as rest-room odours.

For each odour there exists a concentration below which no conscious sensation will be produced; this concentration limit is known as the olfactory threshold or the minimum identifiable odour. As the concentration of the odorous contaminant increases, the intensity tends to increase. Odour strength or intensity does not follow a one-to-one relationship with concentration. When the concentration of an odour contaminant is doubled, the odour intensity is not doubled; a tenfold increase in concentration is usually necessary to double odour intensity.

The relationship between odour intensity and odorous contaminant concentration is given by the Weber-Fechner equation: $P = k \log S$, where P = odour intensity, k = constant, S = odour concentration. This relationship stipulates that the stimulus (concentration) must increase logarithmically for the sensation (intensity) to increase arithmetically. For odorous contaminant measurements, the odour intensity can be considered as independent of ambient temperature and humidity. Odour intensity measurements should be made subjectively according to a grading system from zero (no odour) to four (strong odour).

Field measurements of odorous contaminants may be made by walking or driving through a specific area. Short sniffs of the air are taken to insure that the odour reaches the olfactory epithelium and to minimize the distance travelled between odour evaluations. Whenever a different odour is noted which is not immediately traceable to known conditions (odour exhaust, road tar, burning of wood, etc.) the car is stopped, the engine is turned off and attempts made to detect the odour away from the road. At each location, where an odour is noted, the odour intensity and type are marked on a map. Upon the completion of an odour survey the map is examined to determine if the odour and intensity measurements can point to the odour source.

At times the public may be asked to assist in odour surveys. The public could be asked, for example, to observe the type and intensity of odours three times daily -- before breakfast, when arriving home from work, and before going to bed.

In undertaking an odour survey one must be cognizant of weather parameters. Wind conditions can be estimated from the movement of trees and the blowing of dust; more precise data would be available from a weather station.

Summary of Discussions

The need to proceed in odour testing from dilute conditions to higher concentrations, rather than the reverse, was emphasized from the floor. Dr. Wohlers agreed and noted that this is related to the phenomenon of "odour fatigue" in which the sensitivity of smell is dulled by continued exposure to odours. Elaborating further, he said that personnel involved directly in odour testing should refrain from eating and smoking for at least one half hour prior to beginning a test; in the case of certain foods, such as onions, a considerably longer period is necessary. Dr. Wohlers noted that there is conflicting opinion among experts on the effects of temperature and humidity on the sense of smell; it appeared, that the smelling sensitivity of most persons is optimum at ambient air temperatures close to that of the human body.

The problem of eliminating odours was raised, and Dr. Wohlers said that this could best be accomplished by preventing odour-causing substances from being emitted using high temperature combustion, catalytic oxidation, or sorption; Objectionable odours in confined spaces may be counteracted or masked with more acceptable odours. In particularly odoriferous industries, such as tanneries, fish-rendering plants, and slaughter-houses, he said that buildings might be enclosed, gas discharge volumes reduced to a minimum through optimal space utilization and operation, and final emissions oxidized in catalytic units or by use of chlorine in the scrubbing water spray. In feed lots the spreading of potassium permanganate has sometimes been effective.

Asked whether the "odour-triangle" field technique described earlier by him is intended more for use in evaluating public complaints rather than for quantitative use in establishing dispersion patterns, Dr. Wohlers said it is valuable for both purposes when properly trained personnel are used. As a tool for evaluating odour emission intensity in terms of threshold odour units, a measured volume of gas may be drawn directly from the stack and tested in the laboratory by usual dilution techniques (the stack gas flow rate and temperature-pressure conditions must also be known).

Professor Katz commented that in his experience the field methods of odour testing described by Dr. Wohlers are very useful around oil refineries and paper pulp mills. Public participation in the testing programme, he said, is useful for detecting changes in odour conditions which may relate to plant process upsets and for helping management spot trouble areas.

15. METHODS OF MEASUREMENTS FOR SPECIFIC POLLUTANTS IN AMBIENT AIR

by

Professor P.J. Lawther*
WHO Temporary Adviser

Standard methods for the measurements of specific pollutants are already described in many books and, especially, reference should be made to "Measurements of Air Pollutants - Guide to the Selection of Methods" (World Health Organization, Geneva, 1969) by Professor Katz and the articles of Dr. J. McK. Ellison. In the short talk given a few new methods and modifications of standard methods for specific use in medical research were described.

The standard "D.S.I.R. Volumetric" apparatus is of great value for measuring pollution in terms of smoke (total suspended matter) and sulphur dioxide. The "smoke" concentration is measured by assessing reflectance or transmittance of the stain produced on a filter paper by the smoke collected and reference to a calibration curve enables one to express the results in terms of weight per unit volume of air. The need for frequent recalibration was stressed since the optical properties of smoke differ in themselves and with time. Likewise, it was pointed out that titration of the acid solution through which the filtered gases are passed gives an accurate assessment of SO_2 if this is the only acid gas present and there are no alkaline gases present.

The use of the cascade impactor enables one to examine particulate pollution in different size ranges. The particles so collected may be examined by the light microscope or electron microscope to determine their physical nature; also by treating the slides on which the particles are impacted with reagents, including pH indicators, knowledge of chemical nature of some particles may be gained. Examination of particles by means of phase contrast microscopy has been useful.

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The use of the thermal precipitator has enabled particles of all size ranges to be collected with great efficiency and this method is especially suited for examination of the particles under the electron microscope. As in the case of the impregnation of cascade impactor slides with different reagents, so electron microscopic membranes may be treated with metal film in order to investigate certain chemical properties of fine particles. One of the most valuable results of the use of the electron microscope has been the demonstration of the very great surface to mass ratio of particles produced as the result of incomplete combustion of carbon containing fuels.

The difficulties in relating concentrations derived from stationary samples to human exposure was discussed and the value of the use of masks with air filters to assess shift exposure in industrial atmospheres was described and its application to wider surveys emphasized. This method has been used in gas works for the determination of exposure to polycyclic hydrocarbons. Certain difficulties in sampling these compounds were discussed; they may be underestimated if it is not realized that samples may have been exposed to heat or if there has been failure to protect solutions of samples from sun light which can destroy the compounds.

The difficulties of relating ambient concentrations of carbon monoxide to human health was discussed. The amount in the blood depends on the amount in the air, the time of exposure and the rate and depth of breathing. Short-term ("grab") samples are useful to give an idea of the magnitude of pollution, longer term or continuous sampling is much preferable but the only really valid method is to determine the carbon monoxides as carboxyhaemoglobin in the blood. This can now be done easily using samples of only 0.01 ml blood obtained from pricking the finger.

Similarly, determination of lead in blood and urine of exposed people is of much greater value than determination of air-borne lead.

It is emphasized that the talk was concerned with merely a selection of methods and pollutants to illustrate principles involved and pitfalls to avoid.

Summary of Discussions

Professor Katz asked about the efficiency of retention of small submicron size particles in the lungs and referred to the work of Professor Hatch and others which indicated that below a certain size retention decreased. Professor Lawther agreed that this may happen. He hesitated to put emphasis on this, however, because the vast variety of aggregate types and shapes and the differences in their hygroscopic properties make the problem most complex. He noted also that this problem of retention involved not only the alveoli but also the terminal bronchioles.

Asked whether oil adsorbed on asbestos fibres rather than the asbestos particle itself is the carcinogenic factor, Professor Lawther noted there was some question about this. He cited research in which 3-4 benzopyrene was recovered from asbestos fibres. In his own laboratory, he said, a colleague obtained a carotene-like compound in the oil extracted from asbestos fibres, but this was eventually determined to be a derivative of the plasticizer used in the polythene packing of the asbestos sample. He said there was still considerable question about the biological significance of oil in asbestos and cautioned that it may not be satisfactory to collect samples for this type of biological work in plastic containers.

Asked which is the most practical method to use for sampling, Professor Lawther said this depended on the purpose for which the sample is taken. Thus, the D.S.I.R. would be satisfactory for collection of smoke for surveys in which relation between smoke and cancer were studied and the electrostatic precipitator would be suitable for collection and measurement of the concentration of inert dusts such as those from cement factories. The electrostatic precipitator, however, would not be a suitable sampler for organic compounds if it is also desired to analyse them because of the effect of ozone produced in the precipitator.

Replying to a question on macrophages, Professor Lawther noted that these are important in industrial pulmonary diseases and he discussed briefly some of the medical aspects of interaction between macrophages and fine particles in lung alveoli.

Professor Lawther presented some slides showing stack plumes of moderate height ejecting-plumes at sufficiently high velocity as to cause the plumes to rise above the inversion layer ceiling. Dr. Wohlers and Professor Katz felt that such ceiling heights and wind kinetics were too variable to permit stack design to be based solely on jet lofting and penetration of cloud cover.

16. EQUIPMENT AND METHODS FOR CONTROL OF POLLUTANT EMISSIONS (CITY PLANNING AS A METHOD OF CONTROL)

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

Many times, we are prompted to believe that new techniques must be devised for the control of air pollutant emissions. If one examines the history of the development of air pollution control equipment, one quickly finds that scrubbers were in use before 1860. Bag filters were used to collect zinc oxide fumes as early as 1850. Cyclones were used about 1880. Electrostatic precipitators were successfully demonstrated in 1907. Since then, tremendous improvements have taken place in the hardware (metals, fabrics, motors, etc.) but no new technological breakthrough has been discovered.

The selection of the proper collector for a specific purpose should be made with great care. Unless great care is taken in the choice and selection of a collector, the equipment will not perform as desired. In Figure 6 are listed a number of factors which should be carefully considered before a collector for a specific process is designated. Among the factors to be considered should be the particle characteristics — what is the size, shape, density, corrosiveness, etc. of the particles. One must evaluate the carrier gas characteristics as to temperature, pressure, humidity, etc. Operational and constructional factors must also be considered along with process and economic factors.

Five major pieces of equipment may be used for the removal of particulate matter from stack gases. A settling chamber is the simplest of all devices and depends upon the settling of the particulate matter by gravity; the device is very simple but is efficient only for particles greater than 50 microns. A cyclone depends upon the centrifugal force of the particle in a cylindrical cone; by centrifugal force, the particle is thrown against the side of the container and gradually is worked toward the bottom of the container.

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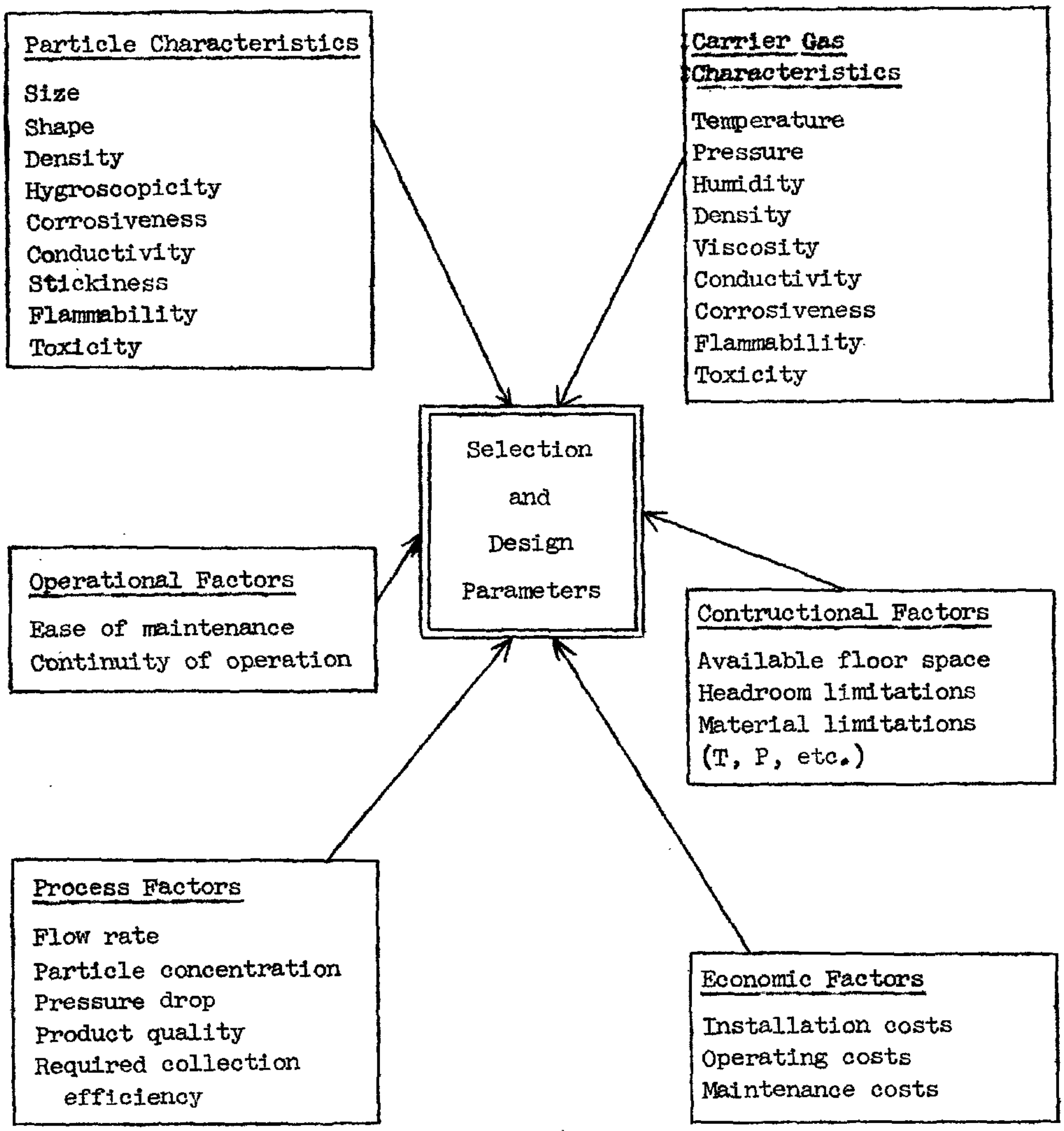
Figure 6

Factors Affecting Collector Selection and Design



The cyclone is a useful collector for particles greater than 5 microns in diameter. A simple scrubber depends upon the interception of a particle by a water or liquid droplet. The dirty gas stream is passed through a shower of water where impaction or interception takes place. High energy scrubbers can remove particles of the order of 1 micron in diameter; simple scrubbers are used for particles 10 to 25 microns in diameter. The electrostatic precipitator depends upon the attraction of a charged particle to a charged plate of the opposite charge. The device is very efficient for particles 1 to 10 microns. The bag filter removes particulate matter by filtration through cloth; the bag filter, like the electrostatic precipitator, removes particles 1 to 10 microns. Table 5 lists operation characteristics of particular control devices as well as economic data. Figure 7 graphs the comparative cost of dust collection versus efficiency for various collectors.

The cost of control equipment must be considered in relationship to the cost of the basic equipment. Generally, the cost of air pollution control equipment approximates 5% of the capital cost of the process equipment. At other times, the cost of the control equipment can be equal to or greater than the cost of the basic equipment. When the cost of the control equipment is equal to or greater than that of the basic equipment, the particulate matter to be collected is valuable or the control of the particulate matter is extremely difficult.

The control methods for gaseous pollutants involve combustion, adsorption, absorption and process modification. The control methods for gaseous pollutants are shown in Figure 8. The combustion control process usually involves the addition of extra fuel to completely burn the undesirable gases. Combustion may take place by either the addition of excess fuel or by passing the gas through a catalytic unit reducing the amount of excess fuel. Adsorption devices contain activated carbon, molecular sieve, activated alumina, and lithium chloride. Absorption of gases depends upon the solubility of the gas in water or chemical solutions. Process modification may involve a fuel switch from coal to oil gas - from the dirtiest to the cleanest type fuel. The use of atomic energy for the production of electric power is another example of a process modification which may be used to reduce pollutants emitted into the atmosphere.

Table 5

Operational Characteristics of Particulate Control Devices

	Settling Chamber	Cyclone	Scrubber (Pease-Anthony)	Bag Filter	Electrostatic Precipitator
Mechanism	Gravity	Centrifugal + Impaction	Impaction + Direct Interception	Impaction + Direct Interception	Electrostatic
Particle size, μ (90% Efficiency)	50	>5 - 25	<1 - 25	<1 - 10	<1 - 10
Operating Data					
Gas flow, cfm	No limitation	up to 50 000	500 to > 25 000	> 20 000	to > 2 000 000
Gas temperature, °F	1 000	700 - 1 000	700	600	to 1 200
Gas pressure, psi	to 150	to 150	to 100	to 50	to 150
Gas velocity, fps	< 10	40 - 80	up to 200	0.02 - 0.1	3 - 25
Draft loss, "H_2O	0.2 - 0.5	1 - 3	2 - 6	3 - 7	0.1 - 0.5
Loading, gr/ft^3	>100	>100	100	<0.3 - 4	0.0001 - 100
Water use, gal/1000 ft^3	-	-	3 - 10	-	-
Economic Data*					
Capital cost, $	~1 800	9 240	21 800	49 300	85 960
Operating cost, $/year	~4 000	4 900	7 950	14 200	2 430
Total cost, $/year	~2 000	5 820	10 100	19 100	11 000
Cost, ¢ /1000 Ef.	<0.01	0.02	0.034	0.066	0.038

* 60 000 cfm, 68°F, 5 gr/ft^3

Figure 7

Approximate Cost of Dust Collection by Means of Various Collectors

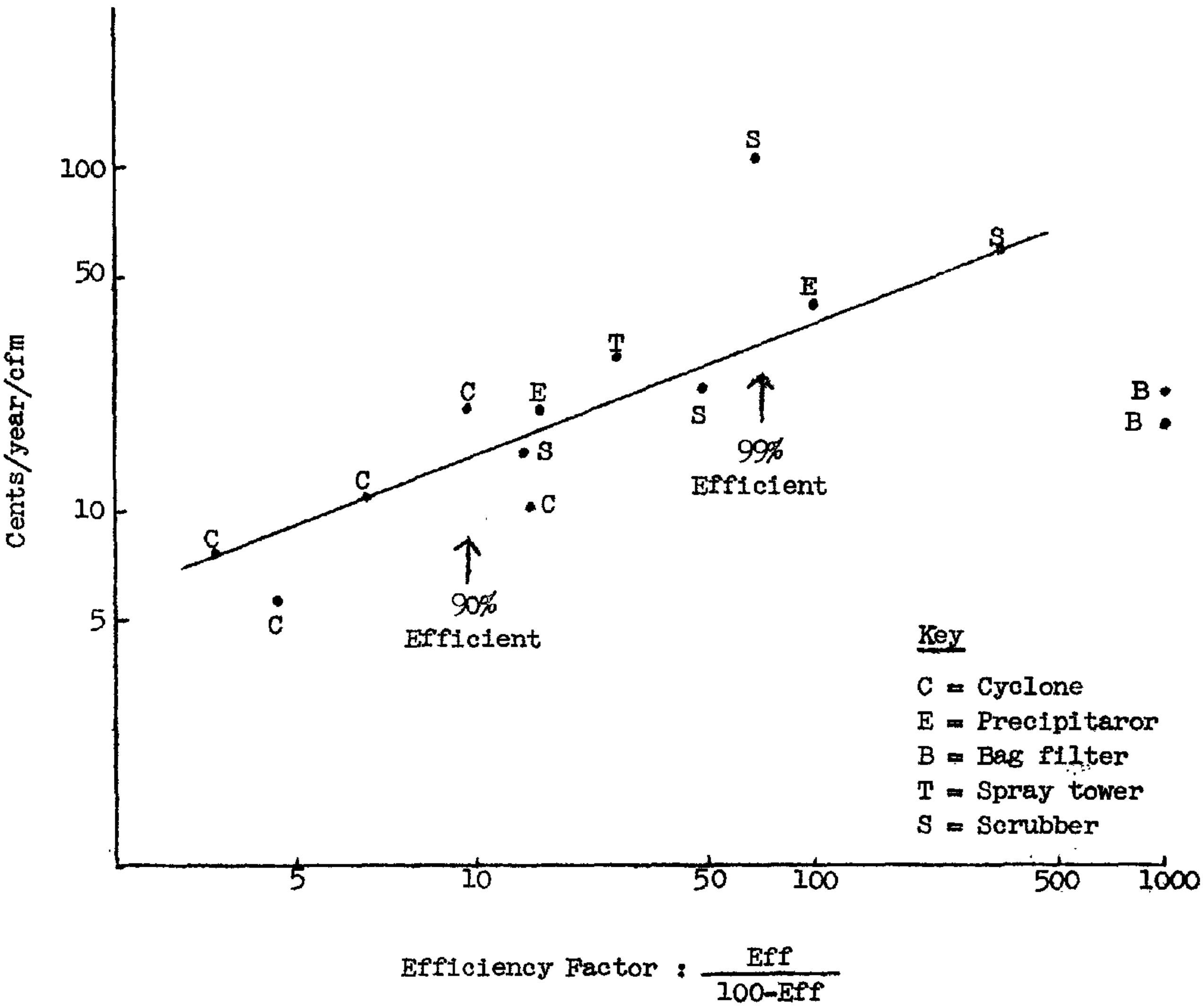
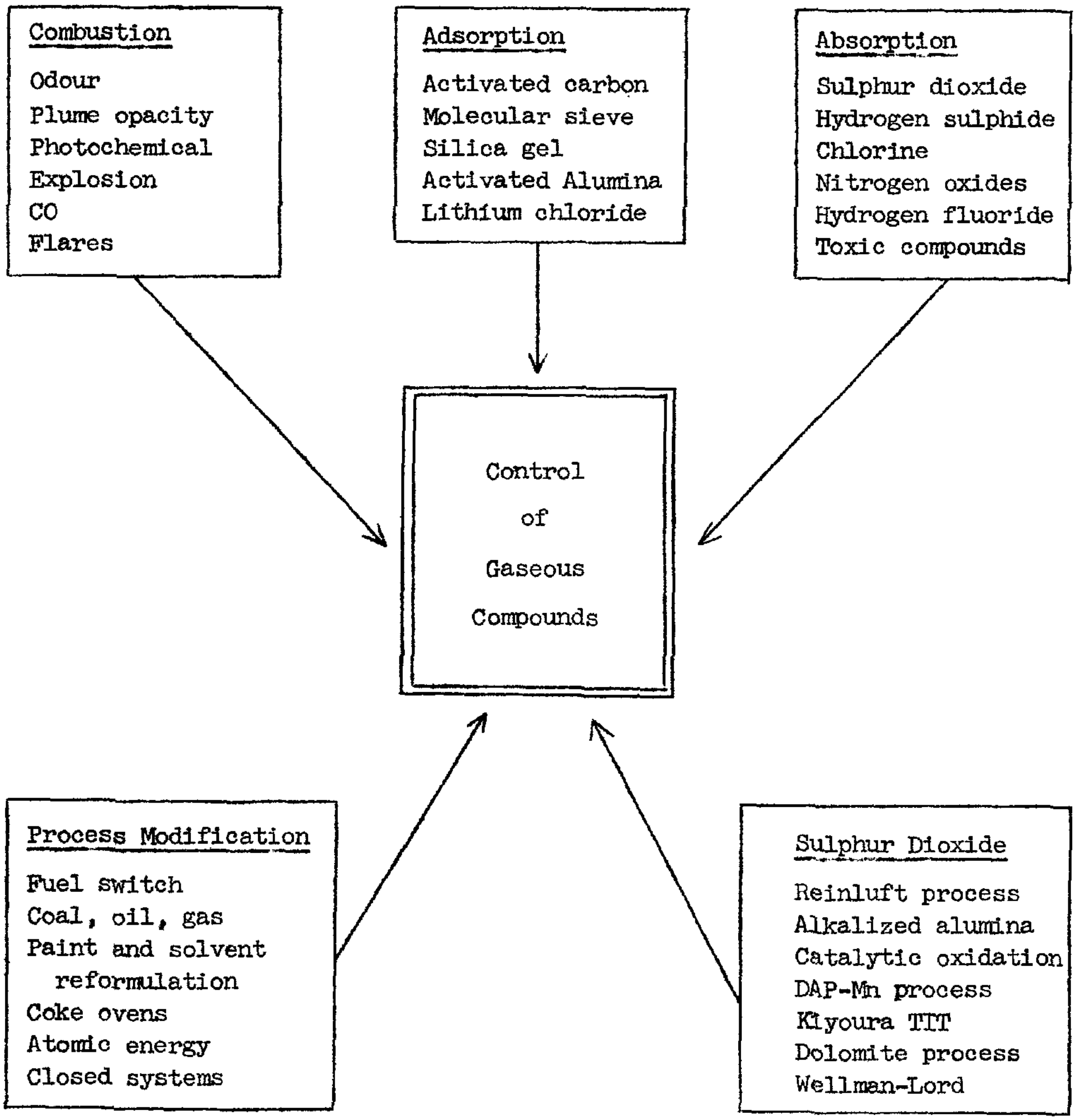


Figure 8

Control Methods for Gaseous Pollutants



Much emphasis has been given recently to the removal of sulphur dioxide from process gases. A large number of processes have been investigated but as yet no process is universally accepted. Figure 9 shows the comparative cost of sulphur dioxide removal processes. All of the processes except one impose an additional cost to the product produced. Only the Wellman-Lord process indicates, at this time, a reduced cost for the product produced. Unfortunately details concerning the Wellman-Lord process are unavailable.

Figure 9

Comparative Costs of Sulphur Dioxide Removal Processes
Total Cost[1]
($ per ton of coal)

Process	When no credit is taken for sale of by-product	When credit is taken for sale of by-product	Products providing credits
Reinluft	2.45	1.30	Concentrated acid at $ 23.50/ton
Alkalized alumina	1.54	0.86 0.32	Sulphur at $ 25/ton Sulphur at $ 45/ton
Catalytic oxidation	1.75	0.72 0.38	Moderately concentrated acid at $ 9/ton Acid at $ 12/ton
DAP-Mn	4.39 [2]	1.10 [2]	Ammonium sulphate at $ 32/ton
Kiyoura TTT	3.66 [2]	0.44 [2]	Ammonium sulphate at $ 32.20/ton
Dolomite (Combustion Engineering Inc.)	0.36-0.63 [3]	0.36-0.63 [3]	
Wellman-Lord Inc.	0.73	0 (-) 0.60	Sulphur at $ 25/ton Sulphur at $ 45/ton

[1] Includes fixed charges.

[2] Per metric ton of fuel oil.

[3] There is no saleable by-product from the Dolomite process. However, in installing this process certain capital equipment savings and operating savings (estimated at 27 cents per ton) are expected. The range of costs represents the cost with and without credit for these savings.

Planning and zoning in air pollution control are used to locate industrial areas so as to preserve air quality of the community as a whole, and to physically separate major polluting areas and residential areas to protect the latter from the former. Planning and zoning for air pollution purposes is usually a difficult task as most urban areas have been fully developed before the concept of planning and zoning for air pollution purposes was considered.

One should consider urban planning for air pollution purposes in the design of new buildings using central heating, the development of public disposal areas for refuse (sanitary landfill), the control of building heights to prevent pollution from one building affecting a resident at a higher level in another building, establishment of weed control programmes to reduce pollen count, the location of large pollution sources at a greater distance from residential areas, and the control of apartment developments in mixed commercial areas so that pollution from commercial premises will not adversely affect residential buildings.

Summary of Discussions

Questions on the pressure differential term appearing in a number of formulae for control equipment efficiencies were raised. Professor Katz, answering for Dr. Wohlers, replied that pressure differential costs money and, in so far as practised, it should be kept to a minimum. The efficiency formulae he said, usually related to weight removal and not particle number removal efficiency. It is most important to bear this in mind since weight varies as the cube of the diameter, so that for a given efficiency, disproportionately fewer numbers of larger particles are removed than is the case for smaller sizes. Very few equipment manufacturers give expected number removal efficiency ratings. Professor Katz also noted that stack velocity measurements may be made at any convenient place along the stack length as long as this was away from the breach effects.

There was considerable discussion about city planning as a factor in amelioration of the effects of air pollution. A number of cases were cited where planned location of industrial areas at considerable distances from residential areas was counteracted by the gradual encroachment of dwellers into the separating zones. As these encroachments eventually engulf the industrial area, air pollution complaints arise. In addition, demands for sanitary and other municipal services also arise in these unintentially built-up areas. Establishment of planned "green belts" between industrial areas and other "use" areas should be part of any city planning scheme, Dr. Wohlers said, and effective legislation and enforcement to keep these protective belts from being encroached upon should be established. Planning should be for fifty to sixty years ahead, it was said.

Dr. Fritschi commented on the question of incineration versus sanitary landfills for refuse disposal, and said it was necessary to look at this in relation to the overall problem of public health and not only as an air pollution control measure. Thus, anaerobic decomposition and rodent problems in sanitary landfills, the relation to various communicable diseases, and the need for land for multiple purposes must be considered as well, and he suggested that some sort of benefit-cost index for this overall concept might be used. Dr. Wohlers noted that there should be no rodent problems in a properly operated landfill, but he could make no statements regarding insect vectors.

17. CONDUCTING AN AIR POLLUTANT EMISSION INVENTORY

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

An emission inventory is the determination of the weight of pollutant emissions from all sources by location and season of the year. Normally considered in an inventory are five categories of emissions - transportation, power generation, industry, domestic heating and refuse disposal. Pollutants considered are sulphur dioxide, nitrogen oxide, carbon monoxide, organic compounds, and particulate matter. In specific cases, it may be desired to investigate other categories as well as other pollutants.

The uses of an emission inventory are many and varied. The emission inventory locates the sources of emissions by geographical areas and determines the weight emissions. The results of an emission inventory may be used for a mathematical diffusion model of the city, for air sampling purposes, for regulation purposes as well as for determining the progress of a control agency with time. The emission inventory is also used for education of the public and training of both industrial and governmental agency personnel. It is considered that the emission inventory is one of the most valuable tools of an air pollution control agency.

The precision of an emission inventory is always a matter of great importance. It is believed that if an emission inventory is well prepared, it is possible to be precise to within 20%. Data showing the precision of different types of emission inventories are shown in Table 6. The first and third columns in Table 6 were completed by two different groups for the Philadelphia area, the middle column was independently based on an evaluation of pollutant emissions on a population basis.

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Table 6

Comparison of Air Pollutant Emissions for Philadelphia Prepared by Different Individuals and Methods

Pollutant	Tons emitted per day		
	RCEO	Population Basis	Philadelphia Health Department
Sulphur oxides	780	870	720
Nitrogen oxides	320	340	300
Organic compounds	770	900	570
Carbon monoxide	2920	3300	2620
Particulate matter	230	-	190

The conduction of an emission inventory depends upon a knowledge of fuels used, number of automobiles, and number, size and type of industry within an area. Once the basic data has been obtained, emission factors are available to determine pollutant emissions based on the fuels, automobiles, types and sizes of industries. Pamphlets are available from the National Air Pollution Control Administration showing both the stepwise procedure for undertaking an emission inventory as well as the factors to be used in the conduction of an emission inventory. Reference should be made to these publications for further details.

A final note may be made that emission inventories can be used for air pollution enforcement purposes as well as for the determination of the weight of pollutants emitted. The most advanced inventory system presently is that used by the City of Chicago which involves a computerized system for data storage and retrieval on all plants, processes within the plant, and an estimate of the emissions of that plant. Much of the same information is used for enforcement purposes.

Summary of Discussions

The importance of educating management as well as the public on the need for air pollution control was emphasized from the floor.

Dr. Fritschi commented on the difficulties of using mathematical models and computer programming, and he asked Dr. Wohlers if his models had served their purpose for predicting amounts of pollutants and dispersion patterns. Dr. Wohlers said the results seem to be within an order of magnitude of actual conditions.

18. CRITERIA OF EVALUATION OF AMBIENT AIR QUALITY RELATED TO HEALTH AND WELFARE (RESEARCH NEEDED)

by

Professor P.J. Lawther*
WHO Temporary Adviser

This topic was also illustrated with slides. The following points were discussed and elaborated upon. Everyone would prefer to breathe unpolluted air but in the absence of a sensible definition of clean air and because so many of man's activities (such as breathing) produce pollutants one must strive to determine what is tolerable and at the same time strive to abate pollution. A common mistake, which can have disastrous consequences, is to regard air quality in isolation from economic factors and other social and medical evils.

For many years limits have been set for the pollution of the air in working environments. In some cases where the pollutant has an easily demonstrable effect the task has been easy; in others "maximum allowable concentrations" are what Drinker called "guestimates". But even in the more difficult industrial situations the problem of air quality is simple in comparison with the problems posed by the effects of dirty air on general populations, which contain not only healthy workmen but the very young, the very old and the sick and feeble. Again, climatic factors may result in relatively infrequent fumigations in which concentrations of pollutants may increase to twentyfold the "normal" value.

It must be realized that to afford complete protection all the time, for every person, may well be impossible in some societies; the abatement of air pollution and research on its effects must be seen in cool perspective and given appropriate priority.

Air pollution is complex; its effects are as yet little understood; the especially harmful ingredients have not yet been identified with certainty.

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Many other factors such as changing social conditions, improvements in therapy, and most important of all, the harmful effects of tobacco smoke, all tend to obscure the picture and make the interpretation of results and trends more difficult, if not extremely impossible.

Summary of Discussions

Dr. Fritschi recounted difficulties he had had in getting opinion response from the public and he asked Professor Lawther about his approach. Professor Lawther said it was important not to be too ambitious, but to limit any query asking for written reply from the public to question.

Concerning the physiological response to CO uptake and its dependence on such factors as time of exposure and concurrent CO_2 intake, Professor Lawther said this also depends on pulmonary ventilation capacity. He again noted that his tests were carried out on a variety of workers, such as traffic police, as well as non-workers. It was not possible to get more than 4% CO saturation in these people. His group is now looking into syneristic possibilities, using antihistamines, alcohol and other commonly imbibed substances in order to evaluate better the effects of CO on the human system.

Asked whether it would be desirable to standardize methods of research to make it easier to compare results from different studies, Professor Lawther said this would not be desirable but that everyone must be extremely critical of experimental work reported in the literature. He criticized the bad editing of many scientific journals being published today. He discussed at some length the problem and importance of devising non-biased testing procedures and of incorporating double blind controls and random input of test factors in experiments requiring evaluation response from test subjects.

Professor Lawther also discussed some of the known physiological effects of CO poisoning, particularly the irreversible chronic after-effects of non-lethal doses.

19. AN OUTLINE OF WHO ACTIVITY IN THE FIELD OF AIR POLLUTION

by

R. Pavanello*

Early work by WHO

WHO activity in the field of air pollution started in 1955 when the WHO Regional Committee for Europe recognized it as a serious problem and concluded that a combined effort by the countries of Europe was required for its solution. The recommendations of that Committee led to the Conference on Public Health Aspects of Air Pollution convened by WHO in Milan in November 1957. Twenty-one European countries participated in this first meeting of its kind in Europe. Observers also attended from the United States, the European Coal and Steel Community and the Organization for European Economic Cooperation. The Conference considered the sanitary engineering problems involved in the prevention of air pollution as well as the public health and administrative aspects.

Many of the participants confirmed, by striking examples of ill effects on man, animals and plants, that air pollution was a serious and difficult problem in their countries, and one that was rapidly getting worse. Although lack of conclusive proof of a direct relationship between air pollution and deleterious effects on human health and well-being was considered a serious handicap to effective action, the Conference was satisfied that there was sufficient information available to press for immediate control measures.

Immediately following the Milan Conference, the first meeting of an Expert Committee devoted to air pollution was convened in Geneva in November 1957. Thus, states the report of this meeting, "the World Health Organization recognizing its responsibility in the matter of air pollution as a threat to the health and well-being of peoples throughout the world, took its first steps to marshal the facts and to suggest procedures by which preventive and remedial action may be taken by its member countries before serious harm is done to the health of their people".

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The Expert Committee discussed the nature and causes of the problem, methods for measuring pollutants in the ambient air, the effects of air pollution and the need for prevention and control measures. The effects of air pollution were divided into four categories, namely (1) effects upon human health, (2) effects upon animals, (3) effects upon vegetation and (4) economic and sociological effects. However, it was the primary concern of the Committee to consider the relationship of air pollution to human health.

That Expert Committee made many specific recommendations relative to (1) standardization, (2) research, (3) collection and dissemination of information, (4) administration and legislation, (5) training, (6) education of the public, and (7) publication of a monograph. The last recommendation led to the publication in 1961 of WHO Monograph No.46, entitled "Air Pollution", a 432-page reference consisting of fourteen chapters, contributed by experts from seven countries.[1]

In 1959, the WHO Regional Office for Europe started a study to determine methods for relating non-specific disease states with air pollution. From this it became clear that there was a widespread but rather unco-ordinated interest in the epidemiology of air pollution, and some preliminary conclusions were drawn from an international symposium held at Copenhagen in December 1960.

The Eighth European Seminar for Sanitary Engineers was also entirely devoted to the subject of air pollution. This meeting, which took place at Brussels in October 1962, provided a forum for the exchange of information on technical and administrative measures for the prevention, evaluation and abatement of air pollution for the participants of the nineteen countries represented. On the basis of specially prepared documentation, the Seminar identified the main air pollution problems in Europe and their causes, reviewed programmes and control measures enforced in European countries, methodology for syrveys and pollutant measurement procedures, and legislative and administrative control measures.

Activities since 1963

The lack of general agreement on fundamental principles on which to base maximum permissible air pollution levels was discussed at another meeting which also dealt with the rationale for air quality criteria.

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[1] Publications in this series appear in English and French, and occasionally also in Russian and Spanish.

In reviewing the situation as regards standards for air quality, it became apparent that although several governments had adopted such standards, they varied widely because they had been based on different guides and criteria. Though no guide or criterion was formulated, certain important principles were agreed upon, and the criteria adopted by some countries to assess air quality, as it relates to human health, property and the environment in general, were reviewed. The role of epidemiological and aerometric surveys in the development of guides to air quality and the role of effects such as damage to vegetation, soiling of surfaces and visibility reduction were also considered.

In 1963 a second Expert Committee on air pollution was convened by WHO. This Committee reviewed the report of the afore-mentioned meeting on air quality criteria and guides, endorsed its general approach to the subject and, in particular, the principles and definitions of criteria and guides to air quality, i.e.

> 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;
>
> 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.

The Committee felt that internationally agreed guides to air quality were desirable and should be set up as soon as feasible. It stressed that pollution of the air by biologically harmful substances resulting from man's activities should be avoided to the maximum extent possible. Concerning emission standards, the Committee states that "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".

In reviewing progress made in air pollution control, the Committee noted that a number of countries had in the 1st few years passed new legislation, that technical means for control had advanced, that methods for monitoring atmospheric pollutants, especially stack emissions, had improved, that heating installations in urban districts were being operated more efficiently, and that town planning, improved traffic regulations and meteorological warning systems had all tended to keep down air pollution in the last years.

The Committee noted the need for controlling automobile and diesel exhaust gases as well as the pollution caused by the combustion of coal. It was recognized that international collaboration was desirable for the resolution of air pollution problems associated with motor vehicles, the elimination of sulphur dioxide from flue gases, and meteorological conditions, to investigate the loss of working hours from ill-health caused by air pollution, to elaborate methods for treating or burning coal in developing countries and to disseminate information on air pollution control.

The Committee made specific recommendations on research, on research co-ordination, co-operative studies on the epidemiological effects of air pollution and commended the WHO practice of awarding fellowships for laboratory and field work. Further study was recommended on internationally acceptable guides for air quality, and it was proposed that a glossary of terms used in air pollution control work be prepared.

The many recommendations of this Committee led among other things to a series of scientific group meetings and, although these scientific groups discussed various facets of environmental pollution, air pollution received considerable attention.

Methods and procedures were discussed for providing a scientific basis for regulations to prevent long-term effects on health from air and water pollutants. Long-term effects were defined as the effects of accumulation and storage of pollutants; the delayed or insidious effects of relatively high concentrations of pollutants, the contributory or accelerating role of pollutants in the development of chronic diseases, in aging and life-shortening; the irreversible, prolonged or repeated impairment in important body functions; changes produced in immunology or other body defences, and in the transmissible genetic material of the body. The long-term effects of air pollutants inhaled into the respiratory system received special attention, the most important long-term effect being the presumed correlation between pollution and chronic non-specific lung disease.

The principal purposes of air pollution measurement were defined: to make a preliminary assessment of pollution problems, to identify sources of pollution, to estimate health effects, to assess air pollution in relation to weather, to evaluate the effects of control measures, to guide economic planning and development. Measurements were also vital for the development of air quality criteria and guides.

In reviewing analytical methods, the importance of simple, sensitive and especially specific methods was emphasized. While apparatus for some of the new analytical procedures was expensive, savings in manpower and the resulting improved specificity and sensitivity in measurements might justify the high cost of certain new equipment. In this connection, WHO was recommended to publish monographs presenting reliable methods for the measurement of individual pollutants thought to be important for public health. Such monographs are now in preparation, while a guide to the selection of methods for measuring air pollutants (the first draft of which was presented to one of the scientific groups) is now in press.

Bearing in mind the recommendations of the 1963 Expert Committee and of the various scientific groups concerning motor vehicle exhausts, a report on the public health aspects of air pollution from diesel vehicles was published in 1967. This dealt with fuels and their combustion products, the effects of incomplete combustion, the differences between petrol and diesel engines; it compared petrol and diesel engines as regards their air-polluting tendencies, and explained the health implications of diesel engine emissions and how to prevent such emissions. The Expert Committee on air pollution organized by WHO in 1968, on the other hand, considered in detail urban air pollutants emitted by motor vehicles, and reviewed methods for sampling and analysing these pollutants, their health effects, their effects on the environment, and guides to air quality, as well as control methods and their efficiency.

The Inter-Regional Seminar on Air Pollution Control, 1967

Training in techniques to combat special health problems has always been a tenet of the Organization's programme. Air pollution control is no exception. A recent example of a group-training activity was the Inter-Regional Seminar on Air Pollution Control, convened by WHO in collaboration with the Government of the USSR in Moscow and Volgograd in 1967. Five WHO Regions were represented at this Seminar which covered: general and organizational problems, meteorological problems in air pollution control, criteria and guides to air quality, air pollution surveys and methods of measurement, health effects of air pollution, and air pollution control technology. A report on this Seminar has been prepared for distribution to all participants and other interested persons and institutions.

The WHO International Reference Centre on Air Pollution

As part of its research programme, at the end of 1967 WHO established an International Reference Centre on Air Pollution, and a number of regional and national reference centres and collaborating laboratories are now being designated to form, together, a world network of institutions. The functions of the International Reference Centre are to advise on research results regarding the health effects of air pollution, on the organization of air pollution surveys, on the identification of measurement of air pollutants and on control methods. It will provide consultant services on research and technical problems, it will carry out research on behalf of WHO, co-ordinate research and evaluate the results obtained by the collaborating laboratories and national institutions, and advise WHO on new research needs. With the assistance of collaborating laboratories and national institutions, it will elaborate methods for identifying and measuring air pollutants and organize and co-ordinate inter-laboratory comparisons on the use of such methods. It will train individual specialists and organize international, regional and national training courses in air pollution control.

As a first task, the International Reference Centre has undertaken a critical review of a number of methods for measuring air pollutants.

WHO Regional Programmes

As already mentioned, the Regional Office for Europe began a detailed study on the health effects of the problem in 1959; in 1962 the Eighth European Seminar for Sanitary Engineers was devoted entirely to control methods and technology, while another European symposium on the health effects of air pollution took place in November 1968, which reviewed and discussed the trend of air pollution in Europe, methods for sampling and assessing the extent of pollution, the health effects and the establishment of guides and criteria for ambient air quality standards.

In the Region of the Americas, work on air pollution started relatively recently. While much valuable research and practical control work has been done in the USA, as to constitute a model of its kind, the problem is just emerging in Latin America. Thus at a meeting of the Directing Council of the Pan-American Health Organization in 1965, a resolution was unanimously approved recommending Ministries of Health to take up the problem and requesting the Pan-American Health Organization to grant technical assistance in this field. Shortly afterwards, a plan was drawn up for monitoring air pollution in urban areas throughout the Region. This surveillance network is now in operation, linking ten large cities spread over nine countries. In the meantime, some air pollution research work had been conducted by the Institute of Occupational Health and Air Pollution Research at Santiago of Chile, an establishment created by the UNDP/SF and for which WHO had been the Executing Agency.

This Seminar has in fact been planned to look into the serious air pollution problems that are becoming manifest in the Eastern Mediterranean Region.

As for the South-East Asian Region, some work on air pollution has been conducted since the inception of the Central Public Health Engineering Research Institute, another UNDP/SF establishment for which WHO was the Executing Agency. This side of the Institute's work will increase in importance now that air pollution problems are starting to cause concern in India and other countries of the Region.

Technical Assistance to Member Countries

Assistance to individual Member Governments is a traditional function of WHO and in the field of air pollution the Organization has since 1960 provided such assistance to a number of countries including: in the European Region - to Turkey, Hungary and Yugoslavia; in the Eastern Mediterranean Region - to Kuwait, Iran, Cyprus, Lebanon and Israel; in the Americas - to Argentina, Brazil and Chile, and in the Western Pacific Region - to Japan and Taiwan.

Collaboration with Other Agencies

As in other facets of its programme, WHO has for some ten years been collaborating with various international bodies in the matter of air pollution - with the Specialized Agencies and their regional commissions, with other inter-governmental organizations and with a number of non-governmental organizations concerned with specific technical aspects of the air pollution problem.

In 1965 WHO presented a report to ECOSOC on environmental pollution - a report that had been prepared in co-operation with ILO, UN, FAO, UNESCO, WMO and IAEA. A further study on the question was requested by the Council, and this was prepared and presented to the 1967 Session of the UN Advisory Committee on Science and Technology and to the 1968 sessions of ECOSOC. It is to be noted that at these sessions a resolution was unanimously approved by the Council calling upon the UN to convene an international conference on problems of pollution of the human environment.

Another cogent instance of WHO collaboration with other UN agencies is its work with WMO, in particular with the working group on atmospheric pollution and atmospheric chemistry of the WMO Commission on Atmospheric Sciences;

the first meeting of this group, in fact, endorsed the WHO recommended units for expressing the results of air pollution measurements. WHO co-sponsored with the WMO the Symposium on Urban Climates and Building Climatology, held in Brussels in October 1968.

WHO, together with the UN and the FAO, participated in the UNESCO Conference on Resources of the Biosphere (Paris, September 1968) and presented a paper on problems of the deterioration of the environment (air, water and soil).

WHO participates regularly in the work of various groups and meetings concerned with air pollution organized by the IAEA, the Economic Commission for Europe, and the Economic Commission for Asia and the Far East.

WHO has constant and continual contacts with the OECD. In 1964 WHO also provided considerable assistance to the Council of Europe in planning and organizing a European Conference on Air Pollution.

The International Union of Pure and Applied Chemistry and the International Union of Local Authorities are the non-governmental organizations most directly concerned with air pollution, and IUPAC in particular has been represented at WHO expert committees and scientific groups. WHO is also in contact with various international unions and associations (e.g. the International Union of Air Pollution Prevention Associations, the National Society for Clean Air of the United Kingdom, and the Air Pollution Control Association of the USA, etc.).

In the course of the next five years, the Environmental Pollution Unit will concentrate on the following aspects of its long-term programme:

i. systematic investigations into and compilation of data on environmental pollution in selected countries by consultants and through technical meetings, designed to identify common problems and the type of WHO assistance needed;

ii. the establishment and development of international, regional and national reference centres and collaborating laboratories in environmental pollution (air pollution, environmental radioactivity, water quality);

iii. establishment and development of applied research institutes (such as the Central Public Health Engineering Research Institute, Nagpur, India) in other WHO Regions (particularly Africa) to serve as centres for applied research and development, as focal points for operational activity or consulting services, for country-wide dissemination of technical information on environmental health, and for specialized training;

iv. establishment and development at Headquarters of an information service on work in environmental pollution carried out by Governments of Member States and other national and international organizations.

More specifically in the field of air pollution the Unit will be concerned with:

a. setting up tentative criteria and guides to air quality;

b. promoting and conducting studies into the effects of air pollution on human health and the environment, and on epidemiological methods of investigation;

c. preparing guides to the selection of suitable methods of assessing and controlling air pollution, and assisting in applying such methods.

Summary of Discussions

Professor Katz commented on the indirect use of experts by international organizations and suggested that experts be hired directly for needed information.

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20. EMISSION STANDARDS THAT MAY BE APPLIED TO SOURCES OF POLLUTION

by

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The development of emission standards that may be applied to sources of pollution is an unnecessarily complicated subject. It is difficult to get scientific personnel to agree on a procedure to be used for the development of emission standards.

One sequence for the development of standards is given below:

1. Prepare air quality criteria - that is, the relationship between pollutant concentration in air and adverse effects.

2. Develop air quality goals or the desired level which the community believes it can "live with".

3. Develop air quality standards which may be capable of achievement in the near future.

4. From air quality goals develop emission goals necessary to achieve desired air quality.

5. From air quality standards, develop emission standards necessary to achieve air quality standards.

6. Develop designed standards - that is site, equipment, size of operation, fuel, etc. - necessary to achieve emission standards.

7. Develop methods for measurement and testing of ambient air, control equipment, and air pollution effects.

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Although the development sequence for air standards was simply stated, the achievement of the sequence is extremely difficult. The sequence of events listed above would be considerably simplified if emission standards were based upon the maximum control possible (stack concentration, process weight, and equivalent opacity) using most modern technology.

Often, procedures used in developing air quality standards involve the use of another community's air as a standard if one considers that the other community's air is desirable in one's own community. One can also use acceptable air quality which existed at an earlier time in setting air quality standards. Another approach is to use existing air quality levels in the area as the basis for regulations. The combination of one or more of these approaches may be used.

Summary of Discussions

See page 128. Combined with discussions of Lecture No. 21.

21. DETERMINING EMISSION REDUCTIONS TO MEET AIR QUALITY STANDARDS

by

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We are finding out that we are changing the natural environment at a rate faster that nature can handle it and at the same time sustain us and our needs. We are not really trying to conquer nature but trying to find a form of co-existence; where man's benefits do not stem from nature's losses.

All of the complexities of the criteria - standards - laws and their enforcement must be considered when one decides what reduction of emissions is necessary to meet air quality standards. The dilemma of this situation is presented in Figure 10. As far as air quality criteria are concerned, it is difficult to relate the control of one pollutant to all pollutants in the atmosphere; one cannot relate a single cause to a single effect. With the multiplicity of pollutants in the air, no one is knowledgeable concerning the synergistic or antagonostic effect of air pollution.

It is quite possible that, with all the confusion among technical people, the only solution to this dilemma is to have the politicians listen to various arguments and then tell the scientist what values should be used as air quality standards.

The cost of air pollution effects must be considered in air pollution regulations. Zoning is a factor. Diffusion equations may be used as an indication of air quality versus emissions. The type of regulation must be considered. And finally for enforcement, the priority and impartiality of the governmental air pollution control must always be foremost in the minds of the public. And the enforcement effort is always hampered with a low budget.

One must always consider the concept and desires of the people in the evaluation of air pollution problems. One such survey was undertaken in the

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Figure 10

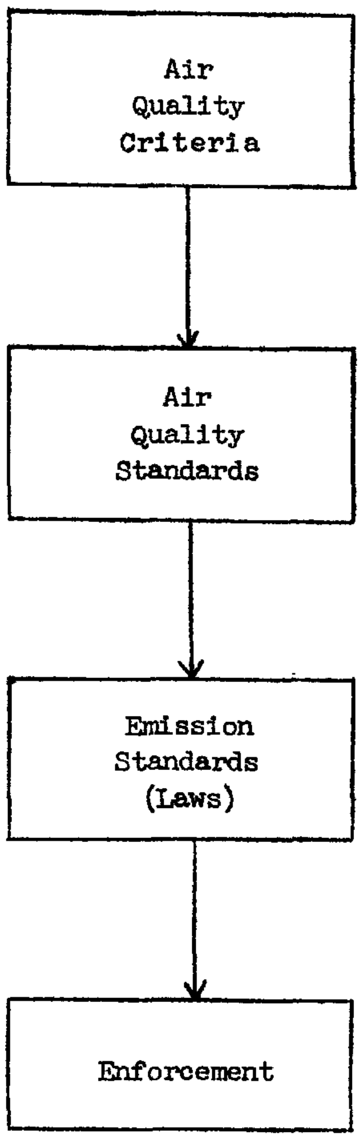
Dilemma of Criteria - Standards - Laws - and their Enforcement

Total Pollution
Ecology
Cause and Effect
Synergism versus Antagonism
USA - USSR

Receptor Condition
Industry Lobby
Urban versus Rural
Sampling Time
Jurisprudence

Cost versus Effects
Zoning
Diffusion Equation
Permit - Non Permit
Role of Government

Priority
Impartiality
Public Backing
Budget



Buffalo (New York) area at two specific time periods - 1959 and 1962. In both surveys it was clearly discerned that air pollution was not foremost in the minds of the people of the area - Juvenile delinquency, communicable disease, unemployment, and alcoholism were factors considered more important than air pollution. If the public is not entirely behind an air pollution control effort, little can be accomplished.

All of these questions could be resolved if air pollutant emissions were controlled to the maximum extent possible using most modern technology.

Summary of Discussions of 20 and 21 above

Professor Katz commented that in establishing emission standards there has been undue influence from industrial hygiene where MAC values have been set on the basis of individual pollutants. In general air pollution, we are dealing with a combination of many substances and in this case all synergistic, antagonistic and mutagenic effects are possible. He also noted that a stack concentration standard does not give an indication of the total daily pollutant discharge unless the flow rate is known; emission standards, therefore, must be considered in the terms of plant size and population. The use of expert consultants and modern technology is no guarantee that results at two plants will be equally good since experts often disagree with each other; therefore, it may be desirable to set standards well below known criteria. Dr. Wohlers said there were three important points to consider in any formulation of standards, namely, (1) grain loading per unit volume for each pollutant, (2) process weight discharge per day, particularly for large plants, and (3) equivalent opacity.

It was emphasized from the floor that in addition to legislation on air pollution control, effective enforcement provisions are required. The ensuing discussion was concerned with various aspects of legislation and enforcement as well as with the effectiveness of voluntary acceptance of controls by industry and by the private citizen. It was said that legislation, to be effective, needs a receptor and this requires a campaign for mass education of the public. In Western countries, legislation on air pollution arises essentially from the pressure of public opinion, but in the developing countries this was not the case.

There was much discussion about optimization of fuel type and use as an air pollution control measure. Professor Katz noted that for power production the trend in this respect might be: coal, oil, gas, atomic power. However, he said, a developing country also had the problem of developing its own natural resources and it might, for example, consider the use of coal resources for industrial operations, where controls are easier to apply, and to use gas or oil for domestic purposes.

22. PLANNING ON AIR POLLUTION MONITORING PROGRAMME

by

Professor P.J. Lawther*
WHO Temporary Adviser

It was stressed that all too frequently programmes are designed without giving adequate thought to the reason for monitoring pollution and that the methods used, the substances measured, the sampling times employed and the length and result of the surveys will all depend critically on the reasons for measuring pollution which must be carefully defined. The following points were emphasized: almost invariably the proper survey of pollution is much more difficult than is at first thought; if trends are to be assessed, very long periods are needed to allow for "normal" variation; if long term samples are needed, the stability of the compounds sampled and their method of storage is important; if international comparisons are to be made, clearance with customs authorities must be arranged for transport of samples, and standardization of equipment methods ensured.

The siting of samplers is of obvious importance and all too often it is forgotten that not only is man the object of the survey but that he himself is the best (and often only) relevant sampling equipment.

Often one forgets that some sampling programmes are unnecessarily comprehensive inasmuch as they duplicate work elsewhere which has already answered the problems posed. An example of this type of duplication is the measurement of carbon monoxide in streets which will be discussed. Of obvious importance is the recognition of the effects of variation in local topography, weather, and population distribution and migration.

Summary of Discussions

Much attention in the discussion was given to carbon monoxide in automobile traffic exhaust. Professor Lawther noted that this was not a demonstrable health problem among traffic police and other workers in areas of heavy motor vehicle usage, and so it is not likely to be a hazard for the general public.

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Problems of emission of pollens and other organic allergens and irritants among cotton workers and in castor bean processing were discussed. Professor Lawther noted that in most cases, allergen effects disappeared when the allergen exposure was stopped. However, it is possible for some lungs to become sensitized and even for fibrosis to develop if the exposure is continued. He said he knew of no cases where cotton fibres were a problem in this respect, but he thought that the castor bean allergen should be studied as a matter of some urgency.

23. THE KINDS OF ACTIVITIES CARRIED ON BY GOVERNMENTAL AIR POLLUTION CONTROL PROGRAMMES (OVERVIEW)

by

Dr. H.C. Wohlers*
WHO Temporary Adviser

An organizational chart for a non-existent air pollution agency may be used as an indication of the kind of activities carried on by governmental air pollution control programmes. The word "non-existent" air pollution agency is used because no air pollution agency would be blessed with the number and variety of personnel shown in Figure 11. Yet, members of an air pollution agency must undertake and complete each of the items listed.

The air pollution agency is established as a result of legislation. Normally a major managing commission or group governs the air pollution agency. The head of the air pollution agency is responsible to this management. The Hearing or Appeal Board is used to settle initial disputes between the air pollution control agency and supposed violators of air pollution regulations. The Technical Advisory Committee develops regulations and evaluates technical factors involved in air pollution control.

Reporting directly to the air pollution control officer are seven divisions - Legal, Business, Technical, Engineering, Field Service, Research, and Public Information and Education. As the name implies, the Legal Division is responsible for legal activities of the agency - court cases, legislative problems, zoning, programme planning, and liaison with other governmental agencies. The Business Division is responsible for personnel and fiscal problems.

The Technical Division is responsible for all scientific factors relating to the agency and air pollution regulations. The Technical Division maintains a laboratory, monitors air, processes data, and is responsible for meteorological and weather forecast problems and special assignments. The Engineering Division is responsible for permits, surveys, inventory and source tests. The Field Service patrols the area and inspectors are the eyes and ears of the air pollution control agency.

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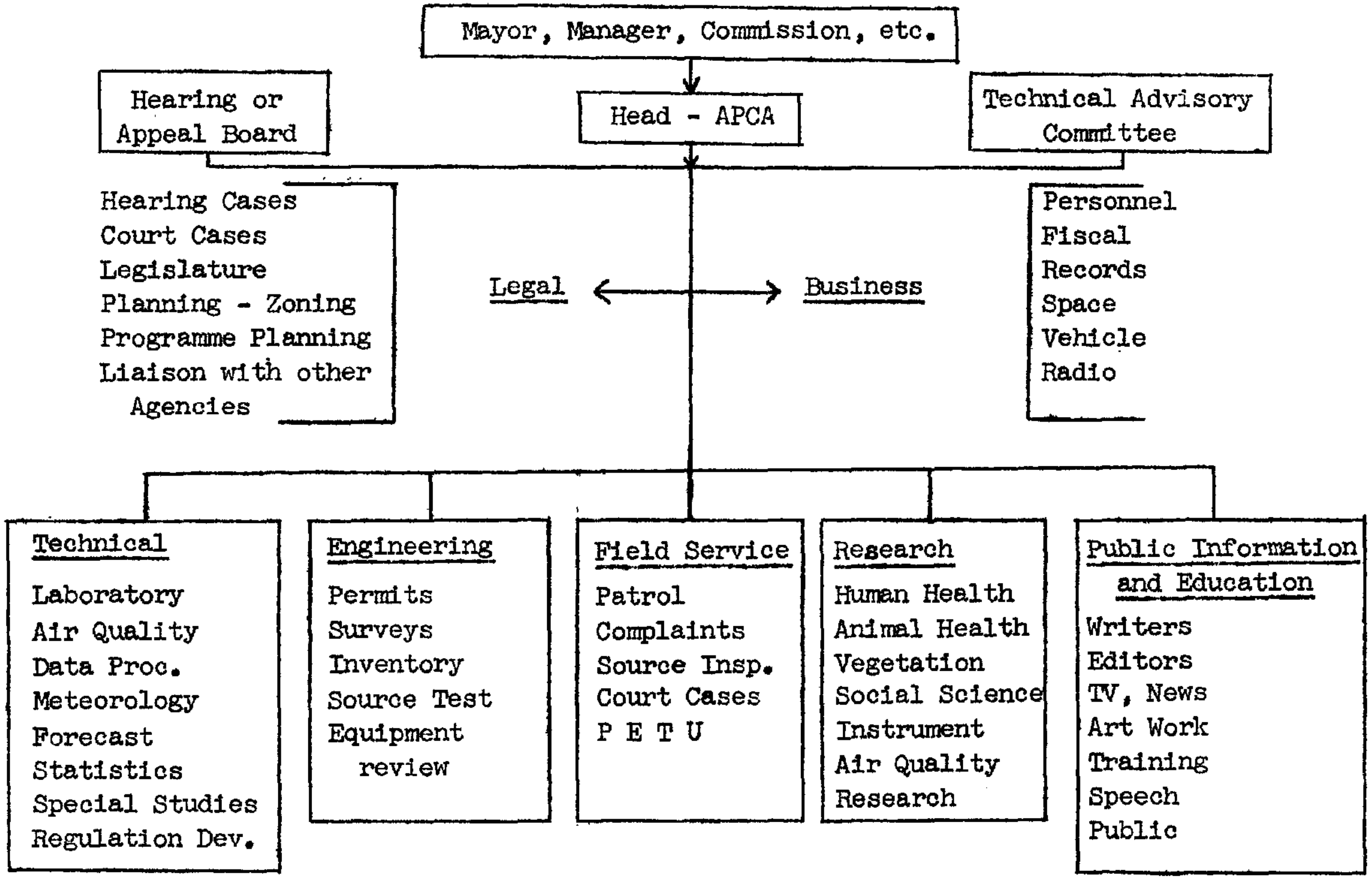
Figure 11

Organizational Chart for Non-Existent Air Pollution Agency



Field Service personnel appear in court to testify as to air pollution violations. The Research Division investigate unknown factors concerning air pollution, of which there are many. The Public Information and Education programme involves writers and editors for preparation of news releases to the public. This Division should have as its prime objective to keep the people informed of the progress of the air pollution control agency. Unless the people are aware that the air pollution control agency is accomplishing the work it is supposed to do, the air pollution agency will have difficulty in obtaining future funds to complete its work.

No Discussions.

24. AIR POLLUTION CONTROL PROGRAMMES AND THEIR LEGAL VALIDITY

by

Dr. Engelbert W. Fritschi*

Introduction

The continued search for scientific knowledge and the continued industrial expansion have resulted in a rapidly advancing and changing environment. Man has the ability and, in most cases, the desire to change this environment to suit his needs. New cities are built to house the growing population, new areas are developed for recreational purposes, and new products are manufactured to satisfy the demands of the society. The period when man adjusted to his environment is changing to the era in which the environment is adjusted to suit man.

As a result of these scientific and technological advances, it is taken for granted that everyday conveniences are readily at hand in most parts of the world. Little or no thought is given by the average society how this high standard of living has been developed. It is sufficient for man to know that there is a constant search in progress to find new and better means for the protection of the society he lives in. Man's present day conceptions of modern living are based on the scientific discoveries which have resulted in the increased comfort and safety of human life during the past few generations.

In his pursuit of an ever higher standard of living man completely overlooked the side effects that may arise from this venture. While some of these side effects may be of little significance to the society, there are some that are of major importance to the health of the individual. Among these harmful side effects, the problem of air pollution has gained strong impetus in recent years. The significance of this problem is due mainly to the sudden increase in population and industry in a certain, confined area. In addition, no thought was given to the harmful effects caused by the emission of the by-products from the everyday activities which are such an integral part of every modern technologically advanced society.

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The fact that air pollution is existing can be demonstrated in every community. It is, however, a bit more difficult to demonstrate its magnitude and extent. Consequently, it is even more difficult to describe the ways and means of abating or even controlling air pollution. Even so the law is as old as or even older than the pollution problem, the difficulties in the control of pollution lay more in the interpretation and in the acceptance of these laws; the most difficult problem for society seems to be its acceptance of the fact that these laws are made for its protection. It is intended herein to describe the problem of air pollution and its legal control from an engineer's point of view who has limited knowledge of this complex problem. It is not claimed that the interpretation of the legal validity of air pollution control is conclusive, but it is hoped that it will inspire the individual to think in depth about this critical problem.

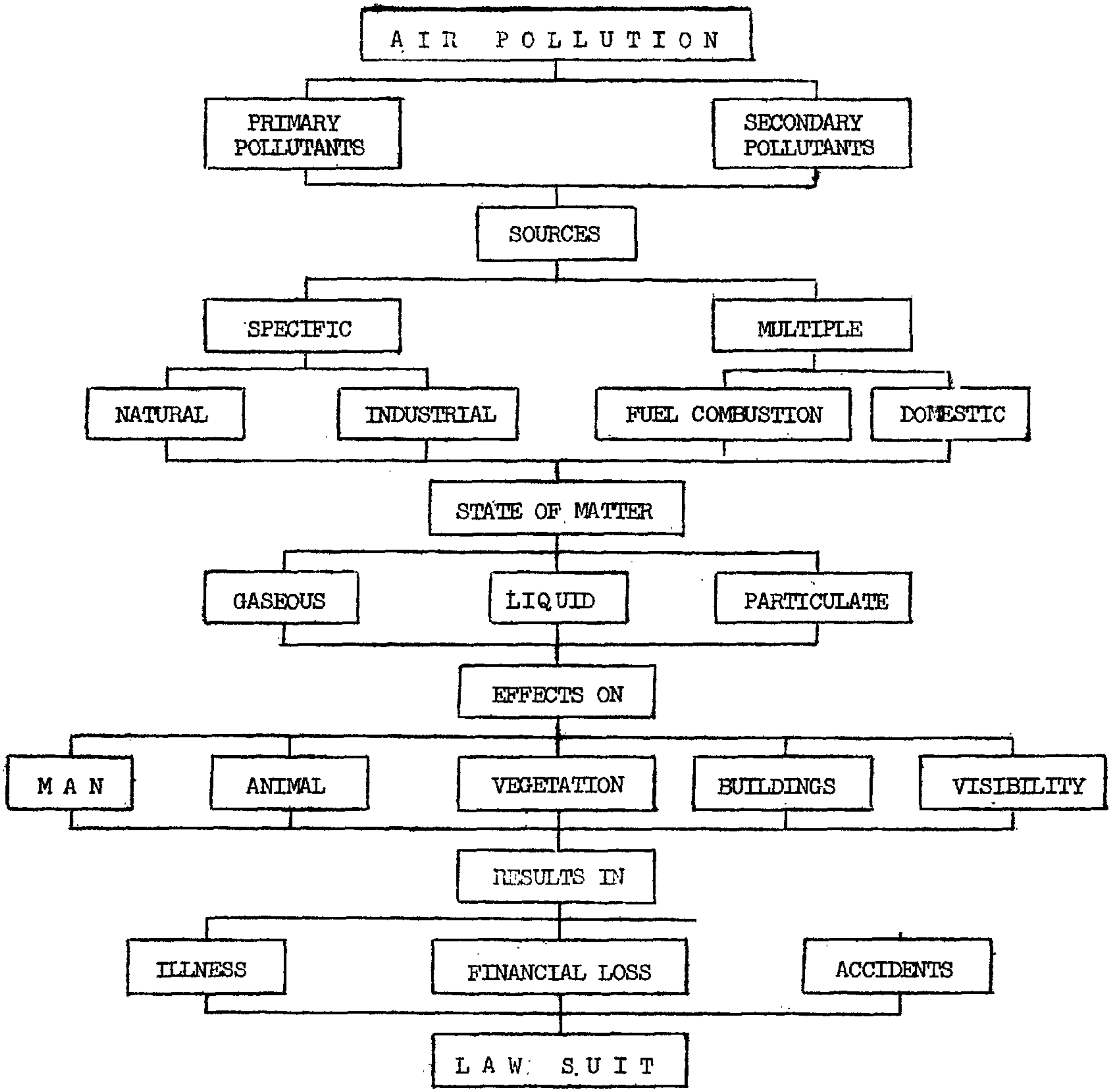
The Air Pollution Problem

The term air pollution comes into being in the presence of man-made or natural substances in the air in such quantities and of such quality and for a certain duration that it will alter its purity and thus adversely affect man's well-being or his property. This definition, although just a single sentence and adapted from the definition of water pollution has a wide latitude or application and may be used to permit the recognition of the pollution, either sensory or by physical measurements. Both methods are used for the identification of pollution, each having its strength and its weakness. These methods, being man-made, are subject to discussion and hence to diverse opinion. It may be well to review the flow chart as illustrated in Figure 1.

While natural air pollution sources have been with man for a long time, the man-made pollution sources have had the greatest impact on his well-being. Of the latter sources, the emission from moving vehicles has, perhaps, focused the greatest attention of the public in recent years. Most of these sources discharge, or emit, chemical compounds of a complex nature and if these compounds interact with the atmosphere in the proper concentration, at the proper time, and under proper meteorological conditions, they produce different compounds by photochemical reactions and hence are termed secondary sources of pollution.

Pollution may be emitted in a particulate, gaseous, or liquid state. Of these three states the gaseous state is of prime importance to the health of man and animals, while the other two states are more detrimental to man's

Figure 1


AIR POLLUTION
PRIMARY POLLUTANTS
SECONDARY POLLUTANTS
SOURCES
SPECIFIC
MULTIPLE
NATURAL
INDUSTRIAL
FUEL COMBUSTION
DOMESTIC
STATE OF MATTER
GASEOUS
LIQUID
PARTICULATE
EFFECTS ON
MAN
ANIMAL
VEGETATION
BUILDINGS
VISIBILITY
RESULTS IN
ILLNESS
FINANCIAL LOSS
ACCIDENTS
LAW SUIT

property. In some cases pollutants may cause a reduction in visibility and thus may result in public traffic hazards. As a consequence, the financial loss to the individual and to his community may be of considerable magnitude. While man may be willing to accept air pollution as a "nuisance" he cannot and he will not tolerate a financial loss. Hence he will seek to protect his assets by one or the other means such as: (1) a complaint to his political representative at the local, state, or national level, (2) seeking an injunction with the local health authorities, and (3) a suit may be filed against the owner, claiming damages. Neither of these ways seems to be a "reasonable" approach to alleviate the problem or at least to control the source within "reasonable" limits. The action of an individual to solve the problems of his society are, in most cases, impeded, for he lacks the ability and the power to successfully solve this difficult task. Representatives of the people at the various levels are, for all practical purposes in most countries, not in a position to solve all these problems for the individual mainly because they are elected by the people but they are supported financially during their pre-election time by the industry. The alleviation or control of the problem by legal court action has been solved satisfactorily in very few instances. This approach has generally caused a great deal of frustration, and the loss of time and even more money than the amount of damage that was claimed by the plaintiff. The plaintiff, being the individual who commences a personal law suit to obtain a remedy for an injury to his rights.

Air Pollution Control

The aims and objectives of controlling any type of pollution are to maintain a "reasonable" degree of a clean environment for the benefit of:

1. Maintaining a high level of public health;

2. Protecting the plant and animal life (natural as well as agricultural);

3. Protecting private and community properties;

4. Continuing economic development and growth;

and thus air pollution is no exception. While standards for the measurement of pollutions in the fields of water pollution and nutrition have been widely accepted, the methods for the quantitative analysis of air pollutants have not had this type of coordination. In addition, the laws and/or regulations for the control or abatement of air pollution are, in some cases, not as clear and specific to afford uncontested enforcement. At the present many of these regulations or laws may be read as:

> "Any person or group of persons discharging such amounts of contaminants into the environment as to interfere with the "comfortable" enjoyment of life is a public nuisance and is guilty of misdemeanour and shall be fined accordingly."

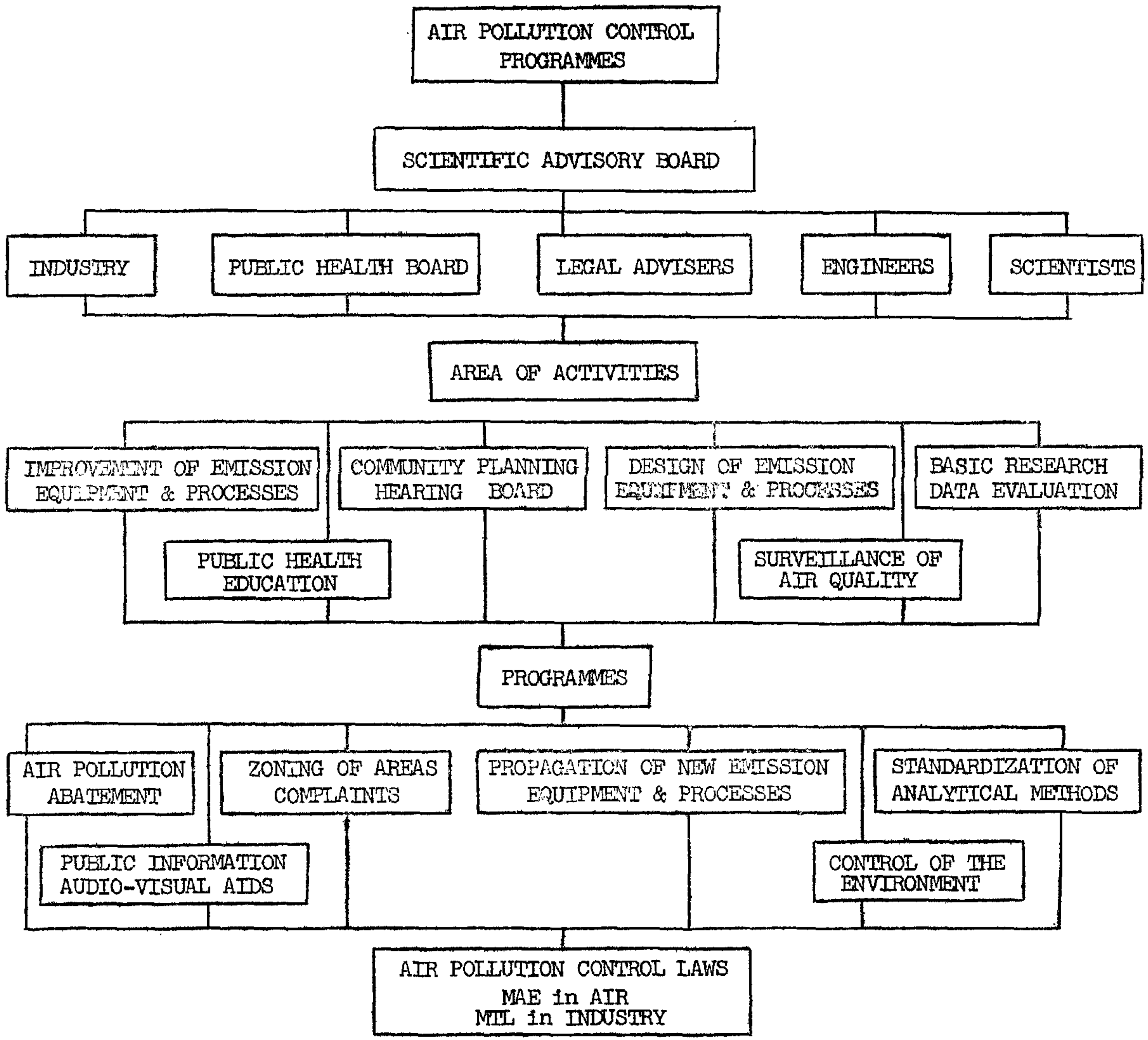
Although the above statement may be a regulation that can be applied to any type of contaminant, it is evident that it becomes subject to many arguments. Many court suits have been dismissed because neither party could define accurately the term "reasonable" in order to enable a discrete ruling by the courts. The term "comfortable" can only be interpreted or defined in accordance with the standard of living of one individual and with his state of mind. Two individuals having the same profession and the same income level may differ completely in their opinion on what is "comfortable". In view of these human variables, in addition to the many variables that are brought about by nature, it seems like an impossible task to find the proper solution to any air pollution programme so that it may stand before any court.

The Air Pollution Control Programme

It is evident from the aforementioned that a sound programme cannot be accomplished by an individual of society. But the problem can and will be solved with the help and coöperation of the various levels of a community. There are many ways in which the solution to this problem can be achieved. Figure 2 illustrates one route to approach to a programme that tends to be economical as well as feasible.

The Air Pollution Control Programme should be organized and directed by a scientific advisory board composed of appointed representatives from public and industrial branches of the community. Each of these representatives should be a qualified professional in his specific field having a sincere interest in the further development of his environment. The final goals to be achieved are: (1) to improve the present conditions of the environment, (2) to control the allowable emission in the future, and (3) to construct air pollution laws that are based on solid knowledge.

Figure 2


AIR POLLUTION CONTROL PROGRAMMES
SCIENTIFIC ADVISORY BOARD
INDUSTRY
PUBLIC HEALTH BOARD
LEGAL ADVISERS
ENGINEERS
SCIENTISTS
AREA OF ACTIVITIES
IMPROVEMENT OF EMISSION EQUIPMENT & PROCESSES
COMMUNITY PLANNING HEARING BOARD
DESIGN OF EMISSION EQUIPMENT & PROCESSES
BASIC RESEARCH DATA EVALUATION
PUBLIC HEALTH EDUCATION
SURVEILLANCE OF AIR QUALITY
PROGRAMMES
AIR POLLUTION ABATEMENT
ZONING OF AREAS COMPLAINTS
PROPAGATION OF NEW EMISSION EQUIPMENT & PROCESSES
STANDARDIZATION OF ANALYTICAL METHODS
PUBLIC INFORMATION AUDIO-VISUAL AIDS
CONTROL OF THE ENVIRONMENT
AIR POLLUTION CONTROL LAWS
MAE in AIR
MTL in INDUSTRY

Perhaps the most important part in this venture is the improvement and the control of the emission of pollutants from the existing industries. These industries, being in operation for many years and contributing to the wealth of the community, are suddenly faced with modifying their emission equipment and thus are burdened with a financial investment that does not result in a direct recovery of their investment. In addition, it is difficult, if not impossible, to force the industry to modify its equipment. The closing of the industry would be the worst of the two "evils", it would result in unemployment and hence in more financial loss to the society.

Another very important factor in this programme is a sound public health education. It is believed in some countries, that the education of the public and the focusing of their attention toward a clean environment has had the best results. Emphasis is placed on the emission of pollution from domestic sources such as heating systems and the burning of garbage on their own premises. In addition, the public should be instructed of the steps to be taken by the individual in case of an emergency due to an air pollution disaster. Audio-visual aids should demonstrate pollutants from all sources for then the individual would obtain a basic knowledge in the identification of the pollution problem. Hence he may be able to aid in the surveillance of some of the sources of air pollution.

To frame the basic findings of the problem in a community and to aid in the regulation of the future, the legal advisers should be chosen on the basis of the merits of their accomplishments. These advisers have a very difficult assignment to perform for they should (1) define the present problem, (2) aid in the legal development of the rules and regulations for the zoning of the community area, and (3) define and establish future laws for the control of pollution. They are, indeed, the centre and core of the programme and they bear a great part of the responsibility for the successful completion of such a venture.

The engineers have so far received very little attention in this discussion, although they participate in a number of areas in an air pollution control programme. Some of the more important functions of the engineers are to (1) develop new equipment and processes for abating air pollution, (2) provide the required assistance in the field operations, and (3) aid and participate in the basic research programme. While anyone may be able to develop the equipment and processes for abating sources of air pollution from existing industries, it is the job of the engineer to do it at reasonable costs. Hence, the engineer is required to demonstrate a broad knowledge of the particular problem and to also demonstrate engineering skill in the approach of the design of the equipment. In addition, a great deal of flexibility is required when communicating with the management of the industry. Many times the engineers are required to aid in the detection and location of the sources of pollution and, hence, in the preparation of the report. This report serves, in many cases, as the basis for legal action and thus requires the engineers to appear as expert witnesses before the courts. Also their participation in the basic research programme enables them to obtain a broader knowledge of the air pollution problem.

It has been demonstrated that complaints have been dismissed by the courts because of poor correlation of the collected data. Therefore, it is evident that the basic research group must solve a number of problems of diverse characteristics. Some of the more important problems that must be solved in the near future are: (1) the determination of the effect of air pollution on man, animals, and vegetation, (2) the development and the modification of analytical methods for the quantitative and qualitative identification of pollutants and hence determine threshold limits, (3) the design and testing of field equipment for monitoring air pollution, (4) the correlation of distinct emissions of air pollutants to meteorological data, and (5) the collection and evaluation and the statistical analyses of the data and thus make recommendations for quality standards.

Legal Bases for the Control of Air Pollution

A review of the previous discussion reveals that a control programme of such magnitude and diversity can only be solved if and when all of the remaining questions are satisfied. With an increase in scientific and technological knowledge it will be possible to legally define some of the terms that are so much subject to arguments at the present. While the present "common law" rules assure a plaintiff of his rights, be it a "private" or "public" nuisance, the distinctions are highly elusive, and if not presented in the proper form of action may result in severe consequences. Hence, it is evident that the basic foundation for a solid and sound air pollution programme must be based on the findings of the scientific advisory board. The transition of the many, presently existing, undetermined variables into determinants of known magnitude will inevitably result in air pollution laws and statutes that will clearly identify such terms as "nuisance, trespass" and "intentional" or "unintentional". In addition it will be possible then to characterize air pollution to the extent where it will be obeyed by every individual of a community without exception.

Conclusion

Although the task of alleviating and controlling the air pollution problem is not an easy one, it will and shall be solved in the near future. The problem has been created mainly by man and thus it can only be solved by man. However it appears reasonable to believe that any society that is faced with this problem will make every effort to alleviate it and those societies, blessed with the absence of the problem, will make every effort to prevent it from encroaching upon them. As air pollution control programmes are being governed more and more by the local authorities, its impact will spread to the state, national, or even international level and hence the laws and statutes may stand before any court without being subject to frustration and ridicule. Finally, this outline is not meant to be a scientific contribution but it is hoped that it will inspire the individual to think of how he can contribute his share for the final solution of the problem. If this has been accomplished, if only to some small extent, this individual is looking most hopefully into the future.

Summary of Discussions

The problems of operating an air pollution control programme with a limited staff and the need for well-qualified personnel was given extended discussion. Emphasis was placed on programme development and on the need for doing this in time before air pollution in this Region becomes overwhelming. The countries of the Eastern Mediterranean Region should not repeat the costly mistakes of the more developed countries. The main problem frequently was how to get started and, it was pointed out, WHO has had some experience in this. Mr Pavanello recounted the experience of Santiago, Chile, as an example and suggested that the participating countries at this Seminar might consider the possibilities of developing effective programmes and of obtaining and training qualified staff through the co-operation of the World Health Organization. Governments who feel a need for developing air pollution programmes might take this matter up with the local WHO representatives.

Another need cited was for a set of standard procedures in air pollution analysis which would have a legal validity comparable to that of the Standard Methods for Analysis in the water pollution field. Professor Katz said that work on this was under way in the United States and he discussed various aspects of the project.

The desirability of having clear-cut standards for simplifying legal action was brought up. Dr. Fritschi said that complete dependence on standards and law for air pollution control is a fallacy and more use should be made of psychology. An industry should be shown how many man-hours and how much money or profit is lost during an air pollution episode as well as how much damage is done to materials, vegetation and animals.

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Dr. H.F. Zaghloul	Sanitary Engineer	Environmental Health, Khartoum

A G E N D A

1. Opening of the Seminar
2. Election of Officers: Chairman, three Vice-Chairmen and Rapporteur
3. Adoption of the Agenda
4. Atmosphere Pollutants and their effects
5. Air Pollution epidemiological aspects
6. Air Pollution problems in the Region
7. Measurement of Pollutant Emissions (methods and demonstrations)
8. Air Pollution emission inventory
9. Air Quality Criteria and Guides
10. Air Pollution monitoring programme
11. Air Pollution control programme (organization, training and legislation)
12. Summary of conslusions and recommendations
13. Closing Session

LIST OF BASIC DOCUMENTS

AGENDA	EM/SEM.AIR.POL./1
PROGRAMME OF THE SEMINAR	EM/SEM.AIR.POL/2
LIST OF PARTICIPANTS	EM/SEM.AIR.POL/3
KINDS AND AMOUNTS OF POLLUTANTS IN THE ATMOSPHERE by Dr. H.C. Wohlers WHO Temporary Adviser	EM/SEM.AIR.POL/4
EFFECTS OF POLLUTANTS ON MAN'S HEALTH (DRAMATIC EPISODES) by Professor P.J. Lawther WHO Temporary Adviser	EM/SEM.AIR.POL/5
EFFECTS OF POLLUTANTS ON VEGETATION by Professor M. Katz WHO Temporary Adviser	EM/SEM.AIR.POL/6
OTHER EFFECTS OF AIR POLLUTION (VISIBILITY DECREASE; SOILING; CORROSION; NEIGHBOURHOOD DECAY) by Dr. H.C. Wohlers WHO Temporary Adviser	EM/SEM.AIR.POL/7
EFFECTS OF METEOROLOGICAL AND TOPOGRAPHICAL CONDITIONS ON DISPERSION OF POLLUTANTS by Professor M. Katz WHO Temporary Adviser	EM/SEM.AIR.POL/8
CALCULATING DISPERSION OF POLLUTANTS FROM STACKS by Professor M. Katz WHO Temporary Adviser	EM/SEM.AIR.POL/9

EQUIPMENT AND METHODS FOR CONTROL OF POLLUTANT EMISSIONS (CITY PLANNING AS A METHOD OF CONTROL) EM/SEM.AIR.POL./17

by Dr. H.C. Wohlers
WHO Temporary Adviser

CONDUCTING AN AIR POLLUTANT EMISSION INVENTORY EM/SEM.AIR.POL./18

by Dr. H.C. Wohlers
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CRITERIA OF EVALUATION OF AMBIENT AIR QUALITY RELATED TO HEALTH AND WELFARE (RESEARCH NEEDED) EM/SEM.AIR.POL./19

by Professor P.J. Lawther
WHO Temporary Adviser

EMISSION STANDARDS THAT MAY BE APPLIED TO SOURCES OF POLLUTION EM/SEM.AIR.POL./20

by Dr. H.C. Wohlers
WHO Temporary Adviser

WHO'S ACTIVITIES IN AIR POLLUTION EM/SEM.AIR.POL./21

by Mr. R. Pavanello
WHO Secretariat

DETERMINING EMISSION REDUCTIONS NEEDED TO MEET AIR QUALITY STANDARDS EM/SEM.AIR.POL./22

by Dr. H.C. Wohlers
WHO Temporary Adviser

PLANNING AN AIR POLLUTION MONITORING PROGRAMME EM/SEM.AIR.POL./23

by Professor P.J. Lawther
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THE KINDS OF ACTIVITIES CARRIED ON BY GOVERNMENTAL AIR POLLUTION CONTROL PROGRAMMES (OVERVIEW) EM/SEM.AIR.POL./24

by Dr. H.C. Wohlers
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AIR POLLUTION CONTROL PROGRAMMES AND THEIR LEGAL VALIDITY EM/SEM.AIR.POL./25

by Dr. E.W. Fritschi
WHO Professor of Sanitary Engineering

LIST OF BACKGROUND MATERIAL

EXPERT COMMITTEE ON ENVIRONMENTAL SANITATION	TRS No. 157
EXPERT COMMITTEE ON ATMOSPHERIC POLLUTANTS	TRS No. 271
EXPERT COMMITTEE ON RADIATION	TRS No. 248
AIR POLLUTION LEGISLATION: STANDARDS AND ENFORCEMENT (by A. Parker - In: Air Pollution, Monograph Series No. 46)	
EPIDEMIOLOGY ON AIR POLLUTION (Report on a Symposium)	PUBL. HLTH.PAP. No. 15
AIR POLLUTION IN EUROPE (WHO/EURO Report on the Eighth Seminar for Sanitary Engineers, 1963)	
AIR POLLUTION: A SURVEY OF EXISTING LEGISLATION (Reprint from the International Digest of Health Legislation, 1963, 14)	
AIR QUALITY CRITERIA (US Committee on Public Works, July 1968)	
ROUTINE SURVEILLANCE FOR RADIONUCLIDES IN AIR AND WATER (WHO, 1968)	
AIR POLLUTION IN KUWAIT (Assignment Report by Dr. P.J. Lawther, WHO Short-term Consultant)	EM/ES/71 KUWAIT 0011
AIR POLLUTION IN TEHERAN (Assignment Report by Mr. J.J. Schueneman, WHO Short-term Consultant)	EM/ES/82 IRAN 0045
AIR POLLUTION IN TEHERAN - COMMISSIONING OF AIR MONITORING APPARATUS AND ADVICE ON DEVELOPMENT OF AN AIR POLLUTION CONTROL PROGRAMME (Assignment Report by Mr. F.E. Ireland, WHO Short-term Consultant)	EM/ES/94 IRAN 0045

OCCUPATIONAL HEALTH IN KUWAIT (Assignment Report by Professor F. Valic, WHO Short-term Consultant)	EM/ES/96 KUWAIT-0019
AN INTRODUCTORY SURVEY OF AIR POLLUTION IN CYPRUS (Assignment Report by Mr. J. Beighton, WHO Short-term Consultant)	EM/ES/101 CYPRUS-0021
AIR POLLUTION IN KUWAIT - A PRELIMINARY SURVEY AND SOME SUGGESTED ACTIVITIES (Assignment Report by Dr. M.S. Abdel Salam, WHO Short-term Consultant)	EM/ES/118 KUWAIT-0011
PUBLIC HEALTH ASPECTS OF AIR POLLUTION FROM DIESEL VEHICLES	WHO/AP/67.28
METHODS OF MEASURING AND MONITORING ATMOSPHERIC NITROGEN OXIDES AND THEIR PRODUCTS (Part I)	WHO/AP/68.31
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AIR POLLUTION ENGINEERING MANUAL (Edited by Danielson)	US PHS Publication No. 999-AP-40
RAPID SURVEY TECHNIQUE FOR ESTIMATING COMMUNITY AIR POLLUTION EMISSIONS by Ozolins and Smith	US PHS Publication No. 999-AP-29
COMPILATION OF AIR POLLUTANT EMISSION FACTORS by Duprey	US PHS Publication No. 999-AP-42
A COMPILATION OF SELECTED AIR POLLUTION EMISSION CONTROL REGULATIONS AND ORDINANCES	US PHS Publication No. 999-AP-43
HANDBOOK OF AIR POLLUTION by Sheehy, Achinger and Simon	US PHS Publication No. 999-AP-44
AIR POLLUTION CONTROL FIELD OPERATIONS MANUAL (Edited by M.I. Weisburd)	US PHS Publication No. 937

REFERENCE MATERIAL AVAILABLE FOR CONSULTATION

RESEARCH INTO ENVIRONMENTAL POLLUTION	TRS No. 406
MEASUREMENT OF AIR POLLUTANTS (Guide to the Selection of Methods by Professor M. Katz)	
URBAN AIR POLLUTION WITH PARTICULAR REFERENCE TO MOTOR VEHICLES	TRS No. 410
AIR POLLUTION ASPECTS OF THE IRON AND STEEL INDUSTRY	US PHS Publication No. 999-AP-1
ATMOSPHERIC EMISSIONS FROM FUEL OIL COMBUSTION An Inventory Guide	US PHS Publication No. 999-AP-2
METHODS OF MEASURING AND MONITORING ATMOSPHERIC SULFUR DIOXIDE	US PHS Publication No. 999-AP-6
SELECTED METHODS FOR THE MEASUREMENT OF AIR POLLUTANTS	US PHS Publication No. 999-AP-11
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